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DEPARTMENT OF REGISTRATION AND EDUCATION

NATURAL HISTORY SURVEY DIVISION
STEPHEN A. FORBES, *Chief*

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ERRATA

Page 57, statistical headings: for *Year 1920* read *Year 1910*; for *Year 1909* read *Year 1920*; in the ratio heading, for *1909* read *1920*, and for *1920* read *1910*. The entries in the Year columns should change places.

Page 85, line 13 from bottom, for *87* read *86*.

Page 88, line 20, delete *red*.

Page 115, line 6, over the column of figures read *Acres*.

Page 136, line 5, for *135* read *131*.

Page 145, *First table*, 4th column, for *35.97* read *33.40*; last column, for .052 read .0418.

Second table, second column, for .2158 read .2004; 5th column, for .1131 read .0977; last column, for .0926 read .0772.

Last table, second column, for .714 read .663 and for total read $4.710; 5th column, for .374 read .323 and for total read $2.201; the last column, for .307 read .256 and for total read $1.700.

Page 146: *First table*, second column, for 8.02 read 7.45 and for total read 52.92; third column, for 3.45 read 2.88 and for total read 19.10; 4th column for 19.28 read 17.90 and for total read 127.18; last column, for 8.29 read 6.92 and for total read 46.35.

Second table, for 43.02 read 38.66.

Last table, for 8.0 read 6.7.

Page 382, line 10 from bottom, for *Platythemis* read *Plathemis*.

Page 385, in list, the specific names of No.'s 33, 35, and 40 should end in *us* instead of *a*.

Pages 445 (line 4), 448 (line 4), 449 (line 23), 454 (line 8 from bottom), read *Belostomidae* for *Belostomatidae*.

Page 457, line 21, for *cornutus* read *cornuta*.

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
DIVISION OF THE
NATURAL HISTORY SURVEY
STEPHEN A. FORBES, Chief

Vol. XV. BULLETIN Article I.

The Apple Flea-weevil, *Orchestes pallicornis* Say (Order Coleoptera; Family Curculionidae)

BY
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and
PRESSLEY A. GLENN

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CONTENTS

Article I.—*The Apple Flea-weevil, Orchestes pallicornis Say (Order, Coleoptera; Family, Curculionidae).** By W. P. Flint, S. C. Chandler, and P. A. Glenn.

Historical

The apple flea-weevil was described by Thomas Say in 1831, from specimens taken in Posey county, Indiana. At that time it was not considered an economic pest. Seventy years later Dr. S. A. Forbes reported in the Transactions of the Illinois State Horticultural Society (1901) that the beetle had been found fairly numerous at a number of points in southern Illinois by Mr. E. S. G. Titus, but no damage to orchards was noticed until 1905 and 1906, when some was reported from the southern and western parts of the state.

In Ohio the insect was not known as an orchard pest until about 1907, when it attracted attention in two adjoining commercial orchards near Delaware, Ohio, in the central part of the state.

The first account of its life history and habits appeared (under the authorship of Mr. C. A. Hart) in 1911 in the 26th Report of the Illinois State Entomologist,† and the first published record of severe damage by the insect was published in 1912 by Dr. S. A. Forbes in the Transactions of the Illinois State Horticultural Society. During that season the weevil appeared in large numbers at several points in southern Illinois and caused damage amounting to a destruction of 25 per cent. to 50 per cent. of the leaf surface of the apples in a number of well-sprayed orchards. It was reported as occurring throughout the state but as doing no appreciable damage in the northern section. In this paper Dr. Forbes, in view of its membership in the weevil family, its infestation of the apple, and its thickened hind thighs and flea-like power and habit of making long leaps when disturbed, gave the species the vernacular name of the apple flea-weevil, and by this name it is now generally known.

During the past decade it has become so destructive over a large area in Illinois and in a limited section of Ohio that serious study of the life history and control of the pest has been made by both the Illinois Natural History Survey and the Ohio Agricultural Experiment Station, and the present publication is issued to set forth the results of these studies.

* The data upon which this article is based, were accumulated for the most part independently by the Illinois Natural History Survey and the Ohio Agricultural Experiment Station and each had made plans to publish. It was found, however, that by combining the data and cooperating in the preparation of a report a much more complete treatment of the subject would be possible. The resulting papers, substantially equivalent, although not necessarily identical in all particulars, are to be published in Bulletin 372 of the Ohio Agricultural Experiment Station, with J. S. Houser as author, and in the Bulletin of the Illinois State Natural History Survey, with authorship as shown herewith.

† In this paper the insect was erroneously identified as *Orchestes canus*, and the remarks concerning its distribution relate to that species.

Distribution

As just indicated, the apple flea-weevil is generally distributed over Illinois and is particularly destructive in the central and southern sections. In Ohio it has been found at Delaware in large numbers, at Wooster and Steubenville in small numbers, and, in correspondence, has been reported from Cincinnati, O., California, O., and Chillicothe, O. It is probably very sparsely distributed over the greater part of the state, but is destructively abundant only in an area of about a square mile near Delaware, in the central part of the state.

In Indiana, according to Prof. J. J. Davis, of the Indiana Experiment Station, it is not on record as doing any notable injury.

In correspondence, Prof. C. R. Crosby, of Cornell University, reports finding the weevil in several New York orchards, though not in destructive numbers.

The general distribution of the species in North America as given by Blatchley and Leng in the "Rhynchophora or Weevils of North Eastern America", is as follows: "Frequent throughout Indiana . . . . several localities in New Jersey and Staten Island; . . . . Ranges from Nova Scotia and Quebec through New England to Oregon, south to Texas."

From this record of its wide distribution it appears to be a native insect which is not normally troublesome but which is quite capable of becoming a pest of prime importance when conditions brought about by particular practices especially favor its increase. A detailed discussion of this point will be found later on in this article.

Description

adult beetle

The apple flea-weevil is of insignificant size and appearance (see Figures 1 and 2). The beetle is shining black and scarcely a tenth of an inch long. It has a curved snout and the hind legs are strongly developed for jumping. Say's original description of the species is as follows: "Black, antennae rufous with a black tip. Inhabits Indiana. Body black, densely punctured; rostrum lineated and punctured; antennae dull rufous, the club darker black; thorax confluently punctured; elytra with punctured striae, the interstitial lines somewhat rough and flat; thighs with a short acute tooth. Length one-tenth of an inch. Var. a. Tarsi piceous. This species is very abundant."

Blatchley and Leng in their "Rhynchophora or Weevils of North Eastern America" describe the species as follows: "Elongate-oval, humeri prominent. Black, shining, sparsely clothed with very short grayish-yellow hairs; antennae and tarsi reddish-brown; club dusky. Beak stout, scarcely as long as head and thorax, coarsely and sparsely punctate. Head finely granulate, sparsely and coarsely punctured. Thorax as broad at middle as long, sides feebly rounded, disc coarsely, very densely

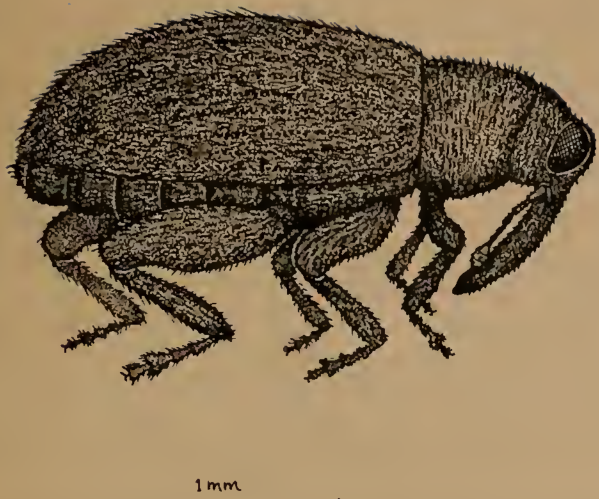

FIG. 1. Adult beetle of the apple flea-weevil. (Magnified 25 diameters.)

FIG. 2. Adults of the apple flea-weevil. (Magnified 10 diameters.)

and shallowly punctured. Elytra oblong-oval, at base two-thirds wider than thorax, striae feebly impressed, their punctures coarse; intervals flat, coarsely rugose, sparsely and finely punctate. Length 2.5—3 mm." [1/10 to 1/8 inch.]

EGG

The egg is about .7 mm. (1/35 inch) long, and about half as thick, pearly white, with ends rather abruptly rounded. It is deposited by the beetle within the midvein or one of the larger veins of the leaf and hence can not be seen unless it is very carefully dissected from the leaf tissues.

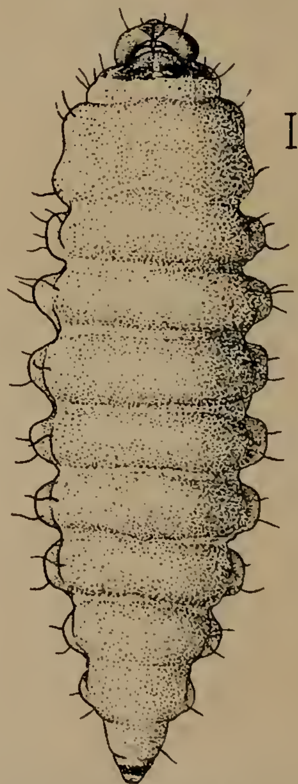

FIG. 3. Full-grown larva of the apple flea-weevil, seen from above. (Magnified 25 diameters.)

LARVA

The larva when full grown measures about one-fifth of an inch in length, and is about one-fourth as broad at its widest part. From the head backward the sharply defined segments gradually increase in width until midway of the body, whence they narrow rapidly toward the anal tip. As might be expected of a typical leaf-mining larva, the body is distinctly flattened. The color is dirty white. (See Figures 3 and 4.)

PUPA

The pupa is at first white, but gradually becomes darker as it approaches the adult stage. It is about three-fifths as long as the larva, regularly oval, and about half as wide as long (see Figure 4).

FIG. 4. Larvae and pupae removed from mines.
(Magnified 6 diameters.)

LIFE HISTORY AND HABITS

The apple flea-weevil passes the winter in the adult, or beetle, stage. Early in July the beetles begin to secrete themselves for the remainder of the summer, the fall, and the following winter under leaves, plant refuse, in the mulch or sod of orchards, or under any other object which will afford protection, but as far as we know, not in the soil proper. By far the greater number seek shelter in apple orchards, but they have been found hibernating in negligible numbers in bunch-grass (Andropogon sp.), blue grass, and trash along hedge rows, and under wild crabs. They show no preference for any side of the tree, but are more numerous where the cover is densest. In partially cultivated orchards they are most abundant in hibernation near the trunk of the tree, as is shown by the following table.

According to this table there were from 1400 to 1700 beetles hibernating under each apple tree in heavily infested orchards of this type.

The heavily infested Ohio orchards had not been cultivated for many years, and a heavy blue-grass sod covered the ground, forming a dense layer of partly decayed vegetation over the entire surface (see Figure 5). Under such conditions the beetles may be found in abundance throughout the orchard, in larger numbers, however, under the trees than elsewhere.

Fig. 5. The heavy sod mulch of the Glenn Sonners (old Vergon) orchard, Delaware, Ohio, in which the beetles hibernated.

RELATIVE POSITIONS OF HIBERNATION IN PARTLY CULTIVATED SOUTHERN ILLINOIS ORCHARDS, 1919, 1920, AND 1921

Location of area	No. of sq. ft. examined	Average No. beetles per sq. ft.
1st sq. ft. from tree	205	28.4
2d " " " "	205	22.6
3d " " " "	205	14.6
4th " " " "	9	10.1
5th " " " "	5	6.6
6th " " " "	6	3
7th " " " "	3	1
8th " " " "	3	0

On unusually warm days of winter or spring when the temperature remains for several hours at 60° or 70° some of the beetles emerge, but they return if the weather cools. At Olney, Ill., during a four-year period, there was nearly a month's difference in the dates when weevils began to leave their winter shelter. In 1921, movement from hibernation began on March 15; in 1918, March 25; in 1919, April 8; and in 1920, March 23. No precise data were obtained in Ohio, but such information as we have, indicates that in the main the beetles are from two to three weeks later in leaving their winter quarters at Delaware, Ohio, than in southern Illinois.

The time of their appearance in spring is not always contemporaneous with the appearance of the leaves. During some seasons they come out in considerable numbers before the foliage is developed and cluster on the swelling buds as if waiting for the leaves to appear. On the other hand, in some seasons the leaves are three-quarters of an inch long before the beetles are abroad. If there are one or two days of exceedingly warm weather before the foliage starts, the beetles appear in advance of the leaves, whereas if the foliage is developed by normal weather the leaves are from ½ to ¾ inch long before the beetles leave their winter quarters. The above observations apply particularly to orchards which are in sod.

In leaving their winter shelter many of the beetles crawl up the trunk of the tree, but most of them crawl to the tip of grass blades or other objects and thence take flight to the branches above. Their flight is erratic and fortunately they do not travel long distances on the wing, and they seem unable to take flight if even a moderate breeze is blowing. If the wind is fitful they cling to their swaying perches, not attempting flight until a lull comes, whereupon great numbers will spring into the air almost simultaneously.

After emerging in spring the beetles begin to mate and to feed upon the swelling buds or expanding leaves. When the foliage is a little further developed egg-laying commences. For this the female seeks the midvein or one of the laterals on the under side of the leaf, and after making a suitable cavity with her snout, deposits therein a tiny egg, closing the cavity afterwards with a bit of excrement.

The eggs hatch in about a week and the newly emerged larva begins feeding in the blind end of the tunnel in which it lies, and proceeds thence to mine out the inner substance of the leaf. At first the mine is threadlike, lengthening in the general direction of the edge of the leaf, and gradually increasing in width. At the edge of the leaf the mine takes on a somewhat blotchlike form and when completed is about two-thirds the size of a dime. The mine is rather conspicuous because the leaf tissue on both its upper and lower sides dies and turns brown.

On an average the larva becomes full grown in seventeen days, whereupon it causes an expansion in a part of the upper and lower surfaces of the mine which takes the form of a blister a little less than

Fig. 6. Injury to the developing foliage by the apple flea-weevil (left) and a normal twig of the same variety taken from the same orchard at the same time. This injury is done by the old adult weevils which have passed the winter in the sod mulch.

a quarter of an inch in diameter. In this swelling the larva changes to the pupal stage, which averages five or six days in duration.

The adults leave their mines during the latter part of May in southern Illinois, and in central Illinois and in central Ohio during the fore part of June. Since there is but one brood per year the beetles which appear in summer survive the winter in hibernation. They feed for approximately a month before retiring to their winter quarters. This feeding period is also the principal migration season, but as the insect is not a strong flier its spread from one orchard to another is surprisingly slow.

The beetles have been found in winter quarters as early as June 15 in southern Illinois, and by mid-July most of them are so concealed. In the Ohio territory and in central Illinois this period is practically complete by August 1, but a few are abroad until early fall. The movement to hibernating quarters is more prolonged than that from these quarters in spring. The time of year for the retreat of the beetles is influenced by the weather, hot weather hastening it, and cool, cloudy weather during the summer months delaying it.

Character of Injury and Extent of Damage

The damage done by the apple flea-weevil consists in the feeding punctures of the weevils and the mines of the larvae. If the weevils have emerged when the buds are just beginning to show green they injure the expanding buds by inserting their beaks into them and, if sufficiently abundant, may prevent their opening. As the leaves open, the beetles continue their feeding, cutting holes entirely through the tender foliage, and occasionally at this stage destroying it outright (see Figure 6). Still later, after the leaves have become full grown, the weevils feed for the most part on the under side, though occasionally one is seen feeding on the upper leaf-surface. They eat out the soft tissue, leaving the epidermis of the opposite side, thus making shallow pits about a twenty-fifth of an inch in diameter. The unconsumed epidermis turns brown a few days after the injury, and later breaks away, leaving a hole in the leaf, and when the attack is severe the tree looks as if it had been riddled with bird shot. Leaves on which several weevils have fed will have from a third to half the surface destroyed. When injured to this extent they drop prematurely, and the punctures also afford easy access for the spores of various fungi. Upwards of 2000 beetles are frequently found on a single tree, and as each weevil makes from ten to twenty feeding punctures a day, it is easy to understand the amount of injury which can be done in the course of a month's feeding. (See Figures 7 and 8.)

The mining of the leaves by the larvae is perhaps a little less destructive in its effect on the host than the feeding of the adult beetles. (See Figure 9.) Where two, three, or even more mines occupy a single leaf, it is rendered almost wholly, if not entirely, functionless. In heavily infested orchards, however, one may find three or four mines to a leaf, and 25 per cent. to 30 per cent., or even more, of the leaf surface is destroyed. From both kinds of injury, in the course of two or three seasons the trees in heavily infested orchards become unthrifty

Fig. 7. Injury to apple foliage by the feeding of the adult beetles in midsummer. The beetles may, when sufficiently abundant, make lace-work of the foliage.

and incapable of a vigorous growth or the production of fruit buds. If the attack continues the lower limbs die, since these are always much more severely injured than the upper ones; the tree is more susceptible to the effects of late spring frosts or other adverse conditions; and the orchard becomes generally unprofitable. (See Figure 10.)

Still another effect is the killing back of all new growth or watersprouts arising from the main branches of the tree. Under some conditions this might be considered a beneficial rather than harmful effect, but it is the practice of some orchardists to utilize these growths in the upper parts of old trees for starting a new top after the original tree becomes too tall. (See Figure 11.)

The weevil has been on the increase in Illinois since 1910 and 1911. In 1913 and 1914 at least 25 per cent. of the orchards in southern Illinois were infested to an extent to cause at least moderate injury to the trees. Many orchards which were well sprayed and partly cultivated lost at least a third of their leaf surface before the middle of July. During the last five years the damage has not been so general, but several localities have suffered every season for the past ten years.

FIG. 8. A view taken when looking up through the foliage of an apple tree following severe midsummer injury by the feeding adult beetles. The leaves look as if riddled by fine shot. Olney, Ill., July, 1915.

The owner of the first orchard in Ohio to become seriously involved had been following for some years a new method of soil management. The trees were growing in sod and each year the grass was mowed and

FIG. 9. Larval mines of the apple flea-weevil in apple leaves.

spread under them. Later, due to shading by the trees, insufficient grass was produced for mulching, and for some years straw or other roughage was hauled in and spread under the trees. During the past few years no mulching has been done and a heavy grass sod has developed. This method has furnished almost ideal hibernating quarters for the beetles, and this is now believed to have caused the outbreak in the Vergon orchard as well as that in the adjoining one owned by the Delaware Apple Company. In these two orchards, containing about seventy acres, the beetle has been increasing in abundance since 1907 and

FIG. 10. Trimming away of dead or valueless lower branches because of successive seasons of flea-weevil injury. Orchard of the Delaware Apple Co., Delaware, O.

has taken a toll of thousands of dollars of profits. Strangely, however, it has not become a pest in any of the other orchards of the Delaware section. The fact that these two orchards are somewhat isolated by a bend in the Olentangy River from the others of the section doubtless has had much to do in restricting the spread of the beetle. Moreover, none of the other orchards have afforded such ideal hibernating quarters as have these two.

The sum total of the injury by the apple flea-weevil is much less in Ohio than in Illinois. The Ohio territory affected seriously is not over a square mile in extent while in central and southern Illinois several hundred square miles are involved.

FIG. 11. The killing of all water-sprouts by beetles feeding on aged apple-trees makes it impossible to rejuvenate the orchard by growing lower tops.

Hosts

By all odds the cultivated apple is the chief host of the apple flea-weevil in Ohio and Illinois. That this is fortunate is evident, since any insect pest which thrives equally well on one or more uncultivated hosts renders its control on cultivated species more difficult. However, the apple flea-weevil is known to feed in the larval or the adult stage on a number of other hosts. What were presumably larvae of this species were seen mining the leaves of the winged elm *(Ulmus alata)*, American elm *(Ulmus americana)*, and elder (Alnus sp.) at Falls Church, Va., and hazelnut *(Corylus americana)*, at Wooster, Ohio. Larvae were found mining the leaves of quince in Illinois and Ohio, choke cherry *(Prunus virginiana)* and hawthorn *(Crataegus mollis)* in Ohio and adults were reared from the infested leaves. Lastly, the beetles were seen feeding on the leaves of the wild crab *(Pyrus coronaria)* in Ohio and Illinois, and are reported by others as feeding on the leaves of willow and on the flowers of service berry (Amelanchier).

In no instance has a wild or unusual host been found severely infested by either the mining larvae or the feeding beetles, even when growing in the immediate vicinity of severely infested apple trees.

Natural Checks on Multiplication

Probably the most effective factor in natural control is the white muscardine fungus (*Sporotrichum globuliferum* Speg.), a well-known fungus parasite of insects, the spores of which germinate on the surface of the beetle, sending their threadlike mycelium into and throughout its tissues and causing its death. It continues to thrive on the carcass and in time its white growth entirely envelops it. During the extremely wet summer of 1915, weevils covered with this fungus could be found literally in thousands under the loose scales of bark on the trunks of apple trees and in the cover around the bases of the trees in Illinois orchards (see Figure 12). The dampness caused by repeated rain had been very favorable to the development of this fungus in orchards that had been heavily infested for several seasons previous, and in some of them the flea-weevil was almost entirely exterminatd. In an orchard at Plainview, Illinois, where at least 30 per cent. of the leaf surface was destroyed in 1914, a careful search of nearly two hours was required to find a single weevil in 1916. No appreciable damage has been done in this orchard during the past five years, although the weevils are now becoming more abundant and were present in considerable numbers during the summer of 1921. It is, however, only during prolonged periods of wet weather that this fungus has ever been an important factor in the control of the flea-weevil. Such general prevalence of this disease has never been observed in Ohio orchards, although beetles dead with it are very commonly encountered there.

FIG. 12. Photograph taken at the base of an apple tree after some of the covering leaves had been removed to show the adult apple flea-weevils dead with the muscardine fungus. About 2/3 natural size. Small white spots are dead beetles embedded in the fungus which killed them. Olney, Ill., Oct. 18, 1915.

Another controlling agency is a group of tiny hymenopterous parasites, of which several species have been bred. These busy little creatures parasitize either the larva or the pupa in the mine, ultimately causing the death of their host. We have never seen such wholesale destruction as that due to the muscardine fungus, but these parasites are undoubtedly an important factor in checking the activities of the insect. For example, on June 12, 1919, material taken at Delaware, Ohio, was found to be 23 per cent. parasitized, and on June 23, 1921, material taken at Wooster, Ohio, was found to be 20 per cent. parasitized. The following species have been reared:

From mines of the apple flea-weevil in apple, *Zatropis incertus* Ashm.*, Epiurus sp.†, *Derostenus pallipes* Gahan*; from those in choke cherry, Pleurotropis sp.*; from those in hawthorn, Sympiesis sp.*, and Eulophid gen. and sp.*

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* Determined by A. B. Gahan, U. S. Bureau of Entomology.
† Determined by R. A. Cushman, U. S. National Museum.

Artificial Control

During the last eight years, experiments have been made in Illinois and Ohio to develop effective methods of control by banding, summer spraying with arsenicals, summer spraying and dusting with contact insecticides, burning in hibernation, spraying and dusting with insecticides in hibernation, poisoned baits offered as the insects are leaving hibernation, and cultivation of the soil.

BANDING

It was at first thought that the emerging beetles crawled up the trunk of the tree in spring and this suggested the possibility of destroying them by the use of sticky bands. Preliminary experiments with tree-tanglefoot bands placed singly about the trunks of the trees at varying heights and doubly at various distances apart, developed the fact that while fairly large numbers of beetles were caught on the bands, there were about as many on the upper as on the lower where two bands were used, showing that many of the beetles flew to the upper parts of the tree instead of crawling up the trunk. Nevertheless a number of experiments with bands were made, with results of which the following is typical:

On April 10 to 14, 1914, a band of tanglefoot three inches wide was applied to the trunks of 500 mature Ben Davis trees in an orchard of 600 trees which averaged ten to twelve inches in diameter. The loose bark was scraped from the trunks and the tanglefoot was applied with a wooden paddle directly to the bark, three rows in the center of the experimental block being left untreated as a check. (See Figure 13.)

On April 20 the trees banded on the 10th and 14th averaged 250 and 200 weevils per band, respectively, but there were many weevils on the opening leaves of the trees. May 5 there was an average of 700 weevils per band, and June 15 practically the same. The insects were distributed quite uniformly over the bands, showing that many had been caught by alighting on the bands and not in crawling up the trunks.

As a supplementary experiment, on April 20, three bands, 18, 12, and 3 inches wide, were placed on one tree at a distance of 2, 8, and 18 feet from the ground, respectively. On May 5 the widest band contained over 1500 weevils; the band 8 feet from the ground, 35 weevils; and that 18 feet from the ground, 4 weevils.

To ascertain whether any benefit had been derived from the banding a number of leaves were taken at random from the banded and unbanded trees, and the larval mines were counted. The results are tabulated as follows.

	Banded with 18", 12", and 3" bands	Banded with 3" bands	Unbanded in same orchard	Unbanded in near-by orchard
Percentage of leaves with larval mines	10.3	16.3	23	36
Average number of larval mines per leaf	1—10	1—6	1—4	1—3

FIG. 13. A single wide band of tanglefoot placed around the trunk of an apple tree. Banding did not prove an effective control, but might be used under unusual conditions.

A man could band from 18 to 20 trees an hour, and it required one and a half to two ounces of tanglefoot to make a three-inch band around a mature Ben Davis apple-tree. The expense of banding would be about $3 per acre.

The results scarcely warrant reliance on this method as a satisfactory control, but it may be serviceable when one of the more satisfactory control measures to be discussed later can not be used.

SUMMER SPRAYING WITH ARSENICALS

Since the larvae of this species are leaf-miners they can not be killed by arsenical sprays, and since the adults feed mainly on the under side of the leaf an arsenical applied to the under surface, theoretically should be effective; but orchards sprayed regularly with arsenicals and fungicides are as severely injured as those not sprayed at all. It was the purpose of our experiments to ascertain whether it was possible to devise an arsenical formula or a method of application such that the weevil could be reached.

Obviously, such a spray should be applied when all the beetles in the orchard are feeding on the leaf surfaces. This occurs first when the beetles leave their winter shelter as the foliage is expanding, and again about mid-June when the insects have just become mature and have left the mines. Many preliminary experiments were made with arsenical sprays in combination with soap and flour paste as spreaders, and with lime-sulfur and Bordeaux as fungicides. Adult weevils inclosed in cages attached to branches of apple trees the foliage of which had been sprayed on both sides with arsenate of lead usually all died within a week.

The repellent effect of fungicides.—Early in the course of summer-spraying, leaves were sprayed with arsenate of lead and water, and arsenate of lead in combination with either soap, flour paste, lime-sulfur, or Bordeaux. When given a choice of these leaves and unsprayed leaves the beetles fed about as freely on those sprayed with arsenate of lead and water, either alone or combined with soap or flour paste, as they did on unsprayed leaves, but they avoided leaves sprayed with arsenate and water in connection with lime-sulfur or Bordeaux. It is possible, therefore, that the addition of lime-sulfur or Bordeaux to the arsenical, as is the regular orchard practice, renders the treatment ineffective by repelling the weevils before they are effectivly poisoned. The following experiment emphasizes this view:

Adjoining rows of apple trees in a commercial orchard were sprayed with an upshoot spray, one row with arsenate of lead and water and the other with arsenate of lead and Bordeaux. Two days later many dead weevils were on the ground under the trees sprayed with arsenate of lead and water but hardly any under those sprayed with arsenate of lead and Bordeaux. All the spraying had been done on the same day and in the same manner and the weevils were equally abundant on the two rows of trees, and the difference in results was evidently due to the absence of Bordeaux in the one case and its presence in the other. This would explain the ineffectiveness of the usual orchard-spraying program in controlling the apple flea-weevil as it is the custom to combine fungicides with the arsenical in the spray mixture.

Supplementary applications of arsenical sprays.—In an orchard which had been sprayed according to the regular schedule for the codling-moth eight trees were given an additional or supplementary spray according to the following formula:

Arsenate of lead paste......................	3 lbs.
Flour	8 lbs.
Water	50 gal.

The spraying was done at a pressure of 150 lbs. with a Friend 45°-angle nozzle, one hose being operated from the tower and the other from the ground, a special effort being thus made to cover both surfaces of the leaves. On the following day 647 dead beetles were counted on 90 square feet of canvas spread under one of the trees. Very few weevils remained on the trees receiving the extra spraying, though they were present in large numbers on adjoining trees which had received the spray of the normal program. On the second day following the application an average of but one weevil was found to every 24 leaves on the extra-sprayed trees, and one on every 6 leaves of those adjoining —a reduction of about 75 per cent. in the number of weevils because of the spray. Eight days after the application the extra-sprayed trees had an average of one weevil to 29 leaves, and the others had one weevil to 6 leaves. The infestation was decreasing on the extra-sprayed trees but not on those not sprayed, although the former were exposed to reinfestation from their neighbors.

Spraying both the upper and lower leaf-surface vs. spraying the upper surface only.—Adjoining the plot of eight trees just discussed, in which both surfaces of the leaves were sprayed, an eight-tree plot was sprayed at the same time with the same mixture, but in this only the upper surface of the leaves was covered. Two days after the application there was an average of one weevil to 13 leaves on the sprayed side, and one weevil to 5 leaves on the unsprayed side. The sprayed side of the leaves was thus much less infested than the unsprayed side, and the leaves sprayed on both sides were still less so, since, as will be recalled, these averaged one weevil to 24 leaves. This difference seems sufficient to warrant spraying both sides of the leaves if this supplementary application of an arsenical is made without the addition of a fungicide.

Tests of different poison formulae.—Two series of tests were made to determine the value of different arsenical combinations, a spray gun being used to throw the spray upward through the tree, and thus to cover both leaf surfaces.

In the first test canvas was spread under the trees to catch the dead weevils. These were collected and counted daily with results shown by the following table.

Materials	Average number of dead weevils per square foot				
	24 hours	26 hours	48 hours	72 hours	Total
Powdered arsenate of lead........2 lbs Lime ....1½ lbs Water ....50 gal	1.7		1.3	.8	3.6
Same formula as above	1.2		.6	.6	2.6
Powdered arsenate of lead........1 lb. Water ....50 gal	2.4	1			

The estimated number of weevils per tree killed in 72 hours was 1628; and five days after the spraying it was estimated that about 50 per cent. of the weevils had been killed on the sprayed trees. No difference was seen between trees sprayed with arsenate of lead at 2 lbs. and at 1 lb. to 50 gallons of water.

In the second test, sprays described in the following table were applied May 2, when the foliage was well developed, and again May 14. For a comparison of results a conical cheese-cloth net, 3½ feet deep and 3 feet across the mouth (see Figure 14), was suspended, following the second application, under a representative tree in each plot, and daily records were kept of the dead beetles. The tip of the net was anchored to a peg driven in the ground by a cord long enough to permit the branch to sway and at the same time to prevent the bag from whipping and fraying in the wind. The accompanying table shows the formulae used and the daily catch.

This experiment was defective in the fact that the small number of trees used and their close proximity permitted the passage of beetles from one tree to another after the sprays were applied, as is shown especially by the appearance of dead beetles under two of the check trees. It is plain, however, that the poison sprays took considerable effect, and the sprayed trees were obviously less injured by the weevils than the check.

Early summer application of the arsenical.—In one instance a spray of arsenate of lead 1 lb., lime 2 lbs., and water 50 gallons was applied to the young leaves with a spray gun at a pressure of 200 to 225 lbs. when the weevils were just emerging from hibernation and before many eggs had been laid. After 24 hours, 48 dead weevils were collected from 192 square feet of canvas spread under the tree, and after 26 hours more, 22 additional weevils were collected.

Materials Used	Daily Catch of Beetles																			Total
	May																	June		
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	
Arsenate of lead powder........ 3 lbs. Water........ 50 gal.	4	2	15	2	2	5	0	*	3	0	0	0	0	0	0	1	0	0	1	35
Arsenate of lead powder........ 3 lbs. Molasses (black strap cane syrup)........ 1¼ gal. Water........ 48¾ gal.	9	7	3	5	4	4	0	*	1	0	1	0	1	1	0	0	0	0	0	36
Calcium arsenate powder........ 2 lbs. Hydrated lime........ 4 lbs. Water........ 50 gal.	3	4	6	3	2	5	0	*	5	0	0	1	1	2	2	1	0	0	1	36
Arsenate of lead powder........ 3 lbs. Copper sulphate........ 4 lbs. Hydrated lime........ 6 lbs. Water........ 50 gal.	0	0	14	3	2	3	7	*	2	0	1	2	4	1	1	0	0	0	1	41
Arsenate of lead powder........ 3 lbs. Soap (common laundry)........ 2 lbs. Water........ 50 gal.	3	6	1	0	1	5	7	*	1	0	1	1	0	0	0	1	0	0	0	27
Check – unsprayed........	0	0	0	5	0	4	0	....	0	0	0	0	0	0	0	0	0	0	0	9

* Raining; no records.

In this test, and in others which we have seen, the chief difficulty with an early seasonal application of arsenicals to the expanding foliage is that when the leaves are unfolding and growing rapidly the weevils can select trees which are free from arsenic. This is particularly true if the beetles are abroad in abundance when the leaf buds are just breaking, and here an additional difficulty is encountered in that there is not enough leaf surface on which the poison can be lodged and held.

FIG. 14. Inverted cloth cone suspended from trees sprayed with arsenicals to test the effectiveness of the several poisons tried.

The residual effect of summer spraying with arsenicals.—One of two adjoining orchards, both badly infested, was treated the second week in June with an upshoot spray of arsenate of lead without a fungicide, at a time to poison the weevils as they left their summer mines and began to feed. The foliage of both orchards at this time was so badly injured by the weevils that it was difficult later to see that any good had been done by the spray; but the following spring, after the adults had emerged from their winter quarters, the number of weevils was very noticeably smaller in the sprayed orchard. To determine definitely the difference in numbers in the two orchards, counts were made from a large number of buds on trees in adjoining rows in the two orchards, and in each orchard on the third and fifth rows from these adjoining rows. In the sprayed orchard 329 weevils were found on 4800 buds, and in the unsprayed orchard 1052 weevils on the same number. Thus over two-thirds of the weevil population was destroyed in the sprayed orchard. Had the spray been applied two weeks earlier, no doubt much injury to the foliage would have been prevented, and in all probability the reduction of infestation the following year would have been equally great.

Summary on summer spraying with arsenicals.—In brief, the general conclusions which may be drawn from the summer application of arsenicals and arsenicals in combination with fungicides are as follows:

In all of the trials save one, a decided repellent effect was obtained when either lime-sulfur or Bordeaux mixture was used in connection with the arsenical, and in this one exception a kill was obtained equal to that following the use of arsenicals alone. In every instance where arsenicals were applied, some killing resulted, but it is an open question whether the percentage of beetles killed or repelled warranted the cost of the extra application. The kind of application required, that is, spraying the under side of the leaves, is wasteful of both material and labor, and is therefore more expensive than the usual application in which no effort is made to cover anything but the upper surface. The only occasion in which extra summer applications of arsenicals might possibly prove profitable would be in excessively severe outbreaks where a partial control might prevent extreme weakening of the trees.

SUMMER APPLICATIONS OF CONTACT INSECTICIDES

Our experiments with summer contact insecticides were all of a preliminary character and need only be summarized briefly. With the exception of the last named, they were all made in June after considerable damage had been done by the new brood of adults. The insecticides used, were scalecide, a mixture of scalecide and soluble sulfur, Lasher's soap, black leaf forty, kerosene emulsion, and nicotine dust. Neither of the first two proved effective at strengths which did not injure the foliage.

Lasher's soap.—Twelve heavily infested trees were sprayed with a solution of Lasher's soap, 10 lbs. to 100 gallons of water. A heavy rain interrupted the work after the tenth tree had been sprayed. Spraying the trees causes the weevils to drop, and nearly all were driven from the trees. A canvas, spread under one of the trees before the spraying began, caught no less than 24,000 weevils, but most of them, though apparently dead, showed signs of life when disturbed. Some were inclosed in a bottle for observation, but less than 8 per cent. recovered. Two days later two more trees were sprayed with what remained of the solution, under the same conditions except that in this case there was no rain. The canvas under one of the trees was blackened with the adults which fell. These, however, were more lively than those in the former trial, and most of them gradually recovered. Only one fifth of the original number remained on the canvas two days later, and many of these were alive. It was concluded that this soap was worthless as an insecticide against the apple flea-weevil, and no further experiments with it were made. Possibly the heavy rain had something to do with the high mortality in the first instance.

Nicotine sulphate liquid.—A number of low-hanging branches were sprayed with the "black leaf forty" brand of nicotine sulphate, prepared as follows:

Black leaf forty	½ ounce
Laundry soap	2 ounces
Water	2 gallons

A canvas was spread under the tree to catch the weevils as they dropped. Some of them showed signs of life and were sprayed again while lying on the canvas. Three hours later all were dead.

Kerosene emulsion.—Branches infested with the weevil were sprayed in the same manner with kerosene emulsion at strengths of 5 per cent., 7½ per cent., 10 per cent., and 15 per cent. The 5 per cent. emulsion did not kill the beetles outright, and it was necessary to spray them as they lay on the canvas to insure their death; but the stronger emulsions apparently killed all the adults hit by them.

To test further the effectiveness of kerosene emulsion, 30 trees were sprayed with a 5 per cent. and 20 trees with a 7½ per cent. emulsion. Two canvases, each 15×30 feet, were spread under the trees while the spraying was in progress, each with a 1×4 inch board along one end as a convenience in moving it from tree to tree (see Figure 15). A man or a boy was needed to handle each of the canvases. As soon as the spraying of a tree was finished the canvas-men dragged the canvas quickly to the next tree, and little delay was occasioned.

The weevils fell on the canvas in large numbers, and here they were sprayed again, practically all of them being thus killed. After the ninth tree was sprayed counts were made of the dead weevils in two areas of a square foot each, 250 weevils being found on one square foot and 300 on the other. It was estimated that there were not less than 80,000 weevils on the canvases, indicating an average of nearly 9000 per tree which were killed by the treatment.

After the spraying was completed, counts were made to determine the comparative numbers of weevils on sprayed and unsprayed trees close together. On unsprayed trees 236 weevils were counted on 1650 leaves and on sprayed trees 40 weevils on 2300 leaves; or .143 and .018 weevils per leaf respectively—a decrease of about 90 per cent. in the number of weevils.

The trees in this orchard were trimmed high and the soil was well cultivated, hence there was nothing to interfere with the movement of the canvases. In another orchard, however, in which the branches hung low, many touching the ground, it was found entirely impracticable to handle the canvases. However, satisfactory results should be obtained with a 7½ per cent. emulsion without the use of the canvas.

FIG. 15. In spraying with some of the contact insecticides it was found of advantage to spread a canvas under the tree while the insecticide was being applied. The fallen beetles were soaked by the liquid and death was more likely to result. The canvas was divided into two parts and an edge of each was nailed to a strip of wood to facilitate handling.

Dusting with nicotine.—The dust used in this experiment was one containing 1½ per cent. of free nicotine, and the application was made with a large-size new model Niagara duster operating at full speed. The work was done about 10 a. m. on a bright sunny day at a temperature of about 70°. The overwintering beetles were feeding in abundance on the newly developed foliage, and were doing noticeable damage.

The application was ineffective, large sheets spread beneath the dusted trees having on them no dead beetles after 10 hours, although the disturbance caused by the operation had caused a considerable dropping of beetles and many were covered with dust. Moreover, beetles placed in the original dust-container in which a little of the material remained, were still alive after 4 hours, unless they had meantime been lying directly in the dust. Such beetles survived one or two hours, but then showed no signs of life.

Summary on summer applications of contact insecticides.—The most promising of the contact insecticides used as summer applications was 7½ per cent. kerosene emulsion. The 5 per cent. emulsion gave fair results when sheets were spread under the trees and the beetles which fell thereon were drenched. If the emulsions had been applied about the middle of April, after the hibernating adults had migrated to the trees and before any considerable number of eggs had been deposited, no doubt a very great reduction in the number of the new brood and in injury to the foliage would have resulted. A spray applied at this time, when there is little foliage on the trees, would also be effective against aphids.

DESTROYING THE BEETLES IN HIBERNATION

As has been shown previously, the adult beetles hibernate in trash in the orchard, and do not go into the ground, and since the period of their retirement is of long duration—from late summer to the following April or May—an excellent opportunity is afforded for effective work, and the following methods were given trial.

Paradichlorobenzene.—Successful use of this material against the peach-tree borer suggested its use against the apple flea-weevil while in hibernation, and it was scattered broadcast under the spreading branches of old apple trees growing in a heavy sod-mulch. The application was made April 12, a few days before the beetles left winter quarters, at rates of 2, 4, 6, 8, and 12 pounds to a tree. It was evidently of no value, since the beetles were quite as abundant on these trees after the beetles emerged, as on their untreated neighbors.

Hydrated lime.—Hydrated lime at the rate of 25 and 50 pounds per tree was scattered under the spreading branches of 25-year old apple trees growing in heavy sod. The application was made April 27 as the beetles were becoming active, and it was thought that they might perish in passing through the dust, but trap cages placed over representative areas under the trees so treated, collected considerable numbers of beetles, indicating that the application had little if any merit.

Fuel oil.—Trees growing in the same orchard in which the immediately preceding experiment was made, were treated with fuel oil spread by means of a common garden-sprinkling can at the rate of 2 and 4 gallons to the tree. The quantities used will not properly cover such an area, and the cost of a sufficient treatment would be prohibitive. Undoubtedly some beetles were destroyed, but the gross effect on the beetle population of the trees was not noticeable. If the oil were applied in sufficient quantity, perhaps 10 gallons per tree, control could probably be secured, since trap cages used on areas so treated yielded no beetles, but possible injury to the trees which might result, still renders the method of doubtful economy.

Poisoned bran mash.—Since the beetles sometimes leave hibernation before the apple trees are in leaf it was thought that a poisoned bait scattered on the grass under the trees might attract the beetles and destroy them. The standard grasshopper formula was used—bran, 20 lbs.; Paris green, 1 lb.; syrup, 2 quarts; 3 grated lemons; and 3½ gallons of water. Two and a half lbs. of the bait was scattered under the spread of 25-year old apple trees on April 27, when the beetles were becoming active and the foliage was just starting. Not only did the bait fail to attract the beetles in the open, but individuals confined with it did not die from eating it.

Spraying the trash under the trees with a solution of potassium ferrocyanide.—In early April, before the beetles became active, the grass and mulch under apple trees in a badly infested orchard was evenly sprayed with enough of a solution of potassium ferrocyanide to make the mulch quite damp. Two strengths of the solution were tried; one of a pound and another of 2⅓ pounds to 50 gallons of water. It was thought that the fumes might kill the hibernating beetles, but no dead beetles were found in the treated areas, and later on, when the beetles emerged, these trees were as severely attacked as their untreated neighbors.

Spraying the trash with other materials.—In 1919, an orchard at Flora, Illinois, heavily infested with weevils, was selected for a series of experiments to ascertain if wetting the refuse beneath the trees with a contact insecticide would destroy the beetles in hibernation. The orchard had been cultivated down the center of the space between the rows but not within six or eight feet of the trunks of the trees. The litter under the trees was of about the usual depth. During the latter part of November plots were laid out six trees square and the litter under the trees was sprayed with enough of the insecticides to wet thoroughly through the cover to the surface of the soil. The amount applied was 15 gallons per tree.

Before the insecticides were applied, counts were made of the numbers of flea-weevils in hibernation about the bases of a number of trees in each plot. The weevils were also counted under five trees left untreated as a check. During the latter part of February another series of counts was made on the same number of trees in the center of each plot and the number of living and dead weevils was noted. The results of these treatments are given in the following table.

Insecticide	No. trees	After spraying, No. weevils alive in:				After spraying, No. weevils dead in:				
		first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	% dead
Scalecide 1—15	2	8	0	1	9	19	11	5	35	80
Scalecide 1—10	2	26	8	21	55	35	41	21	97	64
Black leaf forty 1—500	3	68	103	64	235	25	9	26	60	20
Kerosene emulsion 15%	1	0	0	0	0	48	5	3	56	100
Kerosene emulsion 10%	1	3	0	3	6	79	44	22	145	96
Whale-oil soap 1 lb.—10 gal.	5	261	191	115	567	14	12	10	36	6
Lime, 1 pk. per tree	3	125	78	64	267	3	1	3	7	3
Check	5	90	69	80	239	7	1	1	9	4

Summary concerning measures, other than burning, for destroying the beetles in hibernation.—As is shown, none of the immediately foregoing group of materials (see table) even approached satisfactory control save kerosene emulsion. This proved very effective at 10 per cent. strength, and could probably be used with safety. The cost of treating with kerosene emulsion would be approximately $20 an acre and with scalecide $30 an acre.

BURNING IN HIBERNATION

Without use of blow torch.—The possibility of burning the apple flea-weevil in its winter quarters has probably suggested itself to every one having any experience with the pest, and some of our best results in the search for an adequate control have been obtained by this means. Two different methods were used: burning off the trash and leaves in dry weather, and burning with a torch. Success in burning without a blow torch depends largely on the character of the refuse under the trees and its condition as to moisture content. Two tests were made in the Braden orchard at Olney, Ill., with results as shown in the accompanying table.

Another experiment with surface burning was made in early April, 1920, in the orchard of the Delaware Apple Company, at Delaware, O. This orchard was 10 to 12 years old and had been in grass for several years, so that a well-matted sod had developed. When the burning was done the trash was fairly dry, particularly between the tree rows, and dry enough under the trees so that the fire burned a surface layer up to the trunk though it did not consume all the fallen leaves. Immediately under the trees, however, enough burning was done to cause noticeable injury to the lower branches, as the low-headed type of pruning had been practiced. No noticeable decrease in the number of weevils in this section was found after the brood emerged; indeed the seasonal injury was, if anything, greater, for the burning of the surface cover had exposed the beetles to the spring sun, thus bringing them out of hibernation a few days earlier than on the unburned section. As a result, they attacked the foliage with telling effect as it began to expand.

With blow torch.—This type of burning has proven, under some conditions, the most effective of the control measures tried. If the orchard was partly cultivated, thus forcing the beetles to hibernate on a comparatively small area under the trees, the result was excellent, but if the orchard was in sod, affording hibernating quarters throughout the area occupied by the trees, it was found to be of little value.

Two kinds of torches were used for this work, one burning kerosene and one gasoline. The kerosene torch, of a type commonly used for melting asphalt in paving streets, proved the more effective. It is made by the Houck Manufacturing Co., and consists of a 5-gallon tank equipped with an air-pump and gauge for supplying and registering the necessary pressure. The torch proper is connected to the tank by a flexible hose, and is so constructed that the kerosene is vaporized to form an exceedingly hot blue flame from 8 to 12 inches long and about

Date of burning	No. of trees	Before burning, No. of weevils alive in:				After burning, No. of weevils alive in:				% killed
		first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	
November, 1920	2	24	13	5	42	10	6	4	20	50
February, 1920	3	48	45	21	114	17	14	14	45	71

4 inches wide. One man can operate the machine, stopping occasionally to replenish the pressure by pumping.

In using the torch, all trash and mulch in a circular area some five feet in diameter about the trunk of the tree was burned clean to the dirt. The time required varied with the density and moisture content of the covering. Unless the sod and mulch is especially heavy, effective work can be done in ten to fifteen minutes per tree, but if the sod is very heavy and of long standing, and particularly if it is damp, as much as half an hour will be required for each tree.

Four tests were made: two in the Braden orchard at Olney, Ill.; one in the Tanner orchard at Flora, Ill.; and one in the Vergon orchard at Delaware, O. The following table gives the results obtained in the first three tests.

Further proof that the burning had a marked effect in reducing the number of weevils is seen by contrasting the numbers of mined leaves in the burned and unburned sections the following spring. In the orchard treated at Olney in the winter of 1919-20, 70 per cent. of the leaves in the unburned part and only 34 per cent. of the leaves in the burned area showed larval mines the following spring. At Flora, 28 per cent. of the leaves showed larval mines in the unburned area and 14 per cent. in the burned area.

From examinations made in the Flora orchard at frequent intervals from the time when the beetles started out of their winter quarters in spring it was evident that there had been considerable migration of the insects from the unburned to the burned area.

The fourth test of the blow torch for burning the weevil in hibernation was made at Delaware, O., in the old Vergon orchard, the same type of kerosene torch being used as in the Illinois work. This orchard it will be recalled, had been in grass for many years. Since the lower limbs of the trees had been killed or so weakened by the flea-weevils that they were of little value, they had been removed and the heavy blue-grass sod had become established quite up to the trunks of the trees. Under this condition we found burning difficult, since, if the sod was dampened by rain or snow, at least 30 minutes, and sometimes longer, were required to burn over a circular area five or six feet in diameter, and even after burning for that length of time we occasionally found live weevils within the burned area. Moreover, as shown before, all the weevils were not hibernating within the burned area, but many were in the sod between the tree rows as well as under the spread of the branches, hence it is easily understood why no apparent diminution could be seen the following spring in the burned as compared with the unburned area of this orchard. In this instance, therefore, we were forced to conclude that burning was of little practical value.

Summary on burning in hibernation.—Our experience with this kind of control leads us to believe that surface burning without the

Place and date of burning and other details	No. of trees	Before burning, No. of weevils alive in:				After burning, No. of weevils alive in:				% killed
		first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	first sq. ft. from tree	second sq. ft. from tree	third sq. ft. from tree	Total	
Braden orchard, Olney, Ill. November, 1920 Torch using 1 gal. kerosene for 2 trees Time: 15 min. per tree	25	319	190	155	664	5	1	2	8	98.8
Braden orchard, Olney, Ill. Torch using kerosene	4	83	68	29	180	2	2	2	6	96.7
Tanner orchard, Flora, Ill. Nov. and Dec., 1919 Torch using 1 gal. gasoline to 7 trees Time: 15 min. per tree	5	222	110	72	404	19	14	7	40	90

use of the blow torch is of little practical value, and under some conditions may prove harmful because of the possible injury to low-hanging branches and because it may result in the weevils leaving hibernation early.

Burning with the blow torch is decidedly effective in partly cultivated orchards where the beetles are forced to concentrate for hibernation around the base of the tree because the spaces between the tree rows are either barren or the covering is not such as to attract the beetles seeking winter quarters. Where the orchard is in heavy sod of long standing, burning is not a satisfactory means of control because so much time is required for the operation and because the beetles do not concentrate around the base of the tree.

CULTIVATION

By all odds the cheapest and most effective control measure tried under Ohio conditions is clean cultivation, the object being either to destroy the insects in hibernation by plowing them under in fall or early winter, or else by summer cultivation to eliminate all sod and refuse in which they could find winter quarters.

In November, 1918, four acres were plowed to a depth of 4 inches in the midst of the Delaware Apple Company's 40-acre orchard at Delaware, Ohio, then owned by Mr. Hudson. This particular four acres was chosen because it was the very worst infested section in the property. It had been in grass for twenty years or more, and a very tough sod had developed. Only 15 to 20 square feet remained unturned about the base of each tree, and part of this was unsuitable for the hibernation of the beetles because it was covered with cinders, and because some of the protecting refuse blew away.

The following summer the injury in the plowed plot was very slight, particularly from the beetles as they left hibernation in spring and from the mining larvae; but it became somewhat greater when beetles of the new generation spread over the cultivated plot from surrounding trees. However, the total injury to trees in the cultivated plot was not of commercial importance.

This original four-acre plot has been kept in clean cultivation up to the present time, and at no time during the four seasons have the beetles caused commercial injury. Indeed during most of the time it has required searching to find evidence of the beetles' presence in the more central parts of the plot. Moreover, the cultivation has proven of benefit to the trees. They have taken on new vigor and have been markedly more productive than trees of the same age and variety where the ground had not been plowed.

In the summer of 1821 the remainder of the orchard was broken up by numerous cuttings with a double disc and Fordson tractor, the latter so covered as to pass under low limbs without injury to them (see Figure 16). The following season saw a marked limitation in the numbers of beetles in the entire orchard, and since the sod was almost if not quite destroyed by cultivation the next year (1922), the injury of the present year (1923) has been almost nothing. The original Vergon orchard adjoining this one, but in which plowing was not done until the fall of 1922, has been very heavily infested, and at this time some of the trees are so weakened that they are in a precarious situation.

FIG. 16. Fordson tractor equipped with a shield for orchard work, designed by E. L. Main, Delaware, O. The boards, being smooth, lifted the limbs without injury.

The resident growers who have watched the practical elimination of the apple flea-weevil from the Delaware Apple Company's orchard are firmly convinced, as have been several trained observers who have watched the work, that cultivation has in this instance effectively controlled the apple flea-weevil and at the same time has been of decided benefit to the trees from the cultural standpoint.

It should be borne in mind, however, that the cultivation has been absolutely thorough, and that the work done with the implements has been supplemented when necessary by the use of hoes and mattocks to kill any sod close to the tree trunks. On the other hand, a lack of supplementary hand-work may account for the fact that the beetle is found in some Illinois orchards which have been only partially cultivated.

General Summary

1. The apple flea-weevil, a native insect generally distributed from Nova Scotia and Quebec to Oregon, Texas, and Virginia, has

been found notably injurious only in southern and central Illinois and in a limited district in central Ohio.

2. It feeds in small numbers, as beetle or larva, on a considerable variety of native trees and shrubs, but is definitely injurious only to the cultivated apple.

3. The adult beetle is a shining black, densely punctate snout-beetle, about a tenth of an inch long. It is readily distinguished by its much thickened hind thighs and by its exceptional power of leaping, like a flea, when disturbed. The white to brownish larva, found only in leaf-mines, is flattened cylindrical, tapering from the middle towards both ends. It is about a fifth of an inch long when full grown, and at its widest part a fourth as wide as long. It hatches from an egg laid in one of the thicker veins of the under side of the leaf, and feeds on the leaf parenchyma, making a closed mine or burrow which is finally expanded at its outer end into a blotchlike blister within which the larva pupates.

4. There is but one generation a year, the newly formed adults of which emerge from their mines in May and June, feed on the leaves for about a month, and then, in June and July, leave the tree to conceal themselves in what are to be their winter quarters, under grass, leaves, and rubbish on the ground. Here they remain until spring, leaving their shelter at about the time of the unfolding of the leaf, creeping up the trunks of the trees, or flying to the branches above, and beginning again to feed on the leaves, in which eggs are presently laid for the next generation. The egg period lasts about a week, that of the larva 17 days, and the pupal period 5 or 6 days.

5. Injury is done by both the larval mines and the feeding-punctures of the beetles, usually made in the under side of the leaf. The maximum effect in badly infested orchards is a destruction of the leafage sufficient seriously to weaken the tree and reduce it to worthlessness.

6. The principal natural checks on the multiplication of the weevils are fungus and insect parasites, the former destroying the beetles by wholesale in wet summers and the latter killing the larvae.

7. Experiments with means of control were made by banding the tree trunks with tanglefoot, spraying or dusting the leaves with poisons or with contact insecticides, burning the hibernating beetles in grass and rubbish under the trees, poisoning them there with sprays and poison dusts and by the use of poison baits, and cultivation of the orchard at a time and in a way to bury the hibernating beetles beyond resurrection or to keep the ground free from cover to which they might retreat in summer for concealment and hibernation.

Thoroughly clean cultivation, carried close to the tree, was the most effective of these means, reducing formidable infestations to insignificance and improving the vigor and productiveness of the trees.

Next to this was a spray of kerosene emulsion containing 7½ per cent. of kerosene, which, properly applied, killed practically all the beetles—as many in one instance as 9000 to the tree.

Burning in hibernation by a powerful kerosene blow-torch, of a kind used to melt asphalt in paving streets, was effective and useful when an orchard had been so cultivated as to concentrate the beetles under the trees, provided that the cover was of a kind to be burned completely at a reasonable expense for kerosene and labor.

None of the various other means and methods with which experiments were made, were sufficiently useful or promising to justify their recommendation.

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
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NATURAL HISTORY SURVEY
STEPHEN A. FORBES, Chief

Vol. XV. BULLETIN Article II.

Notes on a Collection of Erythroneura and Hymetta (*Eupterygidae*) chiefly from Illinois, with Descriptions of New Forms

BY

W. L. McATEE

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
April, 1924

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ARTICLE II.—*Notes on a Collection of Erythroneura and Hymetta (Eupterygidae) chiefly from Illinois, with Descriptions of New Forms.* BY W. L. MCATEE.

The collection here reported upon was identified and descriptions of new forms written several months ago, completion of the report being delayed by lack of time to trace out a few loose ends. As a new revision of the genus Erythroneura is under way it is thought best to put on record now these Illinois data. The Eupterygidae were long a favorite group with the late Charles A. Hart, who substantially assisted Gillette's revision (Proc. U. S. Nat. Mus. 20, 1898, pp. 750-773) with loans of material. He had sorted subsequent collections of the State Natural History Survey and had invented manuscript names for most of the undescribed forms. A number of these were independently named in the Key to the Nearctic Species and Varieties of Erythroneura (Trans. Am. Ent. Soc., 46, pp. 267-321, August, 1920) by the writer, who did not have Hart's material at hand at the time. Some of the others are here described and the writer is glad to adopt Hart's MS. names for three of them, namely *lunata*, *oculata* and *rufomaculata*. Many of the specimens of more recent date here recorded were collected by J. R. Malloch, and some of an intermediate period by J. D. Hood. Many records here given are the first since the original description of the forms involved.

GENUS ERYTHRONEURA FITCH

E. vulnerata var. vulnerata Fitch, red form.—Urbana, Jan. 11, 1908, Nov. 11, 1915; St. Joseph, Sept. 3, 1916; No. 25069; also Brownsville, Tex., Nov. 21, 1911, palm jungle sweepings, C. A. Hart.

E. vulnerata var. niger Gillette.—Danville, March 12, 1910; Dongola, Aug. 22, 1916; also Nos. 23671 and 25019.

E. vulnerata var. nigerrima McAtee.—Dongola, Aug. 23; Urbana, Sept. 20, 1916; Algonquin, Oct. 5, 16, 1895; and Nos. 23671, and 25783.

ERYTHRONEURA OCULATA, NEW SPECIES

In outline as seen from above this species resembles *E. vulnerata* Fitch, the shape of the vertex being nearly the same; the venation however is as in my Group 2 (i. e. like that of *E. obliqua* Say). The ground color of the present species is pale greenish yellow, and the most distinctive markings are: a pair of round velvety black spots on the upper part of face near eyes, and a similar pair, closer together on vertex just back of apex; there are also four dark spots in a transverse row on anterior disk of pronotum, a spot on each anterior angle back of eye and a falcate vitta near middle of each lateral margin; the basal triangles of scutellum are velvety black. There are no other dark markings above, but the apical cells and clearer parts of corium especially the long cells between the sectors are chiefly dusky fumose. Red markings are present as follows: a broad, anteriorly convex lunate vitta on middle of pronotum, 3 blotches on each clavus, the middle one largest, 2 blotches between third sector and claval suture, and 2 short lines on second sector; the wings are dusky fumose. Color below smoky-brown, a pale-yellow area about each velvety black spot on face and a top-shaped pale area on middle of front; antennae and legs pale yellowish. Length 3 mm.

Holotype, ♀, Brownsville, Tex., Nov. 30, 1910, in sweepings from weeds, C. A. Hart (Ill. State Nat. Hist. Survey).

E. obliqua var. obliqua Say, red form.—Urbana, Nov. 13, 1915, Nov. 22, 1906; St. Joseph, Nov. 10, 1906; White Heath, May 7, 1909, April 30, 1916; Hopedale, Oct. 2, 1917; and Nos. 156, 279, 3341, and 25018. Yellow form.—White Heath, May 7, 1909; Dubois, Aug. 8, 1917; and Nos. 25764, and 25789.

E. obliqua var. dorsalis Gillette, red form.—White Heath, May 7, 1909; Algonquin, June 12, 1897; and Nos. 4459, 14873, and 25742; also Iowa, Ac. Cat. 910.

E. obliqua var. stolata McAtee.—Savanna, June 12, 1917.

E. obliqua var. noevus Gillette, red form.—White Heath, May 7, 1909; Urbana, Oct. 22, 1916. Yellow form.—Muncie, May 24, 1914.

E. obliqua var. fumida Gillette, red form.—St. Joseph, Nov. 10, 1906; Hopedale, Oct. 2, 1917; and No. 156.

E. obliqua var. electa McAtee.—St. Joseph, Nov. 10, 1906.

E. rubroscuta Gillette.—No. 3171.

E. dentata Gillette.—Meredosia, Aug. 20, 1917. Previously known only from the type material which was collected in California.

E. abolla var. abolla McAtee, red form.—Urbana, Nov. 10, 11, 1915; Dongola, May 10, 1916; Dubois, May 23, 1917. Yellow form.—Monticello, Ill., June 28, 1914; Dongola, Aug. 22, 1916. The specimen from Monticello has diffuse red markings along posterior parts of the sectors especially the third.

E. abolla var. varia, McAtee, red form.—White Heath, June 2, 1917; St. Joseph, Nov. 10, 1906; Urbana, March 24, 1916; Meredosia, May 29, 1917; Dubois, May 22, 1917; and No. 25792. Yellow form.—Dongola, Aug. 23, 1916.

E. abolla var. accensa McAtee.—White Heath, April 30, 1916; Dubois, May 22, 1917.

E. tecta var. tecta McAtee.—No. 16064. *E. sexpunctata* Malloch (Bul. Brooklyn Ent. Soc. 16, No. 1, Feb. 1921, p. 25) is a synonym.

ERYTHRONEURA MALLOCHI, NEW SPECIES

Belongs in Group 4 of my Key, being somewhat intermediate between *E. tecta* and the remaining species; vertex more pointed than in that species and first apical cell small. Color of head and thorax above, pale yellow; scutellum with basal triangles nearly black; tegmen with dusky streaks which occupy nearly all of its surface except inner base of clavus, base of corium, most of costa and distal parts of 3rd and 4th apical cells. Face pale yellow, a v-shaped mark bounding it and clypeus, bluish black, cheeks whitish; body bluish black with pale yellow edgings. Length 3 mm.

Holotype, ♂, Meredosia, Ill., May 30, 1917. (Ill. State Nat. Hist. Survey.)

ERYTHRONEURA LUNATA, NEW SPECIES

Belongs to Group 4 of my Key, having the vertex without dots and more pointed than in *E. tecta* and diverging greatly in coloration from any of the other species. Ground color somewhat opaque whitish, more or less tinged with reddish throughout and with the following distinct pinkish-red markings: fine irrorations tending to be grouped in a transverse band between anterior angles of eyes, and a short posterior median vitta on head, a spot in each anterior angle, more or less of front margin, and a median vitta on pronotum; four posteriorly oblique red streaks from costa of tegmen, one at front of corium, one at each end of costal plaque and one more or less ramose overlying cross-veins. The scutellum has the base narrowly, the basal triangles, and apex dusky to black, and there are two triangular markings on middle of clavus, and two elongate posteriorly directed markings on the corii just outside these, dusky to black, that form when tegmina are folded a broken posteriorly open semicircle; a dusky band extends from hind edge of costal plaque to radial margin, leaving costa and most of the exceptionally long first apical cell clear; this band is interrupted near radial margin by the paler veins; first apical cell with a dark dot near apex, second nearly filled by a dusky marking; fourth dusky at base. Face with an irregular cross-band and short median vitta reddish; genitalia tipped with black, and dorsum of abdomen with two broad dusky vittae. Length 3 mm.

Holotype, ♂, Urbana, Ill., Nov. 11, 1915; and allotype, ♀, White Heath, Ill., May 7, 1909. (Ill. State Nat. Hist. Survey.)

E. aclys McAtee.—White Heath, May 7, 1909.

E. illinoiensis var. illinoiensis Gillette, yellow form.—Hopedale, Oct. 2, 1917; Dongola, Aug. 24, 1916, on grape; and No. 1992. The latter specimen is marked type but it is not referred to in the original description so does not help to settle the question as to what specimen may properly be regarded as the holotype of this species.

E. morgani De Long, red form.—White Heath, April 28, 1916. Yellow form: Kampsville, Aug. 21, 1913, on sycamore; Meredosia, May 28, 1917; St. Joseph, Sept. 3, 1916, on grape.

E. hartii Gillette.—Algonquin, June 12, 1897; Nos. 14873, 18036, 25019, 29785.

E. basilaris var. basilaris Say, red form.—White Heath, April 17, 1909; Urbana, Nov. 13, 1915, Nov. 22, 1906; St. Joseph, Nov. 10, 1906; Hopedale, Oct. 2, 1917.

E. maculata var. maculata Gillette, red form.—Urbana, March 24, 1916, among leaves; Olney, Sept. 21, 1916, on apple; Metropolis, Aug. 20, 1916. Yellow form: Sumner, Aug. 2, 1914; Kampsville, Aug. 21, 1913, on sycamore; White Heath, May 7, 1909; Havana, April 30, 1914; Muncie, May 24, July 5, 1914; Nos. 25, 764, 25805, 40309, 43384, 50835; also Colo. 1751.

E. maculata var. era McAtee, yellow form.—Muncie, Nov. 1, 1913.

E. maculata var. osborni De Long, red form.—No. 156, Hart Coll. Yellow form: St. Joseph, Sept. 3, 1916, on grape.

E. ligata var. ligata McAtee.—Algonquin, May 18, 1896.

E. ligata var. allecta McAtee.—Algonquin, Oct. 29, 1896.

Erythroneura ligata var. pupillata, new variety

Like *Erythroneura ligata* var. *allecta* McAtee, with the addition of dusky coloration over anterior half of clavus and 2 dusky to black vittae on middle of pronotum and scutellum sometimes coalescing to form large blotches. Length, 3 mm.

Holotype, ♂, No. 25069 Ill.; paratypes, same data, also No. 152 Hart Coll., and Urbana, Ill., July 7, 1915, on window. One paratype in writer's collection; other material in collection of Illinois State Natural History Survey.

E. infuscata Gillette.—Dongola, Aug. 27, 1916; and No. 156.

E. vitis var. vitis Harris.—White Heath, May 7, 1909; Clayton, Sept. 30, 1916; Urbana, March 24, 1916, among leaves; Nos. 25018, 25750.

E. vitis var. corona McAtee.—White Heath, May 7, 1909, and No. 156.

E. vitis var. bistrata McAtee.—White Heath, May 7, 1909; Dongola, Aug. 27, 1916.

E. tricincta var. tricincta Fitch, red form.—White Heath, May 7, 1909; Nos. 156, 10819, 25019. Yellow form, White Heath, May 7, 1909; No. 10819.

E. tricincta var. calycula McAtee, red form.—Danville, March 12, 1910. Yellow form, No. 5672.

E. comes var. comes Say, yellow form.—Clay City, Sept. 2, 1909, and No. 17398.

E. comes var. vitifex Fitch, yellow form.—Meredosia, May 28, 1917.

Erythroneura comes var. palimpsesta, new variety

Like *E. comes* var. *vitifex* Fitch except that the red vitta on anterior half of clavus and the adjacent short vitta on corium are overlaid or replaced by black; the lateral vittae on pronotum and the sides of the scutellum also may be dusky to black, and the oblique dusky band across apical cells is well marked. Triangular area below base of antenna, pro- and meso-pleura, base and apex of genitalia and broad vittae on dorsum of abdomen also may be dusky to black. Length 3 mm.

Holotype, ♂, and two ♀'s, one of which is allotype, Forest City, Ill., April 3, 1917. (Ill. State Nat. Hist. Survey.)

E. comes var. elegans McAtee.—Urbana, July 8, Oct. 12, Nov. 14, 1915; McLeansboro, Sept. 3, 1914, on Ampelopsis; White Heath, May 7, 1909; Algonquin, Aug. 28, 1894, Sept. 15, 1895; Nos. 15474, 25018; also Colorado, 1748.

E. comes var. rubrella McAtee.—White Heath, May 7, 1909; Algonquin, Oct. 5, 1895.

Erythroneura comes var. reflecta, new variety

Much like *E. comes* var. *rubra* Gillette in connection with which it was mentioned in my Key, but the pale markings are more extensive, and the red ones instead of being a solid jasper-red as in that form are dilute bluish-red with carmine edgings; the fact that all of the red vittae are of this compound character gives the variety the appearance of having the most complex pattern of any of the *comes* varieties.

Type, ♀, Plummers Island, Md., Dec. 14, 1913, W. L. McAtee; paratypes same locality and collector, Nov. 30, Dec. 21, 1913; Great Falls, Va., April 20, 1916, W. L. McAtee; Chain Bridge, Va., April 16, 1922, J. R. Malloch; Centerville, Ill., Aug. 16, 1914 (Ill. State Nat. Hist. Survey); Iowa City, Iowa, June 4, 1915, L. L. Buchanan; Onaga, Kansas, Jan. 6, 1921, F. F. Crevecoeur.

E. comes var. compta McAtee, red form.—Urbana, Nov. 22, 1906; White Heath, April 17, 1909; Hopedale, Oct. 2, 1917. Yellow form, Dubois, May 24, 1917.

Erythroneura comes var. rufomaculata, new variety

Like *E. comes* var. *compta* McAtee, yellow form, except that the anterior two-thirds of clavus is occupied, saving a clear dot at inner angle, by an orange-red spot, and the adjoining markings of the corium are of the same color.

Holotype, ♀, Clay City, Ill., Aug. 17, 1911; paratypes, same data, also Urbana, Ill., Aug. 23, 1914, on grape; and Ill. 1992 (Ill. State Nat. Hist. Survey).

E. comes var. amanda McAtee.—Nos. 17398, 17399.

E. comes var. ziczac Walsh, yellow form.—Meredosia, May 28, 1917; St. Joseph, Sept. 3, 1916, on grape.

Genus Hymetta McAtee

H. trifasciata var. balteata McAtee.—Urbana, March 24, 1916, among leaves; Dongola, May 10, 1916; Muncie, Dec. 13, 1913; and Nos. 15416, 25807.

H. trifasciata var. albata McAtee.—Clayton, Ill., Sept. 30, 1916.

H. trifasciata var. anthisma McAtee.—Dubois, May 22, 1917; Brownfield, Aug. 17, 1916; Muncie, June 3, 1917; and No. 1992.

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Vol. XV. BULLETIN Article III.

Second Report on a Forest Survey of Illinois. The Economics of Forestry in the State

BY
HERMAN H. CHAPMAN
and
ROBERT B. MILLER

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
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CONTENTS

INTRODUCTION

A forest survey of Illinois was begun by the State Natural History Survey in July, 1919, when Mr. R. B. Miller was engaged for a preliminary general study of the Illinois situation and conditions and for educational and publicity work intended to open the way to active, practical studies on a larger scale. In 1921 three additional foresters, with Mr. C. J. Telford in charge, entered upon a systematic survey of Illinois woodlands with a view to their location and area, their composition and condition, their present management and utilization, and their productivity as shown by the rates of growth of important kinds of trees on various soils, in various situations, under various conditions, and in all parts of the state.

As these data were accumulated, it first became possible to make an intelligent study of the values of our woodlands, of the economics of forest management and production in Illinois, and of the relation of the local supply of forest products, present and prospective, actual and possible, to the demands of our Illinois industries—matters fundamental to any adequate forestry policy, either for the state or for the owner of forest property or of lands especially adapted to forest culture.

This difficult, intricate, and supremely important part of the survey program was taken up by Herman H. Chapman, Professor of Forest Management in the Yale University School of Forestry, and the present report, filed by him for publication in June, 1924, is the product of his work during the summers of 1922 and 1923, supplemented by much additional inquiry carried on under his direction by foresters Miller and Telford, the former especially having been employed during the greater part of two years in the accumulation and tabulation of additional data. All these materials were passed, however, under the scrutiny of Professor Chapman, who is the final authority for the statements, inferences, and recommendations of the report.

Special mention should be made of the cordial co-operation, in all stages of the survey, of the Agricultural Experiment Station of the University of Illinois, which has given us free access to its accumulated data and much valuable information of a more personal character contributed by the members of the Station staff.

Stephen A. Forbes.

Article III.—*Second Report on a Forestry Survey of Illinois. The Economics of Forestry in the State.* By Herman H. Chapman, Professor of Forest Management, Yale University School of Forestry, and Robert B. Miller, Forester, Illinois State Natural History Survey.

Foreword

Although Illinois is known as a prairie state, yet originally over 40 per cent of its area was covered by virgin forests containing magnificent stands of hardwoods. Now ranked as third in the importance of its agricultural products with its forest area reduced to but 8 per cent of the state's surface, and these remaining forests depleted by axe and fire, the state is yet dependent to an enormous extent on the continuation of abundant supplies of wood to support existing industries, furnish labor and livelihood to her increasing urban population, keep down the cost of living, and maintain the prosperity of the farmer, as well as those engaged in mining, manufacturing, and transportation. To depict these conditions, to determine the relative importance of wood in all its forms in the present economic life of Illinois, and to indicate the lines on which it may be possible to develop a sound and comprehensive policy of dealing with this problem of future wood supply, is the purpose of this report.

Wood and the Industries of Illinois

The state has an area of 56,665 square miles, of which 56,043 square miles, or 35,867,520 acres, is land area. Of this, 89.1 per cent is included in farms and 76.1 per cent is actually devoted to crop production. The state ranks third in value of agricultural products, being exceeded only by Texas and Iowa.

The population numbers 6,485,280, giving the state third rank, following New York and Pennsylvania. There are 237,181 farms, averaging 134.8 acres, and 16.9 per cent of the total population, or 1,090,736 persons, live upon these farms, while 68 per cent reside in towns of 2500 or more inhabitants, and 3,095,137 persons, or nearly 48 per cent of the total population, live in Cook and DuPage counties alone. The density of population on the farms alone does not exceed 20 per square mile, while the average density for the state as a whole, including the remaining village and urban population, is 115.7 per square mile, which is exceeded only by eight states, namely,

Rhode Island	566.4	New York	217.9
Massachusetts	479.2	Pennsylvania	194.5
New Jersey	420.0	Maryland	145.8
Connecticut	286.4	Ohio	141.4

In all densely populated states, it is evident that industries other than farming must support a very large proportion of the population and wage-earners. These immense urban populations do not live as parasites on the labor of the farmer. It is not surprising therefore to note that Illinois ranks third in manufacturing, being outranked only by New York and Pennsylvania, and exceeding Massachusetts and other states in which manufacturing is paramount and agriculture of little importance. Transportation ranks next to agriculture and manufacturing in importance as an employer of labor and capital. The fourth great industry in Illinois is mining in which the state outranks all but three other states, Pennsylvania and West Virginia where coal is of first importance, and Oklahoma whose value is found in oil. Bituminous coal is what gives Illinois fourth rank in mining.

The relative importance to the state of these four main branches of industry may be gaged first as giving employment to labor, second as representing invested capital, and third as to the value of their products. Their statistical rank is set forth in tables on p. 48.

The differences between these four groups are brought out by the totals. Manufacturing takes materials valued by the U. S. Census of 1919 at $3,448,270,446 and by employing approximately twice the number of persons shown by its nearest competitor, agriculture, adds about 1¾ times the total valuation of farm products. This requires an investment of relatively one half the capital required in agriculture.

Agriculture, because of the permanent productiveness of the soil and its limited area, has thus already been capitalized at a value nearly four times as great in proportion to gross income as in manufacturing, and with correspondingly lower margin for profits. By working longer hours, and by the part time employment of minors, farmers produce a greater value per person employed than is produced in factories with the aid of the power obtained from fuel and machinery. The great factory for food products represented by the fertile soil and equable climate of Illinois is effectively utilized. The high investment of capital per person

Class of industry	Persons employed	Capitalization	Value added to products
Manufacturing	804,805[1]	3,366,452,969[1]	1,936,974,248[1]
Agriculture	378,129[2]	6,666,767,235[1]	1,118,000,000[5]
Transportation	220,361		
(Steam railroads)	107,116[3]	1,126,087,160[4]	281,423,557[6]
Mining	90,644[1]	116,669,312[1]	178,673,065[1]

Per person employed	Capitalization	Value added to products
Manufacturing	4,182.94	2,406.76
Agriculture	17,630.93	2,956.63
Steam railroads	10,512.78	2,627.27
Mining	1,287.11	1,971.15

employed and the large production per man indicates the degree to which the art of agriculture has developed and, by inference, reveals the handicap under which the owners of farms on the poorer soils compete with their more fortunately situated neighbors, and offers an explanation of the tendency to abandon certain of the less fertile soils.

In steam transportation, as is to be expected, the capital invested,

[1] U. S. Census 1920.

[2] 380,705 less 2,576 employed in fisheries, and lumbering or forest industries.

[3] The total of 220,361 persons covers all forms of transportation including motor, street railway, and water transport. From this, only those engaged in steam railroad transportation have been taken, totaling 107,116 persons.

[4] Capitalization of steam railroads, only. State Commerce Commission, Springfield.

[5] Through the cooperation of Assistant Professor Roscoe R. Snapp of the Department of Animal Husbandry, University of Illinois, a tentative estimate was made of the value of crops fed to live stock resulting in the following figures for which no claim to mathematical accuracy is made.

Value of all feed sold, U. S. Census	$231,733,123
Value of feed bought	64,528,040
Net value of feed sold	167,205,083
Value of animals and animal products produced	570,000,000
Grand total value of animals, animal products, corn, oats, hay, etc., not fed, approximately	737,205,083
Values of wheat, fruits and nuts, vegetables, seeds, miscellaneous crops, eggs, poultry, honey, wool, dairy products, nursery and greenhouse products including forest products, U. S. Census, 1919	380,594,856
	$1,117,799,939

The figure of $1,118,000,000 was therefore adopted as the approximate value of products of Illinois farms. The value of $1,298,906,947 as given by the U. S. Census is stated by that authority to contain duplications from the fact that the products fed to live stock were not separable.

[6] Value added to products is here assumed as equal to the gross freight revenue.

representing permanent improvements or construction, is proportionately large and the earning power per person employed correspondingly high while the percentage of earnings to capital invested is relatively low.

In the mining industry, the capital investment is valued proportionately small. Potentially it is much higher, but as the full value can not be realized except as the product is mined, this prospective income is severely discounted in fixing capital values. The mines fall below the other groups in value produced per person employed, indicating that labor represents a relatively larger portion of the energy expended in comparison to values produced than in other groups.

The extent to which wood is used as raw materials on farms and in the great industries of manufacturing, mining and transportation as well as in construction and public works, and in merchandising and crating goods for shipment, and the relative dependence of these activities upon the continuance of wood supplies are subjects of vital importance to the entire population of the state.

Total Consumption of Wood in Illinois

Wood is used in many forms. The total consumption includes not merely sawed lumber but cordwood, cross-ties, fence posts, poles, piling, cooperage, shingles, lath, logs for veneer, charcoal, pulp, excelsior and other wood products.

Illinois consumed 2,353,662,000 board feet of sawed lumber in 1920, or an average of 363 board feet per capita.* Since the per capita consumption for the entire United States was but 295 board feet in 1919, and was estimated at 316 board feet in 1920, Illinois though known as a prairie state consumes nearly 15 per cent more lumber per capita than the average for the country as a whole. In the Chicago district alone, comprising Cook and DuPage counties, with 3,095,137 population an average of 1,166,820,000 board feet of lumber was consumed during the decade 1910-1920.† For this urban population, the per capita use of lumber based on the 1919 census was 473.9 board feet, which lowers the average consumption for the remainder of the state to 258 board feet per capita. The consumption of lumber on farms as computed in this study is approximately 272 board feet per capita. It is evident, therefore, that the lumber required to support the great manufacturing industries, especially in Chicago, raises the per capita consumption in

* Data furnished by the U. S. Forest Service.
† Based on records of lumber received and shipped from Chicago for decade 1910-19 inclusive.

this state above the average for the districts outside of Chicago and for the nation at large.

Converted into cubic feet of wood required to yield this quantity of sawed lumber, a volume of 392,277,000 cubic feet is consumed, which constitutes 69.96 per cent of the total quantity of wood used for all purposes in the state. An additional quantity is used amounting to 168,442,988 cubic feet, or 30.04 per cent, consisting of cordwood, ties, mine timbers, posts, cooperage, veneers, shingles, piles, and poles. The total consumption of wood for the state is 560,719,988 cubic feet, which is 86.46 cubic feet per capita. To supply this quantity of wood, perpetually, would require an average of about one acre of land for each person in the state or 6,445,057 acres to be devoted to the intensive practice of forestry. Twice this area would hardly suffice to produce this quantity under the present neglectful, wasteful, and injurious practices of handling our woodlands.

The total consumption of wood in the state for an average year is shown in the following table.

Although the per capita consumption of lumber on farms as shown on page 51 appears to be less than for the urban population, yet farmers, as ultimate consumers of wood, require a larger proportion than these figures show, since they are based more upon consumption of lumber by the industries than by the consumer who ultimately receives the

Consumption of Wood in Illinois

Product	Unit	Quantity	Converting factor	Cubic feet	Per cent of total	Per cent exclusive of lumber
Lumber	Bd. Ft.	2,353,662,000	.16⅔	392,277,000	69.960	....
Fuel wood	Cord	950,770	80.	76,061,600	13.565	45.156
Cross-ties						
Steam roads	Piece	6,327,854	4.25	28,630,745	5.106	16.997
Electric "	Piece	292,509	3.5			
Mine timbers	Cu. Ft.	19,710,000	....	19,710,000	3.515	11.701
Posts	Piece	20,680,000	.8	16,544,000	2.950	9.822
Cooperage*	Cu. Ft.	11,483,600	....	11,483,600	2.048	6.817
Veneers*	Cu. Ft.	6,537,600	....	6,537,600	1.166	3.881
Shingles*	Cu. Ft.	5,516,100	....	5,516,110	.984	3.275
Piles	Piece	110,284	22.3	2,459,333	.439	1.460
Poles	Piece	150,000	10.0	1,500,000	.267	.891
Total				560,719,988	100.00	100.00
Total exclusive of lumber................				168,442,988		
Total exclusive of cordwood and lumber..				92,381,388		

* For basis of contents, see Appendix Note 1.

The Annual Consumption per Capita of Lumber for all Purposes *

Class	Population	Wood-using industries M. ft. B. M.	Building M. ft. B. M.	Total M. ft. B. M.
State	6,485,280	1,373,900	979,762	2,353,662
Per capita consumption		217.9	145.73	362.92
Cook and DuPage counties	3,095,137	989,205	465,507	1,454,712
Per capita consumption		319.6	150.4	470.0
Towns outside Chicago district	2,031,443	384,695	217,779	602,474
Per capita consumption		189.3	107.2	296.6
Farms	1,090,736		296,476	296,476
Per capita consumption			271.81	271.81

manufactured articles. The table indicates that the per capita consumption of lumber on the farm for construction purposes exceeds by 86.5 per cent that required for the state as a whole. The rapidly growing Chicago district exceeds this average by only 3.2 per cent, while the remainder of the state's population consumes but 73.56 per cent of the average for building purposes and only 39.44 per cent as much as is required per capita by the farm population. These data also show that the rate of consumption of wood in the wood-using industries in the Chicago district exceeds by 68.83 per cent the rate for towns outside of Chicago and by 46.67 per cent the rate for the entire state. Undoubtedly the greatest economic burden resulting from the depletion of the supply of virgin timber as a source of lumber will fall on the farmer, by increasing his cost of building; and on the Chicago district, by diminishing its wood-using industries.

Production of Wood in Illinois †

Of the total of wood products required to meet the needs of Illinois, the woodlands of the state, 2,863,764 acres in extent, or 44.16 per cent of the minimum required area, yielded but 56,900,000 board feet of lumber, or 2.379 per cent of that consumed. In other products 106,318,627 cubic feet was harvested within the state, amounting to 63.118 per cent of the total consumed. But of these remaining wood

* See Appendix, Note 12.
† For foot-note, see next page.

products, 76,061,600 cubic feet is in the form of cordwood or fuel wood which is but a very small fraction of the total fuel consumption for the state, though it furnishes 25.59 per cent of fuel burned on farms. Of the remainder, totaling 92,381,388 feet, a quantity equal to 30,257,027 cubic feet or 32.75 per cent is grown in the state. Illinois therefore has to import over 97.6 per cent of its lumber and 65 per cent of wood used in industry in forms other than cordwood.

TOTAL PRODUCTION OF WOOD IN ILLINOIS FOR AN AVERAGE YEAR

Product	Unit	Quantity	Quantity in cu. ft.	Per cent of total
1. Cordwood	Cord 80 cu. ft.	950,770	76,061,600	65.768
2. Mine timbers	Cu. ft.	11,960,076	11,960,076	10.342
3. Posts	Post .8 cu. ft.	10,767,752	8,614,202	7.448
4. Lumber	Bd. Ft.	56,900,000	9,333,333	8.070
5. Cross-ties	Tie	1,021,888	4,343,024	3.756
6. Veneer logs	Bd. Ft. log scale 1/6 cu. ft.	24,367,000	4,061,166	3.511
7. Piling	Pile 22.3 cu. ft.	40,474	902,570	.780
8. Cooperage stock	Cu. ft.	375,989	375,989	.325
Total			115,651,960	100.00
Exclusive of lumber			106,318,627	
Exclusive of cordwood and lumber			30,257,027	

BASIS OF THE TOTAL-PRODUCTION FIGURES

1. Total woodland × .332 cord—average derived from 100 per cent of 440 wood-lot owners' replies to questionnaire.

2. 62.3 per cent of total consumption, as indicated by statements in reply to mining questionnaire.

3. Total woodland × 3.76 posts—average derived from 100 per cent of 440 wood-lot owners' replies to questionnaire.

4. Bulletin 1119, U. S. Department of Agriculture, making full allowance for unrecorded customs-mills.

5. Average total production estimated from replies to railroad questionnaire —1921 and 1922.

6. U. S. Census data, 1919—statistics for Illinois.

7. Since the average length of piling from a large number of pieces was found to be 36.27 feet, the average contents was placed at 22.3 cubic feet. The number of cubic feet produced in Illinois was derived from figures in the books of piling contractors showing the number of lineal feet of piling which was secured in the state, this amounting to between 37 and 38 per cent of the total consumption of piling.

8. U. S. Census data, 1919, converted into cubic feet by using the U. S. Forest Service equivalent.

PER CENT OF TOTAL WOOD USED WHICH IS GROWN IN THE STATE

	Per cent		Per cent
Lumber	2.379	Veneers	62.120
Other products ...	65.099	Piling	36.700
Fuel wood	100.000	Cooperage	3.274
Mine timber	60.683	Poles*	
Posts	52.068	Shingles	.000
Cross-ties	15.169		
Average exclusive of fuel wood and lumber...			32.75
Average exclusive of fuel wood only.........			8.169
Wood of all kinds..........................			20.626

* Rural telephone companies use mostly white oak poles, obtained locally for renewals, but it has been impossible to secure any data from these companies on the total number used in the state.

FUTURE SUPPLIES OF WOOD

What can the state do to insure to her major industries the continuance of wood supplies? Shall land now devoted to agriculture be planted to trees to fill this gap between production and consumption so that Illinois shall become self-supporting as to its timber needs? As shown later, the average annual crop of wood per acre which can be grown on Illinois land varies from 16 to 160 cubic feet. At an average production of 87 cubic feet per acre annually which could only be attained by intensive forestry practice it would require 6,445,057 acres or 17.967 per cent of the state's surface, to grow this amount. All but 23.9 per cent of the state is under actual cultivation for crops and this percentage includes cities, mines, and all waste and forest land and unimproved pastures. The maximum area which could ultimately be used for forest production is probably not over 5 million acres. It is evident, therefore, that not even by the devotion of every acre of this land to the most intensive forest cultivation could the industries now dependent on wood continue to exist without relying as at present on importations from outside the state in order to maintain their present scale of operations, irrespective of future increase in population or industry. Failure to obtain these enormous quantities of wood by importation supplemented by growth of local timber will ultimately mean a basic change in industry and perhaps very serious consequences in standards of living and even in the growth and distribution of population. It is out of the question for this state or its citizens to deliberately seek to curtail the production of farm crops, live stock and horticultural products for the sake of growing forests on soils better adapted for these higher uses. The policy indicated is to develop forest production on soils unprofitable for food crops wherever such soils are found so that the state may produce as large a percentage as possible of home-grown timber, and to take a lively interest in national forestry problems and policies which tend to encourage forest production in other states and in the nation at large. With the utmost effort, it would probably take the state 100 years or more to reach a condition of self-support in wood production even on the present basis of consumption.

Illinois must therefore continue to depend in large measure upon regions which possess a greater percentage of true forest soils, from which states it is hoped that timber may continue to be exported provided a surplus is produced within them. Favorably situated to draw with equal readiness from the pine and hardwood forests of the Lake states, the hardwoods of the Mississippi Valley and the uplands of Kentucky, Tennessee, and Arkansas, the largest remaining reserve of southern yellow pine in Louisiana and Texas, and the last great store of virgin softwood timber on the west coast and in the Inland Empire, the industries of the state are assured of the continuance of their supply of raw materials until such time as these supplies *fail at the source* for lack of proper conservation and renewal by forestry measures. That such failure may occur and that the available supplies of virgin timber, especially of the hardwoods which make up approximately 50 per cent of the demands of Illinois manufacturers, will in all probability suffer great depletion within comparatively few decades are facts not open to question.

Illinois industry all along the line faces the prospect of higher costs for wood with growing scarcity of supplies. With the inability to secure the raw materials in proper quantities except at prohibitive price, there arises the problem of substitution of other materials whose cost, as measured by price and utility, shows a favorable margin as against wood.

SUBSTITUTES FOR WOOD

If for all the uses to which wood is put, the human race could find substitutes which would render just as satisfactory service at lower cost, the question of growing timber might cease to be an issue. But as long as wood in any form for any purpose gives greater and better service at less cost, it will continue to be used.

When wood was abundant and cheaply obtained the quantities used per capita were excessive and the waste ran to high percentages. Now that the original forests are melting away, a new factor enters the economic situation, that is, the cost of producing wood as *a crop to replace those supplies.* Will the value of wood as compared with wood substitutes bear this additional charge, when added to the cost of logging, milling, and transportation? Or will substitutes be found more economical and practical than the enterprise of timber production to which the term forestry is given?

In general, it may be said that the use of substitutes for wood is certain to increase very rapidly in the next two or three decades, due to the steady advance to be expected in the cost of wood of all kinds, but that ultimately wood can be grown and placed on the market at costs which for many purposes should easily restore its economic supremacy and use. Such future use of wood and its extent will be limited only by the quantities capable of being produced. Wood production, or forestry, will be one of the safest forms of industry and of investment.

Meanwhile, the prospects in the near future for reduction in the cost of living are not bright, so far as they are affected by the supply and cost of wood. The extent to which industry will be disrupted and costs increased by the withdrawal of wood as a raw material and the substitution of other products, mineral, vegetable, or animal, may be roughly approximated by an analysis of the economic position which wood now occupies in Illinois industry.

The Use of Wood in Manufacturing Industries

Of the four major groups of industry, namely, manufacturing, agriculture, transportation, and mining, the first, or manufacturing, uses most of its required wood-supply in the form of lumber, while the consumption by the other three groups requires a large proportion of wood in the form of round products, such as cordwood, posts, ties, and timbers.

Thus 58.37 per cent of the total lumber requirements of the state are absorbed by the wood-using manufacturing industries, or a total of 1,373,900,000 board feet in 1920, as against 41.63 per cent for lumber required in construction.

A complete study of the consumption of wood in the wood-using industries, which would mean a revision of the bulletin on "Wood-using Industries of Illinois"* (giving data for 1909 and published in 1910) was not attempted. Instead, the total consumption of wood in all forms was studied for certain important wood-using industries and for agriculture, mining, and rail transportation.

* By Roger E. Simmons, Statistician in Forest Products, U. S. Forest Service, under direction of J. C. Blair, Chief, Dept. Hort., Univ. Ill., and H. S. Sackett, Chief, Office of Wood Utilization, U. S. Forest Service.

The manufacturing industries for which this study was conducted were: *railway-car construction* and *repair, farm machinery and implements, wagons and vehicles,* and *automobiles.*

The consumption of wood in these industries, compared with the quantities used in 1909 are as follows in board feet:

	1909	1920	Per cent of consumption in 1920 as compared with that of 1909
Railway cars*	407,333,000	425,000,000*	104.33
Farm machinery and implements	137,157,000	85,867,313	62.60
Wagons and farm vehicles	35,686,000	28,327,875	79.38
Automobiles	652,602	14,177,391	2,172.44

The indicated shrinkage of wood in all manufacturing industries for the state was 22.9 per cent, but hardwood supplies had diminished by 46.49 per cent. Comparing these per cents with the above data, it is seen that the consumption of wood for agricultural machinery and implements, for which purposes hardwoods are largely required, corresponds with the shrinkage in hardwood consumption. One implement manufacturer sums up the situation by stating, "There are numerous places where wood, if of suitable grade, and at equal cost, would be superior to iron and steel, but on account of the growing scarcity we are substituting iron and steel in places where we really prefer to use wood."

The distribution of the remainder of the total quantity of wood used in manufacturing among the groups of industries having the largest consumption is approximately indicated below. The statements concerning the packing-box industry, planing-mill products, and furniture are based upon the 1909 consumption reduced by the average shrinkage of 22.9 per cent applicable to the total for the state. The showing for the rest of the list is for 1920.

	Board feet	Per cent
Car manufacture and repairs.......	425,000,000	30.934
Packing boxes	286,831,275	20.877
Planing-mill products	171,987,618	12.518
Furniture	63,683,636	4.635
Farm implements and machinery...	85,867,313	6.250
Wagons and vehicles...............	28,327,875	2.062
Automobiles	14,177,391	1.032
All other manufactures.............	298,024,892	21.692
Total	1,373,900,000	100.00

* Covers repairs also.

FARM IMPLEMENTS AND MACHINERY

The amount of wood consumed in the manufacture of farm implements and machinery in 1920 as obtained from the questionnaires sent out to the several firms was 84,214,272 board feet, and it was assumed that this was related to the capitalization of the companies which, with the exception of firms rated at less than $10,000, was obtained from the Illinois Manufacturers' Association and the Secretary of State, Springfield. Firms consuming 82,652,082 board feet had a capitalization of $290,133,100, while those representing a capitalization of $5,855,000, or 2.018 per cent, made no report. Assumption that the same rate of consumption applies to those who did not report would add 1,653,041 board feet to the former estimate of those reporting, or a total of 85,867,313 board feet, which it is believed is very nearly correct. A comparison of 1909 and 1920 consumption is as follows:

Class of product	Year 1920	Year 1909	Ratio of 1909 to 1920 consumption
Farm implements and farm machinery	137,157,000	85,867,313	62.6%
Wagons and heavy vehicles..........	35,686,000	28,327,875	79.38%

Relative Importance of Wood in the Manufacturing Industries of Illinois

The manufacturing industries utilizing wood as a raw material entering into their products may be divided into, first, those dependent entirely upon wood, and which would cease to exist with the discontinuance of its use; second, industries largely dependent on wood or making large use of it which would be seriously incommoded by failure of supply; third, industries dependent on wood pulp which would be severely crippled by scarcity of wood; and fourth, industries dependent on wood for minor uses and which it seems probable could survive without serious loss if compelled to make complete substitution of other material for wood. For convenience in tabulation these industries have been designated as A, B, C, and D.

GROUP A. INDUSTRIES DEPENDENT ENTIRELY ON WOOD

In this group come the manufacture of wooden packing-boxes, lumber and planing-mill products, wood furniture, wood and paper pulp, cooperage, wood preservation, and charcoal.

The use of wood for packing and crating illustrates the entire problem of wood in industry. With increasing costs for lumber, many forms of substitutes appeared, such as cartons, most of them made of wood refuse or by-products. Although adopted for a large percentage of the lighter forms of merchandise, damage of goods in transit when shipped in such containers caused the shipper to adhere to wood for so many lines and in such a large proportion of freight shipments that wood for packing boxes was largely retained, and the quantity consumed in this industry alone, in Illinois in 1909 required 21.05 per cent of the entire consumption of lumber in manufacturing, or about 375,000,000 board feet, and this proportion probably holds today. In this form, cheap supplies of wood can render an invaluable service to nearly every form of manufactured products, including many which do not use wood as raw materials.

GROUP A.—INDUSTRIES DEPENDENT ENTIRELY UPON WOOD*

	Persons employed	Capital invested	Cost of principal materials	Value of products	Value added by manufacture
Wooden packing-boxes	4,920	$9,002.089	$10,297,194	$18,856,685	$8,491,880
Lumber and planing-mill products	6,320	24,059,331	20,393.106	34,588.576	13.909,099
Wood furniture .	15,160	35,330,352	22,164,038	49,686,849	26.979.464
Wood pulp and paper	2,002	13,928,741	8.162,201	14,356,529	5,144,076
Cooperage	1,601	4,849,702	7,623,833	11,576.824	3,903.720
Wood preservation	564	2,252,853	1,618,683	3,142,545	1,417.240
Charcoal	27	37,676	17,113	40,565	23,250
	30.594	$89,460,744	$70,276,168	$132,248,573	$59,868.729

All industries in this group are obviously dependent on wood as a raw material and would be discontinued with its disappearance. Together these industries constitute 3.18 per cent of the total of Illinois manufacturing enterprises.

GROUP B. INDUSTRIES WHICH MAKE EXTENSIVE USE OF WOOD

In this second group are found those industries which are greatly benefited by access to abundant and cheap supplies of wood, especially of hardwoods. Their products will show a decided increase in cost with the lessening of this supply or the necessity for using substitutes, and in

* From "Manufactures", 1919, Ill., Fourteenth Census of the U. S. Dept. of Commerce, Bureau of the Census, Washington, D. C.

many instances there will be a loss also in efficiency or satisfactory service.

Lumber and planing-mill products constitute that portion of the industry of lumber manufacture exclusive of logging, which takes place within the state. Logging as an industry in Illinois is relatively insignificant, constituting an enterprise equivalent to less than 1/5 of 1 per cent of the total manufacturing industries. But the planing-mill industry is of greater importance, handling in 1909 12.52 per cent of all lumber consumed within the state, and having closest contact with the building industries and the use of finished lumber for the construction of buildings in cities and on farms, which, with other uses of lumber outside of manufactures, absorb nearly 40 per cent of all lumber consumed in the state.

The manufacture of wooden furniture as an industry must cease to exist with the substitution of metal for wood. This industry will be one of the last to abandon the use of wood altogether, since the preference for wood remains strong enough to permit high prices to be paid for woods of high quality, such as walnut.

Holding chief place among these in point of demand for wood and its place in industry, is the *construction and repair of steam and electric railway cars,* which, while listed under manufactures, is one of the chief uses of wood in the transportation industry. Car-making uses for new cars alone 28.42 per cent of all lumber used in manufacturing, and employs 7.7 per cent of all the factory employes.

Although the use of steel in car construction is increasing, yet out of 158,022 cars of all types made in 1919 in the United States, 66.15 per cent were built with a wooden superstructure on a steel frame, 2.68 per cent were all of wood, and 2.61 per cent had wooden interior finish or linings, making a total of 71.44 per cent of new car construction all or in part of wood.

Agricultural implements and machinery rank next as large consumers of wood, taking 5.74 per cent of all lumber used in manufacture. In this industry, more and more of the parts formerly made of wood are being replaced by metal, and it is difficult to predict how far the substitution will go. The same is true of wagons and vehicles, requiring 2.00 per cent, and to a certain extent of others of the industries shown in tabulation B; but substitution becomes an urgent question first in the great industries which require large and dependable supplies and can not exist on the precarious output of second growth or cut-over areas.

The automobile industry furnishes one of the best illustrations of the importance of wood. The consumption for automobiles in the United States in 1923 is given by the National Automobile Chamber of Commerce as 780,000,000 board feet of high-grade hardwood lumber, in addition to which 200,000,000 feet were used for crating and shipping cars. Michigan of course ranks first among the states, but Illinois occupies sixth place in the value of motor vehicles produced, including bodies and parts, her factories approximating 3 per cent of the total output, which indicates a consumption of 14,177,391 board feet for 1922 and 16,610,292 for 1923. The statement for consumption of wood in Illinois by this industry is by no means complete, since there are several factories making accessory parts, such as bows for tops and running boards of cars, merely as a side-line to some other industry.

There are comprised in this industry three main classes of motor vehicles—passenger or pleasure cars, trucks, and commercial bodies for delivery purposes. Data upon the number of each of these classes are obtainable from the National Automobile Chamber of Commerce, but are not given out by states. By taking their estimate for the amount of wood in each class of car* and using the figures furnished by the United States Bureau of Census on the number of each class produced in Illinois, it is possible to arrive at a fairly accurate figure for the total amount of wood consumed in the state by this industry.

Through the co-operation of the Forest Products Laboratory, Madison, Wisconsin, we were able to obtain the figure of 12,000,000 board feet as the consumption for passenger cars, which varies from 150 board feet for open cars to 325 or even 350 board feet for large closed cars. Truck bodies require each from 200 to 250 board feet and their number is known, but the number of commercial bodies had to be approximated, since the Forest Products Laboratory survey did not extend to commercial bodies. The total stands at over 14,000,000 board feet. This amount is likely to increase rather than decrease from the fact presented by the National Automobile Chamber of Commerce that there is a marked trend towards closed cars, there having been an increase in the use of this type from 9 per cent in 1919 to 35 per cent in 1923, and closed cars require more wood.

Of this 12,000,000 feet for passenger bodies alone used in Illinois, which does not include the lumber used for shipping and crating cars,

* Appendix, Note 3.

the Forest Products Laboratory reports that it was all No. 1 common or better, and was divided on the basis of species as follows: ash, 71 per cent; oak, 10 per cent; maple, 8 per cent; yellow poplar, 5 per cent; birch, 3 per cent; basswood, 2 per cent; walnut, 1 per cent. Ash, because of its moderate weight in proportion to its strength, its high degree of toughness, its comparative freedom from warping, and its ease of working, leads all other woods for this purpose; and it is especially preferred for the bodies of high-class cabs because of its ability to withstand the shocks and jars incident to city traffic, with its occasional accidents. A very large proportion of the ash for cab manufacture is imported from Arkansas.

The great increase in the use of wood with the expansion of this industry can be seen by comparing the consumption in Illinois for 1909 with that of 1920 or 1923. With the decline in the demand for buggies, coming with the introduction of motor-driven vehicles, many small factories began to make automobile bodies; but the amount of wood used by them is inconsiderable when compared with that used by the larger and better equipped shops, which are in some instances connected with railway-car building.*

Steel is substituted for wood wherever possible, and instead of using solid pieces of wood there is a tendency with the perfecting of waterproof glues to use ply-wood made up of thin pieces of veneer; and some firms are producing a veneered top for sedans as one of their specialties.

The importance of this industry for the state as indicated particularly by the number of men employed and value of products manufactured, may be thus shown here in tabular form.

	Number of establishments	Av. number of wage-earners	Wages paid out	Cost of materials	Value of products
Motor vehicles including bodies and parts (passenger vehicles, trucks, etc.)	156	3,885	$5,992,655	$32,200,781	$56,796,893
Motor vehicles (All 4-wheeled motor-propelled steerable vehicles)	22	1,324	$2,126,618	$26,019,704	$41,043,496
Total	178	5,209	$8,119,273	$58,220,485	$97,840,389

* For further details as to consumption of wood in the automobile industry see Appendix, p. 168, Notes 2, 3, and 4.

Group B.—Illinois Industries Largely Dependent upon Wood
Census of 1920

	Persons employed	Capital invested	Cost of principal materials	Value of products	Value added by manufacture
Car construction and repair	61,957	$158,455,923	$121,086,018	$235,915,008	$110,889,474
Agricultural implements and machinery	26,555	150,484,328	62,893,409	128,284,716	63,124,896
Automobiles	10,959	43,584,252	73,476,977	104,883,442	30,929,634
Pianos and organs and materials	9,500	45,409,050	15,156,407	36,255,055	20,716,681
Wagons and vehicles	3,374	16,151,535	8,112,159	15,364,522	7,040,539
Picture frames	2,282	3,257,085	2,658,425	7,160,155	4,417,179
Dairyman's supplies	787	3,175,310	1,293,061	3,505,720	2,183,190
Sewing-machines....	2,501	8,115,991	2,287,574	7,166,783	4,789,751
Handles	1,900	4,074,736	3,983,803	7,339,470	3,296,862
Laundry appliances.	2,446	9,176,002	8,515,647	14,435,533	5,861,444
Cooperage	1,260	4,067,672	2,563,643	5,786,820	3,173,741
Refrigerators	349	898,984	375,815	1,198,255	811,762
Miscellaneous*	8,416	19,289,218	16,848,422	35,178,544	18,061,332
	132,286	458,140,086	$319,251,360	$602,474,023	$275,296,485

This group of industries in which wood is almost indispensable but which may be either forced out of business or be obliged to use substitutes eventually, now totals 14.58 per cent of all Illinois manufactures. That these industries would be tremendously benefited by the continuance of cheap and plentiful supplies of lumber suited to their needs, goes without saying.

GROUP C. INDUSTRIES DEPENDENT ON WOOD PULP AND PAPER

This third group of industries includes printing and publishing, and the manufacture of paper for stationery and other paper goods.

Wood pulp and paper are well-nigh indispensable in this industry and in spite of the relatively small quantities required to supply this demand, which is approximately 4,550,000 cords per year as against 110,000,000 cords used for fuel alone in the United States, yet the limitations of species, cost of transportation, and the relatively large quantities of material which must be assembled at one plant to reduce the cost of manufacture have not only prevented the extensive use of substitutes but have caused the price of pulp wood and of paper to increase constantly, until American operators, dependent on the exploitation of virgin

* For itemization of "miscellaneous", see Appendix, Note 5.

forests with increasing costs of raw material and of transportation, are already facing serious competition from European plants whose supplies are drawn from well-managed forests. This condition is clearly shown by the average prices paid for wood consumed in the manufacture of pulp as given by the U. S. Census for 1919, covering the two previous decades.*

These industries dependent on wood pulp and paper represent a total of 4.73 per cent of the state's manufacturing enterprises.

GROUP C. INDUSTRIES DEPENDING UPON WOOD PULP

Name	Persons employed	Capital invested	Cost of materials	Value of products	Value added by manufacture
Job printing.....	25,059	$53,872,011	$39,332,048	$92,232,447	$52,125,173
Printing and publishing newspapers and periodicals	19,604	54,099,750	10,058,026	26,641,359	16,278,247
Book-binding and blank-book making	2,872	4,703,224	2,581,130	7,477,722	4,839,431
Book publishing and printing...	591	1,415,609	817,281	2,521,467	1,692,249
Printing and publishing music..	241	677,430	375,920	1,211,810	832,603
Stationery goods not specified elsewhere	2,180	7,623,135	3,176,611	8,950,598	5,720,178
Envelopes	1,650	3,994,921	3,281,992	6,431,059	3,104,760
Labels and tags..	914	2,473,797	1,295,883	3,428,419	2,107,909
Paper goods not elsewhere specified	786	2,501,059	2,972,047	5,588,956	2,587,928
	53,897	$131,260,936	$63,890,938	$154,484,837	$89,288,478

GROUP D. INDUSTRIES DEPENDENT UPON WOOD FOR MINOR USES

Frequently these minor uses are very important in the economy of the industry. For example, pattern material essential for foundries is getting so scarce that fabulous prices are paid for rather small quanti-

*Year	Average price per cord	Year	Average price per cord
1899	4.95	1917	11.10
1905	5.56	1918	13.93
1914	8.81	1919	15.95

ties of clear white pine lumber required for this use. In electrical machinery about seven million board feet is used for minor purposes. These two industries alone total 5.07 per cent of Illinois manufacture.

Group D. Industries using Wood in a Minor Capacity

	Persons employed	Capital invested	Cost of principal materials	Value of product	Value added by manufacture
Foundries........	13,297	$34,557,499	$18,580,191	$ 52,109,714	$31,026,971
Electrical machinery.....	36,515	96,811,473	50,258,394	119,528,022	67,901,723
Total........	49,812	$131,368,972	$68,838,395	$171,637,736	$98,928,694

If the fourth group (D) is omitted, and the situation summed up on the basis of those industries which would be seriously crippled by failure of wood supplies, we find that they employ 26.93 per cent of the total labor employed in Illinois manufacturing industries and 20.40 per cent of the capital invested, and that 20.91 per cent of the value added by manufacturing is represented by these industries. The cost of materials, dealing as they do with basic raw products, is 13 per cent of the total costs for all industries and the value of the products is 16.38 per cent of the total value of manufactured products.

Weighting the three groups on the basis of persons employed, capital invested, and value added by manufacture the results are:

	Per cent
A. Industries dependent entirely on wood.......	3.18
B. Industries making extensive use of wood....	14.83
C. Industries dependent on wood pulp..........	4.73
Total largely dependent on wood..........	22.74

Economic Value of Wood Industries

Allowing for materials other than wood used in these industries, it is probable that wood and its uses in manufacture represents between 8 and 10 per cent of the value of all raw products so used, and that its economic value is not less than this proportion to the total manufacturing industry of the state. With failure of the supply, notably of hardwoods, a very large percentage of these industries will be forced either to discontinue operations and seek other forms of investment or to produce a more expensive product of less relative value, or else to

THE RELATION OF WOOD-USING INDUSTRIES TO TOTAL MANUFACTURING INDUSTRIES OF ILLINOIS

Class of wood-using industry	Persons employed, number	Per cent of total	Invested capital, dollars	Per cent of total	Cost of materials, dollars	Per cent of total	Value of products, dollars	Per cent of total	Value added, dollars	Per cent of total
A	30,594	3.80	89,460,744	2.66	70,276,168	2.02	132,248,573	2.43	59,868,729	3.09
B	132,286	16.44	466,140,086	13.85	319,251,360	9.15	602,474,023	11.11	275,296,485	14.21
C	53,897	6.69	131,260,936	3.89	63,890,938	1.83	154,484,837	2.84	89,288,478	4.61
D*	49,812	6.19	131,368,972	3.90	68,838,395	1.97	171,637,736	3.16	98,928,694	5.11
Total........	266,589	33.12	818,230,738	24.30	522,256,861	14.97	1,060,845,169	19.54	523,382,386	27.02
Total of all manufacturing industries of state......	804,805	....	3,366,452,969	....	3,488,270,446	....	5,425,244,694	....	1,936,974,240	....

* Class D, including industries which use wood in a minor capacity, has been omitted in showing the relation of wood-using industries to the industries of the state.

relocate elsewhere, if such location can be found. It is evident that the manufacturers of Illinois and the wage-earners dependent on these investments as well as the state as a whole must take a deep and lasting economic interest in the movement for the establishment of timber production as an enterprise, not only in Illinois but in other states as well. What happens in the southern yellow pine cut-over lands and in the forest areas of northern Minnesota and the upper Peninsula of Michigan, concerns the future welfare of Illinois, which can not afford to remain indifferent to methods or neglect which may result in serious loss through permanent failure of the indispensable flow of raw materials to her wood-demanding industries.

The Consumption of Wood by Steam Railroads in Illinois

Steam railroads in Illinois had a trackage in 1922 of 25,736.24 miles, classified as large roads 23,157.68 miles, small roads 805.13 miles, switching and terminal companies, 1,773.43 miles. Railroads are not only one of the largest consumers of wood in the state but, owing to the preference for wooden ties, will probably remain so. Wood is required by railroads for two major purposes, cross-ties, and cars. In addition, lumber is consumed for buildings and minor uses, while round products are used in the form of fence posts, piling, and poles.

CROSS-TIES AND BRIDGE AND SWITCH TIES

The consumption of cross-ties in Illinois was obtained from figures on total consumption of cross-ties by roads with trackage in Illinois, multiplied by the percentage of trackage within the state. These figures give the total consumption as follows:

Consumption in 1920

Cross-ties, Pieces

Class	Ties laid in replacement and betterment	Ties laid in new track	Total ties
Large roads	5,187,645	220,799	5,408,444
Medium and small roads	218,806	770	219,576
Switching and terminal companies	342,540	40,230	382,770
Totals	5,748,991	261,799	6,010,790
Per cent	95.64	4.36	100

Switch and Bridge Ties, Board Feet

			Total bd. ft.
Large roads	15,562,682	1,194,672	16,757,354
Medium and small roads	694,231	19,377	713,608
Switching and terminal companies	3,270,772	300,470	3,571,242
Totals	19,527,685	1,514,519	21,042,204
Per cent	92.80	7.20	100

The average contents of bridge ties is 58.6 board feet, and of switch ties, 44 board feet. About one third of these classes are bridge ties, and the remainder switch ties, giving an average content for both classes, of 48.867 board feet. Converting the board-foot contents by this factor into ties, indicates the number so used in 1920 as 430,601, and that used in 1921 as 428,737.

The total number of board feet for bridge and switch ties, as taken from the tables for 1920 and 1921, are respectively 21,042,204 and 20, 951,122 board feet. Converting the cross-ties into their equivalent in board feet by using 35 board feet, gives for 1920 a total of 210,377,650 board feet, and for 1921, 202,502,300, or an equivalent in number of ties of 6,010,790 (1920) and 5,785,780 (1921).

The total number of all ties consumed becomes 6,441,391 for 1920 and 6,214,317 for 1921, and the total number of board feet for this number of ties is 231,419,854 for 1920 and 223,453,422 for 1921.

CONSUMPTION IN 1921

Cross-ties, Pieces

Class	Ties laid in replacement and betterment	Ties laid in new track	Total ties
Large roads	4,812,200	232,535	5,044,735
Medium and small roads	236,380	7,916	244,296
Switching and terminal companies	491,978	4,771	496,749
Totals	5,540,558	245,222	5,785,780
Per cent	95.7	4.3	100

Switch and Bridge Ties, Board Feet

Class	Ties laid in replacement and betterment	Ties laid in new track	Total ties
Large roads	15,343,954	1,182,347	16,526,301
Medium and small roads	448,564	37,625	486,189
Switching and terminal companies	3,728,336	210,296	3,938,632
Totals	19,520,854	1,430,268	20,951,122
Per cent	93.2	6.8	100

The following table conveniently summarizes the foregoing details.

RECAPITULATION FOR THE YEARS 1920 AND 1921

Year.	Switch & bridge ties		Cross-ties		Total No. of all ties consumed	Total contents of all ties, board feet
	Number	Contents in board ft.	Number of ties	Contents in board ft.		
1920	430,601	21,042,204	6,010,790	210,377,650	6,441,391	231,419,854
1921	428,737	20,951,122	5,785,780	202,502,300	6,214,317	223,453,422
Average for the two years					6,327,854	227,436,638

CAR MANUFACTURE AND REPAIR

Car manufacture and repair constitutes the second major use of wood by railroads. The total quantity of lumber used in these operations of which actual record was obtained, was 420,087,887 board feet, divided as follows:

Construction of new cars	338,941,801
Repairs	77,146,086
Not specified	4,000,000
Total	420,087,887

It is roughly estimated that the addition of firms not reporting would bring this total to 425,000,000 board feet.

FUTURE REQUIREMENTS FOR WOOD IN THE CAR-MANUFACTURING INDUSTRY

The substitution of steel for wood in car manufacture has made rapid strides in the last decade, but has so far not reduced appreciably the demand for wood in this industry. Cars made entirely of wood now constitute but 2.68 per cent of all cars manufactured, while all-steel cars have increased to 27.95 per cent. But there remains 66.75 per cent of all new construction, which consists of a steel frame with wooden body, and 2.61 per cent with steel body and wooden interior. The type of cars with steel frame manufactured in Illinois requires, for box cars, between 5,000 and 5,500 board feet of wood for construction, while the older type of wooden box-car required between 6,000 and 6,500 board feet, a saving of but 1,000 board feet per car. For flat cars the reduction in wood used is about 1,500 board feet per car, all-wood flats requiring 3,100 board feet as against 1,600 board feet for cars with steel frames. Wooden coaches requiring 25,000 board feet, still utilize 18,000 board feet when steel frames are substituted, while for wood finish in steel coaches, over 6,000 board feet is required. Thus while steel construction is effecting an undoubted saving of wood and adds to the strength of construction, the extensive use of wood is continued by preference to all-steel cars in 72 per cent of new construction at the present time, in spite of the relatively greater increase in cost of wood materials as compared to steel. As in so many other instances, the complete substitution of other materials for wood will not be brought about by relative superiority of the substitute, but solely by the increasing scarcity and rising prices of wood itself.

Taking the total used for car manufacture and repair at 425,000,000 feet in 1923, there has been an increase of 17,667,000 board feet, or almost 5 per cent, despite substitution during the last decade. Partial returns were obtained on consumption of lumber, fence posts, and piling by railroads. The figures were given for the entire systems and prorated to Illinois on the basis of relative mileage, as for cross-ties. The indicated consumption of wood exclusive of car repair for the year 1922 was:

Class	Lumber Bd. feet	Posts Number	Piling Linear feet
Large roads	65,512,789	66,886	219,388
Small roads	1,947,177	952	84,751
Switching and terminal Co's	12,545,696	676	13,862
Total	80,005,662	68,514	318,001

The total consumption per annum of wood by steam railroads in Illinois is thus estimated to be:

Lumber	Board feet
Car manufacture and repair	425,000,000
Miscellaneous uses	80,000,000
Total	505,000,000

	Pieces	Cubic feet	Multiple cu. ft.
Cross-ties	6,327,854	26,893,379	4.25
Fence posts	68,514	54,811	.80
Piling 318,001 (lin. feet)	8,767	195,504	22.30

Cubic equivalent of all except lumber, 27,143,694.
Cubic equivalent of lumber at 6 board feet per cubic foot, 84,166,166.
Total consumption of wood, cubic feet, 111,309,860.
Total board-foot equivalent, 733,936,507.*

Consumption of Wood by Electric Lines and Light and Power Companies in Illinois

During the years 1921 and 1922 there were in operation 3,513.8 miles of electric railways and light and power companies in the state, and for the electric railways 2,450 miles were main track. From the books of the State Commerce Commission at Springfield it appears that the number of new ties laid in all tracks was 292,509 for 1921 and 326,455 for 1922, an average for the two years of 309,482.

Further, from the books of the State Commerce Commission, it was learned that 58 of the roads had made statements as to the average num-

* The converting factor of 6 board feet per cubic foot can be used for piles, poles, posts, and lumber, but for cross, switch, and bridge ties averaging 35.9421 board feet each and 4.25 cubic feet the converting factor is 8.4569.

ber of ties per mile, and weighting these numbers by the mileage of the respective roads it was ascertained that for 2035.82 miles of track 5,-638,321 ties were in service, or an average of 2,770 ties per mile. Since from the new ties laid in 1921 and 1922 we obtain an average for replacements and new construction of 88 ties per mile, we conclude that the average length of service rendered is 31.5 years. Trolley traffic is not so hard on ties as steam traffic because the cars are very much lighter. Some treated ties are used, and in the one case where steel ties were used the cost appeared to be almost prohibitive. The permanent requirement per annum for cross-ties by electric lines and trolley lines may be roughly placed at 312,000 for renewals and new construction*, assuming that there are 9,730,000 ties now in service on the entire 3,514 miles of these roads. In addition to cross-ties, these electric and light and power lines in 1921 required 46,327 poles and 8,042,399 board feet of lumber.

The total wood consumed by electric lines exclusive of lumber used for electric cars, in 1921 was:

	Number	Cubic feet	Multiple
Cross-ties	292,509	1,023,781	3.5
Poles	46,327	463,270	10.0
Total cubic products.......		1,487,051	
	Board feet		
Lumber	8,042,399	1,340,400	1/6
		2,827,451	
Equivalent in board feet......................			18,912,267

The total, for both steam and electric transportation is:

	Cubic feet
Lumber............	85,506,566
Round products.....	28,630,745
	114,137,311 cu. ft. or 752,848,774 board feet

Tie Renewals and Replacements and the Future Tie Supplies for Illinois Railroads

Transportation is literally the life-blood of the industries of the state. Whatever affects the security or cost of railroad operation brings immediate readjustments in both the cost of living and the standard of living.

The security of the road-bed is a necessity in making possible the steady increase in weight and driving power of locomotives, speed of passenger service, and reduction of cost of haul per ton mile. . The

*This was determined by returns from questionnaires sent out to members of the Illinois Electric Railways Association through the courtesy of their Secretary-Treasurer, Mr. R. V. Prather.

weight of the standard rail has been increased; but the foundation of the entire structure of rail transportation is still the wooden tie.

Faced with the possibility of ultimate exhaustion of the supply of wooden ties through depletion of the forest resources, railroad engineers have for three decades experimented with substitutes in order to be ready for the transition when wood was no longer available; but even in the face of threatened serious shortage of supply and in spite of rapidly increasing costs, cross-ties continue to be made almost exclusively from wood.

Not only is the number of ties other than wood now in use infinitesimal, but this substitution is not yet increasing at a rate indicating a tendency to abandon wood. For the year 1920, Census figures show that out of a total of 86,829,307 ties laid in Class I track for replacements in the U. S., but 154,378 were of material other than wood, or 18/100 of 1 per cent.

The two factors which will determine the rate of possible substitution for wood in this field are service and cost. Service means the durability or preservation of the tie in a serviceable condition capable of supporting the rail and preserving the gage of the track. Ties cease to render service when they break, decay, get out of shape, crumble, or in any way lose their form and structure.

Ties in modern road-beds must withstand terrific shock from traffic. Resiliency rather than rigidity is required, and wood presents this quality, while more rigid metal or cement lacks it. Cement ties crumble rapidly and are no longer considered of value. The rigid steel tie, in spite of its less desirable qualities might ultimately supplant wood, but this substitution depends also on relative costs and demonstrated period of service. These factors still favor the wooden tie.

Wooden ties fail from two sets of causes, namely, decay, and mechanical stress which causes the tie to wear out. For these reasons cross-ties were originally made only from woods which possessed the maximum resistance to shock, combined with the greatest resistance to decay when exposed to the surface conditions in the track. White oak and chestnut were the favorite hardwoods, and heart pine the most widely used material in coniferous regions.

TIMBER PRESERVATION

During the past decade the supply of the so-called class "U", or untreated ties, those naturally resistant to decay and therefore not requiring treatment, became insufficient to meet the needs of the roads. No sap ties possessed this quality, and small timber, even of the desired species, would show too large a proportion of sap to class as "U" ties. The roads met this situation, not by substitution but by timber preservation, which enabled them to draw upon a large reservoir of timber of species not sufficiently resistant to decay to have been formerly acceptable. Instead of being confined to white oaks, black locust, walnut, pine, cedar, cypress, catalpa, chestnut, mulberry, and sassafras, and mainly heartwood, the sap ties of all these species, and in addition many new species could now be used. Of these the most important is the red or black oak group, which grows nearly twice as rapidly as the white oak group. Others are the ashes and hickories, honey locust, beech, formerly a wood in little demand in most regions, birches, including the paper birch which formerly was permitted to burn after pine lands were logged, cherries, gums, which constitute an enormous quantity of timber in the South, hard maple, one of the most numerous species in the northern woods, elms, hackberry, soft maple, sycamore, and butternut. Practically the only trees remaining which are unsuitable for ties are such species as cottonwood, tulip-poplar, and basswood, which are too weak to withstand mechanical stress, and are more valuable for other purposes. The expansion of the field of utilization and market for cross-ties to cover practically every species not otherwise valuable found in the wood-lots and forests of Illinois, is one of the most significant and encouraging phenomena of recent years, and is a striking proof of the fact that timber crops, when grown to merchantable sizes, regardless of the species which compose the stand, will in the future find a ready market unless the national neglect of forest production reaches such colossal proportions that entire industries are dislocated and forced to resort to substitutes. Even should such shifts occur through necessity, wood will regain its place at any future time when it is produced in sufficient quantities to furnish a dependable source of supply.

The effect of preservatives upon the life of ties of different species is to establish an average service of from 15 to 16 years per tie including those species formerly rejected, as against about 10 years for the formerly accepted durable species, and 2 to 5 years for the unserviceable kinds. The relative durability is affected by several factors. Very durable woods, such as white oak, do not show a corresponding increase in longevity when treated. The greatest relative gain comes in treating such woods as birch and maple which otherwise decay rapidly.

The period of service is diminished by heavy traffic because of increased wear, and some species, like soft maple and elm, show less relative resistance to heavy than to light traffic when compared with ash, hickory, and red oak. To meet this condition in lines where the traffic exceeds ten million tons annually, tie plates are used which distribute the load and prevent the cutting of the tie by the rail.

The preservation of wood has been standardized by experience until practically all commercial plants use either creosote or zinc chloride or a combination of the two. The wood is impregnated with these materials in closed cylinders under air pressure. The use of creosote is more expensive, and gives greater length of service. The choice of the method is determined by the effort to secure the lowest annual charge for replacements, which is derived from first cost of the treated tie and years of service secured. As ties increase in price the tendency will be to substitute creosote for the cheaper processes.

The following table, prepared for the use of one of the larger eastern roads, shows both the effect of preservation upon the period of service and the shortening of this period resulting from excessive traffic. In final analysis, it is the total work which the tie is called on to perform, in terms of tons of traffic, which will limit the service which can be expected of cross-ties, no matter of what species or how well preserved and protected. Demand for tie timber will therefore increase in the same proportion as the increase in tonnage, and regardless of efforts to conserve the supply by preservative treatment.

The extent to which this economic revolution in the practices of railroads with respect to the utilization of cross-ties has progressed, is shown by statistics of wood preservation for 1921. In that year, 55,383,515 cross-ties were treated in the United States, of which 54,227,471 were for use on steam railroads and 1,156,044 on electric lines. As the annual consumption of ties is approximately 100,000,000 over one half of all ties are now treated. This includes practically all the woods classed as "T", or needing the treatment.

Within another decade, practically all ties except a certain per cent of the more durable "U" ties and ties used by small roads, will receive preservative treatment. The larger roads which have not already adopted the practice *in toto,* are rapidly enlarging their percentage of treated to untreated ties. Partial figures indicate that the roads with trackage in Illinois used, during 1921, 41 per cent of treated ties, and several of the larger systems increased this per cent substantially in 1922.

SERVICEABILITY OF TIES

I. Species native to Illinois

Species	Untreated ties: Heavy traffic Years	Untreated ties: Light traffic* Years	Treated ties: Heavy traffic Years	Treated ties: Light traffic* Years
Ash	3	3	10	16
Beech	4	4	8	14
Birches	2	2	8	14
Cherry	4	6	7	14
Elm	2	3	6	12
Gums	2	2	10	14
Hackberry	2	3	6	12
Hard maples	4	4	10	14
Hickory	3	3	10	16
Honey locust	3	3	10	16
Red oak	5	5	10	16
Soft maples	2	2	6	12
Sycamore	2	2	6	12
White oak				
Heart	8	10	10	16
Sap	7	8	10	16
Walnut, black				
Heart	6	15	8	16
Sap	5	12	8	16
Butternut	1	2	1	10
II. Species not constituting a source of native supplies of cross-ties				
Chestnut				
Heart	3	14	3	16
Sap	2	10	3	16
Cypress				
Heart	4	12	4	14
Sap	3	5	4	16
Douglas fir				
Heart	5	8	7	16
Sap	3	3	7	16
Hemlock	3	4	7	14
Larch	3	6	7	14
Pine				
Heart	6	12	8	16
Sap	3	3	8	16

Southern Illinois is the center of the industry of commercial wood-preservation, containing nine large plants, while three others are located elsewhere in the state. This is due to the strategic location of this region with respect to available supplies of hardwood and pine ties requiring treatment, on the one hand, and to railroad mileage in need of ties on the other. This fact offers a distinct advantage to producers of local tie timbers, which is only partly nullified by the practice of offering uniform prices for ties delivered on the right-of-way.

* Light-traffic tracks are those carrying not more than ten million tons annually.

The effect of wood preservation upon the requirements of Illinois railroads for tie timber is twofold. It greatly increases the potential supply from all, and especially from local, sources, and it cuts the requirements for renewals nearly in half, thus improving the position of the roads from 300 to 400 per cent and postponing the day when the roads will be forced to introduce other materials in place of wood for ties.

The rate of annual renewals is the gage of the length of service of the average cross-tie. For main tracks the number of ties per rail of 33 feet averages 20, giving 3200 per mile, while on side-tracks it runs 18, or 2880 per mile. An average for all track and roads is sometimes taken as 3,000 ties per mile. The annual replacements per mile, divided into this figure, represent the life of the average tie with approximate accuracy after the initial period following construction has elapsed. As new construction has been practically at a standstill since 1915, this figure should gage the future requirements of Illinois roads for tie timber.

Figures for the years 1917-21 inclusive give for all Class 1 railroads of the United States an average annual renewal of 235 ties per mile. This is equivalent to a life of 12¾ years, which indicates, first, the extent to which the more durable woods have in the past been preferred and, second, the transition which is rapidly taking effect. The roads simply could not afford to use ties whose service fell much below 10 years, and made the shift as soon as economic necessity compelled action.

The annual requirements of Illinois roads for replacements are slightly more than this average, being 241.0 ties per mile for replacements alone, and 245.9 per mile when new construction is included. It will require probably ten years to reduce this figure to 174 ties per mile for all tracks, which is the goal set for 100 per cent use of treated cross-ties. Should the mileage of track remain fairly stable at 25,000 miles, this would require 4,350,000 ties annually. Allowing an increase in trackage of 10 per cent and a further increase in renewals due to heavier traffic of 20 per cent upon the ultimate mileage, the number required would be 5,742,000 ties annually.

Unless unforeseen factors arise it appears safe to estimate that a permanent supply of 6,000,000 ties for steam roads alone should guarantee the continuous use of wood for cross-ties in Illinois.

The Uses of Wood in Mining

Mining finds its great importance as a basic industry upon which the entire structure of manufacturing depends for fuel to furnish power, heat, and light, which are equally essential for domestic consumption. Hence the relation of wood-supplies to this industry has an importance much greater than if measured solely by the quantity of wood required in the mining processes.

In Illinois this importance is increased by the fact that 95.2 per cent of the entire mining output of the state is in the form of fuel, of which bituminous coal comprises 77.7 per cent, and petroleum 17.5 per cent. The residual output of 4.8 per cent is made up of limestone 2 per cent, sandstone 7/10 per cent, and other materials 2 per cent.

The production of bituminous coal, according to the reports of the Department of Mines and Minerals, in short tons of 2000 lbs. for the last seven years is as follows:

	Tons
1916	63,673,530
1917	78,983,527
1918	89,979,469
1919	75,099,784
1920	73,920,653
1921	80,121,948
1922	63,276,827
Average	75,007,962

Illinois ranks fourth in the value of all mining products and third in the production of coal, the value of the latter alone in 1919 being $138,767,835. For the year ending June 30, 1921, the number of employes in coal mines was 95,763 and the sum of $80,309,689 was paid out in wages. Illinois coal-mine operators control 799,060 acres of land, of which 754,235 acres is classed as coal land, and 44,825 acres as timber and other lands.

The use of wood is essential to the production of coal at reasonable costs. Coal-mining requires large quantities of small timbers in the round, leading to very close and economical utilization of timber crops and of the contents of trees as contrasted with the waste incidental to cutting for saw-timber only. Supplies of local timber on which freight charges are moderate permit the utilization and later abandonment of timbering in mines, without the excessive costs which would be incurred in the use of substitutes such as steel or cement. In most instances the recovery of such supports is dangerous and impracticable.

The forms in which this wood is needed are props, legs and bars, lagging, caps, mine ties, and lumber.

Props are small timbers, either split or round, used in temporary openings, such as in rooms for supporting the roof. Props run from 3 to 5 inches in diameter at the tip and from 2¼ to 10 feet in length, depending upon the thickness of the coal seam.

The vertical pieces used in the entries and other more permanent positions are called *legs* or *posts* and the horizontal piece is called a *cross-bar* or, more briefly, a *bar*. These may be 6 or 8 inches in diameter at the top end and up to 16 feet long.

Lagging, or *riprap*, consists of small poles or boards which extend from one set of legs and bars to another to keep small pieces of roof or wall from falling into the entries. In most cases the lagging is used only where the ground is loose, as the rooms are usually cut in the coal so that the walls stand well without support. The quantity of this material used in Illinois coal mines is comparatively small.

Caps are pieces of board about one foot square used to place on top of props or legs for the purpose of tightening up the pieces which support the roof. Old props might be cut up and used for this same purpose. The ordinary size for cap pieces is 12x12 inches and 1 inch in thickness. Mine ties may be as small as 3½ feet long by 2x4 inches, and up to 5½ feet long by 5x6 inches. Lumber is used for general construction, and for mine cars.

The production of bituminous coal for Illinois in 1921, of 80,121,948 tons is taken as the basis for determining the quantity of wood required in mining this coal. Of this total, 78,399,082 tons were the output of shipping mines.

The total consumption of wood in coal-mining was obtained for mines producing a total of 22,146,784 tons, or 27.64 per cent of the total output, well distributed over the entire state. The remainder was calculated by proportion, assuming the same rate of consumption. On this basis the coal industry consumed in 1921, 21,552,250 cubic feet of wood in all forms, of which 19,710,000 cubic feet went into the mines in the form of timbers* and the remainder, 1,842,260 cubic feet, was

* All forms of wood were converted into cubic feet by proper equivalent. For props, the truncated cone formula was used:

$$V = \frac{0.2618\ L\ (D^2 + dD + d^2)}{144}$$

where V = volume, L = length, D = top diameter, and d = butt diameter.

For lumber 6 board feet was taken as equaling 1 cubic foot.

An average taken on 3,300,000 pieces indicated that the dimensions of the average mine prop were 5.2 feet long by 5.4 inches at the middle, or a little over 5 inches at the small end, and contained .83 cubic feet. Mine ties averaged .7 cubic feet. Mine caps are of various sizes, but averaged 1 board foot or ⅙ cubic foot. Legs and bars averaged 1.91 cubic feet.

used as lumber, amounting to 11,053,560 board feet, for mine cars and construction purposes.

The consumption of wood per ton of coal mined, was:

For all purposes, including lumber .269 cubic feet.

For mine-timbering, excluding lumber and mine cars, .246 cubic feet.

The forms in which this wood is used, and the quantity of each are shown in the following table.

WOOD CONSUMED IN COAL-MINING IN ILLINOIS *

Class of material	Pieces, number	Average contents, cu. ft.	Total contents, cu. ft.	Per cent of total used	Per cent exclusive of lumber
Props	16,115,640	.83	13,375,989	61.922	67.864
Mine ties	3,844,850	.70	2,691,399	12.459	13.655
Caps	11,413,266	.16⅔	1,902,220	8.806	9.651
Legs and bars	805,220	1.91	1,537,970	7.120	7.803
Riprap, or lagging	....	....	202,422	.937	1.027
		Total	19,710,000	91.244	100.00%
		Total bd. ft.			
Mine cars	36,600	7,978,800	1,329,800	6.320	
Construction	....	3,074,760	512,460	2.436	
Total lumber	....	11,053,560	1,842,260	8.756	
Total both classes	....	....	21,552,260	100.00	

The total consumption for the state was obtained by multiplying the average consumption per ton, .246 cubic feet, by 80,121,948 tons and adding to this total the lumber used in mine cars, which gave an average total per ton of .269 cubic feet.

By applying the distribution per cents already obtained to the total of wood consumed, the total of each class was found, and this was in turn converted into the number of pieces in the class by applying the

* The data were from two sources, those collected by R. B. Miller on 16,642,160 tons of coal, and those by H. E. Tufft, of the U. S. Bureau of Mines, on 5,504,624 tons. The lumber required for mine-car construction was not included in their figures and has been added.

Amount of wood (cu. ft.) required per ton of coal.

Tufft	5,504,624 tons	847,644	.154 cu. ft. per ton
Miller	16,642,160 tons	4,611,243	.277 cu. ft. per ton
Combined and averaged	22,146,784 tons	5,458,887	.246 cu. ft. per ton

Miller's data gave itemized consumption by classes. In tabulation this was used (1) as the basis of cubic contents of average pieces, and (2) was, on this cubic basis, expressed in per cent of the total consumption for each class of products.

average contents per piece already determined. It will be noted that 91.24 per cent of all wood used in mines is in the form of round or hewn products of which but 7.12 per cent are legs and bars of sizes capable of yielding lumber. Thus 84.12 per cent of all the wood used in coal mines consists of relatively small props, mine ties, and lagging, which utilizes trees down to from 3 to 4 inches in diameter breast high.

The only use of wood comparable to this in closeness of utilization is as cordwood for fuel. But the economic value of mine timbers is much higher than that for cordwood, since for the consumption of .246 cubic feet, or, at 80 cubic feet per cord, of 00.3 per cent of a cord, one ton of coal is obtained, having a fuel value, at .8 tons per cord, of 406.5 times that of the wood consumed. It requires a total of 246,375 cords of wood to mine all the coal produced in Illinois, while if wood were substituted for coal as fuel, the requirements would be 100,152,438 cords as against an actual output of 1,024,614 cords, or not much over 1 per cent of these requirements. It is therefore evident that if wood must be grown to supply fuel, its most economical use is by converting this wood into coal through the mining industry, and that the land required to produce mine props is performing a service of very high value to the community.

Cost of Mining-timbers

These relative values are reflected in the prices paid for mining timbers as compared with those for cordwood. The average price paid at the mines for all classes of timber reduced to cubic feet was in 1921, 18.3 cents per cubic foot, which at .246 cubic feet per ton of coal mined gives a cost of 4.5 cents per ton of coal for wood delivered at the mine.*

The price for the larger sizes in the form of legs and bars, was 26.7 cents, or 46 per cent greater than this average, while for mine props it was 16.2 cents per cubic foot, or 11.5 per cent lower. The larger dimensions thus command a price per cubic foot 64.3 per cent greater than the smaller props.

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* Costs of Timber Delivered at Mine, 1921

Summary of Results from Combining Figures of Harry E. Tufft and R. B. Miller

Tufft	8,845,650 tons	$302,298	3.5 cents per ton
Miller	14,049,475 tons	717,601	5.1 cents per ton
Combined	22,895,125	$1,019,899	4.5

The discrepancy in tonnage between this showing for Miller and the number of tons reported on by him in the foot-note on page 78 is explained by the fact that for 2,592,685 tons he had cubic feet of wood requirement but no data on costs.

Reduced to cords by the equivalent of 80 cubic feet per cord, the price paid per cord for wood at the mines was:

Props	$12.96
Legs and bars	21.36
Average, weighted	$14.64

Using 6 board feet per cubic foot, the lumber represented by the larger-sized timbers costs $44.50 per thousand board feet at the mine, while the same equivalent applied, for sake of comparison, to props gives a value of $27.00 per thousand board feet.

It is evident that at these prices, mine timbers will bear the cost of transportation over considerable distances. As the cost of substitutes is still much higher than for wood, and, as the timbers are indispensable to operation, it follows that as long as the freight charges from the nearest available supply do not exceed this margin, the freight will be paid and added to the cost of the timber laid down at the mine. The marketing of small sizes in this form gives a commercial outlet to material otherwise unmerchantable. Yet under present conditions and practices, the immediate supply of timber obtainable for Illinois mines is insufficient for the demand, and is constantly decreasing.

Based on returns from companies mining one fifth of the total output of coal, it was found that for 1921, 62.3 per cent of all wood used was obtained from Illinois sources, and 37.7 per cent was shipped in from outside the state. The centers of largest coal production, in Franklin and Williamson counties, which in 1921 produced 29.3 per cent of all coal mined in the state, are contiguous to the largest timbered area in the state containing the greatest percentage of non-agricultural land. Rather than be forced to pay excessive freight on these low-grade materials, these mines will always offer an active market for locally grown timber. The higher the freight charges the greater the margin in favor of local supplies. As the cost of cutting and transportation to the railroad is apt to be similar for similar conditions, what would otherwise be paid in freight becomes available either as reduced cost to the mines, increased profit to the contractor or jobber who purchases the timbers, or increase in the stumpage value of the timber itself. The closer the competition and the greater the scarcity of timber, the greater the proportion of this margin which will be secured by the owner of the timber in the form of stumpage value.

There are but two factors working against this prospective increase in value to the owner. One is the possibility of substituting other material for wood in the mines, the other, which is a corollary of the first, is the disruption of the business of furnishing mine timbers from a given region because of the extreme scarcity of wood. In either case the tendency of mine operators is to seek a dependable supply, whether of wood or substitutes, that can readily be secured in the needed quantities. For such guarantee of supply, and because of the cheapened cost of business and of handling, larger prices can be paid than for odd lots, insufficient .in quantity, irregular in delivery, and perhaps of variable quality. It follows that local mine-timbers have a great economic advantage over shipments from greater distances, but that to fully secure these advantages, these timbers must show equally good quality and, still more important, be produced in quantity sufficient to supply a large percentage of the requirements of the mines. The kinds of wood used in the mines include nearly all classes of local timber. For legs and bars, where strength is required, white oak is sought. For props, mixed species are used, the only requirements being soundness or unimpaired strength. This undiscriminating market is a great advantage in the utilization of mixed stands.

Most of the mine timbers imported, come at present from the Ozark region of Missouri where large tracts of small white and post oaks are being exploited for this purpose. It is significant that in spite of these rather extensive timber tracts in a contiguous state, the mines of Illinois still draw more than 60 per cent of their timber supply from the second growth and cut-over areas near at hand, and they will continue to do so as long as these timbers can be obtained at prices comparable with those of importations.

In no other industry does the intimate relation between forestry and close utilization of wood appear so strikingly as in coal-mining. No enterprise is more dependent on wood for its operations, and none except the paper industry uses sizes which can be so rapidly, abundantly, and cheaply produced. Yet in spite of these favorable circumstances, it is generally admitted that wherever extensive mining is conducted, the wood required for these operations is becoming increasingly scarce and difficult to obtain. The cure for this situation lies in fire protection and the growing of crops of timber on an extensive scale. Coal-mining will be the first industry to feel the beneficial effect of such practice.

It should be emphasized that nothing but the production of large quantities of cheap timber of small sizes will solve the problem of supply for coal-mining. It is only to a very small degree a question of treating or preserving timbers to prolong their life. Legs and bars which remain in place more than two or three years may be treated profitably, but the entire consumption of these sizes constitutes but 7.8 per cent of total requirements, exclusive of lumber. Ties, constituting 13.65 per cent, might be treated to advantage. But the props, caps, and riprap, or 78.54 per cent of consumption, would seldom warrant the expense of preservation. If about two years of use is secured, they can then be abandoned. The substitution of metal, concrete, or other mineral supports for such temporary entries presents a problem of expense which will seriously handicap all mines which can not continue to secure cheap timber.

If the growth of timber is placed at the low average of 40 cubic feet per acre annually, it would still require less than 500,000 acres of woodland to furnish a perpetual supply of mining timbers for this industry. The mining companies own 799,060 acres, or 60 per cent more land than they need to produce their own supplies. Owing to the small sizes of the average prop or tie, these supplies can be grown in a shorter period than for any other use except fence posts or fuel. Depending on the soil and species, props may be grown in from 15 to 30 years. In actual practice, lands devoted to the growing of timber should produce nearly twice this yield, or one cord per acre. But instead of being cut clear for small mine-timbers, these should be obtained as thinnings made to release the better trees in order to permit the latter to grow into sizes suitable for legs, bars, or saw-timber. Props can also be cut from the tops of trees used for these higher purposes. Under such intensive forest management it will be possible to furnish Illinois coal mines with a perpetual supply of timber for all purposes from the equivalent of 400,000 acres, by utilizing only the thinnings and by-products or cord-wood and tops grown in raising higher-priced timber. It is probable that most companies will fail to improve this opportunity as long as they can continue to obtain their supplies by purchase through middlemen or contractors, preferring this method to the assumption of the enterprise of forestry as a side-issue to their main undertaking. Woodland owners in Illinois are probably assured of a continuous market for mining timber at constantly increasing prices, due to this lack of foresight of the operators in providing for their future needs.

The Consumption of Wood on Farms

The three outstanding uses of wood on farms in Illinois are for lumber, fence posts, and fuel. The consumption of lumber is estimated to average 1,250 board feet per farm, or a total of 296,476,250 board feet per year on the 237,181 farms. These, and other data on use and production of wood on farms are based partly on the results of a questionnaire sent to 1,600 farmers through cooperation with the Office of Farm Organization and Management and the State Leader of Farm Advisers. Each county agent was asked to supply the names of representative farmers in his county who owned woodland. Another list of names of farmers having over 40 acres of woodland was secured through the assistance of Mr. A. J. Surratt, Agricultural Statistician at Springfield. The Natural History Survey takes this occasion to thank the 440 farmers who aided the investigation by furnishing data.

The Consumption of Fence Posts in Illinois

The average farm in Illinois contained 134.8 acres in 1920. The amount of fencing which is required for all farms in the state was derived in two ways. In Bulletin 321 of the U. S. Department of Agriculture on the subject "Cost of Fencing Farms in the North Central States", Humphrey ('16) gives the number of rods of fence per acre for farms of different sizes. Those between 100 and 140 acres require 6.3 rods per acre. The second method was the questionnaire, answers to which covered 121,434 acres. On this area of 189.74 sections there was required 10 miles and 140 rods of fence per section, or 5.2185 rods per acre.

The area of the average farm for which these data were taken was 354 acres. It was assumed that the average of all fences would require 1 post per rod of fence. The ratio of rods of fence per acre increases as the farm-unit diminishes in area, hence a factor of increase of 20 per cent was applied to these figures, which gave a requirement of 6.26 posts per acre for average Illinois farms of 134.8 acres as against 6.3 posts based on Bulletin 321 (in 1916) for farms of 100 to 140 acres.

The average farm, then, requires 843.8 fence posts in good repair. With 31,974,775 acres of farm land in 237,181 farms, the total number of fence posts in place is 200,163,000 in 625,506 miles of fence, equivalent to 25 times the earth's circumference.

As the area of land in farms is not increasing but, rather, diminishing, any tendency to increase the amount of fencing on the average farm is offset for the state as a whole. The quantity of fence posts required annually for farm-fencing will depend upon the need for replacing defective posts. These annual replacements and the ratio they bear to the total number of posts in use is in turn determined by the average length of life of fence posts in the ground. If this is 10 years, one tenth of the number will represent the annual consumption required to keep up the farm-fencing throughout the state.

To determine the average period of renewals two methods can be applied. One is to compute it from the average duration of service of each class of posts, weighted by the proportion of posts of this class used. The second is to compile data on the actual number of posts required to maintain fences which have been in place long enough to need annual replacements.

It was impracticable to determine the percentage of posts of each species on the basis of the data gathered; but by the second method, based on 1800 miles of fence, the average period of service of a post was found to be 9¾ years. This would indicate an annual requirement by farmers in the state for renewals, of 20,530,000 posts, taking no account of the quantity used by other consumers.

In the construction of the original fences on the farms of the state, at least two thirds of the individual owners probably had a source of supply of fence-post material in their own wood-lots, while a large proportion of the remainder could purchase posts from their neighbors at no great distance. These native wood-lots yielded sufficient supplies of the more durable species to satisfy the demand. In the southern portion, white oak was the principal source of supply, with mulberry preferred whenever it was present and walnut used extensively when available. The wood-lots of the northwestern counties yielded burr and post oak, superior even to the white oak in durability. Sassafras was made use of as posts when it had come in on old fields and had attained proper sizes.

But there remained in many of the prairie counties large areas with no timber or post material except at considerable distances. On these farms, hedges of Osage orange were extensively planted in the early days, and small plantations of black locust were set out by many farmers as a source of future post material. Later, about 15 to 20 years ago, hardy catalpa was extensively advertised and planted for the same purpose.

The Osage orange hedges served a double purpose. During their initial period of growth they were substituted for fences. Later, when land became more valuable and many rods of hedges were grubbed out, these old hedges yielded large quantities of posts, averaging from 16 to 20 per rod of hedge, thus furnishing posts for a fence 16 to 20 times as long as the original hedge.

Of late, the supply of post timbers of these more durable species, such as mulberry and white oak, in the wood-lots, has been nearing the point of exhaustion. White oak grows more slowly than trees of the red or black oak group, and on wood-lots which have been extensively cut and grazed is less numerous than red and black oaks in the reproduction which springs up. The close selection of mulberry for posts tends to exterminate this species in mixture. The white or burr oak land in the northwest counties is of a better grade than black oak soils and tends to pass under cultivation. This has increased the use of several less durable species for posts, principally red or black oak, elm, and even such trees as cottonwood, willow, ash, and maple. All these species are short-lived in the ground, and it does not pay to set them unless first treated with preservatives. When so treated, their average life compares favorably with that of untreated posts of the better species.

To determine the average length of service of the more common post-timbers for Illinois conditions, replies to inquiry on this point were tabulated, and the results compared with the standards of durability published by the U. S. Forest Products Laboratory at Madison, Wisconsin. On the basis of the actual experience of over 400 farmers, corrected when the data which they furnished were insufficient and not in agreement with those of the Laboratory, the following (p. 87) standards of durability for posts of these species untreated, were arrived at.

The most striking fact brought out is the remarkable durability or indestructible character of the hedge or Osage orange posts. Hedge has been used for so long in Illinois, and so many replies were received, that this fact, of which abundant corroborative evidence is available, can be accepted as proved. The only question is the length of this period. As with any species of post, this depends somewhat on the size or diameter. But in Osage orange posts this has less effect than for any other species. The sapwood is narrow, and changes to heartwood in 3 to 4 years, and small posts 2 inches in diameter have frequently given service for 50 years. In fact, these small posts wear out by splitting through the driving of staples, before they decay.

AVERAGE DURABILITY OF SPECIES OF WOOD USED FOR FENCE POSTS ON ILLINOIS FARMS, UNTREATED

Species	No. of replies received	Average durability years	Durability based on white oak—10 years (U. S. Forest Service) years	Standard recommended for Illinois years
I. *Durable*				
Osage orange	128	40	25	40
Mulberry	38	20	20	20
Black locust	22	19	20	20
Catalpa	8	16½	15	15
Northern white cedar	40	14½	15	15
Burr oak	45	13	....	12½
Post oak	8	11½	....	11
Walnut	24	9½	11	11
White oak	241	10½	10	10
Sassafras	10	9	....	9
II. *Not durable*				
Elm	8	6	6	6
Black and red oak	39	6½	4¾	5
Ash	3	4	4¾	5
Maple	5	2½	4½	4½
Cottonwood	1	5	3½	3½
Willow	4	4½	3½	3½

REQUIRED RENEWALS OF UNTREATED POSTS

Number of untreated posts required for renewals annually on farm of 134.8 acres (based on 843.8 posts per farm)	Species	Number of untreated posts required annually *per mile of fence*	Number of untreated posts *in each 100 posts* in fence that must be renewed annually
21	Osage orange	8	2.5
42	Mulberry	16	5
42	Black locust	16	5
56	Catalpa	21	6⅔
56	Cedar	21	6⅔
67	Burr oak	26	8
76	Post oak	29	9
76	Walnut	29	9
84	White oak	32	10
94	Sassafras	35	11
141	Elm	54	16⅔
168	Black or red oak	64	20
168	Ash	64	20
187	Maple	71	22⅕
241	Cottonwood	91	28½
241	Willow	91	28½

Number of Posts of Different Species Required Annually per 100 Acres
(Based on 6.26 posts per acre, or 626 per 100 acres)

Osage orange	15 to 16
Mulberry	31
Black locust	31
Catalpa	42
Cedar, untreated	42
Burr oak untreated	50
White oak, old growth untreated	63
Walnut	56
Treated posts of inferior woods—20 years basis	31
On basis of 30 years	21

The figure of 25 years given by the Forest Service is much too low for this species, as evidenced by testimony on the actual life of posts. It probably represents, not the full life of the posts but the life since they were set out. This is the case with many of the Illinois replies.

It is evident, then, that in hedge posts we have material which, size for size, will give twice the length of service of any known wood, and does this without the additional expense of preservative treatment.

In other respects the results obtained from Illinois sources agree closely with the accepted standards, except in the case of some of the less durable species where insufficient evidence was collected. Here the standard adopted agrees closely with that of the Forest Service. The indicated durability of the red oak group is shortened to 5 years. None of these species should ever be used as permanent posts without treatment.

These standards of durability apply to the average post-material as taken from the wood-lot during the past 20 to 30 years. But with the exhaustion of the virgin stand, posts are being taken to much greater degree from saplings, and round posts substituted for split posts of such species as white oak. With the increased rate of growth of saplings on cut-over lands comes a greater percentage of sapwood, which decays more rapidly than heartwood and shortens the average life of these posts.

FUTURE SUPPLY AND PRICE OF WOODEN FENCE POSTS

Data obtained from questionnaires sent out to farmers indicate that in spite of depletion the woodlands of the state are still supplying nearly 50 per cent of the fence posts needed annually on farms for replacements, or a total of 10,031,860 posts. Under existing conditions a shortage of post timber has already developed and will increase in severity. This shortage is being made up in part by importations of white cedar posts from the Lake states, creosoted yellow-pine posts from the south, and locust and red cedar posts from Kentucky and Tennessee.

The species and number of these posts shipped into certain regions of the state is governed, as in the case of lumber, largely by freight rates. During a nine-months period ending June 30, 1923, one southern pine lumber company alone shipped 138 cars containing over 148,000 creosoted yellow-pine posts into the central prairie region of the state. The number of imported posts will probably increase. In the southern part of the state white oak posts sell at the lumber yards for 16 cents and red cedar and sassafras at 30 to 40 cents. Mulberry posts sold in Union county for 7 cents each in the woods, but this species is generally reserved by farmers when selling timber for mine props. In northern Illinois white cedar posts from Wisconsin sell at 25 to 45 cents, red cedar at 45 cents, and creosoted longleaf pine at 50 cents each. Native white or burr oak posts could be bought in the summer of 1922 in northern Illinois for 15 cents and Osage orange and black locust for 40 cents each.

It is probable that sapling or second growth white oak will not last in the ground much over 8 years, hence it will pay to treat such posts as well as those of the less durable species. The open-tank treatment with creosote, in which heavy absorption or practically complete penetration of the butt of the post is secured, is recommended for all species listed on page 86 except red cedar, Osage orange, black locust, mulberry, and catalpa. When so treated, all of the remaining species except willow and cottonwood will last 20 years and probably considerably longer, thus reducing the annual renewal to less than 5 per cent and making red oak, elm, soft maple, and other inferior species last as long as the more durable species. The wood of willow and cottonwood does not take treatment uniformly, and due to this fact posts may develop decay in a shorter time than would be the case with some of the other species. Yet when these two species are available in quantity they will pay for the cost of securing and treating them in spite of this drawback.

According to MacDonald ('15) the total initial cost for treated cottonwood posts 7 feet long and 4½ inches at the top-end is 40 cents with creosote figured at 30 cents a gallon. This makes the annual charge for the post in place 1.6 cents, if it gives a service of 25 years, and 2 cents a year if it lasts 20 years.

In comparison with this the annual charge for an untreated white cedar post costing 35 cents with 10 cents for setting, a total of 45 cents, would be 3.2 cents per year if it lasted 14 years and 4.5 cents if it lasted only 10 years. The results, then, seem to stand 2 to 1 in favor of the treated cottonwood post over white cedar untreated.

Information on the treating of fence posts by the open-tank method is easily procurable from the U. S. Department of Agriculture (Hunt '16)* and several agricultural stations, such as Iowa (MacDonald '15)†, Minnesota, and Louisiana (Mattoon '20)‡, and it is not necessary to go into the details of the process here since so many excellent bulletins have been written on the subject. There is not only a direct saving in the cost of fencing to the farmer by creosoting the non-durable species, but, more important still, if the practice of treating the wood of all inferior species is universally adopted, extending the life of posts to an average of 20 years instead of 10, there will be required in Illinois annually but 10,000,000 posts instead of the present 20,000,000 or more. By adopting preservative treatment of fence posts the farmers of Illinois can produce enough fence posts, at the present rate, to supply from the farm woodlands all of the needs of the farms for fencing.

THE USE OF SUBSTITUTES—CAST IRON, STEEL, AND CEMENT POSTS

Unless home-treating of fence posts is practiced to a greater extent by Illinois farmers, the unsatisfactory service and frequent renewals resulting from the use of the more numerous inferior species and the increasing prices of durable or treated posts will result in the substitution of steel, iron, and concrete posts. Good authorities say that approximately 1,800,000 steel posts alone were sold in Illinois in 1922, to say nothing of concrete and cast-iron posts, and such sales will undoubtedly be increased by advertising.

Undoubtedly great advances have been made by manufacturers in the production of substitutes for the wooden post, and the steel or iron post may have certain advantages which are strongly pressed. Among these it is mentioned that time is saved in building fence since the posts are driven into the ground, the bearing-surface being increased by anchor plates; that the steel posts act as conductors during lightning storms; that fence-rows can be burned out without damaging the fence; that frost heave is eliminated; that there is no expense for staples, and that the farm can be given a neater appearance by the use of uniformly shaped posts,—all of which are good selling points for the agent.

Among the types of metal posts on the market may be mentioned those made of steel, and of galvanized and cast iron, the last two being un-

* 1916 Hunt, George M. The Preservative Treatment of Farm Timbers. U. S. Dept. of Agr. Farmers' Bulletin 744, Washington, D. C., Sept. 21, 1916.

† 1915 MacDonald, G. B. Preservative Treatment of Fence Posts. Bulletin 158, Iowa Agricultural Experiment Station, Ames, Iowa, August, 1915.

‡ 1920 Mattoon, W. R. Treating Fence Posts on Farms. Circular No. 37, Extension Division Louisiana State University in Cooperation with the U. S. Dept. Agr. Baton Rouge, Louisiana. March, 1920.

doubtedly the most durable, and of course more expensive. The weak points in steel posts mentioned by the Ohio Agricultural Experiment Station, poor quality of metal and too thin material, are being overcome by some manufacturers. Greater care is being taken in the selection of steel and the posts are being made heavier in cross-section, some being of the same shape as a railroad iron. Such steel posts sell for about 45 cents each and are rated by the manufacturers with a durability of 15-25 years, although according to the Ohio Agricultural Experiment Station, which made exhaustive observations on over 10,000 steel and concrete posts, "this type of post has not been in use long enough to judge of its merits". Galvanized iron posts, round in form, are made which spread when driven into the soil, giving them a firmer anchorage. These, which require no staples, cost 55 cents each and are rated with a durability of 22 years. The manufacturers of galvanized steel windmill towers are making posts of the "angle iron" variety, lighter than those of the "T" form, which sell for 45 cents each, and they claim that some of their windmill towers of the same material have been in service for 30 years. Makers of cast-iron posts claim that the purchase of steel posts is a waste of money, and no one doubts the durability of cast iron who has seen it used for underground water-pipes. As with untreated and treated wooden posts, the relative value of steel or other substitutes must be determined by comparing the average annual charges for the various kinds, including the setting and renewal of the posts over a period of years sufficiently long to afford a fair comparison.

We were not able to get a reliable estimate as to the number of concrete posts used in Illinois yearly. Although of higher price when purchased than steel, they have the advantage that with proper molds they can be made on the farm with farm labor. It has been demonstrated that they need to be reinforced and even then, due to difference in composition of materials and faulty workmanship, they have not given as good an account of themselves as expected. The Ohio Agricultural Experiment Station places the concrete post in about the same class as catalpa or white cedar, the later type used by the Big Four railroad showing from 10-30 per cent disintegration in from 8 to 15 years.

The existing information on the relative efficiency of steel and concrete posts does not permit of the conclusion that they have as yet established their superiority over either the durable species of post timber or the inferior species when properly treated. Substitution is yet accompanied by considerable risk and, as in other instances, is being brought about, not by the proved superiority of the substitute but by the progressive exhaustion and failure to replace the needed supplies of wood for this purpose.

Consumption of Wood for Fuel on Farms

The largest consumers of wood for fuel are those who own wood-lots and cut their own wood. A certain amount of wood is sold to city and town dwellers and to farmers who do not own woodland, but this quantity is limited by the comparatively high cost of transportation of wood and the greater labor required in cutting and splitting, storing and piling the wood for use as compared with coal, as well as by the necessity of seasoning green wood. To dwellers in Chicago, wood is a luxury and not a staple. The abundance and wide distribution of coal throughout the state and its greater convenience in handling and storing, smaller requirement in labor, and greater facility for heating and holding fire over night in cold weather have led to a wide substitution of coal for wood, even for domestic purposes, on farms which have wood-lots. Coal and oil almost completely replace wood as a source of power in industry.

From the returns of a questionnaire* it was calculated that farmers consume 93.166 per cent of all the wood burned for fuel; and that wood supplies 25.59 per cent of the combined or total consumption by farmers of wood and coal. The consumption of fuel oil was not obtained, and would reduce the percentage of wood to the total of all fuels used by farmers. The basis of this calculation is the questionnaire to farmers, which indicated that as a class they purchased as much wood as they sold, and hence consumed the equivalent of the production of cordwood from farm wood-lots, leaving the cities to be supplied by the equivalent of cordwood from remaining timber lands. The average yield per acre annually was .332 cords, or a total consumed on farms alone, of 885,792 cords from 2,668,050 acres of farm wood-lots. By using standard weights of wood of different species, and computing the true average based on an approximate per cent of different species used as cordwood, a fuel equivalent of .8 ton of bituminous coal was obtained to one cord of air-dry wood. A cord of black locust or hickory is the equivalent of a ton of coal. A cord of oak is approximately equivalent to .9 ton of coal; beech, walnut, and ash to .8 ton; red maple, gum,

* See Appendix, Note 6, for tabulated data.

sycamore, and elm to .7 ton; yellow poplar and cottonwood to .6 ton; willow and basswood to .5 ton.

It was found that the average farm of 140 acres which burned wood exclusively used 21.4 cords per year, while on farms which burned both coal and wood 13.4 cords were used and 7.66 tons of coal. Farms burning coal only consumed 9.8 tons per year. The wood burning or wood and coal burning farms were those which had fairly large wood-lots, and the average of wood on all farms using it wholly or partly for fuel was 16.1 cords per year. From this figure, divided into the assumed total wood-production for farms of 885,792 cords, it is indicated that about 55,018 farms, or 23.3 per cent of all farms, use wood for fuel at this average rate of consumption per farm, while 76.7 per cent burn coal or oil exclusively. When the acreage of woodland per farm is more than 5 acres, 98.1 per cent of the owners make considerable use of wood for fuel, but when the wood-lot drops below 5 acres per farm, only 44 per cent of such owners burned wood for fuel. These small wood-lots are often grazed and park-like, or are prized for shelter or appearance, and are not adequate as a source of wood fuel.

The indicated consumption of coal by farmers is 2,061,046 tons. The assumed 885,792 cords of wood produced on farms at .8 ton per cord gives the equivalent of 708,634 tons, or a total equivalent of 2,769, 680 tons for the farmers of the state as a whole, of which wood forms 25.59 per cent in fuel value. While 23.3 per cent of all farmers burn some wood, 7.9 per cent still burn it exclusive of coal and 15.4 per cent burn both coal and wood.

A significant fact brought out by this inquiry is that those farmers who have a plentiful supply of wood-fuel use considerably larger quantities of fuel than when forced to buy coal. Based on fuel equivalents, farmers burning only wood consume 176.5 per cent of the heat units consumed by farmers burning only coal, while those who supplement the use of wood by purchasing some coal consume 177.3 per cent of the heat units consumed by those burning only coal. This discrepancy is too large to be completely offset by the supplementary use of kerosene or other fuel oils by those who do not have wood to burn. Farmers who have wood-lots apparently live in greater comfort than those who do not. Yet the coal-burning farmer pays as much for his smaller quantity of fuel as his wood-burning neighbor, even when the cost of labor and a fair price for stumpage is charged against the wood. The average cost of coal to farmers was $6.60 per ton. For wood the cost of stumpage plus labor cost was $2.94 per cord, or the equivalent of $3.67½ per ton of coal, a saving of 45 per cent over coal-prices, which indicates that wood obtained from the wood-lot or neighbors at $2.94 a cord gives 79.6 per cent greater fuel-value for species with .8 tons fuel value per cord than coal at $6.60 per ton. The relative amounts spent on fuel at these values, and assuming all wood as purchased, are as follows:

Coal-burners		
Coal 9.8 tons at $6.60........................		$64.68
Coal-and-wood burners		
Coal 7.66 tons at $6.60........................	$50.56	
Wood 13.4 cord at $2.94........................	$39.40	$89.96
Wood-burners		
Wood 21.4 cords at $2.94......................		$62.92

Considering the fact that labor by the farmer, his family, or hired help is in 90 per cent of all cases expended in place of money, the cash outlay of those who burn both coal and wood is probably less than for coal-burners, while those burning wood exclusively expend considerably less cash. Where labor is used in winter months which would otherwise be laid off, it helps to solve the problem of steady employment, and still further increases the advantage of the use of wood for fuel.

The drawbacks to the use of wood for fuel lie in the labor required for its handling, and, in regions where labor is scarce, coal may be used for this reason. Wood, being more bulky than coal, will not stand transportation by either wagon or railroad over long distances in competition with coal, hence for any but local consumption on short hauls, wood loses the economic advantage which it bids fair always to retain for home use on farms.

The sale of cordwood at luxury prices in large cities is of less importance in the general economy of the state, though it is frequently a source of profit to land-owners who happen to be favorably situated. Otherwise, most of the profit from such sales is absorbed by transportation, and by local wood dealers*.

Sources of Supply of Woods for Illinois Consumers

Sawed lumber is not only the most important and valuable of the forms of wood consumed in Illinois, but it is the class of which the greatest per cent is imported, and from the farthest points. But 2.4 per

* For figures indicating total consumption of cordwood in Illinois for the years 1917, 1919-1921 inclusive, see Appendix, Note 7.

cent of the lumber required in the state is home-grown and a part of that is shipped to Indiana and Missouri.

Of the 2,353,662,000 board feet of lumber consumed in the state, 2,310,453,000 is imported, and 43,209,000 is home-grown and consumed within the state. The sources of this imported lumber are given in Table on page 97.

The cost of lumber to the consumer in Illinois has risen rapidly in recent years and this rise has exceeded that of other commodities.* Since the cost of raw materials is the automatic regulatory factor which reflects growing scarcity as contrasted with demand, the behavior of lumber prices and the causes of these fluctuations are worth examining. If other materials will serve as satisfactory substitutes for lumber for all purposes, the prices of the latter can not rise much higher than those of the substitutes without driving lumber from the market. It is because lumber is still in demand and substitutes are not yet accepted in so many lines, that these lumber prices can and will continue to rise until the economic advantage of cheap lumber is completely lost to the consumer.

Lumber prices have risen because of several factors. First is the general rise in the price of all commodities as the result of the lessened purchasing power of money. In this, lumber has obviously shared. Second is the increased distance of haul from mill to consumer, which takes the form of freight charges. Third is the increase in freight rates of late years. Fourth is the increased cost of logging and transportation to the mill, due to rising prices of wages, but, in addition to these, a fifth factor is the increasing inaccessibility of the remaining timber. Lastly comes actual exhaustion or serious diminution of the supply, until it fails to meet demand. This is followed by breakdown and exodus of the manufactures which depend upon wood for raw materials.

The first of these six factors needs no demonstration and would work no great hardship were prices and wages adjusted rapidly and equitably to the new standards. It is the fact that wood prices rise faster than those of average commodities, which indicates the existence of more serious conditions.

The increased distance of haul is the most influential factor affecting prices. When the Chicago market was supplied largely from the Lake states by water transportation, prices were abnormally low. With

*Since 1865 the average price of lumber in the United States has risen 300 per cent, while the average prices of other commodities have risen during this period but 40 per cent.

the cessation of this barge traffic, an increasing proportion of the supply came from the South, which still furnishes over 50 per cent of the total. Freight charges rose sharply. But already 25.85 per cent of shipments come from the Rocky Mountain and Pacific Coast region, 18.58 per cent coming from two states, Washington and Oregon, with an average freight rate nearly twice that from the South. Within the next decade, these percentages will be reversed and the proportion shipped from the far west will inevitably rise to more than one half of the total, while that from the South will be correspondingly reduced by depletion and exhaustion of her virgin timber lands.

Even the western timber is not unlimited. The area upon which it grows is scarcely a tenth of that which bore the forests of southern yellow pine, and while the stand is heavier per acre, the demand of the entire country will be concentrated upon it. Imports into far eastern states are increasing rapidly and are successfully competing with southern yellow pine.

Freight rates advanced sharply during the war and will probably never recede to their former levels.

There is no question about the greater costs of logging nor the relative inaccessibility of much of the timber which is now being logged. Operators are forced to cut the more accessible timber first, when prices are low and margin for profit and stumpage is small. By the time these easy chances are cut over, prices have usually risen sufficiently to permit the logging of more remote stands. Finally, in a region of high prices near to markets, the most difficult chances can be logged at a profit, and the margin will bear the cost of long freight hauls to bring timber from remote regions, and of expensive operations in those regions to tap the reservoirs of timber in rough mountainous districts, by means of logging railroads, flumes, or other costly improvements.

With the exhaustion of the supply in any locality and the change from an exporting to an importing region, the average local prices are fixed by imports and based on cost of obtaining this imported lumber. The residual local timber-supplies then advance rapidly in value, especially in stumpage value. It follows that those who hold such residual stumpage profit largely by such holdings. This factor operates powerfully to make the local production of timber profitable, since such products get the advantage of the freight differential and can easily undersell the imported product if of equal quality, and still return large profits to the owner or producer. But if through complete breakdown of supply, the more important wood-using industries are driven out of Illinois or forced to close, the tendency will be to ruin the markets for the more valuable products and take the cream off of the profits of forestry.

STATES AND REGIONS EXPORTING LUMBER TO ILLINOIS

The question as to where this enormous quantity of lumber, amounting to 98.16 per cent of the quantity used annually in the state, is obtained and whether such importation can be continued is one of vital interest to its citizens. For convenience, the states exporting lumber to Illinois have been assembled in ten groups, to conform to the grouping used in Bulletin 1119 of the U. S. Department of Agriculture on the Lumber Cut of the United States, 1870-1920. Only those states within each group which shipped lumber *to Illinois* in 1920 were included. The groups, ranked in their relative importance as sources of lumber shipped to Illinois, and the states from which lumber was imported in that year are as follows:

1. Southern Group: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Oklahoma, Texas.
2. North Pacific Group: Washington, Oregon.
3. Lake states Group: Michigan, Wisconsin, Minnesota.
4. North Rockies: Idaho.
5. Central: Indiana; Kentucky, Missouri, Tennessee, West Virginia.
6. South Pacific: California.
7. South Rockies: Arizona, Colorado.
8. North Carolina Pine: Virginia, North Carolina, South Carolina.
9. Northeastern: Maine, New Hampshire, Pennsylvania.
10. Prairie: Kansas.

These groups of states shipped to Illinois in 1920, the following quantities of lumber.

Group	M. Ft. B. M.	Per cent of total
Southern	1,196,797	50.85
North Pacific	437,206	18.58
Lake states.........	383,811	16.31
North Rockies......	115,968	4.93
Central	112,487	4.78
South Pacific	42,924	1.82
South Rockies.....	12,299	.52
North Carolina Pine	4,564	.19
Northeastern	3,365	.14
Prairie	1,032	.04
		98.16
Illinois	43,209*	1.84
Total	2,353,662	100.

Separated into softwoods, or conifers, and hardwoods, the shipments were approximately as follows.

Group	Conifers M. Ft. B. M.	Per cent	Hardwoods M. Ft. B. M.	Per cent
Southern	1,004,684	54.206	192,183	38.420
North Pacific.......	436,637	23.559	569	.114
Lake states.........	211,906	11.433	171,905	34.366
North Rockies......	115,806	6.248	162	.032
Central	21,271	1.148	91,216	18.235
South Pacific	42,910	2.315	14	.003
South Rockies	12,299	.660		
North Carolina Pine	3,353	.181	1,211	.242
Northeast	2,441	.132	924	.185
Prairie	310	.017	722	.144
Total	1,851,547		458,906	
Illinois	1,902	.103	41,307	8.259
Total	1,853,449	100.	500,213	100.

Total consumption 2,353,662,000 feet B. M.

* The total production of lumber in 1920 in Illinois was 56,900,000 board feet. The residue was exported into adjoining states.

Per Cents of Total Shipments from Different Regions, Represented by Conifers and Hardwoods

Region	Per cent Conifers	Per cent Hardwoods	Per cent Total
Southern	42.686	8.165	50.851
North Pacific	18.551	.024	18.575
Lake states.........	9.003	7.303	16.306
North Rockies	4.920	.007	4.927
Central	.904	3.875	4.779
South Pacific.......	1.823	.001	1.824
South Rockies	.522	....	.522
North Carolina Pine	.142	.051	.193
Northeast	.104	.039	.143
Prairie	.013	.031	.044
	78.668	19.496	98.164
Illinois, local.......	.081	1.755	1.836
Total	78.749	21.251	100.

Several important points are emphasized by these figures. Hardwoods, which in 1910 supplied more than half of the raw material for the wood-using industries of Illinois and in 1920 about one fifth, must evidently continue to be secured, if at all, from eastern sources. The central hardwood region, or states contiguous to Illinois on the east, south, and west, supply but one fifth of the hardwood lumber used. One third continues to come from the Lake states notwithstanding the fact that two of these states, Minnesota and Michigan, are now importing a large per cent of their total consumption of lumber (Michigan imports 70 per cent of her lumber for all purposes). Nearly 40 per cent is obtained from the South. In each of these general regions the supplies of virgin timber from which these shipments are being drawn are dwindling rapidly.

Hardwoods usually grow on the better types of soil in these states, which, when cleared, are of potential value for agriculture. There exists in the Lake states a certain residue of poor soils which might grow hardwoods, but, on the whole, the poorer grades of soil in these states are suited to the production of conifers and will not grow commercial hardwoods. This is also true of the hardwood lands of the Southern states. Here the hardwoods occupy river bottoms almost exclusively, areas of alluvial land subject to occasional floods, most of which, like the Mississippi bottoms in Illinois or those of the Cache River, are capable of drainage and agricultural development. The poorer uplands are occupied largely by pine. With the completion of cutting by present operators, this 40 per cent of hardwoods will cease to be a factor in Illinois industry.

When these facts are realized, the significance of the local supply of hardwoods is emphasized. Illinois will never produce conifers, or softwoods, on a large scale, for the reason that both soil and climate favor hardwoods instead, and wherever such conditions exist, hardwoods are capable of crowding out conifers in natural competition. In spite of the great drafts upon local supplies for round products, which absorbed 91.27 per cent of all hardwoods produced, the remainder, or 8.73 per cent, which was sawed into lumber and used in the state, supplied 8.26 per cent, or one twelfth of the present consumption of hardwood lumber, from forests which, on the whole, have not only received no care or protection, but which have been exposed to the ravages of uncontrolled fires since the advent of the white settler a century ago. If capable of conversion entirely into lumber, the Illinois production of hardwoods would have supplied almost the entire quantity of hardwood lumber consumed. As will be shown, the area of land in the state unsuited to agriculture is for the most part well adapted to the production of hardwood timber of fair or even of superior quality. The state thus possesses unique natural advantages within its own borders for producing the raw materials most needed by its wood-working industries. It is obvious that Illinois must depend on importations for its softwood lumber. But it is *equally certain* that an adequate permanent future supply of hardwood lumber from outside sources may not be forthcoming.

Softwoods, or lumber from cone-bearing trees, forming approximately 79 per cent of the total consumption, furnishes all but about 10 per cent of wood used for structural material or building, and in 1920 supplied two thirds of that consumed in the wood-using industries. How large a factor these supplies of softwood timber are in the prosperity and progress of the state can be realized by a rough appraisal of its value, which at an estimated price of $50.00 per thousand board feet would amount annually, for conifers, or softwoods, alone, to about $93,000,000.

In the decades from 1850 down to 1900, by far the greater proportion of this lumber came from the pineries of Michigan, Wisconsin, and Minnesota. Only when these supplies began to wane could southern pine compete in the Chicago market with the lake shipments of white pine or even rail rates from Minnesota. Meanwhile the magnificent forests of the Pacific coast, unexcelled in quality and stand per acre but restricted in area as compared with southern yellow pine, struggled against the handicap of heavy freight rates over distances more than twice as great, and entered the market only by virtue of better grades and light weights.

During the present decade these conditions are again changing rapidly, and for the first time western lumber is entering the market on a large scale in direct competition with southern shipments. The proportion now stands, Southern states, 54.38 per cent of all conifers; Western states, 32.78 per cent, or nearly one third of the total; Lake states, 11.43 per cent, and all other sources 1.41 per cent.

The cut of southern pine is already past its maximum. Another decade will see the position of southern and western supplies reversed, with the Lake states still nearer complete exhaustion. The effect of this process is best brought out by an analysis of the comparative cost of freight on this lumber from the different regions to Chicago. Whenever it becomes necessary to secure the major portion of the lumber for Illinois from Washington and Oregon, not only will the freight charges on this lumber for these distances, which are over 2,000 miles, be added to the price of the western lumber, but the same differential or margin may be added to all other lumber of similar grade shipped from near-by points or from the South.

The regions producing softwoods and hardwoods may be combined and grouped into four general ones: Southern, Western, Lake states, and Central (including Illinois and the Northeast). The supply furnished by these respectively is shown in the following table.

Region	M. Ft. B. M.	Per cent of total	Per cent of lumber shipped into state
Southern, including North Carolina group	1,201,361	51.04	51.99
Western	608,397	25.85	26.33
Lake states	383,811	16.31	16.61
Central, including Illinois and Northeastern group	160,093	6.80	5.07
	2,353,662	100.	100.

FREIGHT CHARGES

An exact determination of the freight charges incurred on lumber from outside the state is impossible, but by computing the approximate average weight of lumber per thousand feet, board measure, and, from freight rates, the rate per thousand feet board measure by regions, these charges may be ascertained with accuracy sufficient for the purpose of this study.

The table following gives these average weights and freight charges and the total for each region by states.

FREIGHT CHARGES ON LUMBER SHIPPED INTO ILLINOIS IN 1920

Group	Quantity shipped M. Ft. B. M.	Average weight per M. Ft. B. M. lbs.	Average cost per M. Ft. B. M.	Total freight charges
Southern	1,196,797	2,980	$12.414	$14,857,452
North Pacific ...	437,206	2,716	19.028	8,319,179
Lake states......	383,811	3,123	5.407	2,075,398
North Rockies....	115,968	2,461	16.572	1,921,786
Central	112,487	3,666	11.26	1,266.442
California	42,924	2,440	17.32	743,443
South Rockies ...	12,299	2,398	10.85	133,489
North Carolina Pine	4,564	3,610	16.838	76,850
Northeast	3,365	2,852	13.99	47,076
Kansas	1,032	3,033	9.40	9,700
Total	2,310,453	Av. 2,949.1	Av. 12.746	$29,450,815

The rates used and resultant charges per M. Ft. B. M. are shown in the table following.

FREIGHT BY RATES AND WEIGHTS OF LUMBER FROM SELECTED POINTS IN EACH STATE. 1920 RATES

States	Mileage basis used	Rate per 100 lbs.*	Freight per M. Ft. B. M.	Total cost of freight
Louisiana	1,149	.44	$13.11	$5,755,080
Mississippi	828	.40	11.92	2,796,551
Arkansas	670	.385	11.47	2,331,770
Texas	1,056	.44	13.11	2,099,173
Alabama	784	.41	12.22	1,035,522
Florida	1,028	(.39)	11.62	476,733
Oklahoma	740	(.335)	9.98	199,130
Georgia	881	.39	11.62	163,493
Average weight per M. ft. B. M.	2,980 lbs.	Av. rate 12.41	....	14,857,452
Washington	2,325	.73	19.82	6,133,120
Oregon	2,291	.72	17.11	2,186,059
Average weight per M. ft. B. M.	2,716 lbs.	Av. rate 19.03	....	8,319,179
Wisconsin	263	.14	4.37	847,937
Minnesota	608	.205	6.40	698,457
Michigan	310	(.21)	6.56	529,004
Average weight per M. ft. B. M.	3,123 lbs.	Av. rate 5.41	....	2,075,398
Idaho	1,737	(.685)	16.85	1,314,266
Montana	1,578	(.65)	16.00	607,520
Average weight per M. ft. B. M.	2,461 lbs.	Av. rate 16.67	....	1,921,786
Missouri	527	.29	10.63	471,929
Tennessee	527	.36	13.20	515,182
Kentucky	388	.31(?)	11.36	168,048
Indiana	193	(.175)	6.41	65,798
West Virginia	534	.31	11.36	45,485
Average weight per M. ft. B. M.	3,666 lbs.	....	Av. 11.26	1,266,442
California	1,981	.71	17.32	743,443
Average weight per M. ft. B. M.	2,440 lbs.	....	....	....
Arizona	1,717	(.45)	10.79	128,451
Colorado	1,174	.535	12.82	4,948
Average weight per M. ft. B. M.	2,398 lbs.	....	Av. 10.85	133,489
North Carolina	1,059	.49	17.69	40,138
South Carolina	1,036	.47	16.97	24,962
Virginia	809	.395	14.26	11,750
Average weight, per M. ft. B. M.	3,610 lbs.	....	Av. 16.83	76,850
New Hampshire	1,258	(.475)	13.54	41,026
Pennsylvania	620	(.365)	10.41	2,061
Maine	1,355	(.475)	13.54	650
Average weight, per M. ft. B. M.	2,850 lbs.	....	Av. 13.99	43,737
Kansas	....	(.31?)	9.40	9,700
Average weight per M. ft. B. M.	3,033 lbs.			
				Total $29,447,476

Rates in parentheses are for 1923; the rest for 1920.

The total freight bill may now be compared by regions with the shipments of lumber from the same regions.

Region	Total freight bill (dollars)	Per cent by regions	Per cent of shipments by regions
Southern	14,934,302	50.71	51.99
Western	11,117,897	37.75	26.33
Lake states	2,075,398	7.05	16.61
Central and East.	1,319,879	4.48	5.07
	29,447,476		
	Average freight rate per M. ft. B. M.	Average weight per M. ft. B. M. lbs.	Freight rates per 100 lbs. cents
Southern	12.43	2,980	41.70
Western	18.27	2,641	69.18
Lake states	5.40	3,123	17.29
Central and East.	11.29	3,637	31.04
Average, weighted	12.80	2,950	43.38
	Rate in per cent of average rate	Rate in per cent of Lake states rate	
Southern	96.12	241.17	
Western	159.47	400.12	
Lake states	39.85	100.00	
Central and East.	71.55	179.52	

These figures reveal the influence of freight charges in increasing the price of lumber to Illinois consumers. A shift of the center of production to the South added $7.03 per thousand board feet in freight alone, to the cost of all lumber from that section. The further shift to the far west increased the freight bill by $12.87 over the Lake states and by $5.84 over the southern shipments. These discrepancies become greater when weight and not volume is compared, for the average western shipments are 339 lbs. lighter per thousand feet board measure than those from the South, 482 lbs. lighter than Lake states shipments, which include hardwoods, and 996 lbs. lighter than shipments from the central hardwood region, in which hardwoods predominate. Comparing the average rates per 100 lbs., it is seen that the shipments from the Lake states can be brought to Chicago for 40 per cent of the average cost of freight by all-rail shipments, a fact which in itself indicates that the great and now largely devastated pineries of these states form the natural economic unit for supplying Illinois with softwood lumber in the future. Again, it is seen that already the average freight rate on all lumber, by weight, has risen above that from the Southern states, due to the 60 per cent greater cost and the increasing quantity of western lumber. Finally, the southern freight rates are seen to average nearly two and a half times those from the Lake states, while the western freights reach four times the Lake states rates. At present, these western freight rates are fixed partly to meet southern competition. The rate per mile on 100 lbs. of lumber for the different regions is shown below.

Region	Aver. haul, miles	Aver. freight rate per 100 lbs. (cents)	Aver. rate per mile of haul on 100 lbs. (cents)
Southern	952	41.70	.0438
Western	2,158	69.18	.0321
Lake states	371	17.29	.0466
Central and East.	496	31.04	.0625

Thus the present rate on western lumber per 100 lbs. for one mile is but 73 per cent of that from the South. If raised to an equal rate, the cost of freight from the West would be increased 26 per cent over present rates. This will probably not occur, since long hauls are given a proportional reduction in rates over shorter hauls on account of equality of terminal charges. But with southern pine eliminated, the tendency will be for the railroads to secure an upward readjustment of freight rates on western lumber, the only other restraining influence being water transportation.

That the freight bill on lumber, now close to $30,000,000, will steadily increase by the substitution of western for southern and Lake states lumber is inevitable. With this increase, the consumer will have to pay proportionately more for his lumber than this increase indicates, since basic costs delivered become the basis for computing retail expense and profit. But the greatest danger lies in the fact that by the law of marginal costs, the prices of southern and Lake states softwood lumber will ultimately be determined by that of the Pacific coast shipments, and this freight charge will be added, not merely to these western shipments but to the entire remaining supply. The deduction can be drawn—since southern pine lumber can be produced in reasonable quantities to replace the vanishing present supply and can be laid down at 60 per cent of the cost of western lumber—that, next to the Lake states, the South should eventually furnish the larger part of the needed lumber to Illinois in the more or less distant future. Pacific coast timber can be shipped by water to the Atlantic seaboard at less cost than to Chicago by rail.

The percentage of shipments from the far west will rapidly increase as the eastern region declines, and in the decades of 1930-1960 this region must supply by far the larger portion of the quantity used, at steadily increasing prices. This condition will make it more and more profitable to grow timber as a crop in regions located nearer the consumer and with lower freight charges. Because permanently prevented by her climate and soils from ever producing an appreciably large per cent of softwood lumber, Illinois has a direct economic interest in the proper management of these great pine regions to the north and south, and her citizens should emphasize this fact on every possible occasion. Meanwhile the state, by a vigorous forest policy, may succeed in producing within her borders a substantial proportion of the hardwoods needed in many lines of industry.

Retail Prices for Lumber in Illinois

No exhaustive study was made of the retail prices of lumber in Illinois, but the effect of the exhaustion of the Lake states pineries, and later of the increasing scarcity of eastern timber and shifting of the center of production towards the far west, can be seen by exhibiting the average prices by years of a few standard grades of lumber for the past few decades. These are given for the decades up to 1900, and for each year since that date, to exhibit the course of lumber prices during the war and their subsequent stabilization at a level considerably higher than before.

Retail Prices, Chicago Market, 1850 to 1919, Inclusive

Northern White Pine, Common Boards

Year	Price per M. ft.	Year	Price per M. ft.
1850	$ 9.75	1908	$31.50
1860	9.57	1909	31.00
1870	10.92*	1910	30.75
1880	12.00	1911	31.00
1890	13.17	1912	31.25
1900	18.81	1913	33.80
1901	19.25	1914	33.00
1902	21.25	1915	33.67
1903	21.86	1916	35.50
1904	23 17	1917	45 75
1905	25.67	1918	55.75
1906	30 00	1919	61.60
1907	33.50		

* Gold.

*Southern Yellow Pine—Finish, S2S**

Year	Price per M. ft.	Year	Price per M. ft.
1900	$33.80	1912	$ 40.00
1901	30.62½	1913	45.60
1902	34.50	1914	40.33
1903	35.00	1915	39.00
1904	33.86	1916	40.50
1905	38.83	1917	51.54
1906	41.50	1918	64.17
1907	39.50	1919	89.91
1908	38.18	1920	143.94
1909	37.73	1921	80.00
1910	37.33	1922	94.17
1911	37.33		

* Surfaced on 2 sides.

Northern White Pine—Clear Boards (Rough)

Year	Price per M. ft.	Year	Price per M. ft.
1850	$17.00	1909	$90.00
1860	26.45	1910	91.25
1870†	39.57‡	1911	92.00
1880†	43.50	1912	92.00
1890	43.17	1913	97.00
1900	57.53	1914	97.33⅓
1901	60.53	1916	99.50
1902	77.00	1917	116.87½
1903	85.00	1918	129.00
1904	84.33⅓	1919	151.83⅓
1905	84.00	1920	225.00
1906	90.00	1921	225.00
1907	94.37½	1922	230.00
1908	90.62½		

† Data from "Industrial Chicago," Vol. V, p. 194, by George W. Hotchkiss.
‡ Converted from currency to gold basis.

Southern Yellow Pine

No. 2 Common Boards S1S or S2S 4″ and 6″*

Year	Price per M. ft.	Year	Price per M. ft.
1902	$19.33	1913	$25.44
1903	20.00	1914	23.47
1904	20.00	1915	24.73
1905	21.66	1916	26.40
1906	25.00	1917	33.98
1907	23.44	1918	44.35
1908	20.51	1919	53.57
1909	20.88	1920	67.73
1910	19.95	1921	38.20
1911	21.20	1922	42.10
1912	23.45		

* Surfaced on 2 sides.

Douglas Fir No. 1 Common 2 × 4; 16′

Year	Price per M. ft.	Year	Price per M. ft.
1905	$22.00	1919	$53.57
1910	23.00	1920	67.73
1915	24.73	1921	38.20
1918	44.35	1922	42.10

Oak, Clear, Quarter-sawed White 2¼″

Year	Price per M. ft.	Year	Price per M. ft.
1900	$ 66.00	1919	$190.00
1910	83.00	1920	360.00
1915	92.00	1921	182.00
1918	113.00	1922	165.00

Oak, Plain-sawed White 2¼″

Year	Price per M. ft.	Year	Price per M. ft.
1910	$ 57.00	1920	$260.00
1915	63.00	1921	137.00
1918	80.00	1922	125.00
1919	138.00		

Chicago prices for mixed lumber up to 1910 were:

Year	Price per M. ft.	Year	Price per M. ft.
1860	$ 8.26	1890	$15.16
1870	10.95*	1900	14.04
1880	12.70	1910	24.49

* Gold.

SUMMARY CONCERNING PROPORTION OF WOOD PRODUCTION TO WOOD CONSUMPTION IN ILLINOIS AND CONCLUSIONS THEREFROM

Referring to the table on page 52 we see that the wood-lots of the state have depreciated until at the present time two thirds of their entire yield is fire-wood only, which supplies farmers with one fourth of their fuel, so that for this inferior purpose alone the output would supply but half the quantity burned; and a ready substitute exists in the form of coal. The veneer industry, especially for low-grade materials used for fruit packages, can not afford to import logs from long distances hence it imports less than 40 per cent of its logs, and the local supply is rapidly disappearing. About sixty per cent of the post and mine material, which can be filled by products of small sizes, is still obtained from local timber but with increasing difficulty, while the supply of cross-ties has dropped to about 15 per cent of consumption. In the case of lumber, but 2.4 per cent is produced locally, although of hardwoods the state supplies 8 per cent of the consumption. This means that trees of larger sizes are becoming increasingly scarce. The total consumption of wood of all kinds including fire-wood is five times the rate of production, and when fire-wood is excluded, only one twelfth of the wood products consumed annually are grown within the state.

Two conclusions may be drawn form this summary. First, it is evident that as a state Illinois can continue to obtain twelve times as much wood as is produced from her own woodlands only so long as other states consume less than they produce, for when the surplus in the exporting states is used up, the remaining wood will tend to stay at home and be manufactured near the source of production. The state will continue to secure a portion of this wood, by paying sufficiently high prices to draw it away from competitors in spite of the advantage of freight differentials, but as it costs less to ship manufactured products than logs or lumber, these wood importations will be largely of high-grade lumber as long as such may be obtained. It is equally evident that this great excess of consumption of lumber over actual rate of home production is a purely temporary condition made possible by a store of original growth which by this process is being depleted and destroyed. When there is no wood remaining, wood must cease to be used. The consumption of wood in the country at large will probably within 50 years drop perforce to a point which no longer exceeds growth, and will then be 100 per cent of production. Unless imported from foreign countries, America will be producing as much wood as it consumes. How much that will be will depend upon the success of the efforts put forth to grow wood on forest lands. Already many Illinois industries are feeling the pinch of scarcity and must either migrate, substitute other materials for wood, or discontinue. The state and its population can not afford to neglect its 5 million acres of potential woodland. Not only can this area be made to produce from 250,000,000 to 400,000,000 cubic feet of wood, or from one half to two thirds the total present consumption, but by better management the percentage of the more valuable products can be greatly increased, reducing the percentage of cordwood proportionately, and relegating it largely to the salvage of waste in tops and slabs. With this conservation of her potential forest resources, the state will receive tremendous benefits in all lines of industry through the increased or maintained prosperity flowing from the forest industries and production.

The Forests of Illinois, Original and Present

THE ORIGINAL FORESTS

The pioneers who were to settle in this region, viewing for the first time extensive natural prairies, were so impressed that they named Illinois the prairie state. Yet it appears that over 40 per cent of the state was originally wooded.

Estimates made by early explorers, and later tentatively confirmed by the State Soil Survey, indicated that this forest area was about one third of the state. A map prepared from the reports of the Soil Survey reveals the original distribution of this timber. The southern counties were all heavily timbered. These timber areas extended northward along all the streams, diminishing in quantity and area as the land became more level and true prairie more abundant. An extensive belt of woods followed the Mississippi and the Illinois rivers, and in the northwestern counties woodland again increased in area.

By carefully checking existing records it has been concluded that the original area of woodland in the state was larger than these previous estimates have indicated, being approximately 15,588,965 acres, or 43.46 per cent of the total of 35,867,520 acres of land in Illinois.

The manner in which these forest areas have thus been reconstructed brings out points of considerable interest. In conducting the intensive work of soil-mapping, the Illinois Soil Survey found that a very sharp distinction existed between prairie soils and forest soils in the amount of humus content. The soils which had been continuously in prairie, under a heavy sod of grasses, contained about twice the per cent of humus that was found in soils of similar origin and structure, but which had continuously borne forest-cover. This difference was caused by the effects of the grass roots, which filled the upper layers of the soil with vegetable matter and excluded air, favoring the accumulation of humus, while, by contrast, tree roots in decaying admitted air and were oxidized, while most of the tree litter was burned, or oxidized, on the surface.

The balance between forest and prairie seems to have remained fairly constant over a considerable period and to have been determined by two factors, topography and soil being one, and fire the other. Wherever the surface was broken or hilly, as along streams, tree vegetation became established, aided by soils which contained coarser materials, while on the flat, poorly drained prairie the soil was a black loam, of a fine texture which is less favorable for tree growth even in planted groves than for farm crops. Trees might and probably would have invaded the prairies in spite of these handicaps of soil and drainage had it not been for fires in the grass, which must have burned at frequent, perhaps annual, intervals. The prevailing winds are southwest. Almost without exception, the map of forest soils shows that the strips of timber along streams were considerably wider on the north or east banks than on the south or west. The fires on the exposed banks confined the timbers closely to the stream, while this stream-barrier permitted the forest to creep out in the lee of the protection thus afforded. While clearing has over wide areas removed all traces of the original forests, the record of its previous existence is thus imbedded in the character of the soil itself, and the reliability of the classification thus indicated has been abundantly proved in areas where the evidence still remained in the form of stumps, or remnants of the forest itself.

Based upon these soil classifications, the Soil Survey states that in 44 counties for which records are completed, a total of 6,105,032 acres was originally forested. A map showing the gross areas of these forested soils for all counties indicates that approximately 50 per cent of the state might have originally had timber cover. But there exist many smaller areas of prairie soils within these districts. For the 44 counties above mentioned, it was found that the area of forest soils as shown by the map was apparently 7,016,223 acres, thus indicating that but 85.73 per cent of the apparent forest area was actually forested, or 6,105,032 acres.

For the entire state, a gross area of 17,838,971 acres of original forest soils was indicated by this soil map. Applying the same reduction per cent to this figure, the resulting net area originally forested was indicated as 15,293,349 acres, or 42.64 per cent of the state. This rough check was then confirmed in another manner.

The forty-four counties on which the Soil Survey figures were based are distributed as follows:

In the sixty-one counties lying in the north half of the state thirty-two were covered and twenty-nine omitted. In the forty-one counties making up the more heavily wooded southern half, twelve were covered and twenty-nine omitted. It is these southern counties, whose weight is thus considerably lessened, which raise the total of wooded area above the one third, which applied more correctly to the remainder of the state than to the whole. A separate computation of these two groups of counties gave areas originally wooded as follows:

Northern group, 61 counties

From map, 32 counties...........	4,665,049 acres
Actually compiled	3,928,101
Difference	736,948
or 15.797 per cent	
From map, 61 counties..........	8,656,683.
15.797 per cent..................	1,367,496
Net area forested...........	7,289,187

Southern group, 41 counties

From map, 12 counties..........	2,308,838
Actually compiled	2,086,931
Difference	221,907
or 9.611 per cent	
From map, 41 counties..........	9,182,288
9.611 per cent....................	882,510
Net area forested...........	8,299,778
Total for state, area forested...	15,588,965 acres

These original forests showed an unusual variety of species. The gums, cypress, and similar subtropical trees grew in southern Illinois, while tamarack, arbor vitae, and associated sub-arctic species could be found occasionally in the northern part of the state. Between these extreme zones grew the wealth of hardwoods dominantly oak in character which reached their culmination for this continent in the lower Ohio and Wabash valleys. This hardwood forest varied, for different sections of the state, in species composing the stand and in the forms of trees. Thus in the southern uplands the forests were continuous and show a greater variety of species as well as a generally better growth for similar species than in the northern upland stands. These southern forests were noted for the high quality of the timber which they contained. In the northern uplands the trees grew in open park-like formations, thinning in the advance toward the prairie to the fire-scarred and gnarled outposts. There is evidence that the forests were constantly endeavoring to encroach upon the prairie, but that annual fires generating an intense heat in the abundant grass-cover burned back the tree seedlings and served as a check upon the advance of the forest. The pioneers describe the old forests of the prairie counties as being stands of grove-like aspect bordering streams and thinning rapidly as the prairie was approached. Toward the margin, the forest floor was carpeted with a dense growth of seedling sprouts growing between the scattered old trees. These seedling sprouts were killed annually by the fires. The forests in the lower Ohio and Wabash basins were the finest hardwood stands in America. Those of the southern uplands were excellent in character. The forests in the valley of the larger streams of the central and northern parts of the state were but slightly inferior to those of the Wabash-Ohio basin. Those of the smaller streams near the prairies were open and park-like.

Several local variations are worthy of mention. While dominantly hardwood in character, yet conifers were found in the original forests. Cypress extended up the Ohio and Wabash rivers and along the lower Mississippi for several miles. Probably the best stands of cypress were found in the Cache River basin, where it grew pure or mixed with tupelo gum. One small grove of shortleaf pine occurs on the dry slopes of the westernmost bluff of Union county and another group occurs in a sandstone ravine in southeastern Randolph county. White pine grew along the river bluffs in several regions north of the Illinois River, the southernmost outpost being on a bluff of the Spoon River in Knox county. The red cedar was found generally throughout the state on the drier bluffs.

Throughout the state may still be found small remnants of these original forests. Studies made in the best of these are tabulated below. The average yields for the original virgin stands for the respective regions of the state were lower than those shown for the limited areas measured.

DATA OBTAINED FROM STUDIES MADE IN THE BEST ORIGINAL FORESTS OF ILLINOIS

I. Cypress bottom, Cache River. Based on strip line of 3.94 acres

Species	Cypress	Soft maple	Carolina poplar	Elm	Ash	Hickory	Hackberry	Total
No. of trees per acre D. B. H. 6″ and up	70	3.3	12.7	2	2	.5	1	91.5
B. F. yield per acre	13421	291	141	50	12	9	7	13931
Max. D. B. H., inches	30	29	20	17	15	10	12	
Max. height, ft.	100	80	70	60	80	60	50	

II. Ozark uplands, agricultural soil, Union county. Based on ½ acre plot

Species	Wh. oak	B. oak	Tulip	Hickory	B. gum	B. walnut	Sassafras	Total
No. of trees per acre D. B. H. 6″ and up	10	12	8	6	2	2	4	44
B. F. yield per acre	1836	4460	5480	286	270	210		12542
Max. D. B. H., inches	25	31	27	13	13	15	14	
Max. height, ft.	90	100	100	65	60	65	40	

III. Little Wabash basin*, White county. Based on 3.03 acres

Species	Wh. oak	B. oak	Sw. gum	Bl. gum	Hickory	Elm	Sassafras	H. locust	Ash	Bl. Wal.	Total
No. of trees per acre D. B. H. 6″ and up	15.5	4.3	10.2	3.3	11.2	3.6	1.3	.3	2.3	1.0	53.0
B. F. yield per acre	15503	2529	5643	188	2334	100		230	493	63	27083
Max. D. B. H., inches	40	36	34	16	32	15	14	22	22	17	
Max. height, ft.	130	120	125	70	120	90	80	125	110	70	

IV. Kaskaskia bottoms, Randolph county. Based on 1 acre

Species	Wh. oak	Pin oak	Hickory	Hackberry	Ash	Elm	Total
No. of trees per acre D. B. H. 6″ and up	3	14	10	2	5	11	45
B. F. yield per acre	423	9680	3880	10	545	1736	16274
Max. D. B. H., inches	22	39	25	9	20	32	147
Max. height, ft.	90	105	100	40	90	80	505

V. Upland, McDonough county. Based on 4 acres

Species	Wh. oak	Bl. oak	Hickory	Cherry	Elm	Bl. Walnut	Basswood	Total
No. of trees per acre D. B. H. 6″ and up	26.25	12.5	8.75	1	5.75	2	.75	57
B. F. yield per acre	3977	947	271	59	346	110	50	5760
Max. D. B. H., inches	30	22	17	15	18	16	18	
Max. height, ft.	80	80	70	60	70	60	70	

For a thousand tree-generations these forests held the land. The Mound-builders followed the dim trails and vanished. The later Indians altered them less than the beetles. In the hundred years that the French held the settlements the forests were as when the Mound-builders found them. Then entered the white settler, and in one tree-generation the forest areas were reduced from 15,588,965 acres to 2,863,764 acres of woodland, or but 18 per cent of the former area, largely cut over. Of the stands of virgin forest there survives a mere remnant.

The pioneers coming from the east and from Kentucky, where the very habits of living were moulded by association with the forest, knew the value of the woodland. Experience had taught them that the finest hardwoods grew on the most fertile soils and led them to think that areas naturally devoid of trees were barrens. So coming upon the great expanse of Illinois prairie they sought out the forested bottoms for home sites. Even had the pioneer appreciated the superior agricultural value of the prairies he could not have settled there at that time. He had not yet emerged from the period of incessant frontier warfare and the forests often concealed his home. Nor was he familiar with the walled-in well,

* For figures on individual trees of original forest see "Additional Notes on the Native Trees of the Lower Wabash Valley", Robert Ridgway. (Proc. U. S. Nat'l Mus., Vol. 17, 1894, pp. 409-421.)

and so sought out a site near a running spring. The forests were the only source of fuel and building material and he was ill-equipped to haul heavy loads over great distances. The prairies were swept by intensely hot fires, the winter winds found nothing to break their bleak force, and innumerable malarial mosquitoes bred in stagnant pools. For several years prairie land could be bought for five dollars, while forested land sold for thirty-five dollars an acre.

Thus we find the flow of settlers in the early decades of the past century at first a mere seepage creeping over the heavily forested areas of the southern part of the state, skirting the prairie, extending back up the rivers, ever following river and forest, held from the prairie until about 1830. The tide of immigration became ever greater, crept out from the margin of the woods in the early thirties, and suddenly flooded the prairies in the late thirties. In 1830 the prairies had scarcely been touched by settlement. By 1840 less than one twenty-fifth remained unsettled. This last frontier was not the rough forest land, but parts of Ford, Iroquois, and Champaign counties.

Settlement in Illinois in its effect upon the forests but repeated the conditions of the older-settled states. The loamy bottomlands and best soils were cleared. Generally the logs were heaped and burned. The rougher slopes and poorer soils remained in forest. Although for the most part destructive in his attitude toward forests, yet throughout the uplands in the central and northern parts of the state, it happened that probably for the first time in the nation's history the pioneer unwittingly improved these forests. When in the thirties the prairie sod was broken, forest fires were checked. The seedling sprouts which sprang up yearly after the fires, now developed into a thick stand of saplings. The demands of the region for fuel and building material resulted in cutting the older inferior overwood. Free from shade the saplings quickly developed into a dense even-aged stand and even encroached upon the prairie where not checked by the plow.

The settlement of the prairie increased the value of the limited wooded parts of the prairie counties. Settlers would not buy prairie land unless several acres of woodland were included. This frequently resulted in the wood-lot, which supplied the fuel and building material, being several miles from the farm.

Two events ocurring about 1860 reversed the relative values of prairie land and forest land for the prairie regions. The railroads came to the farms, bringing building material and coal. The base-burner coal stove was patented and added comfort to the life of the prairie farmer. From this date forward the forests did not greatly increase in value, but prairie land began its climb towards $250 per acre. Thus the timber-land owner was under a pressure to clear wherever tillage was possible, and this has been the trend to the present day.

Present Forested Areas and their Relation to Land Economics in the State

The figures given for the present wooded area in Illinois are as yet tentative, pending the completion of the forest survey now being conducted. They are based upon data gathered in 33 counties north and west of the Illinois River and 13 counties in the southern part of the state.

Those areas of woodland more than 5 acres in extent were mapped and their totals found by counties. Two other sources of information were available as checks. The 1920 census reported farm woodland by counties, and in 1922 crop reports were made showing farm woodland. The forest survey included all woodlands, the census and crop surveys included only woodland on farms. It was shown by comparison that the census returns were about 36 per cent higher for timber on farms than actually shown by survey for total timber. The crop reports were less than two per cent higher than the survey. In computing the total timber on farms the nature of the ownership of the timber-lands was taken into consideration. If the county had large areas of timbered bottomland, was evidently a county where mine-company holdings were important, or for any reason contained considerable bodies of timber-land not on farms, the crop report figures were ordinarily used to compute the area of woodland on farms. If the timber-land was entirely on farms the survey figures were used. To get the total timber for the state the survey figures were used where complete, and crop-report figures where the survey has not yet been completed.

The preliminary result gives:

Areas of woodland on farms	2,668,050
Area of woodland not on farms	195,714
Total area of woodland in state	2,863,764

This total is 92.3 per cent of the area shown by the census of 1920 as contained in farm woodlands alone, and when the 195,714 acres above indicated as not included in farms is added to the census figures, this total, based on actual mapped areas supplemented by crop report data, falls to 86.8 per cent of the census figures. If the original forested area of the state was 15,588,965 acres, this indicates that 82 per cent of the forest lands has been actually cleared and is either under crops, or pasture, or is classed as waste or eroded land, and has ceased to be forest or woodland.

The changes wrought in this remaining one sixth of the state's woodlands by lumbering, fire, and grazing have steadily reduced the stand of timber in both volume per acre and number of trees, and if continued unchecked must finally result in an almost complete ruin of this residual area for forest production by natural processes.

Classification of Timber by Regions

The wooded regions of Illinois can be divided, first, into bottomland and upland, with a further classification of each of these based on the prevailing soils and species. The regional classes might be arranged for the state as follows:

I. BOTTOMLAND

a. Southern cypress.—This extends from Wabash county south along the Wabash, Ohio, and Mississippi bottoms to McClure, in Alexander county, and is found also in the Cache River bottoms. Mixed with the cypress are such species as sweet gum, silver maple, elm, willow, ash, cottonwood, and Carolina poplar. In the Mississippi bottoms and in the Cache River bottoms, in addition to these species is found tupelo gum.

b. Mixed hardwood.—This extends from the northern range of cypress along the flood-plains of the principal rivers, Mississippi, Illinois, Kaskaskia, Wabash, and the lower reaches of the Little Wabash and the Embarras. It is characterized by a great diversity of species and shows the best growth rates and yields of any type in the state. It is composed of such trees as the gums, sycamore, ash, hickory, pecan, elm, cottonwood, silver maple, and pin, swamp-white, burr, white, Schneck's and overcup oaks, in the south; with white, swamp-white, burr, pin, and shingle oaks, elm, hickory, ash, soft maple, river birch, hackberry, sycamore, and cottonwood in the central and northern sections of the state.

c. Gray clay bottoms of the Big Muddy, Saline, upper Little Wabash and upper Embarras. Pin,. shingle, swamp-white, white, and post oaks and ash, elm, hickory, and sweet gum are typical trees.

d. Alluvial strips along the secondary streams throughout the state. Soils are mixed loams and fertile. Basswood is a common tree in the northern region and black walnut grows freely.

e. Sand-plains and dunes.—These are found along the middle Illinois River in Mason county, southern Whiteside, and western Lee, Henderson, Kankakee, Grundy, and Iroquois counties. While found on and near bottoms they yet may have a desert vegetation. Black-jack oak *(Quercus marilandica)* is found on the poorer sites, with black oak, hickory, and white oak on the better ones. The types *d* and *e* are really intermediate between bottomland and upland types.

UPLAND

a. Ozark upland.—This is upland south of the limit of ice invasion, extending from southern Jackson county through southern Williamson, Saline, Pope, and Gallatin counties. Characterized by beech, hard maple, red, black, white, and shingle oaks, hickories, tulip-poplar, ash, red gum and black, elm, wild black cherry, black walnut, and cucumber-tree.

b. Loessial uplands bordering the Mississippi, Illinois, and Wabash river flood-plains. In the south, along the Mississippi and Wabash rivers, are found all species common to the Ozark upland and, in localities, considerable basswood in addition.

c. Gray silt loam uplands of the Illinois glaciation, in the interior of the state extending from the Ozark uplands north to the Wisconsin moraine and black soil belt. Characterized by post, black, shingle, white, and pin oaks and hickory.

d. Yellow silt loam uplands of central and northern Illinois. Characterized by a good growth of black, white, and burr oak, and hickory, with black walnut and black cherry on the better and scrub oak on the poorest soils.

The tamarack swamps of Lake county, the white pine of Ogle county, and the shortleaf pine in Union, Jackson, and Randolph counties are of ecological interest but are not important timber types.

Included in these forest areas at present are stands of every size and all ages from saplings to over-mature virgin stands. In general the bottomland stands throughout the state show a greater diversity of species than the upland stands and are not usually even-aged. Again, in uplands of the southern part of the state, removal by species or by occasional larger trees has resulted in stands of uneven age. In the northern part of the state the upland stands are usually even-aged and from sixty to eighty years old.

The original forests probably averaged 8,000 B. F. per acre. The present forests for the entire state average approximately 1,435 B. F. to the acre. The better stands of upland even-aged immature timber of the northern part of the state run from 3,000 to 6,000 B. F. per acre. Trees below 16 inches are numerous; above that size, very few.

The all-aged upland forests of the southern part of the state have been overcut and not enough trees remain to insure maximum yields. The bottomland stands throughout the state vary within greater limits as to yield and representation of species, but probably show a higher average than the uplands. The final class of forested lands which are worthy of consideration are the sands supporting black-jack oak and the gray clays supporting post oak. Yields of such stands are very low and seldom produce any materials other than fuel, posts, and mine props.

Sample Stands and Yields—Upland

I. Even-aged immature fully stocked stand, age 85 years. McHenry county
Based on strip line of 7.6 acres

Species	White oak	Black oak	Hickory	Cherry	Total
No. of trees per acre D. B. H. 6" and up	19.5	50.4	6.8	1.3	78.0
B. F. yield per acre	522	1836	83	26	2467
Maximum D. B. H. inches	21	20	13	13	
Max. height, ft.	70	70	60	60	

II. Even-aged immature fully stocked stand, age 71 years. Whiteside county
Based on 1 acre

Species	White oak	Black oak	Cherry	Elm	Hickory	Total
No. of trees per acre D B. H. 6" and up	69.0	18.0	2	13	9	111
B. F. yield per acre	5667	900	132	633	150	7482
Maximum D. B. H. inches	21	17	17	21	15	
Max. height, ft.	70	70	60	60	60	

III. Even-aged immature fully stocked stand, age 90 years. St. Clair county
Based on 1 acre

Species	White oak	Black oak	Totals
No. of trees per acre D. B. H. 6" and up	70	60	130
B. F. yield per acre	4482	6770	11252
Max. D. B. H., inches	17	23	
Max. height, ft.	71	80	

IV. Even-aged immature fully stocked stand, age 62 years. Knox county
Based on 1.06 acres

Species	White oak	Black oak	Hickory	Ash	Totals
No. of trees per acre D. B. H. 6" and up	62.3	91.5	5.66	1	160.46
B. F. yield per acre	1052	4770	170	8	6000
Max. D. B. H., inches	19	21	13	7	
Max. height, ft.	70	71	50	50	

V. All-aged stand. Ozark uplands. (Average based on 182.3 acres)

Species	White oak.	Black oak	Beech	Hickory	Tulip	B. Gum	Maple	Ash	Misc.	Total
Trees per acre D. B. H. 6" and up	17.4	28.8	8.8	11.92	2.53	2.14	1.39	1.25	2.51	76.74
Bd. ft. yield	465	603	404	316	114	100	103	37	86	2228
Max. D. B. H.	34"	30"	32"	26"	26"	27"	31"	21"		
Max. ht. ft.	100'	90'	100'	100'	60'	60'	60'	60'		

The original stands have been altered by cutting, fires, and grazing. In the southern part of the state the stands were first cut over for choice yellow poplar, black walnut, and white oak. Later, other species were harvested, but the tendency has been to remove the valuable species from the stand, leaving the less valuable, defective, and diseased trees. This in itself increased the proportion of undesirable trees. These latter species then became the seed-producers of the forest, and the succeeding stands contain a higher per cent of undesirables. Along with this, periodic burning in this region has kept out all but the most fire-resistant reproduction. This combination of causes was unfavorable to restocking by the more valuable species. Recently the markets have absorbed practically all species down to comparatively small diameter limits. Consequently in cutting-practices very few trees of any kind are left. The opening up of the stand to light, results in a stimulation of weed-growth and the periodic burnings prevent the establishment of a second crop. This fire damage is an especially serious factor in the strip of forested bluffs bordering the Mississippi plain from southern Randolph county south to central Alexander county and in parts of the uplands of Gallatin, Saline, Pope, and Hardin counties. These areas should produce much more timber than is now being grown.

The forests of the south-central part of the state from Carbondale to Pana, roughly representing the extent of the Illinoisian glacial deposit, are a reflection of the extremely poor soils which characterize this region. Post oak is the prevailing species on the poorest soils, a very limby black oak and hickory come in on the better soils, with white and black oak on the better-drained slopes. Along the stream bottoms very good timber is produced, but the general type of growth for the uplands is poor. Fires are not common, grazing is not practiced, and the stands are well stocked, even frequently overstocked, but tree growth is very slow. As one approaches the Wabash on the east or the Mississippi and Illinois rivers on the west the tight gray clay soils are modified by sands and loess, tree growth is better, and a wider range of species is found. In these latter regions fires are not common nor is grazing of the woodland the rule.

The stands of the uplands from about Pana north, or roughly corresponding to the Wisconsin glacial area, show a tendency toward an even-aged type of from 60 to 80 years of age. Where not grazed they are generally well stocked and thrifty; but grazing wood-lots is the common practice throughout this area, resulting first in the formation of a sod, and ultimately in the conversion from a wood-lot to a treeless pasture.

The bottomlands of the central and northern parts of the state are largely cleared. Where forests persist they are uneven-aged, heavily stocked with saplings and large defective trees, and have evidently produced excellent timber.

The history of Illinois forests thus parallels that of other states to the east, south, and north, where in the pioneer era, enormous energy was expended in hewing farms out of the forests. The great advantage which Illinois possessed in having nearly 60 per cent of her area already bare of trees and this on the most fertile soils, released that much more energy for forest clearing, and by subdividing the forests into wood-lots and distributing it among numerous owners, insured the rapid diminution of area which has occurred.

The interplay of the three tendencies to decrease our cultivated land, increase other unimproved land than forest on farms, and reduce decidedly our farm woodland area during the decade of 1910 to 1920 is forcibly shown in the following tables easily deduced from the agricultural statistics for Illinois from the U. S. Bureau of Census.

a. Decrease in area of land under cultivation:

Year	Acres of improved land	Per cent of total land area of the state	In other classes
1910........	28,048,323	78.20	21.8
1920........	27,294,533	76.098	23.092
Decrease	753,790 acres or 2.7%		

b. Increase in area of other unimproved or waste land on farms:

Year	Unimproved land, acres	Per cent of total land area of state	Per cent of forest area
1910........	1,326,735	3.69	42.1
1920........	1,577,663	4.4	56.2
Increase	250,928 acres 18.9%		

c. Decrease in area of woodland on farms:

Year	
1910........	3,147,879 acres
1920........	3,102,579
Decrease	45,300 acres or 1.4%; rate of clearing, 4530 acres per year.

Out of a total land area in Illinois of 35,867,520 acres, about 31,-974,775 acres, or 89.1 per cent, is in farms. The ownership of the 8,572,987 acres of untilled land in the state may be shown as follows:

Classification of land not tilled

	Acres	Per cent of total area of state
Included in farms.......	4,680,242	13.04%
Not so included..........	3,892,745	10.05%
Total	8,572,987	23.09%

A study of these figures shows that the area of improved land in farms in the state reached its highest point of 28,048,323 acres in 1910 and that in the last decade it has decreased 2.7 per cent. The waste land on farms has increased 250,928 acres or 18.9 per cent, while our forest area has shrunk 45,300 acres in the last ten years, or at the rate of 4,530 acres per year.

These figures have added significance when taken with those from adjoining states, which indicate that the tide of pioneer effort in land-clearing is on the ebb, and that at least for the present in all states of the eastern wooded area, more land is being abandoned than is being brought under cultivation annually. Even in a state as fertile, and with so large a proportion of its surface arable, as Illinois, a large residue of land is found which has never been cleared because it was unfit for agriculture, and another large acreage has been cleared which after trial has evidently proved to be of such low agricultural value that its use for crop production has been abandoned as unprofitable.

The amount of land unsuited to ordinary farming because of its hilly character, which makes the soil subject to erosion when cleared and renders its cultivation unprofitable in comparison with more level and fertile areas, has been the subject of careful investigation by the State Soil Survey. January 4, 1917, Professor J. G. Mosier summed up the conclusions reached by that department in the following letter:

UNIVERSITY OF ILLINOIS

AGRICULTURAL EXPERIMENT STATION

URBANA, ILLINOIS, *January 4, 1917.*

DR. S. A. FORBES,
University of Illinois.

DEAR DOCTOR FORBES: In reply to your inquiry concerning the amount of hilly land in the state not suited for ordinary farming, will say that the area of such land covers approximately 17 per cent of the state, or 6,000,000 acres. This large area is very irregularly distributed, but is principally along the larger streams, as the Rock River, Mississippi, Illinois, Sangamon, and some minor ones.

The Ozark Ridge in southern Illinois gives rise to a large area of very hilly land. All of this was originally forested, but since it has been cleared, much of it has eroded so badly that profitable crops can not be grown any longer, and much of it is being abandoned or used for pasture.

In the seven southern counties, approximately 55 per cent of the area is of this kind. In the counties bordering the Mississippi, approximately one-third is too hilly to be farmed successfully, while along the Illinois to La Salle, probably 25 per cent of the counties are made up of this land.

As to the distribution of this soil; in Johnson county it constitutes 67 per cent of the area and is made up of the two types, yellow silt loam and stony loam. Edwards county contains about 24 per cent and is composed of the types, yellow silt loam, yellow fine sandy silt loam, and yellow sandy loam. Cumberland county is considered a level county, and yet 10 per cent of its area is too hilly to farm successfully. This land comprises the yellow silt loam and yellow sandy loam.

The only use that can be made of this land is for pasture or forest. In many places it is left in permanent pasture. There is little doubt, however, but that if this could be re-forested it would become a source of permanent income to the owner. The abandoned land is growing up to persimmon, sassafras, and some other forms that are of little value from the forestry standpoint.

Very truly yours,

(Signed) J. G. MOSIER.

In July, 1923, the areas of land of hilly and broken character, or so-called eroded lands, were given for 44 counties by Professor R. S. Smith, Assistant Professor of Soil Physics in the College of Agriculture, as 2,004,860 acres, or 11.8 per cent of the total area of these counties. These are the same counties on which the per cent of forest lands was based. The area of these 44 counties was 16,934,240 acres, or 47.21 per cent of the land area of the state. If this proportion held good, the area of eroded lands for the state would be 4,232,367 acres. But the southern half of the state containing 41 counties included but 12 of the 44 counties measured, and so is not weighted properly. Correcting this average by weighting these two sections, gives a total of hilly or so-called eroded land of 4,810,149 acres.

Eroded land as described by the Soil Survey is land the original surface of which has been washed away, leaving as a rule what is known as yellow silt loam as the present surface, although the erosion sometimes reaches deeper to other subsoils. Such land is commonly subject to still further erosion which may in time injure it severely, but it is not now necessarily unfit for general agriculture. It is impossible to state with any certainty the absolute area within the state which is better fitted for the growing of forest crops than for tillage, improved pasturage, or orchards, since this will vary with economic conditions as well as with soil quality and physical drawbacks. Not all of the so-called eroded land is unsuited to agriculture; on the other hand there are some areas of sandy land, or of tight clay soils, and some bottomlands subject to overflow which it will not pay to drain. To these could be added a considerable acreage in the aggregate representing wood-lots, plantations, windbreaks, and hedgerows, on better soils. The total area in Illinois which is or could be forested is probably equivalent to 4,810,149 acres, or 13.41 per cent of the state.

What condition is this area in at present? It is probable that all but a very small fraction of the remaining woodlands of 2,863,764 acres, amounting to 7.98 per cent of the state's surface, are included in this acreage. This leaves 1,946,385 acres as the approximate area which has been cleared for either agriculture or pasturage, or has been used for hillside orchards. Subtracting the area of 1,577,663 acres listed by the Census as waste lands, leaves a possible net acreage in productive use other than either woodland or agricultural crops, of 368,722 acres.

Since no attempt has been made to segregate the timber-covered areas of land which will ultimately be cleared for agriculture, though the total has been deducted from or charged against the area of hilly, non-agricultural land, it is probable that in the form of groves and plantations, or wood-lots fully as large an area of the more level lands in the state will be retained in timber voluntarily as will be needed for pasturage or orcharding on the non-agricultural soils or steep hillsides. Of the 368,722 acres of soil not accounted for by woodland or by waste land in farms, a certain per cent must fall in the area not included in farms.

The existence of a very considerable area of land actually abandoned or waste, equal to 55.1 per cent of the total existing woodlands in the entire state, and not classified by the owners as pasture lands, indicates that whatever may be the ultimate division of use of non-agricultural lands between pasture and forests, the present forest area may be increased one half without taking an acre from any existing use. The soils of many of these hilly areas are easily eroded. This is especially true of the yellow fine sandy silt loam, yellow silt loam, and yellow sandy loam types in the southern counties, though examples of advanced erosion are not lacking elsewhere as set forth by Bulletin 207* of the State Agricultural Experiment Station. These hilly areas constitute the larger percentages of the non-agricultural or absolute forest soils of the state.

Two other classes of soil are found, which under certain conditions should be in forest. The first is wet lands which are infertile when drained, or which can not be drained successfully. In this class come many islands in the Mississippi River, and areas not protected by levees. Other tracts may be found, of which certain lands along the Big Muddy River in Jackson and Union counties are examples, where the soil is a tight clay which does not repay the expense of drainage. The total area of undrained bottomland is steadily diminishing and in time will become a negligible quantity, while the fertility of such soils and the drainage taxes which they must pay in organized districts force their improvement and cultivation at the earliest possible moment. Many stands of young timber of rapid growth may yet develop on some of the least desirable

* University of Illinois, Agricultural Experiment Station, Bulletin 207. "Washing of Soils and Methods of Prevention", by J. G. Mosier and A. F. Gustafson, Urbana, Illinois, April, 1918.

of these areas before the time when they are finally cleared for cultivation.

The second type of soil on which forests may be grown is sand. In several areas, of which examples may be found in Whiteside, Lee, Mason, and Kankakee counties, soils of a very sandy character occur, sometimes taking the form of dunes. In Mason county, success has been attained with alfalfa on much of this soil. A great many plantations of black locust have been made, few of which have done well. Cottonwood makes good development on these sands. There is great possibility that various conifers may make profitable crops on such sands. The state should vigorously undertake experimental work in reforesting typical areas of all soil types whose agricultural value is questionable.

The Production of Wood on Illinois Farms; the Actual Number and Total Acreage of Farm Wood-lots; the Average Area of Wood-lots for the Farms having them and for the State

The economic importance of the wood-lot on Illinois farms depends upon the total area in farm wood-lots and the number of owners, from which can easily be ascertained the average area of wood-lot per farm and for the farms of the state. It is to be expected that in a state where 43.46 per cent of the original area was forested, including practically all of the more hilly and eroded sections and poorer soils, the farms which were carved out of these woodlands would still retain forested areas perhaps more or less denuded of merchantable timber, but not yet converted into cleared pasture or tilled fields.

As to the first item, the preliminary figures of the State Natural History Survey indicate that the total farm-woodland area of the state is 2,668,050 acres. But the number of farms actually having woodlands is not easily ascertained. The United States Bureau of Census does not give this information, although it does collect figures on the total acreage of farm woodlands in the various states. The number of Illinois farms reporting merchantable timber through the Census for 1919 was but 20,051, which indicated a reluctance to report timber of taxable value, and a condition of depletion or over-cutting which has reduced the majority of woodlands to brush areas or young saplings.

Again, forest products of some sort were reported to the Bureau of Census as being sold from 37,874 farms in the year 1919; but it is improbable that this represents the entire number owning wood-lots. Even if every wood-lot had merchantable timber that could be sold every year, not all of the owners would have the time to cut and market it. The most common product of the wood-lot is fire wood for home consumption, but only 13.63 per cent of farmers who cut wood sell it to others, while only 7.34 per cent of wood-lot owners cut cross-ties for sale. Lumber is largely cut on the farms for home use, though in most instances when this occurs some surplus is sold. The number of wood-lot owners cutting lumber, according to data based on farm woodland questionnaires, was only 60.66 per cent. Fence posts were produced on 86 per cent of the wood-lots, but largely for home consumption. All of this goes to show that the number of farmers reporting wood-lot products for sale is not a reliable index of the total number of owners, but that the number is very much greater than 37,874.

The number of farms having wood-lots may be based on the amount of wood fuel burned on the average farm, which was found to be 16.1 cords. The farmer who produced cordwood, according to the farm woodland questionnaries, cut an average of .332 cords per acre annually, which for 2,863,764 acres of woodland in the state would make a total production of 950,770 cords. Farmers own 93.166 per cent of this woodland, and on this basis would produce 885,792 cords of fuel wood per year, which at 16.1 cords per year would supply 55,018 farms with fuel. Since the number of wood-lot owners producing their own fuel annually was 87.36 per cent, this gives the number of wood-lot owners as 62,978, which is about twice the number of those selling forest products from the farm. This gives an average area per wood-lot of 42.36 acres, and an average area of woodland for all farms of 11.25 acres.

A calculation based upon forest survey figures for certain counties where they have been completed, supplemented by crop-report returns from county assessors, shows a total of 2,668,050 acres of woodland on farms owned by 98,307 farmers. This would give an average wood-lot area of 27.14 acres per farm, or for all the farms of the state one of 11.239 acres, and for each person living on farms one of 2.44 acres.

It has been shown that to supply the wood consumption of the state requires the product of from one to two acres per person, depending upon the fertility of the soil and the skill of the owner in forest production. This area of 2.44 acres per person on farms indicates that the woodland owner can, if he desires, supply the entire needs of the farming population of the state for wood in the future but that little or no surplus would be left for the remaining industries or population. By simply supplying their own needs, farmers owning woodland could sell two thirds of the products, either to other farmers or to other industries. Since the marketing of products will follow the natural economic trend, farmers who do not own wood-lots will suffer from lack of adequate timber supplies as keenly as any other class of the population.

WOOD AS A CROP

The enterprise of producing wood as a crop for Illinois land is subject to the same physical and economic conditions as govern the growing of agricultural crops, fruits, or live stock.

The profits to be derived from wood production depend upon the price of the products on the market, the continued demand for these products, the cost of harvesting and marketing the crop, and, finally, upon the productiveness of the crops themselves compared with the cost incident to growing them.

Wood as a crop requires the practically exclusive use of land for a long period of years. In theory, land devoted to wood crops should remain in woodlands. The devotion of land to this crop, therefore, means its withdrawal from agricultural production, just as the clearing of woodlands means the withdrawal of land from wood production. When woodland is cleared for farming, the expense of the operation is often heavy enough to absorb all the revenue derived from the crop of timber which is cut at the time, thus reducing the value of the woodland as such to zero, but putting it in condition to realize presumably higher values for farm crop production.

Since both agricultural and horticultural crops require a very high proportion of labor annually to grow, harvest, and market them, and the amount of this labor is for the most part determined not by the abundance of the crop but by the area which it occupies—especially for field crops, it follows that with successively poorer grades of soil, or with lessened productiveness or increased costs per acre, a point is soon reached where the costs absorb all the income and the use of such lands for food crops leads to progressive impoverishment of the soil and of the owner, resulting in ultimate abandonment.

By contrast, in forest crop production the cost of labor and annual cultivation is reduced to a remarkably low point. Natural processes need only to be successfully initiated by the establishment of the crop and its later protection from destructive agencies and the stand develops with a minimum of attention. This great reduction of cash outlay and labor costs permits the use for wood crops of practically every acre of land which is too poor to yield profits in food production, and this use for forest crops promises to yield a profit or large return over and above the actual outlay in cash or labor, a return running into hundreds, even thousands per cent.

Against this certainty of large economic returns in yields of wood there are two obstacles which diminish the financial profits to owners of forest lands, namely, the cost of marketing the crop and the time required to produce it. Since the value of wood is determined, for any owner of woodlands in any given region, by the market prices which wood products command at the nearest point of delivery, his profits are limited by this price less the cost of getting the wood to the market. But often the initial form of the product, such as logs, must undergo further manufacture, or the product is bought by jobbers or middlemen who endeavor to keep down the price to the producer. Still more frequently it happens that the purchaser buys the standing timber at a lump sum and the owner fails to realize the value of his stumpage.

Again, wood in any form is both a bulky and heavy product. A cubic foot of green hickory weighs 42 pounds; one of oak, 35 pounds or more. A cord weighs between 3100 and 3750 pounds. Transportation costs are based largely on weight, and to stand a long train-haul from the forest to the market the price per cubic foot or per pound must show a margin over this cost, plus costs of labor in cutting, shaping and loading, freight, remanufacture, and wholesale and retail delivery. As all of the above processes constitute well-organized businesses which will operate only on the basis of securing a living profit, the owner of timber stumpage, even if he receives a fair price, gets what is left after these demands are satisfied, and this margin may be too small to defray any costs incidental to crop production. This partly explains the phenomena of cheap stumpage values and low returns which even now are manifest in regions which have an excess of woodland over farm land, or are located far from markets.

But the same economic processes which have operated to keep down values of timber as a crop in the past, bid fair greatly to increase these values in the future, provided sufficient wood is produced to maintain the customs of its use in major industries, and to prevent the too complete substitution of other materials for wood.

Prices for wood have increased more rapidly than for other products, and more rapidly than costs of labor and transportation. This leads directly to an increase in the margin left for stumpage values, and this margin has increased, on the average, at a more rapid rate than the prices for finished products. As products become scarcer, the factor of competition becomes more active, and the producer stands a better chance of receiving his fair share of the final market value. This process raises the value of wood crops on all areas regardless of their location. It makes possible a profit or stumpage value on hitherto inaccessible tracts, but the chief advantage is to the owner of woodland located near markets, and whose costs of marketing are comparatively low.

If this is the situation with timber as a crop grown for sale, the value of such crops grown for home consumption is still further enhanced. Every farmer is a large consumer of wood crops, as will be shown later. With no home product he is forced to buy wood at the highest retail price, paying all the costs and profits exacted in the course of transportation for long distances, and rehandling by dealers. To the extent that he can supply his own needs, the only costs to him are those of labor and contract-sawing, and those incident to growing the crop. It is the purpose of this investigation to determine the value of such wood crops to the farmer as a consumer, as well as a producer for the market.

In the selection of the species of trees to grow, the woodland owner is largely influenced by the condition already established by natural processes on his woodland. Trees show fully as great an adaptation to environment as any other plant association, and from the first settlement of this country the character of the forest growth has been relied upon to indicate that of the soil itself. In practically all the eastern states, the dearth of tree-vegetation indicated impoverished soil. Until the nature of prairie soil became known, early settlers avoided it for this reason. It is a safe maxim that unless proved otherwise by experience, the best trees to grow on a given site are the species which naturally grew there in the virgin forests, and that trees, such as catalpa, found in nature only on rich well-drained soils, will not produce satisfactory forest crops if introduced on a poorer or drier site.

Again, trees inured to unfavorable conditions, like the pines, may grow very rapidly on better soils, but will fail to reproduce naturally in competition with the species found on such habitats.

Wood crops, as to species of trees grown and quality produced, are, therefore, less adjustable or less easily modified than food crops. Once the choice is made it must be followed through to maturity. Often this choice is already determined, as in well-established forests. Aside from these features the producer has several advantages. He can often choose between different kinds of product into which he can convert his timber. He can postpone harvesting his crop in times of depression and put it on the market when prices are high. He can produce different quantities of products of different classes by postponing or withholding harvesting of a portion of his stand, or selected trees. In addition, he can greatly modify or increase the value of his crop by selection of species for harvesting, taking out the more worthless for fire wood and reserving the more valuable for higher uses. When creating a new forest by planting he can exercise choice of species, just as a farmer can decide as to what he shall plant, and, like the farmer, his success will depend on his ability to select the crop which is adapted to the soil and site, and not merely on his skill in planting trees or potatoes.

The relative productiveness of different forest soils can be judged by the volume measured in cubic feet of wood produced annually. To obtain this figure is not an easy process unless the wood crop on the area is all of the same age, otherwise it can not be known whether the amount cut from the lot represents the growth of a definite period or is merely the accumulation of an indefinite number of years. Again, wood crops must be measured for volume production when they have attained a reasonable maturity, else the average annual production is not fairly realized. Potato crops, measured when half grown, do not show full production. But all field crops reach definite ripeness while with woods crops this period is comparative only, and the measurement of many different stands is necessary to determine the approximate period of highest average annual crop-yields, and those of greatest production of money income.

This study will be undertaken in Illinois during the years 1924 and 1925. Meanwhile preliminary figures show that an acre of soil grown to hardwoods will produce annually from 16 to 160 cubic feet of wood. The production of wood, as may be expected, is in direct ratio to the fertility of the site. This is illustrated by the following samples.

Extremely dry sandy hills may yield less hardwoods per acre than the lowest yields which are recorded. If planted to suitable conifers, the apparent yields may be doubled, yet when weight is considered may not exceed greatly that of hardwoods. The maximum yields on any site can only be secured by the growing of species, best adapted to this site and to the condition of the land at the time. When land is bare

PLOT YIELDS (ONE ACRE EACH)

Plot location	Species	Age years	Cubic feet contents	Mean annual growth cu. ft.	Weight produced per year in pounds
1. Prairie, agricultural	Catalpa	15	2430	162	4350
2. Alluvial bottom ...	Maple, ash, elm, sycamore	37	5361	144	4595
3. Prairie, agricultural	European larch..	52	5792	111	3414
4. Alluvial bottom....	Sycamore, burr oak	30	3087	103	2994
5. Prairie	Black walnut....	50	4965	99.3	3777
6. Upper Miss. bottoms	Maple, elm, pin oak, others ...	25	2119	85	2185
7. Hilly upland.......	White pine	75	6383	85	1929
8. Alluvial bottom....	Pin oak, black oak, red gum, ash, others	25	1800	72	2451
9. Hardwood bottom..	White oak, cherry, hickory, others.	25	1456	58.0	2049
10. Prairie	Black walnut.....	63	3427	54.4	2069
11. Upland, hilly.......	White oak, black oak, others.....	71	2991	42	1561
12. Sands	Black oak, others	70	2660	38	1365
13. Upland, thin rocky..	White oak, black oak, hickory...	85	1376	16.2	604

or cleared it is often possible to start with a rapidly growing species that would not succeed in competition with well-established natural vegetation.

The indicated yields in pounds per acre on different classes of soils compare favorably with the yields of agricultural crops.

Prices per pound for wood crops may be based on an average weight of 35 lbs. per cubic foot for comparison. Taking average prices received, as given by replies to the questionnaire, these were:

	Decimals of 1 cent per lb.	Ratio of value of fuel wood
Veneer logs	.92	5.1
Posts	.85	4.7
Piling	.657	3.65
Lumber	.62	3.4
Cross-ties	.54	3.0
Mine timbers	.43	2.4
Fuel wood	.18	1.0
Cooperage	.62	3.4

Owing to the fact that a large percentage of the forest crop may be composed of the cheaper grades of wood, such as cordwood, the average price per cubic foot may fall considerably below that for the highest products. On the average farm wood-lot it was found that the proportion of the various classes of product obtained were as follows:

	Per cent	Proportion of average price
Fuel wood	65.68	.118
Mine timbers	10.33	.044
Posts	7.44	.063
Lumber	8.19	.051
Cross-ties	3.75	.020
Veneer logs	3.51	.032
Piling	.78	.005
Cooperage stock*	.32	.002
Weighted average price per lb.	.....	.335

It is thus seen that the crop from the farm wood-lot averages 0.335 cents per pound. This price is due to the large proportion of low-priced fuel wood. This price is equivalent to $6.70 per ton while the more valuable products bring prices of over $18.00 per ton. The average crop per acre now being harvested is 1415 pounds or about ¾ of a ton, worth $4.74, or a crop value of nearly $5.00 per acre annually.

These comparatively low prices per pound as compared with concentrated food crops are offset by a much lower cost of actual outlay per pound in the production of the timber crop so that the net profit over cash expenses greatly increases the favorable position of this crop in land economy.

The chief objections urged against actually undertaking to grow timber as a crop are based, not so much on the yields per acre or prices which are possible as on the crop-period or time required, which for private enterprise is often regarded as prohibitive, and which results in the accumulation of interest deemed necessary to return a given per cent on the investment, and of taxes at compound interest.

For farmers who own wood-lots there are several strong arguments offsetting these factors. In the first place, the wood-lot, unless already badly cut over or nearly ruined by grazing, is often if not usually in position to sustain an annual production approaching the full possible yield of the land in wood crops. It is a going business and, if managed as such, incurs no compound interest charges since each year's expense is met by income from cuttings. This is the ideal condition to maintain, and is exemplified by many wood-lots carefully preserved and cared for, in the southern portion of the state, which continue to yield quantities of high-grade lumber, posts, and other products.

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*Cooperage stock taken as of same value as lumber.

In the second place, it is not necessary to wait 30 to 80 years for yields from a wood-lot. The intensive use to which a farmer can put the small material enables him by thinnings to obtain fuel, stakes, fence posts, and other small-sized material in not over 15 years; even within 8 to 10 years when plantations are made on bare soil, and these returns carry the investment until the more valuable material is ready for cutting, and pay the taxes.

The question of taxes is one which requires legislation or change in practice. But in small wood-lots taxes are not the factor which will either encourage or prevent the practice of forestry to any great extent, for the reason that ordinarily the taxes on this land would be about the same whether or not forest crops were grown, and the crop offers a means to pay these taxes, while non-productive land does not. As between pasturing and forest crops, the question is one of relative net annual income to the farm as a whole as well as to the land so used. This will be discussed later. Forest land is usually classed as unimproved and as such bears a lesser valuation than improved land. Such a practice, of valuing forest lands lower than lands producing agricultural crops or orchards, is sound in theory and practice, since, as shown, forests are crops which can and should normally be grown on poorer soils unsuited to higher uses of food production, hence worth considerably less per acre than a good quality of agricultural land. When small quantities of high-grade agricultural lands are devoted to the production of special forest crops, such as hedge or catalpa posts, the values of the crops are or should be sufficiently high to bear the usual taxes on lands of this value.

One principle can be clearly laid down which will remove any injustice in taxation of forest property. Growing timber itself should not be taxed, but only the land upon which it grows. It is as sensible to tax growing crops of grain as to tax repeatedly the same crop of timber during its growth.

To determine whether the woodland property belonging to the farmers of the state is now producing crops which measure up to the possible yields of such lands, the returns from 440 wood-lots were tabulated. The table on page 134 gives the results obtained. In column 2 is indicated the area out of the total of 19,986 acres which yielded products of the designated kind within a period of 5 years for lumber, and 3 years for other products. Fuel is cut annually on most wood-lots, and a very high proportion amounting to 86 per cent still continue to yield fence posts for the annual upkeep of the farm. A significant figure is the proportion of wood-lots yielding saw-timber, 60.66 per cent of those reported falling in this class.

This, however, is probably higher than would apply to all farm wood-lots, for a large proportion of them have been already stripped of the more valuable trees which produce sawlogs. Based on indications from total yields of saw-timber for the state, there are probably 30 per cent of the wood-lots which still contain crops of this class of timber.

PRODUCTION OF WOOD ON FARM WOOD-LOTS, TOTAL FROM 19,986 ACRES OF WOODLAND COVERED BY FARM QUESTIONNAIRE—440 ANSWERS

Class of material	Area cut over to obtain yield	Per cent of area of all wood-lots	Unit of measurements	Quantity	Yield per acre cut-over, units	Yield per acre of total area, units
Fuel wood ...	18,158	90.85	Cord	6,631	.365	.332
Lumber	12,124	60.66	Bd. Ft.	862,306	71.12	43.145
Fence posts ..	17,197	86.04	Post	75,210	4.37	3.763
Hedge posts ..	767	3.84	....	....	....	....
Cross-ties	1,467	7.34	Tie	9,591	6.54	.480
Mine timbers .	1,721	8.67	Cu. Ft.	61,144	35.5	3.059
Piling	335	1.68	Piece	1,069	3.19	.053

Included in fuel wood are sales of cordwood from 2134 acres, or 10.68 per cent of the area.

The production of wood on farms is not confined to wood-lots. Hedges yield considerable quantities of posts and fuel. Willows and other trees springing up along streams and on small corners or patches of rough ground are periodically cleaned out and used for fuel or even for posts, and the aggregate production of wood from these sources is sometimes sufficient to supply a considerable proportion of the fuel for the farm at least, and for the state must reach a considerable total.

In order to measure the actual yields of the wood crop and value the different products on a comparative basis, each product must be converted into cubic feet, to serve as a common standard. (For converting-factors, see Appendix, Note 8.)

On this basis, the yield in cubic feet from an acre of woodland as returned by owners, was as shown by the following table.

YIELD PER ACRE OF WOOD ON FARM WOOD-LOTS
BASED ON ANSWERS TO QUESTIONNAIRE

Character of products	Unit of measure	Quantity per acre	Converting factor per cubic foot	Yield per acre cubic feet
Fuel	Cord	.332	80	26.560
Lumber	Bd. Ft.	43.145	.16⅔	7.191
Posts	Post	3.763	.8	3.010
Cross-ties	Tie	.48	4.25	2.040
Mine timbers	Cu. Ft.	3.059	1.	3.059
Piling	Pile	.053	22.3	1.185
				43.045

If as shown on page 115, the total area in farm wood-lots is 2,668,050 acres, this area divided among the 237,181 farms of the state gives 11.239 acres of woodland per farm.

The yield per farm, or per average wood-lot, on this basis of wood material is given in the table on page 138.

In thus endeavoring to measure production of wood crops by merely recording the yields obtained on an average acre of a large total area of woodland from questionnaires sent to selected individual owners, two factors of error may be present. First, those responding may possess the better grades of woodland, or may have more recently sold or cut timber crops. This would tend to raise the indicated yields above the true average. Second, the amounts cut on given areas in given years, even when distributed over the total area of woodland involved, does not necessarily indicate what the *growth* was on these areas for the same period, or even their average annual production, since it may mean, rather, a mere removal or cutting into the accumulated capital of the wood-lot. The rate of cutting may exceed the annual average rate of growth, or be less than this growth. The owner may cut his crop clean and entirely replant or permit sprouts and seedlings to restock the area. The capital of a wood-lot is like a sum invested permanently whose interest only is to be expended. If in any period, less than the interest is used, the capital increases. Continual expenditure of more than the interest diminishes not only the capital but the annual income as well, and ultimately will dissipate the resource. But unlike money, this forest capital can only increase by means of the interest earned, or growth, hence if "cut clean" or completely dissipated it takes many years to build it up again to its full productiveness.

The annual yield of these wood-lots as indicated by the farm questoinnaire was 43.045 cubic feet per acre. When we compare this yield with the data shown in Table on page 135, indicating the productiveness of different classes of soil, it is evident that average grades of forest soils will grow this much wood annually, hence it is possible to grow timber fast enough to maintain the present rate of cutting forever, and it may be possible to double it. But the probability is that, instead, this yield will continue to decrease. There are two reasons for this. First, the maintenance of an annual cut requires the reservation of a certain quantity of wood capital in the form of young trees partly grown. Depending on the products desired and the period required to produce them, the growing stock required may be roughly calculated by taking one half of the total growth or final yield of the crop. For example, if the yield is 40 cubic feet per year and can be harvested at 50 years, the crop yields 2000 cubic feet. Then 1000 cubic feet per acre is a normal forest capital; actually somewhat less than this quantity will suffice. But if the stock or capital is exhausted by clear-cutting for cordwood or mine timbers, it drops way below this required minimum, and when this happens it becomes impossible to maintain the same rate of yield until the gradual processes of growth have again built up the stock. This scarcity occurs first for the larger and more valuable products, such as saw-timber or veneer logs. The smaller the material harvested the sooner it can be replaced and the greater the probability of sustaining the yield. The second factor is far more serious, and consists of destroying the reproduction which would naturally take the place of the timber removed. When this happens for any cause, such as fire or excessive grazing, there is no hope of ever restoring the yield to its former volume until such cause is removed and the reproduction re-established, perhaps by expensive measures followed by the long wait for the new crop to mature.

The average acre of woodland in Illinois now contains but 635 cubic feet, which, for a low average yield of 43 cubic feet per year, would indicate that this yield can be maintained only on the basis of cutting the material at an age of 30 years. This period is insufficient to produce saw-timber or even cross-ties and will yield only posts, mine timbers, and cordwood. Either the future yields of Illinois wood-lots will be confined to these products after the residue of the larger trees remaining has been cut, or else the cut must actually be reduced considerably below 43 cubic feet per acre in order to grow new crops of these more valuable products.

It is fair to assume, therefore, that the process of denudation or exhaustion of the average or normal forest capital has proceeded to the danger point, and that this annual cut of 43 cubic feet is not at present being replaced, but that the cut actually constitutes a further depletion of the remnant of forest capital, and may further reduce the yields and growth in the future. The steady diminution of the cut of saw-timber per decade in Illinois gives evidence of this tendency. Census figures give the following production for the state in timber.

Year	Board feet	Year	Board feet
1879	334,244,000	1909	170,181,000
1889*	218,938,000	1919	64,628,000
1899	381,584,000	1920	56,900,000

The percentage of sawed lumber to total output of wood has undoubtedly fallen off faster than the total production, since this material came from the older or virgin growth of timber of which there now remains but a fragment of the original stands. Some of the above output undoubtedly represents clearing of land for agriculture.

But as these figures of actual cut in cubic feet per acre are shown to agree closely, though accidentally, with the yields of wood crops possible on the poorer grades of land which can be termed forest soils, they will serve as an indication, not merely of the present money-yields from farm woodlands, but of the minimum net income which the continuous use of such lands for wood crops may be expected to produce without undue or unusual expense in crop production and by the same natural processes as have served to grow these crops in the past. Great improvement over these figures is possible in the way of increased yields and better money-returns through thinnings and improved prices.

These actual yields as reported on wood-lots were then compared with the total production of different classes of material for the state, in order to correct any error occasioned by departure of the replies from this average due to selection of better wood-lots. The figures on total production used for this basis are given in the table on page 138.

In applying these totals to the wood-lot areas it was assumed that these would produce fully as much per acre as the total woodlands of the state, given as 2,863,764 acres.

*See Appendix, Note 9.

In determining the average yield per acre of farm wood-lots it was considered more accurate to assume that when the total production of the given class of product for the state was known, that for the farm woodlands would bear the same proportion to this total as the woodlands themselves bore to the total forested area. This proportion is 93.166 per cent. The alternative of multiplying the results obtained from questionnaires representing 440 units of 19,986 acres, or 86/100 of 1 per cent of the farm woodlands was considered less reliable and in some instances was manifestly in error for the state as a whole. Production of cordwood and of fence posts was based upon this question-

PRODUCTION OF WOOD FROM ILLINOIS FARM-WOODLANDS OF 2,668,050 ACRES

Product and unit	Total for farm woodlands	Average per acre	Average per wood-lot of 27 acres
Fuel wood cords	885,792	.332	8.96
Mine timbers cubic feet	11,142,700	4.176	112.75
Posts piece	10,031,860	3.76	101.52
Lumber board feet	53,011,340	19.869	536.46
Cross-ties piece	952,050	.357	9.64
Veneer logs board feet	22,701,710	8.508	229.72
Piling piece	37,708	.0141	.38
Cooperage stock cubic feet	350,293	.131	3.54

QUANTITIES OF WOOD CUT ANNUALLY FROM FARM WOOD-LOTS

Product	Per acre cubic feet	On 11.239 acres cubic feet	On 27 acres cubic feet	Per cent of total
Cordwood	26.56	298.50	717.12	65.68
Mine timbers	4.176	46.93	112.75	10.33
Posts	3.008	33.81	81.22	7.44
Lumber	3.311	37.21	89.40	8.19
Cross-ties	1.517	17.05	40.96	3.75
Veneer logs	1.418	15.94	38.29	3.51
Piling	.314	3.53	8.48	.78
Cooperage stock	.131	1.47	3.54	.32
Total	40.435	454.44	1,091.76	100.00

naire, since state-wide figures on production were not available and for cordwood were open to question. It will be noted that while the yield from the questionnaire was 43.045 cubic feet per acre, that obtained from the check in total state production was 40.435 cubic feet, or nearly identical. But the average wood-lot yields a greater proportion of its output in the form of cordwood and mine timbers and less high-grade products, such as lumber, than did the selected lots, hence its net revenue will be lower.

The percentages shown in this table indicate that at present nearly two thirds of the wood produced by farmers goes into wood fuel, which is the cheapest product of the wood-lot. Eleven per cent is utilized as lumber or veneer logs and a little under 5 per cent as cross-ties, piling, or cooperage stock, while mining timbers absorb over 10 per cent and posts nearly 8 per cent, or a total of nearly 85 per cent in small sizes. Although these proportions clearly indicate that the wood-lot is not being worked to its capacity for crops of highest value, yet it must be pointed out that logs measuring less than 9 inches at the small end will yield less than 50 per cent of their contents as lumber. Even with full and close utilization the proportion utilized will be

Diameter at small end (inches)	Per cent utilized as lumber
9	50.7
8	47.7
7	44.8
6	39.5
5	34.4
4	23.8
3	10.5

A tree which will cut one log 9 inches at the small end inside the bark and 16 feet long will measure from 12 to 13 inches outside the bark at 4½ feet, or 13 to 15 inches on the stump. Hence it is not possible to convert a large percentage of a stand into sawlogs unless the timber has been allowed to reach an age of 70 to 80 years. Even where this age is attained it will follow that unless logs are cut to 5- and 4-inch tops a very large percentage of the stand will not make log timber and will probably be better utilized in the form of posts or mine timbers provided the resultant return per cubic foot is better.

Were all stands to be grown on a rotation capable of producing lumber it is probable that the yield of saw-timber might be raised to about 50 per cent of the total cubic contents, but not to much more than this. This would increase the output of sawlogs fourfold on the basis of present production. But if the yield per acre were also increased by at least 50 per cent, which is easily possible, the capacity of the present farm woodland area would be at least six times the yield of lumber and logs now being cut within the state, and would then equal the total annual output of the virgin forests of the state during the decades of their highest production. It is improbable that this result will be attained from the existing woodlands because of the pressure for cutting at earlier ages and for bulky products, such as mine timbers or fuel. But the yield of saw-timber can at least be increased threefold by proper management and its percentage of the total crop doubled, so that one quarter of the cubic yield will be in this form, which bids fair to be the product most needed in future farm maintenance, and the most expensive to purchase.

Consumption of Wood on Illinois Farms

As stated on page 83, the three major forms in which wood is consumed on farms are fuel, posts, and lumber, amounting to 576 cubic feet per farm. An additional 7.33 cubic feet of wood is used annually on farms for shingles. (Appendix, page 171, Note 10.) But the farmer is also the ultimate consumer of much of the wood which enters into the construction of manufactured products, such as farm machinery, boxes and crating, furniture, paper and utensils of various kinds. The total consumption for such purposes in the state has been considered under manufacturing industries but it was not possible to compute the amounts consumed on farms. This consumption, however, must be charged to the farmer's account and added to the more obvious major forms of wood which he uses and which to a considerable extent he can produce in the wood-lot. A deduction should of course be made to the extent to which steel and cement are used as substitutes for wooden posts. But in spite of this reduction the actual consumption per farm will be somewhat greater than that shown in the table which follows.

Consumption of Wood on Farms Annually

Class of product and unit	Total consumed on farms	Average per farm	Average per farm, cubic feet
Fuel wood, cords	885,792	3.734	298.72
Lumber, bd. ft.	296,476,250	1,250.	208.33
Posts, pieces	20,534,690	86.578	69.26
			576.31

The balance between farm consumption and farm production of wood may be shown best by assuming that the existing woodlands averaging 27.14 acres each, on 98,307 farms, is equally distributed among the 237,181 farms of the state, giving each a wood-lot of 11.239 acres.

PRODUCTION PER AVERAGE FARM ON 11.239 ACRES OF WOODLAND

a. Products useful on farms

Product and unit	Quantity	Cubic feet
Fuel wood, cords	3.728	298.50
Lumber, bd. ft. (including veneer logs)	318.9	53.15
Posts, pieces	42.26	33.81
Total produced of these classes		385.46

b. Products not useful on farms

Product and unit	Quantity	Cut, cu. ft.
Mine timbers, cubic feet	46.93	46.93
Cross-ties, pieces	4.012	17.05
Piling, pieces	.158	3.53
Cooperage stock, cu. ft	1.47	1.47
Total not useful on farm		68.98
Total grown on farm		454.44

These values are derived from table on page 138 by multiplying the product of one acre of woodland by 11.239.

Thus the average farm wood-lot of 11.239 acres produces 25 per cent of the lumber, 49 per cent of the posts, and 26 per cent of the fuel used on the farm, which is a total of 385 cubic feet of wood or 67 per cent of the total wood requirements of the farm. In addition it produces for sale in the form of mine timbers, cross-ties, piling, and cooperage 69 cubic feet, bringing the total production to 454 cubic feet or 79 per cent of total consumption.

Offsetting this, the farmers secured from sources other than the farm wood-lots of the state 51 per cent of the wooden posts, 75 per cent of the lumber, and 74 per cent of the fuel used on farms.

The farmer who is actually harvesting products from his wood-lot consumes his own output in the following quantities: fuel wood, 85 per cent; lumber and veneer logs, 53 per cent; posts, 92 per cent. The amount which he sells forms a relatively small part of the total farm consumption in the following percentages: fuel wood, 14 per cent; lumber and veneer logs, 12 per cent; posts, 4 per cent. The enforced purchase of a material capable of being produced on the farm wood-lot is a serious economic handicap to the farmers, which is becoming increasingly evident in the steadily advancing prices he must pay for wood or its substitutes. The value of this wood crop can be measured in two ways, first as a saleable product, second as taking the place of material which must otherwise be purchased. High prices lead inevitably to the curtailment of the use of both wood and its substitutes. Less fuel is burned; buildings in need of renewal are not renewed; and money which would appear as a profit is sunk in the cash outlays for upkeep.

The farmer who possesses an average wood-lot of 27 acres is cutting annually less fuel than the average farmer consumes in a year; if expressed in wood, 8.964 cords as against 14.6 cords consumed in the form of wood or coal.* In lumber and logs he produces 766.14 board feet as against 1250 board feet used. This will supply him with all his heavy timbers and fencing and all of his rough lumber, requiring the purchase of only the finishing grades.. He produces 101 but requires only 86 fence posts annually. His total requirements including the exclusive use of wood fuel are 1990 cubic feet. He produces 926.03 cubic feet of these same classes of material representing, however, a surplus of posts, and a deficit of lumber and cordwood. To balance this required expenditure he produces for sale 165.73 cubic feet of mine timbers, cross-ties, piling, and cooperage stock. A 27-acre wood-lot in the average neglected condition of woodlands today supplies the farmer with 55 per cent of his wood consumption and if adequately managed the increased production and sale of merchantable products will make him permanently independent of outside markets for wood or wood substitutes, and relieve him of the cost of purchasing fuel, building material, and fencing for all time. If coal is substituted in the ratio of 7.66 tons to 13.4 cords of wood, shown as the average for those farms using wood and coal together, and the wood-lot managed for the production of larger percentages of higher grade material, the area may be further reduced to about 16.7 acres for the average farm. Under these circumstances there is in the present area of woodland enough productive capacity to supply two thirds of the farms of the state with wood forever.

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*See Appendix, Note 11.

STUMPAGE PRICES IN ILLINOIS FOR SAW-TIMBER

From data gathered by the U. S. Forest Service in Illinois, Indiana, and Ohio, based on 14,102,000 board feet of logs, the average price received at the mill for hardwood logs was $24.92 per thousand board feet. Based on 26,537,000 board feet of logs, the average price received for hardwood stumpage was $12.86 per thousand board feet. This leaves a margin for cost plus profit in logging, of $12.06, agreeing closely with the results of the questionnaire, which indicated that average costs of logging plus 20 per cent profit was $12.32.

The returns from the Illinois questionnaire were not sufficiently numerous to indicate a safe average price of stumpage for saw-timber. This varied from an average of $19.86 for the higher grades of logs, to $5.22 for low-grade timber. This would indicate that the average of this much larger quantity, or $12.86, may be safely adopted as the average stumpage value of saw-timber for the years 1919 to 1922, in Illinois.

By species the yearly average figures show a wide variation, from a maximum of $85.00 per thousand for walnut in 1920 to a minimum of $3.29 for sycamore in 1922. Little reliance can be placed on these specific averages. Walnut commands the highest stumpage prices, followed by ash and hickory. Veneer logs of white oak command prices up to $25.00 per thousand board feet, while the poorer grades of oak lumber are sometimes sold at less than one half this price. The value of stumpage is residual or marginal and is thus dependent on the total of costs incurred to bring the logs to the market, as well as on the price received for these logs, or for the lumber, or products.

The receipts and stumpage values for saw-timber were slightly influenced by the demand for walnut during the war. This species constituted 13.07 per cent of the total reported sold, while census figures for 1919 show that 3,690,000 board feet was produced in the state, or 6.48 per cent of the total. The relative amount of walnut in the returns from farm questionnaires is, therefore, twice as great as the average per cent for this species in the total state output, and with its high stumpage value of $49.29 per thousand board feet tends to raise the average price of stumpage above the actual.

The average price of oak stumpage at $32.44 is undoubtedly higher than cash prices paid for such stumpage by purchasers, who have not often gone much above $25.00. But the greater portion of the lumber reported was cut by the owner and sawed in a customs sawmill. The owner thus realized both stumpage and 20 per cent profit, which, at the average price of $53.07 for the lumber, netted him $32.44 stumpage and $3.42 profit on costs of logging.

This stumpage contained a considerable percentage of veneer logs of white oak, and to this extent represents a type of timber found only in the remnants of the virgin forest and not likely to be reproduced in the future. But other species, especially red and black oak, will furnish materials for timbers and other domestic use, which, while not bringing as high a price on the market, will serve as fully acceptable substitutes in framing buildings for which purchased lumber would cost approximately the same price as that received for the saw-timber sold. The sale of lumber at low prices is not justified where it can thus be used for local purposes. Returns of 6.46 per cent of the total quantity reported were for inferior species which brought a net price of $29.23 per thousand board feet, leaving but $8.70 stumpage value. 1920 Census figures give an average of all species for Illinois as $8.59.

The tendency for stumpage values to absorb an increasing per cent of final value of the product is well illustrated by the prices paid for walnut timber, which averaged $49.29 on the stump. So great is the demand for this lumber in certain lines of manufacture, especially furniture and gun-stocks, that buyers usually purchase it on the stump, and even buy and grub up large stumps if still sound in order to get the wood they contain in the crown and upper roots. Yet buyers are not averse to purchasing walnut groves at much less than these figures whenever the purchaser is in ignorance of the value of his stumpage and there is absence of local competition.

Wood-lots containing virgin white oak are now quite scarce in southern Illinois, and the entire region has been gone over thoroughly. A few owners are found who sell each year a small number of choice trees as logs, at satisfactory prices to net them an annual income from the wood-lot. But except for such species as walnut, which can continue to be grown in plantations, on good soil, the day of the large high-grade sawlog is about over for Illinois woodlands, and the saw-timber of the future will be obtained more largely from 12 to 14-inch trees than from those 20 to 25 inches in diameter. Such trees can be produced in shorter periods and will suffice to supply the needs of the farm in this direction. The sale values, costs of cutting and hauling, and stumpage values of the remaining products were derived from the averages of the replies to the questionnaire to farmers. The resultant income derived from the average wood-lot is shown in the following tables.

SALE PRICE AND STUMPAGE VALUE OF PRODUCTS GROWN ON WOOD-LOTS

Product	Unit	Contents cubic feet	Sale value	Stumpage value
Fuel wood	Cord	80	$ 5.06	$ .92
Lumber	M. ft. B. M.	166⅔	35.97	12.86
Veneer logs	M. ft. B. M.	166⅔	53.61	33.10
Posts	Post	.8	.24	.136
Mine timbers ...	Cubic feet	1.	.15	.052
Cross-ties	Tie	4.25	.81	.323
Piling	Pile	22.3	5.12	3.15
Cooperage	Cubic feet	1.	.216	.216

VALUE, COSTS, AND NET STUMPAGE VALUE PER CUBIC FOOT FOR WOOD PRODUCTS ON ILLINOIS FARMS

Product	Sale value	Cost of logging	Profit of 20% on logging	Stumpage value plus profit on logging	Net stumpage value
Fuel wood	$.0633	$.0432	$.0086	$.0201	$.0115
Lumber	.2158	.1027	.0205	.1131	.0926
Veneer logs	.3217	.1027	.0205	.2190	.1985
Posts	.2962	.1050	.0210	.1912	.1702
Mine timbers.....	.1510	.0910	.0182	.0600	.0418
Cross-ties	.1899	.0948	.0189	.0951	.0762
Piling	.2296	.0778	.0156	.1518	.1362
Cooperage	.2158	.1027	.0205	.1131	.0926

VALUE OF PRODUCTS GROWN ANNUALLY ON 1 ACRE OF WOODLAND

Product	Sale value	Cost of logging	Profit of 20% on logging	Stumpage value plus profit on logging	Net stumpage value
Fuel wood	$1.681	$1.147	$.228	$.534	$.305
Lumber	.714	.340	.068	.374	.307
Veneer logs	.456	.146	.029	.311	.281
Posts	.891	.316	.063	.575	.512
Mine timbers....	.631	.380	.076	.251	.175
Cross-ties	.288	.144	.029	.144	.116
Piling	.072	.024	.005	.048	.043
Cooperage	.028	.013	.003	.015	.012
Total	$4.761	2.510	.501	2.252	1.751

VALUE OF PRODUCTS GROWN ANNUALLY ON WOOD-LOTS

Average wood-lot per farm, 11.239 acres			Average actual wood-lot, 27 acres	
Product	Sale value	Stumpage value	Sale value	Stumpage value
Fuel wood	$18.89	$3.43	$45.39	$ 8.23
Lumber	8.02	3.45	19.28	8.29
Veneer logs	5.12	3.16	12.31	7.59
Posts	10.01	5.75	24.06	13.82
Mine timbers.....	7.09	1.97	17.04	4.73
Cross-ties	3.24	1.30	7.78	3.13
Piling	.81	.48	1.94	1.61
Cooperage	.31	.13	.76	.32
Total	53.49	19.67	128.56	47.72

RATIO OF STUMPAGE VALUE TO SALE VALUE OF PRODUCT

Product	Per cent
Fuel wood	18.16
Lumber	43.02
Veneer logs	61.72
Posts	57.44
Mine timbers	27.78
Cross-ties	40.12
Piling	59.26
Cooperage	41.93

RATIO OF STUMPAGE VALUE OF PRODUCTS IN TERMS OF STUMPAGE VALUE OF CORDWOOD (BASED ON CUBIC FOOT VALUE FOR EACH PRODUCT)

Lumber	8.0
Veneer logs	17.3
Posts	14.8
Mine timbers	3.6
Cross-ties	6.6
Piling	11.8
Cooperage	8.0

The second table on this page indicates that four fifths of the value of a cord of fuel wood is represented by labor costs, while this proportion drops to two thirds for mine timbers, nearly 60 per cent for lumber cross-ties and cooperage, and to about 40 per cent for piling, posts, and logs of high quality.

At present prices and costs, fence posts are by far the most profitable wood crop that can be grown. This product commands a fair price nearly equal to that of the highest quality of lumber, when comparison is based on cubic contents of the tree required to yield each product respectively. But it requires 100 years or more to grow logs suitable for high-priced veneers, and 50 to 70 years for good piling, while posts can be grown in from 15 to 25 years depending on the soil. By comparing the second table on page 145 with these values, it becomes evident that, in spite of the advantage to the farmer of cutting his own fuel, the practice of utilizing growing timber for this purpose exclusively or to too great an extent does not pay. As shown, the ratio of sale-value per cubic foot of these products to cordwood varies from 2.4 for mine timbers up to around 5 for posts and veneer logs, 3.0 for cross-ties and about 3.5 for lumber, piling, and cooperage. But the true comparison is found in the relative stumpage values, for these measure the value of the timber crop itself and not merely the return of cost of labor in harvesting. These ratios are shown in the last table on page 146.

On the basis of these relative crop values, the wood-lot should evidently be managed so as to produce as great a volume as possible of the higher priced products, utilizing only the non-saleable tops, limbs, and slabs as cordwood.

The loss through converting a stand into cordwood when it will make other products is shown in the following table, assuming a stumpage value of $1.00 per cord for cordwood.

Product	Unit	Value if converted into cordwood	Actual value	Loss by converting to cordwood
Lumber	M. B. F.	$2.08	$12.86	$10.78
Veneer logs	M. B. F.	2.08	33.10	31.02
Posts	Post	.010	.136	.126
Mine timbers	Cubic Ft.	.0125	.052	.0395
Cross-ties	Tie	.053	.323	.270
Piling	Pile	.279	3.15	2.871

A cord of wood has an actual stumpage value of 92 cents but if it can be converted into other products the value is as follows:

Lumber	6.18
Veneer logs	15.91
Posts	13.60
Mine timbers	4.16
Cross-ties	6.09
Piling	11.29

The time element in growing timber must be considered in this comparison. Posts and mine timbers may be grown in practically the same period as cordwood, with the exception of bars and legs which require about twice as long. Setting this period at 25 years, lumber, cross-ties, and piling will require approximately 100 years, or 75 years longer. With cordwood at $1.00, the value of the other products in order to earn 3 per cent compound interest on price alone, regardless of growth or volume, would be:

Lumber, cross-ties, and piling 75 years	$ 9.18
Veneer logs, 105 years	$22.28

The actual prices and per cents earned are:

	Price per cord	Per cent
Lumber	$ 6.18	2½
Cross-ties	6.09	2½
Piling	11.29	3¼
Veneer logs	15.91	3

The average annual income from farm woodlands is indicated as standing around $1.688 per acre for stumpage alone, clear of all expenses of harvesting. It is obvious that such income per acre will not indicate a value equal to corn land. But corn land would grow from 2 to 3 times as much wood as this per acre annually. True forest soils, too rough and hilly or with soil too poor in quality to permit of profitable agriculture, will not command corn-land values nor a tenth part of them. The capitalized value of an income of $1.688 at 5 per cent is $33.76 per acre. But this allows nothing for cost of crop production. In a wood-lot which is normally stocked with many-aged trees, has abundant reproduction, and every prospect for continuing to produce the normal yield of the soil every year, the only deduction from the above value per acre would be such annual expenses including taxes, as are required to protect and maintain the stand in its healthy and productive condition. Even if these expenses reached 50 cents per acre, which, capitalized, is $10.00, the value of the property would still be $23.76. Reproduction in such wood-lots is by natural processes largely, and the chief expense is vigilance to keep fire out of the lot.

The above value of course represents that of the land with its stock of standing trees, and not the bare denuded soil, which is worth very much less than this amount. True forest land of this quality is assessed in the southern counties at around $5.00 per acre.

Forests as a Crop on Soils of Different Qualities

INTRODUCTORY

The practice of forestry, or forest culture, will produce crops of timber yielding from 50 to 100 per cent more per acre in annual growth than the average now being harvested, of less than 45 cubic feet per acre. A considerable proportion of these increased yields will be obtained in the form of thinnings in even-aged stands. When no cutting is done in a stand or crop until it is finally ready to harvest, the surviving trees which make up the crop at that time constitute a very small per cent of those originally composing the stand. When it happens, as in plantations for post timber, that all the planted trees, thanks to an even start, survive for a time, the rate of growth in diameter soon shows a marked falling off and the growth on the whole stand tends to stagnate until the numbers are reduced by competition and the survivors obtain the increased crown-space required for thrifty development.

In cultivated stands of timber this reduction of numbers, instead of being left to nature, with consequent injury to the stand and loss by decay of the dead trees, is forestalled by removing a sufficient number of trees at from 5 to 10-year intervals to release those selected for the final crop. The ultimate number per acre will depend on the age and size of the crop which is desired. Plantations seldom have over 2000 trees per acre, and unless very early thinning is possible they will not be set closer than about 6×6 feet apart, or 1210 trees per acre. At 15 years, post timbers may be cut from such plantations. At 40 years, under natural conditions, this number would not be over 800 trees. At 60 years it would have diminished to 450, while at 80 years, about 270 trees would survive on an acre. Normally, but one half to two thirds of this number should be permitted to survive.

Without including the income possible from such thinnings or advance yields, the value of the final crops produced on typical acres of Illinois woodland can be calculated.

PLANTATIONS IN STARK, OGLE, AND CHAMPAIGN COUNTIES

The possibility of supplying home-grown posts on prairie farms is illustrated by yields of catalpa plantations at 15 years from time of planting. Many such plantations in the state have been absolute failures, but this is due to ignorance as to the soil requirements of the tree. Catalpa will not develop even into post timber unless planted on land of high fertility and supplied with abundant moisture.

Plot 1*. *Catalpa Plantations in Stark county.*

Yields from plantations in Stark county, at 15 years, planted 3 feet apart in rows 6 feet apart, produced 2,430 cubic feet of wood, equivalent to 162 cubic feet or 1.8 cords per year of growth. From these trees 2,000 posts averaging 4 inches could be cut, leaving 830 cubic feet or 34 per cent in the form of stakes and small fuel wood which equals .612 cords per year. The annual average production is, then, 133 posts and .612 cords of stake or fuel wood per acre. According to table on page 86, the requirements of an average farm of 134.8 acres if catalpa is used, are 56 posts yer year, or for 100 acres, 42 posts. In order to maintain perpetually the fences on the average farm all posts needed will be furnished by a plantation of .42 of an acre or .315 acres respectively. In other words, the posts may be grown on the farm by devoting a little over 3/10 of 1 per cent of the fertile or crop area to this crop.

The value of these posts, per year, at 30 cents each, is $40.00, and the cost of cutting and hauling should not exceed 6 cents each, or $8.00 per acre, leaving a net stumpage value or income per acre annually, of $32.00 on an average annual expenditure, for planting, of $2.00 (if cost of establishment is $30.00 per acre). If this sum of $30.00 per acre is expended to establish a plantation the outlay per post is 1½ cents, which in 15 years will return 30 cents minus 6 cents for cutting at present prices, with the owner in position to profit by every increase in value of post material from now on. This first cost and taxes are the sum total of actual expense in growing this post timber. It is frequently argued that compound interest on these expenses should be included as a cost, since the money so expended might be earning interest for 15 years at 6, 7, or 8 per cent. Quite true; but the investor who puts his money out at these rates does not consider this interest *a cost* to him, it is, rather, his *income*. In the same manner, the compound interest on the cash costs of a plantation may be computed if desired, but these do not represent a dollar expended nor do they increase the actual cost a cent. They do enable the farmer to judge how good his investment is; but here again, the returns if gaged by compound interest are better than those ordinarily secured by investors who receive annual interest payments, since compound interest, especially at rates of 6 to 8 per cent, increases much faster than simple interest at the same rates. In

* These numbers refer to the plots listed on page 131.

compound interest the money is already reinvested at the end of the year, with no temptation to spend it or expense and delay in placing it.

Gaged by direct comparison, then, an outlay of $2.00 per acre annually, or a total of $30.00 for one acre, will return a net income of $32.00 per acre annually after an initial period of 15 years has clapsed, or $480.00 on one acre. Spread over the period of waiting, this means a return of the original cost, plus $30.00, or an income of $1.00 per year for each dollar invested, which is $30.00 per acre annually over and above cost of the crop. After the fourth or fifth year, at most, no further expense is required nor is any labor of crop production involved.

Money can be borrowed on farm property at 6 per cent. Land at $250.00 per acre must produce a net income of $15.00 clear of expenses to justify this value.

If compound interest at 6 per cent for 15 years is required, the land, bare of trees, at the year of planting is worth for a crop of catalpa posts $261.55 per acre as follows:

Taxes per acre at $1.84 for 15 years, compounded....	$ 42.83
Initial costs, $30.00 for 15 years........................	71.89
Total costs	114.72
Net income every 15 years..............................	$365.28

Discounted as a recurring crop or rental this gives the above land a value of $261.55. The rental at 6 per cent on this value is, per acre, $15.69 annually.

Catalpa when grown in this manner as a crop on rich agricultural soils yields over twice the cubic volume per year that can be expected on true forest soils of average quality. Early maturity into post sizes and a high per cent of utilization in spite of the small sizes of the trees, due to using the material in the round, give 66 per cent merchantable. No account has been taken of the other 33 per cent of wood or stakes, which will serve to defray any protection costs. The wood, even as fuel, should be worth $3.00 per cord, and serve to reduce the coal consumption or to supply kindling. The yield of this material, 830 cubic feet, is equivalent to 10.6 cords per acre, which at $1.00 per cord stumpage gives $10.60 or 70 cents per acre annually.

After such a plantation or system of post-production becomes established, the property, or land with growing timber, increases rapidly in value and becomes worth much more than $261.55. If a plantation of 15 acres is established by planting 1 acre per year, or one of an acre in extent by putting in 1/15 acre each year for 15 years, the plantation will be worth per acre, $469.33.

The annual costs distributed over each acre are:

Taxes on $250.00-land	$1.84
Planting and other expenses	2.00
Total cost	$3.84
Stumpage value of crop cut annually per acre	32.00
Net income per acre annually	28.16
Capitalized at 6 per cent	469.33

If 5 per cent were used, values of land and property would be proportionately higher.

Catalpa posts constitute a crop which may be profitably grown on $250.00 land. They can not ordinarily be grown with profit, except on land of good quality. Catalpa, to succeed as a crop and to produce in 15 years the indicated yields of 2 good posts per tree, requires in the selection of the site and soil as great care as for any variety of farm crop. A failure with an annual crop may be remedied in one season, but with trees the loss extends over the entire period of growth and is cumulative. Just as corn and other field crops become unprofitable when grown on marginal land, since the rate of income to expense diminishes, so in the planting of this species the same principle holds good. Plantations require a considerable initial investment, which must be returned with interest to justify the venture. On poor soil, either sandy or dry, or stiff clay, compact silts, or other soils of medium or low agricultural value, catalpa is a failure and should not be planted.

This species, therefore, is a tree with special adaptation as a post timber—though not so durable as hedge, black locust, or mulberry—but with very exacting requirements as a crop, which makes it profitable to grow in competition with field crops on good soil rather than on the poorer natural forest-soils of the state. The utilization of an area of a little over 3/10 acre for every 100 acres of crop lands, on farms without other timber, for the purpose of furnishing a perpetual supply of fence posts of good quality, seems justified by the demonstration that the value of such land for this crop equals that for its use for other purposes.

Plot 7. *White Pine in Ogle county.*

The planting of white pine may be possible in limited areas which are free from the competition of hardwood sprouts, and in the northwestern portion of the state. The growth of this species in the limited area in Ogle county approaches the maximum yields obtainable in northern Minnesota and Wisconsin. This stand at 75 years of age has produced lumber of the finest quality though deficient as yet in the quantity of lumber of clear grades suitable for pattern stock or other special uses. The stumpage value of such pine timber in Minnesota has reached an average of $20.00 per thousand on sites approaching this in accessibility. At 39,690 board feet the value of the crop is now $793.80 per acre, giving an average yield per year for the total period, of $10.58 per acre, exclusive of the possibility of thinnings. It is not permissible to use over 4 per cent compound interest to apply over a period as long as 75 years, and any investment which yields this total, which returns 18 times the initial investment, must be considered a very profitable one.

This seeding was natural, hence the only expense was taxes. The value of the crop, $793.80, properly discounted, would indicate a land-value of $44.23, which at 4 per cent would yield an annual rental of $1.77 per acre. Annual taxes would have to be met in theory from this rental.

These data indicate that crops of white pine should not be grown upon agricultural soils in place of farm crops, but that they possess possibilities for sandy or poor soils whose value falls below $40.00 per acre. Once the forest on such soils is brought to a condition of annual yields, the value per acre based on gross income would be $\frac{10.58}{.04}$ or $264.50 per acre, approximately that of good agricultural land. But this value includes the average stand of half-grown timber. It is just these timber values which restore the balance of value to the poorer classes of soil and cause these soils to bear their proportionate burden of production and of taxes. On poorer sands, experiments should be made with other pines.

These pines on account of their straight form and comparative lightness of wood produce a far greater ratio of lumber per cubic foot of wood than do hardwoods, and the proportion is still greater when weight is considered, or fuel value.

Plot 3. *European larch in Champaign county.*

This species weighs 30.65 lbs. per cubic foot as against 22 lbs. for white pine. The yield of a plantation of larch at Champaign on rich black loam exceeded that of the pine in Ogle county in weight per year, giving 3,414 lbs. annually as against 1,929 lbs. for pine. In cubic feet, the relative yields were, for larch 111 cu. ft. annually and for pine 85 cu. ft., but reduced to board feet, larch yielded but 491 ft. per year as against 529 for pine. The larch plantation was but 52 years old, had never been thinned, and had stagnated badly for over a decade, else this latter comparison might have been more favorable. Used as lumber, this species is not as valuable as the white pine. At $15.00 per thousand stumpage, the crop is worth at present, based on a yield of 25,552 board feet, $383.28 per acre, which at 5 per cent discounts to $32.92 per acre, giving a rental of $1.65 per acre. This allows nothing for the expense of planting, or for taxes. At $15.00 for planting, the soil value shrinks to $16.63, yielding $.83 with which to meet taxes.

Larch can not be raised on agricultural soils for saw-timber at a profit. It grows well on black loam soils and would pay better returns if cut at an earlier age for fence posts.

PLANTATIONS IN EDGAR, FULTON, AND WHITESIDE COUNTIES

Plot 5. *Black walnut in Edgar county.*

Plantations of this species if on soil of good agricultural quality will yield up to 100 cubic feet and 3,000 lbs. of wood per year, giving, as in this case, over 300 (328) board feet per year on an acre. Average prices for walnut logs of good quality, on the stump, are about $50.00 per thousand feet B. M. This crop yielded 16,432 board feet, valued at $821.60 per acre, at 50 years of age, or an average per year of $16.43. Without considering expense, the indicated soil-value at 4 per cent is $134.54. From this, planting must be deducted, which at $15.00 per acre, discounted, still leaves a value of $117.08 per acre for the land if put to this use, equivalent to an annual rental of $4.68 from which to meet taxes. This indicates that walnut plantations, while they may serve as a grove and shelter or windbreak in part, give the soil a reasonably high value though not as high as under farm crops. Plantations made for the purpose of producing large trees should if possible be of walnut, at least in part, due to the relatively high stumpage value which should be maintained or even increased in the future if sufficient quantities of the species are produced to maintain its use. Its qualities for certain purposes, such as gun-stocks and furniture, are so superior that its future use seems assured.

Plot 2. *Plantation of Hardwoods in Fulton county on alluvial bottom.*

Alluvial bottoms subject to flooding and capable of being drained, produce rapidly growing crops of hardwood timber of good quality within reasonably short periods. This plot in Fulton county yielded 4,595 pounds per year, or 144 cubic feet of wood, and at 37 years of age had produced a possible cut of 13,412 board feet of lumber or 362 feet per year. Due to the small sizes produced at this age, the maple, elm, and sycamore lumber would not command a high price as such. Ash, composing 9 per cent of the stand, has a higher value. Adopting the average value of $12.86 per thousand board feet, the crop of timber is worth $172.48 per acre. In addition to the sawlogs, 29.8 cords of wood are yielded from tops, limbs, and smaller trees, worth 92 cents per cord on the stump, or $27.42, a total of $199.90 per acre.

Using 5 per cent for this period of 37 years gives a soil value of $39.34 per acre, equivalent to a rental of $1.96 per year out of which to pay taxes. There is no expense for planting. Such soils, unless stumpage prices received are considerably higher than $12.86, can not be retained as forest land if they are capable of being drained and farmed; but if not, the forest crop gives them a definite productive value and should not be neglected.

Plot 11. *Oaks in Whiteside county on hilly land.*

This typical plot, on land of poor agricultural value, yielded at the rate of but 1,561 lbs. or 42 cubic feet per year, or about the average which the woodlands of the state are now yielding under the existing lack of management. The species were 89 per cent oaks, and at 71 years would give 7,427 board feet of lumber, or 105 feet per year, worth at $12.68 on the stump, $94.17 per acre. In addition, 1,124 cubic feet of mine timbers can be secured, at 5.2 cents stumpage per foot, or $58.45, leaving a residue of 3.32 cords at .92 or 3.05, a total yield per acre of $155.67 or $2.19 per year. Such investments if capitalized at 4 per cent indicate a soil value of $10.24 per acre, equivalent to a rental of 41 cents per year to meet taxes. Such lands if valued at more than $10.00 do not pay 4 per cent compound interest on timber crops, though it must never be lost sight of that over 70 years this rate gives a return of 155.7 per cent on the dollar, or $15.57 for every dollar invested and that when established as a business yielding annual returns, such crops give the soil with its average stand of half-grown timber a value of $54.75 per acre, which is higher than they would have for any other purpose if essentially unprofitable for agricultural use.

The Grazing of Farm Woodlands

Grazing or pasturage forms an alternative use for practically all farm woodlands in Illinois. Being under fence for the most part, it is an accepted practice in the farm economy to give certain classes of stock the run of woodlands to get what grazing they can.

The attitude of farm wood-lot owners toward this portion of their holdings is shown by the results of the questionnaire as follows:

Land which should be cleared for agriculture	16.45 per cent
Land which should be cleared for pasture	15.00 per cent
Total which owners desire to devote to other use than woodland	31.45 per cent
Land which should be permanently retained as woodland	68.55 per cent

This large percentage, over two thirds, of the present woodland area which the owners desire to retain as woodland indicates the increasing value placed upon forest property by farmers, without any systematic effort by the state to demonstrate this value, or to educate such owners in the possibilities of timber as a crop, or the methods of production. Nevertheless the tendency in the past to regard all forest land as non-productive and to clear it as rapidly as possible still sways the thought of many who own woodland which occupies fairly level and fertile soil. A certain percentage of this remaining woodland probably should be cleared and will be in time. If the owners' estimates are carried out the ultimate area of farm woodland will shrink from its present acreage of 2,668,050 acres to 1,828,948 acres. An area of 442,894 acres will be added to the cultivated lands, and 400,207 acres to cleared pastures.

It may be seriously doubted whether such results will actually be secured as a whole, for parallel to the possible clearing and conversion of these woodlands there has appeared a marked tendency towards abandonment of the poorer grades of farm land as unprofitable for cultivation. In the one decade from 1910 to 1920 an area of 753,790 acres went out of cultivation, or more than the total combined area of proposed clearing of woodland for grazing and cultivation. Again, on the estimates of farm owners, some 221,477 acres, or an area 55% as great as that to be cleared for pasture, should be restored to forest by planting. Without doubt the area which could be profitably planted or restored to forest is many times as large as this, but the individual farm-owners do not yet see the value of such a policy, or else they are so impoverished by endeavoring to cultivate inhospitable soils that they have no desire to undertake forest improvement for the sake of the future.

The questionnaire returns indicate an average of two acres of forest plantations for every hundred acres of woodland, but it is not thought that a complete census would quite bear out this total, which would indicate 53,361 acres of forest plantations in the state. Considerable planting has been done, however, especially in prairie sections, and when these are added Illinois may well have over 40,000 acres all told.

In spite of the intention of Illinois farmers to retain over two thirds of their present wood-lots as forest land, grazing of stock is practiced on 84.57 per cent of all farm woodlands, and stock is excluded from only 15.43 per cent of the total. The practice is thus well-nigh universal of considering the woodland as available for pasture, due partly to convenience and the arrangement of fences, partly to the desire for shade for the stock in hot weather, but primarily to the desire to extract from the woodland a greater annual return. This pasturage yields an annual income and increases the carrying capacity of the farm in live stock. It utilizes land which has generally been regarded as non-productive of income. So logical does its use as pasturage appear that exclusion of stock even from the residual 15 per cent is not usually intentional so much as it is due to inaccessibility, lack of fencing, or inconvenience. This practice will continue unless woodland owners become convinced that it does not pay. To demonstrate this two questions must be correctly answered. First, do forest crops pay better than grazing or pasturage? Second, are the two uses incompatible or mutually exclusive? It is generally conceded that the quality of grasses growing under the shade of timber is poorer than when grown in sunlight, and that the grazing on a woodland or shaded pasture is poorer, in contrast with open lands, in direct proportion to the amount of shade.

The carrying capacity of more or less open woodland pastures, was found by E. R. Hodson, of the U. S. Forest Service, to be 2.4 acres per head of cattle. Its value in Illinois is estimated at one fifth of that of good bottomland pasture. In Ohio, the value of the grazing is placed at an average of 35 cents per acre as against \$2.00 to \$4.00 for good grazing. The most liberal estimate of the value of grazing on woodland pastures for Illinois is from \$1.00 to \$1.50 per acre annually, or not half the value of improved pastures, which are placed at \$3.00 per acre.

Stock does not need the amount of shade furnished by such woodlands. A few scattered trees in an open pasture are sufficient for this purpose. The value of woodland for pasture is unquestionably increased from 100 to 200 per cent when totally cleared of forest growth, or improved. When the forest is completely destroyed this land should bring in a revenue from pasturage of about $3.00 per acre.

By comparison, it is seen that the stumpage value of the products now being taken from the average wood-lot per acre, without care or management, are valued at $1.688 per year, and that these products bring $4.76 per acre when sold. But when it is realized that the greater portion of these products are used on the farm and take the place of an equal quantity of wood or wood substitutes which would otherwise have to be purchased, the economic value of the farm woodland begins to be evident.

A rough comparison of the values of these home-grown products and their substitutes is shown below:

Product	Produced on farm	Purchased
Fuel, per cord............	$ 5.068	$ 5.28
Fence posts, per post......	.237	.40
Lumber, per M. ft. B. M...	25.00*	50.00

When it is considered that the labor expended in the harvesting of the wood crops can be distributed over the slack seasons and that this tends to give steady all-year round employment, the actual value to the farmer of the crops from his wood-lot must be placed considerably higher than the net stumpage value which he would obtain if he sold the wood in place and did not receive any of the benefits of using it for farm needs. At a conservative estimate, the average acre of farm woodland is worth as much in annual income to the farmer as this same acre would produce if totally cleared for grazing. But can this income be obtained and at the same time the land be used for grazing and thus a larger total revenue be obtained? Universal observation and experience in the hardwood forests of Ohio, Indiana, and Illinois answer this question in the negative. To be sure, the timber which the land has already produced will continue to live in most instances until felled and removed, hence will yield its value to the owner. But this value does not necessarily represent net annual income, and will not, unless a quantity equal to that removed is being added to the forest by growth.

The rate of growth of the standing trees diminishes noticeably on areas heavily grazed, and some trees die from trampling. But even in this way the effect of grazing upon income is not brought out in its

* Stumpage $12.86 plus cost of logging and profit, $12.14.

true aspects. In order to perpetuate this annual yield of the wood-lot it is not sufficient that the existing stand continue to lay on wood, for every time a tree dies or is cut the stand becomes thinner and more open. Under normal or natural forest conditions, young saplings are constantly springing up to replace the veterans and fill in these gaps. The forest is densely stocked with trees of all ages and sizes. Very little grass is on the forest floor, and but little underbrush. A carpet of leaves, slowly decaying into humus, keeps the soil moist and permeable to water. The forest thrives, and the trees are healthy, sound, and vigorous. Many wood-lots in southern Illinois well cared for by their owners, show such conditions.

But on woodland areas which are grazed by cattle, horses, or sheep, a change sets in almost immediately, and continues progressively as long as the practice is maintained. The stock devour readily all the leafy foliage within reach, and this includes all seedlings and young saplings not too tall for them to get at the crowns. Their trampling hardens the soil and decreases its moisture content. Under these conditions, the removal or death of an old tree is not followed by a thicket of vigorous young reproduction, but instead a permanent opening is formed. These openings extend, and grasses, resistant to grazing, form a sod which makes it difficult or well-nigh impossible for tree-seedlings to start, or else favors the less valuable species, such as ironwood or elm, instead of oaks, tulip-poplar, and basswood.

The process of degeneration may be prolonged over a period of half a century, but the forest is doomed as certainly as if it were allowed to burn over every year or two. With the final cutting of the last decrepit veterans, the revenue for the woodland ceases, the forest capital is bankrupt, and the only possibility of annual income lies in continuing the practice of grazing which has brought about this destruction, meanwhile possibly permitting the barns to deteriorate because the high price of lumber makes the cost of their replacement prohibitive.

It is certain that such a policy is self-determinative. The forest land is not being used as such, and the future forest revenue is being sacrificed for the sake of an immediate return for grazing, which in itself does not constitute a complete or efficient use of the land. The general policy indicated by these facts is the separation of forest from pasture. The two uses are actually incompatible. The forest will not reproduce in the presence of grazing, yet its presence depresses grazing values. The continuance of this policy is a deliberate rejection, whether conscious or otherwise, of the policy of growing wood crops for the farm. Instead of retaining two thirds of the farm woodland as forest, the owners are actually engaged in clearing for pasturage 85 per cent of their present woodlands by a most inefficient and time-consuming method.

It seems probable that a more enlightened and profitable policy would be to recognize this conflict, and to definitely decide upon the areas desired for permanent forest and for permanent grazing. Then these areas should be separated by fence, excluding the stock from the true forest area, and the pasture areas should be cleared as rapidly as possible of all forest growth. The relative percentage of forest and pasture desired must be worked out by each owner, with the advice of the state department of forestry as to true forest values as a guide in this determination.

Fire in Forest Lands

Forestry Circular No. 2 of the Natural History Survey has set forth the damage done by fires in Illinois woodlands. It is sufficient here to summarize.

In the hardwood forest areas, which comprise practically all of the Illinois woodlands, fire is an unmitigated evil. There is no class of fire which does any benefit whatever to the forest. It neither benefits reproduction nor reduces the danger of subsequent fires. Instead it makes the recurrence of fires more certain and their character more disastrous. There is but one thing which fires accomplish; they progressively destroy the forests. The process is much the same as that of grazing. The reproduction of seedlings is killed as fast as it occurs, and this eventually—by opening up the forest and bringing in heavy sod and a tangle of briers and brush—prevents tree reproduction from surviving or even starting. Fire acts far more rapidly and disastrously than grazing upon the mature stand. Occasionally the entire stand is killed. With hardwoods this usually occurs when the stand is fairly small and young. The butts of the older trees, even though protected by heavy bark, are sooner or later fire-scarred by killing the cambium or live tissue on the most exposed side and this would eventually, perhaps many years later, cause the destruction of the tree by rot and blow-down. It is safe to say that every fire permitted to burn through a woodland area destroys the equivalent of a year's increase at the very least.. This when harvested would be worth from $3 to $12 per acre.

Most fires destroy far greater values than this. *Periodic fires* burning at *three* or *four-year intervals*, or even at ten-year intervals, may destroy all the reproduction for the period; hence effect a loss equaling from three to ten times the annual income, when harvested. This loss is seldom visualized or reckoned, but constitutes a damage far greater in its eventual total than the complete destruction of the existing stand of old timber. It would be as sensible for a farmer to try to continue a live-stock industry and pay no attention to losses of young stock because at the time of birth they had no market value as for an owner of forest land to expect to continue to derive revenue from it while permitting fires to consume the progeny of the forest.

The questionnaire here gave interesting results. Out of 217 replies 44 or 20.28 per cent were not opposed to fire in wood-lots, in fact favored it, while the remaining 173 or 79.72 per cent desired its complete exclusion. As was to be expected the chief cause of fire in these woodlands is the hunter or camper. Fox hunters, bee hunters, coon hunters, nut and berry pickers, and ginseng hunters are all charged by the woodland owner with a share in the guilt. The following causes were listed by the given number and per cent of owners, and the list serves to indicate the relative prevalence of these agencies in the starting of fires:

	No.	Per cent
Campers and hunters	103	35.7
Carelessness	54	18.7
Burning to kill insects	37	12.8
Brush and grass burning	32	11.1
Railroads	26	9.0
Smoking	25	8.7
Lightning	8	2.7
Incendiary	3	1.0
	288	99.7

Of these causes the burning to kill insects and the burning of brush and grass are due to practices of the land owners. Comparatively few railroad fires occur since most railroads do not run through forest lands, yet such fires do occur frequently along timber stretches, especially in southern Illinois. The Chief Entomologist of the Natural History Survey, in an effort to correct the practice of broadcast burning of woodlands against the chinch-bug, has called attention to the fact that these insects do not hibernate in damp or shady spots, but seek the sunny borders of woods or fence-rows, where it is comparatively dry. The burning-over of a wood-lot to kill bugs when a 50-foot strip along the south border would get them all is as bad as burning down a house to roast the pig instead of using the oven.

In most regions the individual wood-lot is fairly well protected against fires occurring on the land of others. Cultivated fields and roads form effective fire-lines, hence the predominance of the fire directly set by persons making use of the woodland, and abusing the privileges thus accorded them by burning over the property. A certain measure of protection may be had by posting such lands against all trespassers, but in the greater areas of forests in southern Illinois the ability of the owner to keep fire off his land is largely determined by its location, and where it is surrounded or joined on one or more sides by unprotected forest-lands constant vigilance is necessary in the dry seasons to prevent the inevitable annual fires from burning him out. As a result, some owners secure protection by back-firing at the first intimation of the approach of the blaze and thus secure immunity at the sacrifice of other lands; while others, less favorably situated, make no attempt to check the fire but breathe a sigh of relief when the conflagration is over for the season and their buildings are still standing.

The owners who by reason of fortunate location or diligence have succeeded in excluding fires and who have in addition kept out grazing, have had the reward of seeing their forest areas restocked densely with all manner of vigorous young trees. The reproduction of these hardwoods in southern Illinois is especially prolific and when lacking, the cause is not far to seek. Many of these owners take great pride in their wood-lots as well they may, but for one wood-lot so nurtured there are twenty which show the frightful ravages of either fire or grazing, or of the two combined. These, and not timber-cutting, are the factors which threaten to destroy 90 per cent of the remaining forests of Illinois and put an end to their productiveness and future yields. If the present practices of firing the woods and grazing are continued, then inside of two more decades the production of Illinois woodland will drop permanently to not over a fifth of its present low capacity. More may be accomplished and at less cost by correcting these conditions in existing woodlands than by replanting an area equally great at enormous outlay.

A Forest Policy for Illinois

The woodland area of Illinois is comparatively small, yet together with the waste lands which might be forested it comprises some five million acres capable of producing at least 250,000,000 cubic feet of wood annually. The present annual production is but 115,000,000 cubic feet, and is rapidly diminishing. The stock of timber or forest capital is being exhausted with no thought of the future and no wide-spread application of sound principles of crop renewal and production. Grazing is progressively ruining the best forest areas and fires are destroying the poorer and less well-protected tracts. Yet these forests are still supplying one half of the farmer's total needs for wood, one sixth of the railroad ties used in the state's transportation system, sixty per cent of the timber used in its mines, thirty per cent of the piling and twenty-five per cent of the farmer's fuel, and one half of his fence posts. The exhaustion of these supplies will be felt in several industries, but its influence will fall most heavily upon the farmer who, deprived of local sources of wood for fencing and buildings, will be forced to pay increasingly higher prices for these necessities or cease to operate.

On the other hand, the ownership of ninety-three per cent of the woodlands of the state is in the hands of these farmers, who would be the largest beneficiaries of their intensive use. There is enough woodland on farms to supply all the present needs of these farmers for wood products if the wood-lots are properly managed. Farmers can get along without extending their areas of pasturage, but they can not avoid the use of wood or high-priced substitutes. Those who still have an over-abundance of wood and perhaps have had wood for sale and failed to realize a profit, are too apt to underestimate the value now and in the future of the home supplies which they are drawing upon. They see only the labor of getting out the wood crops. The farmer, because of his ownership of comparatively small areas of woodland, can give it more intensive care than any other class of owner and can make it produce more per acre. His utilization can be practically 100 per cent. The tops not suitable for lumber, ties, or even posts or props, can still find service as home fuel or even sale as cordwood. It is to the farm-owners of woodland, then, that the state must look first for the turn of the tide and the establishment of proper practices in the care of forest lands. With farm wood-lots in thrifty condition there will be a constant production for sale of railroad cross-ties, mine timbers, and even saw-timber, as well as of cordwood for consumption in cities.

The farm owner knows many things about his woods, but as a rule he does not know enough about either the possible future value of this woodland or the methods necessary for its protection, reproduction, and management. Farmers were slow to recognize the need of agricultural experiment stations and county farm bureaus. They will more readily admit their need for information regarding their wood-lots. Information must be formulated regarding production on farm wood-lots, and disseminated throughout the state by means of direct contact with the farmers and by co-operation with the county farm advisers.

Next in importance in this program of farm extension in forestry comes the teaching of farm forestry at the state university, in order to supply its agricultural students with basic information on the management of such woodlands for use either in the rôle of owners or as teachers and demonstrators connected with farm-extension work as county agents.

The first duty of the state is to provide for this instruction. This should require a definite organized department of forestry as one of the main branches of the state experiment station at Urbana. The purpose of this department should be, first, to establish experimental areas in forestry, located at several points within the state on different classes of soils, on which experiments may be conducted in the management of existing tracts of natural forests, the reclamation of eroded lands by forest planting, and the testing of methods of treatment of woodlands for greater profit.

Second, from the results of these experiments supplemented by extensive observations and study throughout the state, definite practical recommendations should be formulated for the management of farm woodlands and this information should be carried directly to the farmer by personal contact as well as by bulletins and other methods of promoting publicity.

Third, Illinois must make a definite effort to put an end for all time to forest fires. This will ultimately mean, at least in certain portions of the state, a system of fire-wardens similar to that in successful operation in other states. A system of unpaid local or township fire-wardens might be inaugurated to begin with, until experience indicates the needed measures for improvement. The laws now on the statute books prescribing penalties for the setting of fires in woodlands are probably sufficient with a slight overhauling. The essential thing is to have fire protection of forested lands placed under the jurisdiction of some branch of state government sufficiently interested and with machinery at its command for the successful enforcement of the fire laws.

Fourth, the state should acquire by purchase a tract of about 75,000 acres in certain counties in the southwestern portion containing the largest unbroken areas of forest land, and consequently most exposed to damage by fire. Upon this area fire-protection should be undertaken by the use of modern methods and equipment already successful in many other states, such as look-out-towers, paid fire-wardens, and a telephone and trail system. The cost should be kept within reasonable proportions, based on the area acquired, but the protection should extend over the entire region tributary to the state-holding of land. As is now the case in Ohio, it would be desirable for this organization for fire-protection in the comparatively small and relatively inaccessible state forest area to be placed under the direct jurisdiction of the state forestry division at the agricultural experiment station rather than have it attached to some other administrative department where it would not receive proper attention or guidance and might completely fail of effectiveness. All such projects on the part of the state, for the present at least, must be purely educational in intention, the purpose being to reach and influence the farm-woodland owner as rapidly and effectively as possible.

The establishment of forest parks for recreation, as exemplified by the creation of the Cook County Forest Preserves, is not forestry in the economic sense, nor is it intended to provide supplies of wood for Illinois industry or consumption. There are several areas of woodland of great scenic beauty in the state where the timber is still preserved by the owners. These tracts should be acquired by the state or by counties as parks and managed as such for the absolute preservation of the forests and the beauty of the site. The management of these park areas requires but a limited knowledge of forest economics or silviculture, though this knowledge is helpful in protecting and improving the forest. The urban populations of the state will be directly and intensely interested in these park projects, which should be encouraged in every possible manner. But for the present at least, they should be kept sharply distinct from forestry, and their acquisition and management should not be confused with that of state forests acquired for forest production or with the project for farm wood-lot extension.

Opportunities for the State of Illinois to constitute large public holdings of forest land, outside of a few tracts in the south, are circumscribed by the divided and scattered character of the remaining timber lands which will continue to be owned by farmers as part of the farm economy. The great wood-using industries of the state, now drifting with the tide and for the most part adopting a fatalistic attitude regarding the future of their wood supplies, should be the first to encourage the forestry movement in the nation at large, and in this movement the general public of the state, through the State Forestry Association and other organizations, should heartily join.

APPENDIX

NOTE 1.—Cooperage, Veneers, and Shingles.

For cooperage, U. S. 1921:

	M pieces	Multiple for cubic feet	Cubic feet
Tight staves	532,000	83	44,156,000
Heading	178,000	333	59,274,000
Slack staves	362,000	25	9,050,000
Heading	333,000	167	55,611,000
Hoops	21,500	25	537,500
			168,628,500

For veneers, U. S. 1921:

576,000 M ft. B. M. log scale.

Based on log scale, a divisor of 6 is used for cubic feet = 96,000,000 cu. ft.

For Illinois, no statistics on consumption of cooperage stock or veneers are available, hence the quantity consumed must be obtained by proportion from the total produced in the U. S. The result can only be an approximation, but it is more accurate to include such an approximated total than to omit the item altogether. For total cooperage and total veneers, then, the per cent consumed has been based, not on relative population nor on the relative per cent of manufactures in the state to total for U. S., namely, 8.12 per cent, but on the state's relative consumption of lumber, which is 6.81 per cent, falling below the other two figures.

Total cooperage, 1921:

168,628,500 × .0681 = 11,483,600 cubic feet.

Total veneers, 1921:

96,000,000 × .0681 = 6,537,600 cubic feet.

These quantities may be considerably in error on the basis that Illinois consumes larger or smaller proportions of the total production than those adopted.

Shingles.

The consumption of wooden shingles in Illinois was based on the same percentage, namely, 6.81 per cent of the total for the United States

Total consumption in U. S., 1921:
9,192,704 M shingles.
Conversion factor 9 cubic feet per M shingles.
9,192,704 M × .0681 = 626,023 M, or
× 9 = 5,634,207 cubic feet.

The years on which our data are based are given below:

Fuel	1922	Veneers	1921
Cross-ties	1921-1922	Shingles	1921
Mine timbers	1922	Piles	1922
Posts	1922	Poles	1922
Cooperage	1921	Lumber	1920

NOTES 2, 3, AND 4.—Automobiles.

NOTE 2.—Although cars are made largely of other materials, yet the average quantity of wood used in their construction was:

Year	Passenger cars, board feet	Trucks, board feet	All cars, board feet
1921	184.8	231	189
1922	173.6	217	176

NOTE 3.—Consumption of lumber in the United States for Automobiles (from National Automobile Chamber of Commerce):

1920	Passenger cars	1,883,158	board feet.
	Trucks	322,039	" "
	Total used, approximately	400,000,000	" "
1921	Passenger cars	1,514,000	" "
	Trucks	147,550	" "
	Total lumber used	313,800,000	" "
1922	Passenger cars	2,406,396	" "
	Trucks	252,668	" "
	Total lumber used	468,074,640	" "

NOTE 4.—According to the Forest Products Laboratory, the proportion of lumber used in passenger cars and trucks bears the relation of 160 to 200. U. S. figures show that in 1922 trucks made up 9.5 per cent and passenger cars 89.5 per cent. Multiplying 160 by 89.5 and 200 by 9.5, a weighted average of 162.2 is obtained. But the total average is actually 176 feet, or 108.5 per cent of the trial average. The average for each class is obtained by increasing the 160 to 200 feet by 108.5 per cent, which gives the values shown in table ...

The figure on consumption for both classes has been obtained by taking 3 per cent of the output of the U. S. for each class, autos and trucks, and multiplying by these figures. The Forest Products Laboratory gives 12,000,000 board feet for passenger car bodies alone, not counting blocking and other incidental uses. It is not certain whether the figures for actual output for Illinois are 3 per cent for each of the two classes, which would indicate for passenger cars 12,532,531 board feet and for trucks 1,644,860 board feet, but the agreement with the above figure is significantly close.

NOTE 5.

GROUP B—CONTINUED

MISCELLANIES ITEMIZED. CENSUS OF 1920

	Persons employed	Capital invested	Cost of materials	Value of products	Value added by manufacture
Ship and boat building	139	479,365	209,189	461,226	246,080
Wooden goods not specified	215	581,630	402,071	820,475	413,033
Baskets	63	67,217	79,312	167,299	86,366
Hand-stamps	337	569,960	346,255	1,013,769	656,658
Models and patterns	649	689,598	347,536	1,636,787	1,269,133
Miscel. Instr.....	766	1,416,943	773,058	2,170,915	1,371,601
Phonographs	2,225	6,570,855	7,007,723	12,841,682	5,745,424
Pipes—tobacco ..	129	438,869	150,570	456,011	299,831
Show-cases	250	611,000	463,765	1,026,844	556,203
Athletic goods...	602	1,533,149	1,134,868	2,309,768	1,140,101
Toys and games..	753	1,094,674	1,010,181	2,130,968	1,101,540
Trunks	1,495	3,639,108	3,824,742	7,292,902	3,439,462
Cigar boxes	254	404,946	292,086	694,664	396,235
Wood engraving..	259	227,963	165,066	826,342	659,383
Total	8,136	18,325,277	16,206,422	33,849,652	17,381,050

NOTE 6.

DATA ON FUEL USED ON FARMS*

Classes of farms†	Total number of answers	Coal-burners		Coal-and-Wood burners			Wood-burners	
		Tons	Average acreage of farms	Coal Tons	Wood Cords	Average acreage of farms	Cords	Average acreage of farms
Up to 200 acres in size	171	9.8	141	7.66	13.4	141	21.4	136.5
From 200 to 400 acres in size	182	13.3	281	7.70	14.3	279	26.1	277
From 400 to 600 acres in size	43	15.8	517	8.20	17.9	478	24.3	498
Total	396							

* Obtained from replies to farm-woodland questionnaire.
† Large acreages, where there might be several tenants, are omitted

NOTE 7.—The U. S. Department of Agriculture has figures which indicate a consumption of cordwood for Illinois as follows:

1917	2,400,000 cords
1919	1,896,000 cords
1920	1,422,000 cords
1921	1,659,000 cords

These figures are considerably in excess of the deductions made by this study and, if correct, indicate a production of cordwood for 1921 of .591 cords per acre of woodland for the state, in addition to the yield of all other products. It is not thought that such yields are probable. If correct, it indicates a still more rapid exhaustion of the forests of the state by over-cutting.

NOTE 8.—For cordwood, 80 cubic feet is taken as the converting factor. For saw-timber, the lumber output is reckoned as requiring 1 cubic foot from the tree to produce 6 board feet, giving a factor of .16⅔. For fence posts, an average size of 4 inches at the top end of a 7-foot post was fixed, giving about .8 cubic feet per post. For cross-ties, 35 board feet per tie, and 8⅓ board feet per cubic foot gave 4.25 cubic feet per average tie, allowing for waste in hewing.

Mine timbers were estimated directly in cubic feet by converting factors as follows:

Mine props	.83 cubic feet
Bars and legs	1.91 cubic feet
Mine ties	.70 cubic feet

which was found to be the average for material consumed in the mines. (See p. 77 on consumption of timber in mines.)

Piling was taken as averaging 22.3 cubic feet per piece.

NOTE 9.—Tabulation of census figures for lumber production by decades in Illinois shows 334,244,000 B. F. in 1879 and 56,900,000 in 1920. During the eighties and nineties the relatively high production was largely accounted for by logs imported from other states. During the eighties Rock Island county produced annually 70,000,000 B. F., leading all other counties. The second in amount at that time was Massac county with 14,000,000 B. F. The Rock Island production was from Wisconsin and Minnesota white pine logs, the Massac from both local and imported hardwoods. The importation of logs into southern Illinois is probably still considerable, but it is negligible elsewhere.

NOTE 10.—Consumption of shingles on farms.

It is assumed that the same proportion of shingles is consumed on farms as of lumber. This is 31.522 per cent of the total for the state. This proportion of 5,516,110 cubic feet of shingles gives 1,738,788 cubic feet consumed on farms, or 7.331 cubic feet per year. This is a total of 193,198 M shingles, or 814 shingles per year on each farm, taking no account of the substitutes for shingles, which considerably increase the total of roofing used.

NOTE 11.—Total coal and wood, 2,769,680 tons, converted to cords by .8 equivalent and divided by 237,181 farms.

NOTE 12.—Origin of data concerning consumption of lumber.

In distributing the total quantity of lumber, 2,353,662,000 board feet, consumed in the state in 1920, accurate statistical data are not available. The results are approximate only, and are based on percentages derived from previous studies and partial data. The total consumption of lumber in the Chicago district in 1920 was 1,454,712,000 board feet*. This agrees closely with the average for the decade 1911-21 of 1,466,820,300 board feet. In 1909 the total consumption of lumber in the Chicago district was 1,622,690,000 board feet of which the building trades used 31.172 per cent, or 505,835,000 board feet, and the wood-using industries, 1,116,855,120 board feet or 68.83 per cent.

Assuming that the same ratio of consumption applies between the building trades and the total consumption in Chicago for 1920 as for 1909 and applying this 32 per cent to the total consumption in the Chicago district for 1920 the building trades would have consumed in that year 465,507,000 board feet, which would leave 989,205,000 board feet for the wood-using industries of Chicago alone. The best information available in Chicago for 1923 places the consumption by the building trades at 600,000,000 feet, so that it seems safe to place the annual consumption for that purpose at between 500 and 600 million feet, exclusive of planing-mill products.

That there has been a decrease in the total consumption of wood in these wood-using industries in the last decade is indicated by the apparently large decrease in the amount of hardwood timber shipped into the state (page 98). The decrease in Chicago alone, on this basis, is indicated as approximately 11.5 per cent since 1,116,855,120 board feet was used in 1909 in these Chicago industries. Outside of Chicago the

* Chicago Board of Trade.

apparent decrease had been greater. Chicago manufactures constitute 72 per cent of the manufacturing industry in Illinois. Applying this per cent to wood-using industries, the indicated consumption of wood in these industries outside of the Chicago district is 384,695,000 board feet and the total for the state is 1,373,900,000 board feet. The indicated decrease in wood consumed outside of Chicago by these industries, based on 664,681,000 feet in 1909, is 42.12 per cent and for the state as a whole is 22.9 per cent. The consumption of lumber for building purposes in the state as a whole including Chicago is thus indicated as 979,762,000 board feet and in the state outside of the Chicago district as 514,255,000 board feet. Of this amount, approximately 296,476,250 board feet is used on farms or an average of 1250 board feet per farm annually, leaving 217,778,850 board feet for building construction in towns other than the Chicago district (Cook and DuPage counties).

ERRATA

P. 85, line 13 from bottom, for 87 read 86.
P. 115, in table, for areas and area, read acres.
P. 136, line 5, for 135 read 131.

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE
NATURAL HISTORY SURVEY
STEPHEN A. FORBES, *Chief*

Vol. XV. BULLETIN Article IV.

A Preliminary Report on the Occurrence and Distribution of the Common Bacterial and Fungous Diseases of Crop Plants in Illinois

BY

L. R. TEHON

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
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BOARD OF

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CONTENTS

ARTICLE IV.—*A Preliminary Report on the Occurrence and Distribution of the Common Bacterial and Fungous Diseases of Crop Plants in Illinois.* BY L. R. TEHON.

The common diseases of crop plants, caused by the attack of parasitic fungi and bacteria, take an annual toll of the crops of Illinois that runs into values the magnitude of which is seldom realized; and the fact that Illinois stands second, among the United States, to none but Texas and Iowa in the value of its agricultural products lends an especial significance to their destructiveness.

As early as 1881 the State Laboratory of Natural History, since merged in the State Natural History Survey, undertook the study of the parasitic fungi of the state, and in that and the following year A. B. Seymour was employed to make an extensive collection of diseased plants. Studies based upon Seymour's collection, but confined to identification and classification, were made later by T. J. Burrill on the rust-producing fungi, and by Burrill and F. S. Earle on the powdery mildew-producing fungi, of the state.

In the forty years which have elapsed since Seymour made his collection, the classification, the structure, and the life histories of the bacteria and fungi which cause the diseases of crop plants have been the subject of extensive and exhaustive investigation. As a consequence, little of economic significance now remains to be done in that direction.

The next important step in the study of plant diseases is concerned with epidemiology—the fluctuation in severity and abundance from year to year exhibited by all diseases. An explanation of the causes underlying these fluctuations promises things of the greatest importance to the growers of our crops in the improvement of control measures and the regulation of times and methods of their application.

A necessary preliminary step is the accumulation of a complete catalog of the kinds of diseases present, and of accurate information concerning their distribution and severity in our state. With this purpose in mind the Natural History Survey began in the summer of 1921, and continued through the summers of 1922 and 1923, an examination of the crops of the state[1] the results of which are incorporated in these pages.

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[1] The work has been carried on under the general supervision of Dr. F. L. Stevens, Professor of Plant Pathology in the University of Illinois, and under the direction of the writer. The rapid progress made is due in a large measure to the enthusiastic and capable assistance in the field of P. A. Young during the summers of 1922 and 1923, and of O. A. Plunkett, C. L. Porter, and C. O. Peake, during the summer of 1922.

The reader will find that the diseases discussed in this preliminary report are grouped according to the crops which are subject to them. Because of the great importance of the cereal crops their diseases are discussed first. Following them are the diseases of forage crops; the diseases of fruits, including small fruits; the diseases of vegetable and field crops; and the important diseases of a few commonly grown ornamental plants. The plan of the discussion has been to give in each case a brief description of the disease, a short summary of its history in Illinois, a statement of its distribution as now known, some indication of the crop losses for which it is held responsible, and, finally, a brief statement of the usual methods of control.

As a basis for the interpretation of the discussions, available information on the distribution and value of each crop has been summarized in a preliminary paragraph or two accompanied by an illustrative map.[1] This information has been taken from the reports of the State Agricultural Statistician as printed in the "Illinois Crop Reports" issued by the federal Bureau of Markets and Crop Estimates, and from the reports for 1920 of the Bureau of the Census.

Accompanying the discussion of each disease is a map showing its known distribution in Illinois. For the purpose of the report the county has been selected as the unit for expressing occurrence since it would be obviously impracticable to show on so small a map the actual place at which the disease was found. The county serves as a practical unit for the additional reason that diseases found in one field or in one orchard usually may be found in the fields and orchards throughout a considerable area of neighboring territory.

It is not to be assumed that at this stage of the survey the maps will show the entire range or the only places of occurrence for any disease; actually, they show only those counties in which the disease has been found during our three seasons of work; but even with this limitation they emphasize the almost universal prevalence of many diseases and the limited occurrence of others.

In discussing the damage which diseases do to crops, use has been made of estimated crop reductions, which are summarized in the text and given in detail in tables at the end. The estimated reductions represent the effect which each disease has had, in the judgment of experienced and competent workers, upon the yield of the crop in any one season. Estimates are commonly expressed in percentages; and the equivalent loss, in terms applicable to any crop, is arrived at in the manner illustrated by the following example:

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[1] In order to have the maps illustrate clearly the relative importance of crops in the several parts of the state it has been necessary to choose an arbitrary unit in each case, such as 1,000 acres or 2,000 bushels, to be represented by a single dot; but, when a county grows an amount which involves less than the arbitrary number, a dot has been used to indicate that the crop is grown there. As a consequence, when a county contains a single dot, the reader may interpret it to mean that less than the amount indicated as equivalent to a dot on that map is grown there.

It has been estimated that during the year 1921 the scab disease caused a reduction of 4 per cent in the state's wheat yield; leaf rust, 1 per cent; stem rust, 0.5 per cent; loose smut, 3 per cent, and all other diseases, 1 per cent. These, when added, give a total reduction of 9.5 per cent. The actual wheat yield of the state for that year is reported to have been 45,234,000 bushels. By considering that the absence of disease would have resulted in an ideal, or 100 per cent, yield so far as damage from disease is concerned, it can be seen that with diseases present the actual yield was only 90.5 per cent of the ideal. A 100 per cent yield may then be calculated as 49,982,000 bushels. With this figure as a basis the probable losses from disease-attack can be transferred from indefinite percentages to their more concrete and understandable equivalents in bushels. Thus an estimated reduction of 4 per cent from scab infection becomes equivalent to 1,999,000 bushels; and a 3 per cent reduction from loose smut infection becomes equivalent to 1,499,000 bushels

With the exception of the year 1923, the loss figures showing percentages and bushels have been taken from "The Plant Disease Bulletin. Supplement: Crop Losses from Plant Diseases in The United States". This is a publication issued by the Plant Disease Survey of the United States Department of Agriculture. It is based upon information supplied from each state by persons interested in, and familiar with, crops and their diseases.

Equivalent valuations have been figured in all cases in terms of the market price, usually as of December 1, reported by the State Agricultural Statistician in the "Illinois Crop Reports".

Observations which have been introduced in order to show how prevalent and how destructive diseases may become should serve a further purpose—that of impressing upon the individual farmer his need for taking every available precaution to prevent the occurrence of similar devastating outbreaks among his own crops.

Diseases of Cereals

Wheat

Under average conditions wheat ranks third among the cereal crops of Illinois in acreage and production, and second in value. Its place in the system of crop rotation suitable to Illinois soils is so difficult to fill with other crops that its continued importance is assured. Both spring and winter wheats are grown in the state, the latter in all parts of the state and the former in only the northern third. About three million acres are devoted to wheat each year, approximately 160,000 of which are seeded to spring wheat. The importance of the wheat acreage in various parts of the state is indicated on Map 1. Since 1921 there has been a steady increase in acreage, due no doubt to a more general use of such satisfactory hard winter-varieties as Turkey 10-110, Kanred, and others. The estimated value of the wheat crop in Illinois has varied in recent years from $16,000,000 to $72,000,000.

Each season the wheat crop is affected adversely by the attack of fungous diseases. The effects of the diseases are shown by reduced yields and often by the inferior quality of the grain. There are many of these diseases, and the injuries suffered from their combined attack always result in appreciable losses. Estimates of these losses were placed as low as 4.4% or 2,726,000 bushels in 1918, and as high as 22.0% or 18,524,000 bushels in 1919. During an average year it is thought that the reduction in yield for the state as a whole is between 8% and 9%.

There is much variation from year to year in the severity of one or more of these fungous diseases. Some are serious every year, and most of the others cause important injury some seasons or in restricted localities. Their destructiveness calls for the thoughtful attention of the wheat grower.

Rusts

Two rust diseases have been found on wheat in Illinois. The one known as *leaf rust* is the more prevalent. *Stem rust* is common but seldom causes the tremendous losses here that it does farther north.

Leaf Rust

Caused by *Puccinia triticina* Eriks.

Leaf rust is the most common and the most important of the wheat diseases occurring in Illinois. Even in years unfavorable to its development it is so abundant that nearly every plant in every field has become infected by the time the grain is mature. Its effect upon the crop is manifested by weakening of the stalks and sometimes by badly shrunken or "shriveled" grain. In extreme cases the weakening of the stalks results in a falling and lodging of the straw, which increases the destructiveness of the disease by making it difficult or impossible to harvest the crop.

The disease appears as small reddish spots mostly upon the leaves but occasionally upon the stems. These spots, which lie beneath the epidermis of the leaf and between the veins, are rarely more than one sixteenth of an inch long, but several together may be much longer. The breaking of the epidermis reveals a mass of orange powder within the spot. The grains of powder are the spores of the fungus, and each grain, or spore, is capable under proper conditions of starting a new infection.

In Illinois, infection takes place either in the fall or spring. The great acreage of winter wheat gives this rust an opportunity to develop serious infections during the fall on young wheat, and these infections live over the winter, producing spores the following spring and thus continuing the spread of the disease until the grain matures. Following the maturity of the grain, the rust develops a "resting stage" which is to be found chiefly upon the under side of the leaves and on the stalks, where it appears as covered spots, similar in size and shape to the others but *black*.

The period between harvest and the appearance of the new crop is bridged[1] by infections on volunteer wheat in clover and other secondary crops. There is an alternate stage,[2] similar to that ascribed to stem rust, which occurs on 12 species of meadow rue (Thalictrum), but it is noteworthy that in Illinois our common meadow rue *(T. dioicum* L.*)* has not been found rusted.

The history of the introduction and spread of leaf rust in Illinois is not known. The first definite record of its occurrence in this state is a specimen collected by A. B. Seymour in McHenry county August 22, 1881. The following year specimens were collected in Adams county June 26, 29, and July 6, and in McLean county July 17. In 1883 C. A. Hart collected leaf rust in Adams county, and during later years G. P. Clinton made several collections in Champaign, Ogle, and Knox counties. H. W. Anderson has collected specimens in Pike county, and H. L. Bolley[3] has recorded its presence in eastern Illinois in 1905.

Field observations of the past three seasons have brought together a large quantity of additional data on the distribution of the disease throughout the state. In 1922, specimens were collected in 140 places distributed widely over the state and showing the occurrence of leaf rust in 82 of the 102 counties. Those counties from which specimens were not secured are widely dispersed, and are so distributed that collections made in adjacent counties indicate the occurrence of leaf rust in them as well.

During 1923 additional collections of rust were made, resulting in a large compilation of field notes. From these the distribution of leaf rust is seen to include practically the entire state, as shown on Map 2. Indeed, from our observations it appears highly improbable that in the whole state there occurs a single field of wheat in which at least some leaf rust can not be found.

Losses from this disease are difficult to determine, but for the years 1919-1923 inclusive they have been estimated to vary from 0.5 per cent (221,000 bushels) in 1920 to 10 per cent (5,543,000 bushels) in 1922 (see Table 1). The annual losses can not be apportioned among the counties nor according to any lateral or longitudinal division of the state. There is to be seen, however, a marked correlation of abundance and severity of infection with the growing of soft winter-wheats such as Red Wave, Early May, Fultz, Blue Stem, Harvest Queen, and Fulcaster.

The variation of leaf-rust infection from season to season depends, as is indicated in Table 2, upon both the number of infected stalks and

[1] Valleau, W. D., Over-summering of leaf rust of cereals in Kentucky. Phytopath, 13: 338-340, 1923.
[2] Jackson, H. S., and Mains, E. B., Phytopath, 11: 40, 1921; also Jour. Agr. Res. 22: 151-172, 1921.
[3] Sci., n. s., 22, 51, 1905.

the amount of diseased leaf-tissue[1] on each stalk. Of the two, the amount of diseased leaf-tissue is the more important, since, as is indicated in Table 3, it varies more than the number of infected stalks and is more closely in accord with the estimates of loss.

In 1918 and again in 1923, when the estimated loss from rust was low, the infected plants numbered more than 80 per cent. The increase in the number of infected plants in 1922, when loss was estimated at not less than 10 per cent, was not more than 15 per cent, while the increase in diseased leaf-tissue on each plant at the same time was 24.1 per cent greater than in 1923, and 47.5 per cent in excess of that in 1918.

Variations in the amount of infection in different places and in different years are definitely attributable to climatic conditions throughout the growing period of the crop. Leaf-rust infection of wheat in Illinois begins in the fall previous to the harvest. How far fall infection may influence the seriousness of the spring attack is not entirely evident, but it is noteworthy that in the fall preceding the very severe epidemic of 1922, winter-wheat fields were in many places so thoroughly infested with rust as to assume an orange tinge, visible from a long distance.

Moisture and warmth in the fall are conducive to abundant infection of the young crop, and the survival of the fall infection is limited in varying degrees by the severity of the winter. Whatever infective material remains alive until spring serves as a source of inoculum for the spread of the rust, and the amount of new infection at this time will be influenced favorably or unfavorably by the presence or absence of suitable climatic conditions.

The importance of leaf rust as a limiting factor in the production of wheat in Illinois is not a matter of light concern. It is true that in certain sections even in years of serious epidemics, there is only a slight loss, but these sections are not the large wheat districts of the state. The part of the state in which leaf rust is most abundant and generally most severe concides with the region of greatest wheat production. Estimates made following the 1922 epidemic and reproduced in Table 4 show the seriousness of the disease in 12 of the most important wheat counties of the state. The total-loss estimate for these counties was 1,373,588 bushels, which may be valued at $1,469,739.16.

Complete prevention of leaf-rust attack and its consequent injury to the wheat crop in Illinois is at present impossible. The fact that the rust overwinters upon the wheat and does not commonly have an alternate host precludes the possibility of control through eradicating other hosts. Hard winter-wheats are more resistant than the soft varieties, and losses may be considerably reduced in places where these wheats make a good crop. Where hard wheats are not satisfactory the ultimate use of special resistant strains of the soft wheats appears to be the ultimate solution. The experiments of the U. S. Department of

[1] The amount of diseased leaf-tissue is measured by a scale prepared by the Office of Cereal Investigations of the U. S. Department of Agriculture, in terms of the amount of leaf-surface occupied by the rust spots.

Agriculture and the Indiana Agricultural Experiment Station indicate the possibility of developing rust-resistant strains from the soft wheats, and the already-proved occurrence of these strains in such varieties as Fulcaster, Fultz, and Red Cross should be especially encouraging to the wheat growers in our own soft wheat regions.

Stem Rust

Caused by *Puccinia graminis* Pers.

The second of the two rusts occurring on wheat in Illinois is stem rust, variously known as "rust," "black-stem-rust," "black rust," and "red rust." During the early spring this rust appears upon growing wheat plants, showing as red eruptions upon the stems and leaf sheaths. These eruptions are distinguishable from leaf-rust spots in part by their location upon the stems, but more certainly by their appearance. They are usually two to four times longer, or more; the quantity of spores seems greater and more bulging; and the epidermis appears torn and ragged around the edges of the spots.

Just previous to the maturity of the wheat this rust, like the leaf rust, develops a resting stage, the spots of which appear much the same as those of the red stage in size and shape, but are black. This black stage, or "black rust," serves to carry the fungus through the winter months and to furnish infective material for the production of the alternate stage upon the common barberry in early spring. Recent propaganda on barberry eradication in the north-central states has made the life history of this fungus, its seriousness as a crop pest, and its prevalence in wheat regions matters of common knowledge.

Of the cereal rusts occurring in the United States, stem rust is undoubtedly the most important. It is estimated that since 1918 the crop reduction for the United States in any one year from this source has not been less than 804,000 bushels. In Illinois, however, stem rust is not, during average years, the serious menace that it is in the grain states of the north and west. Nevertheless the annual toll taken by this disease in Illinois is one not to be overlooked. Burrill[1] estimated that in 1885 the loss from stem rust in Illinois amounted to $1,875,000, and in 1917 W. P. Flint reported a loss of 10 to 20 per cent of the crop. Estimates of loss in Illinois for the years 1918-1923 inclusive have varied as indicated in Table 5, from a trace in 1918 and 1922 to 901,800 bushels in 1923, valued at approximately $829,600.

The history of stem rust in Illinois is more definitely traceable than that of any other disease. The first record of occurrence is a specimen collected by A. B. Seymour in McLean county July 11, 1881. During the same season Seymour collected stem-rust specimens in Marshall, McHenry, Piatt, and Tazewell counties, indicating that at that time the disease had a wide-spread distribution over the northern half of the state.

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[1] See Stevens, F. L., Diseases of economic plants. (1921) p. 12.

In 1911 Burrill reported its occurrence in Champaign and Montgomery counties, and in 1918 various persons made collections of it in Boone, Cook, Lake, Williamson, Henry, Winnebago, Macoupin, and Bureau counties. E. F. Guba made an additional collection in DuPage county in 1919. At present stem-rust is known to be present on wheat in 68 of our 102 counties, as shown on Map 3. These 68 counties are so distributed as to represent all parts of the state.

Seasonal variation in the prevalence of stem rust, like that of leaf rust, depends upon the number of infected wheat plants and the amount of infection on each plant. The variation in crop loss is, however, slight, seldom amounting to more than 1 per cent. Stem rust appears later in the season than leaf rust, and the early maturity of our winter wheats not only greatly curtails the period through which injury to the crop may occur, but necessitates proportionately greater degrees of infection for every degree of estimated loss. This fact is illustrated in Table 6. The effect of the joint occurrence of relatively large amounts of diseased leaf-tissue and high percentages of infected stalks became apparent in 1923, when the estimated loss reached 1.5 per cent.

Our observations, summarized in Table 7, show definite differences in susceptibility to rust infection among wheat varieties. In general the soft winter-wheats which are grown in the southern part of the state are more susceptible than the semi-hard wheats of the Crimean type grown farther north. This is noticeable not only in many fields over wide areas, but also in adjacent fields.

Control of stem rust in Illinois is difficult. The extreme length of the state from north to south, together with its peculiar latitudinal situation, presents many diversities of condition including variations in soil, temperature, moisture, and physiography. Correlated with these conditions are diverse factors of an epidemiological nature which serve to complicate the problem further. The growing of resistant varieties such as the hard winter wheats, where these are suitable to local conditions, will serve to minimize crop losses from stem-rust attack. The present tendency throughout the state to increase the acreage of the Turkey wheats promises to materially curtail losses from rust.

In those sections where only the soft wheats appear to be suitable the early maturity of the crop serves in a large measure to prevent very serious crop losses. Nevertheless as considerable difference in resistance to rust appears to exist in the more common varieties of soft wheat under field conditions, a judicious selection from those kinds least susceptible to attack is quite worth while when practicable. Field observations during 1923, when stem rust was especially abundant, show the different percentages of stalks infected for seven varieties of soft wheat, as indicated in Table 8. Red Cross, Indian Swamp, Fultz, and Fulcaster appear less susceptible than Red Wave, Mediterranean, or Red Chaff.

Throughout the northern third of Illinois spring wheat is grown to some extent, and it is in this section of the state that the common barberry (*Berberis vulgaris* L.) may be expected to play a part in the development of spring stem-rust infections. That the barberry does initiate some of the northern infections is apparent, since stem rust makes its appearance in the north and in the south almost simultaneously. In 1923 the first rust infection was found in southern Illinois June 4 and in northern Illinois June 7. The severity of the northern winter makes it unlikely that northern infections could arise simultaneously with southern infections without the presence of the barberry. Stem-rust infection has been found on the barberry in 23 counties,[1] as shown on Map 4. Most of these counties lie in the northern third of the state, and it is the belief of those engaged in the eradication of the barberry that local epidemics of stem rust are traceable to the barberry. Undoubtedly eradication of this shrub northward will result in a marked reduction of stem rust, and the losses it occasions, in that section of the state.

Smut Diseases

Three of the four smut diseases of wheat occur in Illinois. They are widely distributed over the state, and cause a considerable crop loss each season. Two of them affect the wheat heads, while the third attacks the leaves.

Stinking Smut

Caused by *Tilletia laevis* Kühn

Stinking smut, also known as "bunt", fills the grains with a black mass of fungus spores without changing the external appearance of the head. The appearance of diseased heads is nearly normal, and usually it is not until the wheat is harvested that the presence of the disease is discovered. During threshing many of the infected grains are broken, and the liberation of the smut is accompanied by a very noticeable foul odor.

The first record of stinking smut in Illinois is a specimen collected by G. P. Clinton at Urbana June 30, 1892. July 28 of the same year N. W. Graham collected the disease at Carbondale. During a field survey made in 1918 by the Office of Cereal Investigations of the United States Department of Agriculture 51 fields examined in Illinois showed an average of 1.8 per cent of diseased heads, but the distribution of infection is not apparent from the report. In a second survey, made in 1919, among 92 fields examined in Illinois the heaviest stinking-smut infection found was 24 per cent, and the average for all fields was 0.3 per cent.

From the estimates of crop losses shown in Table 9 the seriousness of this disease is apparent. Loss from stinking smut is capable of accurate estimation, since each infected head is entirely destroyed. Hence the percentage of infected heads in a field represents the loss in yield

[1] Recent information on the occurrence of stem-rust infection on the barberry was furnished by Gordon C. Curran, State Leader of Barberry Eradication in Illinois.

in that field, and the average percentage of infected heads in the fields of the state represents the loss for the state. Complete data are not always obtainable, but estimates indicate losses varying from a trace to 6 per cent of the state crop.

There is a further loss from this disease through dockage when smutted grain is sold. The presence of stinking smut in threshed wheat tends to give it an offensive odor. When the amount of stinking smut is great the odor is so pronounced that it reduces the value of the grain for milling purposes, and most dealers impose a dockage, or reduction in price, upon such wheat. Dealers often refuse to purchase badly smutted wheat.

The occurrence of stinking smut in Illinois is shown on Map 5. Its distribution coincides with regions devoted to wheat production, but it is rarely found in the northern or southern thirds of the state.

Examinations of fields in many parts of the state in 1923, the results of which are given in Table 10, suggest the field-by-field prevalence of this disease and indicate the severity of infection and loss on the average farm. An average infection of 4.08 per cent was found in 1140 acres distributed among 22 counties. All degrees of infection were found.

While the acreage examined is not large in comparison with the total wheat acreage of the state, if 20 acres be taken as the average amount of wheat per farm it may be inferred that data from 57 average farms are included. These are widely distributed over the state, and may be considered as representative of conditions of infection to be found on the average farm. Not every wheat field measured up to the average amount of stinking-smut infection, but other fields showed sufficiently greater amounts to bring the average infection for each field up to 4.08 per cent.

The yield per acre of wheat for the entire state for 1923 is estimated at 18 bushels. At this rate the 1140 acres examined would yield 20,520 bushels, but this is less by 4.08 per cent than it might have been without stinking-smut infection. The yield from this acreage with stinking smut absent would have been 21,111 bushels; hence there is an apparent reduction in yield of 861 bushels which, when distributed among the 57 average farms represented, gives a loss in yield of 15.1 bushels per farm. With stinking-smut infection absent the individual farmer might have secured the same yield from 19 1/6 acres that he was able to secure from 20 acres with stinking smut infection present; or had he chosen to plant 20 acres free from stinking-smut infection, he might have secured a yield of 375 bushels in place of 360 bushels.

Mention has already been made of a cash loss in marketing smutted wheat. This loss takes the form of a dockage in the price, which amounts in practice to a reduction in grade. When wheat is offered for sale it is graded, and the current market-price for the grade applied. Assuming that a load of wheat grades "Hard Red No. 1," should stinking smut be found in the wheat it will be regraded "No. 1—Smutty" and a reduction made in the price in proportion to the amount the dealer believes the wheat has been damaged.

Actual figures on dockages of this kind for the 1922 crop are given in Table 11, in which appears a reliable report of the marketing of 1,082,913 bushels of wheat in 26 representative counties. Of the crop reported on, 25,865 bushels or 2.38 per cent were so badly smutted that a dockage in price was applied, averaging 7.44 cents per bushel and amounting to a total of $1,924.36. Had it been possible to include all instances of grain so badly smutted as to be unfit for sale these figures would have been noticeably increased.

The highest dockage actually applied was 10 cents per bushel and the lowest 2 cents. The largest amount of smutted wheat reported from any one county was 6,850 bushels, or more than 10 per cent of the crop reported on from that county, while the smallest amount, aside from those reporting none, was 100 bushels or about 1/400 of the reported crop.

Although the crop of the state was more than 50 times the amount reported, the report may be considered representative of dockages applied throughout the state. On this basis, among the 55,432,000 bushels produced in 1922 there would be 1,324,824 bushels smutted, and the total dockage for the state at the average rate of 7.44 cents per bushel would amount to $98,566.90. If one adds to this amount the cash value of field losses estimated in Table 9 at $1,157,740, the total loss to the wheat growers of our state in 1922 from stinking-smut infection reaches the astonishing total of $1,256,306.90, which is more than 2.1 per cent of the entire value of the harvested crop.

A similar but more complete dockage report for the 1923 crop, summarized in Table 12, includes 43 counties and 3,002,523 bushels of wheat, of which 143,184 or 4.4 per cent were smutted and 105,574 or 3.51 per cent sufficiently smutted to receive an average dockage of 4.88 cents per bushel, making a total loss of $5,157.57.

The greatest amount of smutted wheat reported from any one county was 28,200 bushels and the smallest 150. The highest dockage reported was 15 cents per bushel and the lowest 1 cent. In addition to what is shown in the table many indefinite but reliable reports were received of buyers refusing to purchase very severely smutted lots of wheat. In many cases lightly smutted wheat was received at elevators and mills without a dockage being applied.

The 1923 report includes approximately 1/20 of the state's crop. If it be considered typical of the entire crop there would be in the 1923 crop 2,110,914 bushels sufficiently smutted to bring about, at the average rate of 4.88 cents per bushel, a total cash dockage on the state's wheat crop of $103,012.60.

If one adds to this the field loss shown in Table 10 of 2,558,000 bushels valued at $2,102,520, he finds indicated a total cash loss of

$2,505,532.60 from stinking-smut infection in the state's wheat crop. This loss represents slightly more than 4.26 per cent of the total value of the wheat crop harvested in 1923.

Field observations on the amount of stinking smut in varieties of wheat commonly grown in Illinois as shown in Table 13 indicate that soft wheats are more susceptible to smut infection than the hard winter wheats.

When stinking-smut infection is present in wheat, several methods are available for preventing its appearance in succeeding years. These methods include change of seed, crop rotation, and seed treatment. Change of seed is often effective if care is taken to see that the new seed is not infected with stinking-smut spores. Crop rotation is useful in reducing the amount of infective material in the soil. Seed treatment, however, is by far the most effective means of control. Infection resulting from spores in the soil is usually slight. The greatest amount of infection comes from spores carried on the seed. If these seed-borne spores are killed very little smut infection will be found in the succeeding crop.

Three methods of seed treatment, or seed disinfection, are in common use: (1) Formaldehyde in the proportion of 1 pint to 50 bushels of seed is sprayed over the seed, the whole throughly mixed and covered for five hours. (2) Copper-sulfate solution in the proportion of 1 pound of bluestone to 10 gallons of water is also used. The seed is dipped in this solution, thoroughly wetted, and then dried. Both the formaldehyde and copper-sulfate treatments, though effective, are attended with difficulties in the using, and if not carefully handled are apt to cause some injury to the seed.

More recently there has come into use (3) the copper-carbonate dust treatment, in which copper-carbonate powder is thoroughly mixed with the seed at the rate of 2 ounces per bushel. This dry treatment may be applied at any time before planting. It does not materially injure the seed and may be depended upon to reduce stinking-smut infection to a minimum.

A more consistent use of seed treatment throughout our state is greatly to be desired. In the past it has been the custom of growers to wait until serious losses occurred before using preventive measures. A consistent program of seed treatment employed each year will not only obviate the necessity for special efforts, but will also prevent the constant loss from light infections that occurs each year.

Loose Smut

Caused by *Ustilago tritici* (Pers.) Rostr.

Another smut disease of wheat occurring in Illinois is *loose smut*. This is more generally distributed throughout the individual fields of the state than stinking smut, but is, on the whole, much less abundant. It is known throughout the state as "smut," "loose smut," and "black head."

It appears at the flowering time of wheat. The glumes, flowers, and grain are entirely destroyed, and their place is taken by a loose mass of olive-green or black powder. By harvest-time nothing remains but a little black powder on the top of the stalk where the head should have developed.

The black powder on the diseased heads is blown by the wind to the flowers of healthy plants, infecting them with the disease, and as the grain develops, it also is infected. When such an infected grain is used for seed it produces a plant bearing a black head, from which no new grain can be harvested. The infection is carried in this way from crop to crop *inside* the seed.

The earliest records of loose smut in Illinois are specimens collected by A. B. Seymour in McLean county June 27, 1879, and in Champaign county June 5, 1882. Later collections were made in Champaign county in 1888, 1889, 1891, and 1892.

The distribution of this disease, so far as it is known to us at the present time, is shown on Map 6. It is known to occur in 55 counties, most of which lie in the southern two thirds of the state and comprise the wheat-producing section.

Loose smut is an important factor in lessening the production of wheat in Illinois. Over a period of seven years there has been, as is shown in Table 14, a yearly infection, and consequent loss ranging from 1.5 per cent or 899,000 bushels in 1923 to 3 per cent or 1,644,000 bushels in 1922. The average annual loss for the 7-year period from loose-smut infection was 2.43 per cent.

In 1922 an examination of 81 fields, summarized in Table 15, indicated an average loose-smut infection of 2.13 per cent. These fields were distributed among 26 counties and included 1756 acres.

A similar examination in 1923 indicated, as shown in Table 16, an average loose-smut infection of 1.56 per cent in 254 fields distributed among 40 counties. A total of 4,849 acres was covered, averaging slightly more than 118 acres for each of the 40 counties.

The average production of wheat per acre in 1923 was 18 bushels. On a farm growing 20 acres of wheat the production would be 360 bushels. However, this is only 98.44 per cent of what the crop might have been had loose-smut infection not been present. Production without smut should have been slightly more than 365.7 bushels, or an increase in yield of 5.7 bushels, worth in cash $5.35. This increase is equivalent to the crop harvested from 0.32 or nearly ⅓ of an acre; hence the farmer stands to lose not merely $5.35 worth of salable grain, but also the cost of grain production for nearly ⅓ of an acre for the entire season. The total of the two is an item not to be overlooked in the economics of production, whether from the standpoint of the individual farmer or from the standpoint of the state's agricultural interests.

Control of loose smut, while attended with some difficulty for the inexperienced, is thoroughly practicable and should be much more commonly undertaken. Seed should be thoroughly cleaned, and then soaked for from five to seven hours in water at about 62 to 72° F. It is then placed in small bags which can be readily handled, and immersed for one minute in a tub of water heated to 110°-120° F. At the end of the minute it is immersed for ten minutes in a tub of water heated to 129.2° F. and kept at that temperature. The temperature of this tub must not rise above 131° F. At the end of the ten-minute period the wheat is cooled in a tub of cool water and spread out to dry. If the treatment is carefully done, and an accurate thermometer used, there will be no injury to the seed and practically perfect smut-prevention will be obtained.

Flag Smut

Caused by *Urocystis tritici* Kcke.

A third smut disease of wheat occurring in Illinois is *flag smut*. It attacks the leaves of the wheat plant and appears at first as lead-colored stripes, and those eventually break open, disclosing a mass of smut spores. Diseased plants are usually so deformed that they do not mature. Very rarely does a diseased stalk bear grain.

Flag smut was first found in Illinois (and in the United States) in 1919 in a few fields near Granite City in Madison county. In 1920 it was found scattered over an area of about 2,500 acres in the same region. Since that time, through the search made by the State Department of Agriculture and the Natural History Survey, the disease has been found to occur in the nine counties shown on Map 7. During 1923 it was also found rather wide-spread in Missouri and Kansas.

In Illinois this disease has been most abundant and most serious in the soft-wheat region in the American Bottoms in Madison and St. Clair counties. Here, in certain wheat fields in 1923, infections involving more than 20 per cent of the stalks were seen. The area of infestation in the seven contiguous counties shown on the map appears to be continuous. At present only a few fields in the southwestern part of Logan county are known to be infested, and in Hancock county just one infested field has been found.

Flag smut is an extremely serious disease. Season by season the limits of its known occurrence are being extended, and the farmers of the state will do well to watch carefully for it in their fields. Once found, every effort should be made to keep it under control.

As a means of control two procedures are possible, and both should be used. All seed wheat should be thoroughly treated with copper-carbonate dust before planting. The method used is that described for stinking smut (see p. 184). Wherever possible, resistant varieties such as Fulcaster, and the Turkey wheats should be used.

Scab

Caused by *Gibberella saubinetii* (Mont.) Sacc.

Scab is one of the very serious diseases of wheat in Illinois. Like the other diseases which appear in epidemic form, its distribution appears practically coextensive with wheat-growing. When heads begin to mature, a pink moldy growth may be seen at the base of infected spikelets. These spikelets turn yellow or brown, ripening prematurely, and the grain which they bear is shriveled and often fungus-covered.

The first record of the occurrence of scab in Illinois is its presence near Kappa, Woodford county, in 1896. The next definite record is by H. W. Anderson, who reported it in 1918 as "unusually severe," causing 5 per cent loss near Decatur and some damage in Rock Island, Winnebago, and Lake counties. As indicated on Map 8, it is known to occur at the present time in 45 counties, most of which lie in central and southern Illinois. Their general distribution suggests, however, that this disease occurs over the entire state.

The importance of scab as a wheat disease in Illinois during the years 1917-1923 inclusive is indicated by the estimated losses shown in Table 17, which range from 1 per cent or 616,000 bushels in 1918 to 18 per cent or 15,156,000 bushels in 1919.

During 1922 this disease was not found in great abundance in the fields of the state, but in 1923 it appeared to be more prevalent. An examination of 2050 acres of wheat distributed among 24 counties in 1923 revealed a scab infection involving 3.26 per cent of the heads, on each of which 51.14 per cent of the spikelets were diseased, which indicates a loss of 1.66 per cent of the crop in the fields examined. This, however, includes all the observations made during the season, and it is probable that the early reports are not as typical as the more severe infections found later in the season.

A considerable difference in the amount of scab infection was observable on different varieties of wheat. Eight varieties on which special observations were made showed an average infection of 2.3 per cent, as indicated in Table 18, with individual varieties varying in amount of infection from 0.248 per cent to 6.43 per cent. The average percentage of infection on five varieties was less, and on three varities more, than the average for all as shown in Table 19. The amount of departure from the average varied from 2.05 per cent less in the case of New Columbia to 4.13 per cent more in the case of Turkey Red. Varieties indicated in Table 19 as having infections less than the average should be useful in regions where scab is serious.

The fungus causing scab on wheat also causes a serious corn disease, and it has been demonstrated that the disease lives in the soil on corn debris. For the prevention of serious losses from scab it is important to select varieties of wheat showing a degree of resistance to the disease, to employ a rotation scheme calling for the separation of wheat and corn on the same land by at least one year's planting of a non-susceptible crop, and to use particular care in field culture, seeing that corn stalks are either removed or completely plowed under.

Septoria Diseases

Of these diseases there are two. One attacks the leaves of the wheat and is known as *speckled leaf-blotch;* the other appears especially on the glumes and is commonly known as *glume* blotch. Little is known of their early occurrence in Illinois. Between June 18 and 28, 1919, three slight infections and one of 10 per cent were found by workers of the United States Department of Agriculture, but the localities are not known. The seriousness of these diseases emphasizes the need for effective control measures.

Speckled Leaf-Blotch

Caused by *Septoria tritici* Desm.

Every season there appears on the leaves of wheat plants spots of discolored, diseased tissue. In unusual seasons this spotting may become so severe as to injure all of the leaves seriously and to kill many of them. The disease first appears as a more or less oval brown spot. Later, several spots may grow together, occupying a large part of the leaf surface. As the spots grow older, they show tiny black specks irregularly distributed over them. The presence of the specks—which are the fruiting bodies of the fungus causing the disease—gives the disease its name.

There are no early reports of the presence of speckled leaf-blotch in Illinois, but in 1919 S. C. Chandler collected it at Ashley, Washington county, April 14, and in Perry county April 19. These two collections constitute the first actual record of this leaf blotch in Illinois. During 1922 it was found in Saline county, but the abundance of leaf rust that season probably prevented its being noticed elsewhere. In 1923 leaf rust was markedly less abundant, and reports of speckled leaf-blotch were proportionately more numerous. The disease was already prevalent to a considerable extent when field work was begun, as is shown by our first report of it, a 20-acre field of Red Wave in Madison county having an infection involving 75 per cent of the plants, Table 20. Fully 25 per cent of the leaf surface was occupied by spots, and the lower leaves of the plants were so seriously infected as to have the appearance of "firing." From that time on, the disease was found to be prevalent and abundant wherever looked for. Speckled leaf-blotch is now known to occur in 23 counties distributed widely over the state, as shown on Map 9.

The infections found in wheat fields in the 23 counties are shown in Table 20, from which it appears that 89.4 per cent of the wheat plants were diseased, and that 32.2 per cent of the leaves on each diseased plant showed leaf blotches. On this basis it would appear that this disease injured 28.78 per cent of the leaves of the wheat plants grown in the state in 1923. It is not to be supposed that such a marked injury can result otherwise than in an appreciable reduction both in the quality and quantity of grain produced.

In the examination of fields for this disease the variety of wheat was recorded for 2,499 acres. As shown in Table 21, there were notable differences in the amount of infection found on nine varieties. Among the soft wheats Fulcaster, Fultz, and New Columbia appear to have suffered most, while Red Cross and Red Wave both appear to have shown some resistance. Of the hard winter wheats Turkey 10-110 showed the most disease, and Turkey Red and Black Hull were about equal in resistance.

No practical means of control for this disease is yet known, but the differences among several varieties of wheat in susceptibility to attack suggest the advisability of planting the less susceptible varieties where speckled leaf-blotch is prevalent.

Glume Blotch

Caused by *Septoria nodorum* Berk.

The glume blotch disease of wheat had not been definitely reported in Illinois previous to 1923. A single instance of infection was found June 18 in a field near Waterloo, Monroe county. In this field more than 80 per cent of the plants were diseased, and on individual heads the infection involved from 40 per cent to 100 per cent of the spikelets. Undoubtedly this disease is of much more common occurrence than our observations indicate.

Anthracnose

Caused by *Colletotrichum cereale* Manns

This disease has probably been present in Illinois for many years, though there are no definite reports of its presence previous to 1923. During the 1923-season anthracnose infections appeared in serious amounts in the regions shown on Map 10, and Black Hull, Fultz, Red Wave, Turkey Red, and Turkey 10-110 were the varieties diseased. Red Wave and Fultz showed most serious infections.

As it appeared in 1923 this disease was a serious one, causing weakening and falling of the straw, premature ripening, and lodging of the grain in the field. Losses in seriously infested fields were great.

Foot-rot

Caused by *Helminthosporium* spp.

Under this name are included a number of wheat troubles variously known as "foot-rot," "root-rot," "rosette," etc. Attention was first called to the serious nature of these diseases in Illinois in April, 1919, when they were mistaken in certain fields in Madison county for Australian take-all. Later in the same year foot-rot was found in Sangamon and Mason counties. In one instance a 50-acre field suffered an actual reduction in yield of 40 per cent, but in most cases the reduction was less than 20 per cent.

Since that time a foot-rot of the same general character has been found in several parts of the state, and this disease is now known to occur in the six counties shown on Map. 11. Where it has occurred it has been local in character and confined to small spots in a few fields. It is only in unusual years or under very unusual local weather-conditions that it may be expected to become generally serious.

Should it become generally prevalent or serious, resistant varieties such as those developed and recommended by the Illinois Agricultural Experiment Station may be planted.

Black-Chaff

Caused by *Pseudomonas translucens* E. F. S.

This bacterial disease appears as black sunken stripes running lengthwise of the glumes. In severe cases it may cause the grain to shrivel.

A single report of the presence of this disease in Illinois was made by Dr. Erwin F. Smith,[1] who reported a slight infection in Knox county, Map 12, in 1917.

Miscellaneous Diseases

Powdery mildew, resulting from the attack of a superficial fungus *(Erysiphe graminis* DC.*)*, has not been of great importance in Illinois. It was seen and collected by H. W. Anderson at Granite City, Madison county, May 16, 1919, and this is the only definite record of its presence in Illinois at the present time.

Dying of wheat stalks resulting from the attack of a mushroom (*Marasmius scorodonius* Fr.) was reported in 1923. A specimen collected at Worden, Madison county, June 19 shows the sporophores of the mushroom growing directly out of the basal internodes of the wheat culm. This is extremely rare, however, and is not the source of any loss.

Oats

The oat crop in Illinois has been and probably will continue for some years to be one of great importance. It forms a definite part of the cropping plan practiced on most farms in the state. Since 1920 the acreage has varied between 3,860,000 acres in 1922, with a crop of 110,010,000 bushels, and 4,594,000 acres in 1921, with a crop of 121,741,000 bushels.

The acreage seeded to oats in each county in 1922 is indicated on Map 13. Every county in the state has at least some acreage. Hardin county, with 500 acres, grows the least, and Iroquois, with 215,500 acres, grows the most. By far the least acreage is found in the southern and

[1] Plant Disease Survey Bul. 2: 98-99. 1918.

western parts of the state, while in the northern and eastern parts large acreages occur. If a line be drawn approximately from Rock Island through Havana to Mattoon and eastward, it will be found that nearly 85 per cent of the states oat acreage lies north of the line, with especial concentration in Lee and Ogle counties to the north, and Iroquois, Champaign, and McLean counties to the east.

Crown Rust

Caused by *Puccinia coronata* Cda.

Crown rust of oats is similar in many ways to stem rust of wheat, and one may easily be mistaken for the other since both attack oats. As a rule, however, the black stripes of the crown rust do not appear broken and ruptured as do those of stem rust, but remain covered by the epidermis of the plant.

This disease was first reported in Illinois in Adams county in 1881 by A. B. Seymour. It has since been found by Seymour, Anderson, and others in McLean, Tazewell, McHenry, and Lake counties. Its distribution as now known is shown on Map 14. It is prevalent in all parts of the state.

It has been estimated that during the year 1919-1923 inclusive, crown rust caused a reduction in the oat crop varying from 1 per cent in 1919 to 4 per cent in 1922. As indicated in Table 22, these reductions ranged from 1,323,000 to 4,583,000 bushels and in valuation from $782,000 to $1,787,000.

In 1922 an examination of 42 fields of oats, distributed among 23 counties and including 538 acres, indicated an average crown-rust infection involving 91,038 per cent of the stalks and an average amount of diseased tissue per stalk of 58.05 per cent. In 1923 a similar examination, covering 69 fields distributed among 26 counties and including 1226 acres, showed a crown-rust infection involving 90.85 per cent of the stalks and an average amount of diseased tissue per stalk of 36.94 per cent. These differences between two years are shown in Table 23 in connection with estimated percentages of crop reduction, and from this comparison it appears that the annual variation in crop-injury is, as in the case of the wheat rusts, not so much a matter of the number of diseased plants, as of the amount of diseased tissue on each plant.

Crown rust has an alternate stage on the buckthorn (*Rhamnus cathartica* L.) similar to that described for stem rust of wheat. In northern Illinois, where this shrub is commonly used for hedges, it has been responsible for local epidemics of considerable importance.

Control measures involve the use of resistant varieties,[1] among which are Appler, Burt, Early Ripe, Golden Rustproof, Green Russian, and

[1] Durrell, L. W., and Parker, J. H. "Comparative Resistance of Varieties of Oats to Crown and Stem Rusts," Iowa Agricultural Experiment Station Research Bulletin 62, 1920.

Ruakura. Further control may be secured by the removal of cultivated or wild buckthorn shrubs in the neighborhood of oat fields.

Stem Rust

Caused by *Puccinia graminis* Pers.

The stem rust disease of oats is similar in appearance to stem rust of wheat, and the two diseases are caused by the same fungus. On oats in Illinois stem rust appears much less commonly than crown rust and is not often severe in its attack.

The earliest record of this disease in Illinois is a collection by A. B. Seymour from McLean county in July, 1881. Further collections were made by him the same year in Champaign, Fulton, McHenry, and Piatt counties. No further collections or records appear to have been made until 1922, but in that and the following year a distribution of stem rust was found as shown on Map 15. Probably it is much more wide-spread.

Oat losses from stem-rust attack are rarely severe. Estimates made since 1919 attribute to this disease only a trace of loss annually. An examination in 1923 of 22 fields distributed among 15 counties and including 765 acres indicated that 16.31 per cent of the stalks were infected and that the average amount of diseased tissue on infected stalks was 27.97 per cent. The amount of disease per stalk for all plants, on this basis, would be 4.56 per cent—an amount so small as to have practically no effect upon the expected yield.

Control of stem rust of oats may be secured in the same manner as on wheat. (See p. 180.) The oat varieties which show resistance to stem-rust infection are few and include especially White Russian, Green Russian, and Ruakura.

Loose Smut

Caused by *Ustilago avenae* (Pers.) Jens.

Loose smut of oats is similar in appearance to that of wheat already described. The heads are attacked, and the grains transformed to masses of black powder. Losses from this disease are large, and its importance is great. Estimates of crop reduction due to this disease, shown in Table 24, for the years 1917-1923 inclusive range from 5 per cent to 7 per cent—equivalent to 5,790,000 to 18,395,000 bushels, with values ranging from two to eleven million dollars.

The earliest record of this disease in Illinois is a specimen collected by A. B. Seymour at Normal, McLean county, June 26, 1879. In the following years Seymour made collections in Adams, Lake, and McLean counties, thus demonstrating a rather wide occurrence of loose smut in northern Illinois. In 1900 A. D. Shamel sent out from the Illinois Agricultural Experiment Station an inquiry concerning the occurrence of oat smut in the state. In summarizing the returns, he stated that smut occurred in 12 counties, for the most part widely distributed over the state.

and that the loss that season probably reached $5,000,000 or about $45.00 for every 40-acre oat field.

Oat smut is now known to occur in all but 21 of the 102 counties of the state. Its distribution, as shown on Map 16, is so general that one may reasonably suppose that it actually occurs in every county.

In 1922 an examination of 121 oat fields was made to determine the amount of loose smut present in the average field. These fields were distributed among 43 counties and included 1242 acres. The average infection amounted to 8.36 per cent, which is equivalent to a crop reduction of the same amount. A similar examination was made in 1923 of 111 fields distributed among 41 counties and including 1596 acres. The average loose-smut infection was 5.54 per cent.

The value of seed treatment as a means of loose-smut control was apparent in several instances. In 1923 eight fields in 6 counties and including 170 acres, had been planted with treated seed. The average infection found in these fields was 0.42 per cent, or 5.12 per cent less than the average found in fields generally. In terms of the average yield of the state the grower whose oat seed was treated should have secured a yield per acre 1.73 bushels greater than the grower whose seed was not treated.

Seed treatment is accomplished most easily and satisfactorily by using formalin according to the "dry" method. Formalin, or 37 per cent formaldehyde, diluted with an equal quantity of water, is sprayed over the seed, as it is shoveled from one pile to another, at the rate of 1 quart to 50 bushels of seed. The seed is then covered for 5 hours and is then ready for planting.

Corn

In terms of acreage, and in terms of money value, corn is the most important crop grown in Illinois; and the importance to the nation of Illinois' corn crop compares favorably with that of other states. In the years 1920 to 1922 (Surratt, A. J., Illinois Crop Summary, Dec. 1, 1922, Circ., 323, p. 60) Illinois was second only to Iowa in acres planted to corn, and production during those years was also second only to that of Iowa. The yield per acre for the state as a whole is, however, remarkably low, ranging during those years from 34 to 35.5 bushels. Practically every state in which similar conditions are approximated is reported to have much higher yields per acre. The extensive reach of Illinois from north to south may be responsible in some measure for this difference, since low yields occur in the extreme south and high yields in the north. The greatest corn acreage lies in a district running east and west through the central two-thirds of the state, and here the yields are neither very high nor very low.

In spite of the fact that corn constitutes by far the most important cereal crop in Illinois its diseases appear not to be so well understood or so amenable to control as those of wheat. The diseases of corn include smut, rust, and a long list of others generally grouped under the inclusive list "root-, stalk-, and ear-rots." Among this group are diseases resulting from a number of parasitic and semi-parasitic fungi, and at least two kinds of bacteria. Recognition of these diseases is, even to experts, often a difficult matter.

The losses from corn diseases in Illinois are almost beyond estimation, affecting, as they do, not only the ultimate yield from the stand, but the development of the stand itself. Crop reductions from all reported diseases during the years 1917-1923 inclusive, have been estimated, as indicated in Table 25, to have varied from 2 per cent in 1917 to 20.5 per cent in 1923. The cash value of these reductions would vary between seven and fifty-six million dollars.

Root-, Stalk-, and Ear-Rots

Included in this category are a number of diseases the nature of which is not entirely understood. Among the fungi responsible are *Gibberella saubinetii* (Mont.) Sacc., *Fusarium moniliforme* Shel., and *Diplodia zeae* (Schw.) Lev. Despite the little knowledge of these diseases now at hand, they are among the most important affecting corn, and well deserve the amount of attention they are now receiving at the hands of investigators.

Estimates of crop reductions from these diseases have been made for 1918-1923 inclusive, and are brought together in Table 26. These estimates range from 3 per cent in 1918 to 15 per cent in 1923, or from 10,870,000 to 59,525,000 bushels and the valuations for the 6-year period ranged from $7,385,000 to $38,691,000. Large as these estimates may seem they are probably far below the actual loss.

Root- and stalk-rots of corn are chiefly caused by the fungi *Fusarium moniliforme, Diplodia zeae*, and *Gibberella saubinetii*. The degree of injury done by these organisms is dependent upon the relative susceptibility of the corn plant in the various stages of its development and the effects of the attack appear as rotted roots, barren stalks, or poorly filled ears.

Ear-rots are due to the same fungi as the root-rots, but the importance of the fungi is in the following order: *Diplodia, Gibberella,* and *Fusarium*.

The *dry ear-rot* caused by *Dipolodia zeae* is the source of considerable damage each year. In 1911 Burrill recorded the presence of this rot in 14 counties scattered throughout central Illinois. He estimated the damage to be from 1 per cent to 5 per cent, and noted that there was very little of this disease in the extreme northern and southern sections of the state. In 1912 he recorded it as having been more prevalent than in 1911.

The distribution of these various rot-diseases of corn in Illinois is probably wide-spread. So far as known to us, it is shown on Map 17. The 1923 observations, while not capable of a statistical summary, show the severity of these diseases to be very great. In 15 fields examined in

8 counties and including 303.5 acres, an average of 5.26 per cent of the plants were affected with rot.

Control of these diseases lies in the selection of disease-resistant varieties and the use of disease-free seed, the balancing of nutritive elements in the soil, and the use, in some cases, of seed treatments.

Corn Smut

Caused by *Ustilago zeae* (Beck.) Ung.

This is the most conspicuous of the corn diseases. All aerial parts of the corn plant are subject to its attack. In its final stage it results in the production of large malformations filled with smutty black powder, each grain of which is a spore capable of reproducing the disease.

The annual crop reductions from this disease during a 5-year period varied, according to the estimates shown in Table 27, from 1.5 per cent to 3.5 per cent. While the mere statement of so small a percentage each year is not impressive, the equivalent reduction in bushels, from seven to twelve million, is startling.

The first record of corn smut in Illinois is found in a collection by A. B. Seymour at Camp Point, Adams county, in 1879. The disease was collected again in 1881 in McHenry, Piatt, McLean, and Champaign counties by Seymour. Subsequent collections show the presence of smut in Champaign county in 1890, 1891, 1893, 1895, 1896, and 1897.

These early records are sufficient to show that corn smut had attained a rather wide distribution in the state a quarter of a century ago.

The present known occurrence of this disease in Illinois is shown on Map 18. It is apparent that it is prevalent in all parts of the state. However, as the map indicates, it is most abundant and most prevalent in a region running east and west through central Illinois. This region is the "corn belt" of the state, and it is here that corn smut is of greatest importance. In 1922 it was found in 55 of the 102 counties of the state. During that season it appears to have been especially prevalent in the southern tip of the state and throughout the northwest.

Field observations in 1923 in 26 fields (648 acres) scattered through 17 representative counties indicated an average of 7.35 per cent of smutted plants. Probably this is not indicative of the seriousness of infection throughout the state, since in making the notes from which the figures are drawn, corn in all stages of development was seen.

There is little evidence of resistance among the corn varieties seen. Under favoring conditions, however, Democrat corn always appears more severely smutted than other kinds.

Very little can be done in the control of corn smut. The fungus appears able to live through the winter in manure and in corn refuse, so that there is an abundance of infectious material ready to attack the new crop. Wider spacing of plants for more thorough ventilation, later planting, and an endeavor to destroy the conspicuous spore-masses of this fungus will help to keep the disease in check.

Brown-Spot

Caused by *Physoderma zeae-maydis* Shaw

This disease is usually of minor importance in Illinois. It was first discovered here in 1911,[1] but the locality in which it occurred is not known. A specimen has been preserved which shows that it was present in Champaign county in 1912.

Brown-spot is now known to occur in 26 counties with the distribution shown on Map 19. Although our losses from it are not usually great, it may in unusual seasons become so severe as to do serious damage. This was the case during 1923, when an examination of 15 fields distributed among 10 counties and including 381 acres showed an average of 83.4 per cent of the stalks to be diseased.

The fact that this disease can, under favoring conditions, produce such severe infections emphasizes the need for keeping it under control. In general this depends upon the usual sanitary practises of crop production—clean fields, good seed, and the disposal of diseased plants elsewhere than in manure. The field notes summarized in Table 28 indicate that the Yellow Dent corn commonly grown throughout most of the state shows the greatest resistance under field conditions, and Democrat comes next. Certain special varieties appear to show high susceptibility. Should the brown-spot disease become a serious menace in any district where unusual varieties are commonly grown, a change to Yellow Dent or Democrat may be found advantageous.

Rust

Caused by *Puccinia sorghi* Schw.

This disease is similar to the rusts of other cereals. It attacks the leaves and produces short rusty-red stripes. The fungus causing it has an alternate stage which occurs on the wood sorrel (Oxalis), but this stage has never been found in Illinois. Corn rust probably overwinters by means of its summer spores.

Specimens collected by A. B. Seymour in 1881 and 1882 show that corn rust was present then in at least eight widely scattered counties in the northern half of Illinois. In 1911 Burrill recorded its presence in Montgomery county, and in 1912 in Union county; E. F. Guba collected it near Galesburg in 1919; and a further collection was made in Champaign county in 1919 by H. W. Anderson. At present it is known to occur in the 16 counties shown on Map 20.

[1] Barrett, J. T. *Physoderma zeae-maydis* Shaw, in Illinois. Phytopathology 3: 71. 1913.

Very little loss has ever been attributed to this disease. In 1919, a year when the rust seems to have been unusually abundant, only a trace of loss was reported. The disease is apparently limited in distribution, being confined for the most part to the northern section of the state, and even there it is seldom abundant. No satisfactory method of control is known, and it is doubtful whether one is needed with a disease of such slight importance.

Rosen's Disease

Caused by *Pseudomonas dissolvens* Rosen

This bacterial disease is characterized by the rotting of the basal internode of the stalk. As the rotting progresses, the stalk becomes weakened in spots and leans sidewise. The progress of the rot is such that a continual leaning of the stalk results in further twisting, so that by the time the stalk is down the remaining fibers of the diseased internode may be twisted as much as two and a half complete turns.

It was found in Illinois in 1921 in two counties, Jackson and Randolph, where it was reported as serious in the fields affected by it. In 1922 it was again found in small amounts in a single field in Union county, where it was reported to be causing the death of 1 per cent of the stalks. In 1923 it was seen in Alexander county, where an examination of 100 acres revealed two infected stalks. As indicated on Map 21, its distribution is limited to four adjacent counties in southwestern Illinois.

Rosen's disease of corn is not yet well known, and control methods have not been worked out.

Black-Bundle Disease

Caused by *Cephalosporium acremonium* Cda.

The black-bundle disease of corn has not been commonly recognized in Illinois. It appears, however, to be an important disease.

Its appearance in the field is recognizable from the fact that the affected stalk takes on a striking red color. As the disease progresses, the stalk begins to wilt at the top, the red color spreads downward throughout the stalk, and the entire stalk wilts and dies. A slashed stalk shows the bundles to be discolored and blackened.

The present known distribution of this disease is shown on Map 22. Undoubtedly it is much more widely distributed.

Its seriousness where seen, is indicated from an examination of three fields comprising 9 acres in Champaign county. In one field 1 per cent of the stalks were diseased, and in each of the other two fields 2 per cent of the stalks. In Clark county an examination of 4 fields comprising 75 acres showed 1 per cent, 2 per cent, 2 per cent, and 3 per cent of the stalks diseased. The percentage of infection is directly correlated with loss, since infected stalks are usually sterile or bear only nubbins.

Control consists in using carefully selected seed known to be nearly disease-free.

Stewart's Disease

Caused by *Pseudomonas stewarti* E. F. S.

One of the serious diseases of corn is Stewart's disease. Ordinarily it is most serious on sweet corn, but under certain conditions field corn may also suffer severely. The bacterium which causes the disease invades and plugs up the fibers of the stalks, thus interfering with the development of the plant.

Stewart's disease is known to occur in 9 counties as shown on Map 23.

An examination of sweet-corn fields in seven counties during 1923 indicated that an average of 13 per cent of the stalks were diseased. Such a percentage of infection is certain to result in a noticeable reduction in yield and indicates the necessity for using early-maturing varieties. Northern-grown seed appears to be least often diseased and may be used to advantage.

Rye

Rye is one of the less important of the cereals grown in Illinois, coming after oats but before barley, and the crop of the state has had an annual valuation of approximately $3,000,000 during recent years. Small acreages are to be found in every county in the state, but the greatest acreage is in northwestern and western Illinois, where, in 1922, it reached a total of 120,000. The smallest acreage is in the extreme southern tip of the state, where, in 24 counties, only 4,000 acres were planted in 1922. The distribution of rye acreages is shown on Map 24.

Brown Rust

Caused by *Puccinia dispersa* Eriks.

Brown rust is the most common and most serious disease of rye in Illinois. It is comparable on rye to the leaf rust (*P. triticina* Eriks.) of wheat. It appears especially on the leaves, where it produces small oval spots, distinguishable from the spots of stem rust in part by their position on the plant but more particularly by their much smaller size and definitely brownish color. The amount of infection is generally light, and the loss is usually estimated as a trace to 2 per cent.

Early reports of brown rust in Illinois are few. A. B. Seymour made the first collection in La Salle county in June, 1882; Burrill reports its presence in Champaign county in 1911; and a collection was made by H. W. Anderson at Urbana, Champaign county, June 10, 1919.

It is known to occur in 14 counties distributed widely over the state, as shown on Map 25.

Examinations made during 1922 in 13 fields distributed among 11 counties indicated that an average of 40 per cent of the stalks were rusted, and similar examinations made during 1923 in 20 fields distributed among 14 representative counties and including 209 acres indicated that an average of 90 per cent of the stalks were rusted, the diseased leaf-tissue averaging 35.3 per cent on each infected plant and 31.7 per cent on all plants.

No satisfactory means of preventing the occurrence of this disease is known.

Stem Rust

Caused by *Puccinia graminis* Pers.

Stem rust of rye is similar to the stem rust of wheat previously described and is caused by the same fungus. In Illinois, however, it appears to be much less prevalent on rye than on wheat.

Although this disease has undoubtedly been present in the state for many years, it was definitely reported for the first time in 1918, when it was collected in McHenry county. In 1922 it was found in 10 counties scattered through northern Illinois. Its known distribution, as shown on Map 26, includes 16 counties, most of which are grouped in the northern part of the central section of the state.

Aside from the eradication of the common barberry, no satisfactory methods of control are known.

Ergot

Caused by *Claviceps purpurea* (Fr.) Tul.

Ergot attacks individual grains in the rye heads, causing them to become greatly enlarged and distorted. The disease does not often cause much loss, since it is seldom present in fields, and usually only a few grains in a head are diseased. The greatest danger from this disease lies in the poisonous nature of distorted grains. Seriously affected rye, or wheat that has become mixed with rye, should not be fed to stock when this disease is present in any quantity.

Few reports of the presence of ergot in Illinois have been made. In 1919 it was present in several fields in Carroll county, and the infection is said to have been fairly heavy but appears to have been controlled by a change of seed. In 1923, and for several years before, there were light infections in a few fields in Ogle county. Usually the most serious infections are to be found on rye growing in wheat. An example of this is found in observations made in Hancock county in 1923. Several fields of wheat badly mixed with rye showed from 30 to 90 per cent of the rye heads infected, with from 10 per cent to 60 per cent of the grains diseased. Aside from the loss in production, such grain would be wholly unfit for feeding purposes.

The known occurrence of this disease, as shown on Map 27, indicates a fairly wide-spread distribution in northern Illinois.

Many other grains and grasses are susceptible to ergot attack. Cutting them about flowering time prevents the spread of the disease; and infected seed may be cleaned of it by floating out the ergot grains in a 20 per cent salt solution.

Scab

Caused by *Gibberella saubinetii* (Mont.) Sacc.

Scab on rye has the same appearance as scab on wheat. It is not known to be especially prevalent. A trace of infection was reported in a 5-acre field in Christian county in 1923—the only definite record of occurrence in Illinois. Control measures for this disease on rye are the same as those recommended for wheat scab. (See p. 187.)

Leaf Smut

Caused by *Urocystis occulta* (Wallr.) Rab.

Leaf smut of rye is very similar in appearance and in its effect upon the plant, to the flag smut of wheat, and the fungi which cause the two diseases are much alike.

Leaf smut attacks the leaves, forming long black stripes. As the leaf dies, the black stripes break open, shredding the leaves and letting loose large quantities of smut powder, the grains of which are the spores by which infection is spread.

The earliest definite records of occurrence are two collections made in Lake county in 1918 by J. L. Smith and by L. W. Almy. The known occurrence of leaf smut, shown on Map 28, includes 5 widely separated counties.

The presence of this disease in any quantity is certain to result in serious losses. Fortunately the amount of infection in Illinois is small, and except in isolated cases only slight losses occur. In individual fields, however, serious infections sometimes occur which result in large crop-reductions. The control measures recommended for flag smut of wheat will prove effective for this disease. (See p. 186.)

Barley

Least important of the cereals grown in Illinois is barley, yet between 170,000 and 190,000 acres are grown each year from which are harvested about five million bushels, valued in 1922 at over three million dollars. The distribution of the acreage is shown on Map 29, from which it is apparent that intensive production of this crop is limited to the northern quarter of the state. Although nearly every county grows some barley, more than 90 per cent of the acreage lies in this section of the state, and it is here that the diseases of barley are of most importance.

Leaf Rust

Caused by *Puccinia simplex* (Koern.) Eriks. & Henn.

Leaf rust of barley, which is similar in appearance to the leaf rusts of wheat and rye, is not known to be of common occurrence or to be widely distributed in Illinois. It is known to occur in the two counties shown on Map 30, but is undoubtedly prevalent at least throughout northern Illinois.

Stem Rust

Caused by *Puccinia graminis* Pers.

Stem rust appears to be of comparatively rare occurrence on barley in Illinois. In appearance it is the same as stem rust on wheat, oats, and rye. Wild barley (*Hordeum jubatum* L.) is often infected with stem rust, but it appears not to have been definitely recorded as appearing on cultivated barley previous to 1918. In that year H. W. Anderson collected a specimen of it near Halfway, Williamson county.

Stem rust is now known to occur on barley in the six counties shown on Map 31. As seen in the northern counties, the infection was much more severe than is usually found on the other cereals subject to this disease.

Eradication of the common barberry in the northern counties should help to control this disease.

Loose Smut

Caused by *Ustilago nuda* (Jens.) K. & S.

Loose smut of barley is the most serious of the barley diseases. In appearance it is very similar to loose smut of wheat. The heads are transformed to masses of loose black powder. The spread of infection occurs at blossoming time, and diseased grains, which develop in an apparently normal way, perpetuate the smut. Plants growing from infected grain produce the worthless smutted heads.

The known distribution of loose smut, as shown on Map 32, includes 11 counties, of which 9 lie in the northern part of the state, and 6 are important barley producers. The disease appears widely distributed over the state, but is found most abundantly in northwestern Illinois in the region where the barley acreage is greatest. During 1923 examinations made in 11 fields distributed among 6 counties and including 92.5 acres indicated that an average of 6.4 per cent of the stalks were diseased. This is equivalent to a crop reduction of the same amount. While this figure may not be representative of the amount of disease to be found in all the fields of the state, it is indicative of the seriousness of the disease and emphasizes the value of seed treatment. The methods of seed treatment recommended for loose smut of wheat will be found effective. (See pp. 185-186.)

Covered Smut

Caused by *Ustilago hordei* (Pers.) K. & S.

This disease, which is hardly distinguishable from loose smut in the field, has been found in Illinois once only. C. L. Porter collected it at Galena, Jo Daviess county, July 26, 1922. There was very little infection found, and the damage was slight. Probably this disease is much more wide-spread.

Barley Stripe

Caused by *Helminthosporium gramineum* Rab.

Stripe is next to smut the most serious disease of barley, and causes heavy losses each year. Its appearance is so characteristic as hardly to allow of its being mistaken. The leaves of diseased plants show wide longitudinal stripes in which the green has turned yellowish or brown. Diseased plants are dwarfed, die early, and rarely produce well-filled heads.

It is known to occur in 5 counties, as shown on Map 33, but is probably more generally distributed.

Its serious nature is apparent from 9 fields examined in 1923, in which an average of 31 per cent of the plants were diseased.

Stripe is readily controlled by means of a "wet" formalin seed treatment. The formalin is diluted at the rate of 1 pint to 30 gallons of water. The solution is then thoroughly mixed with the seed. After being covered for two hours the seed is ready for sowing.

Diseases of Forage Crops

During ten years preceding 1922, the tame hay acreage in Illinois averaged 2,970,000 acres, yielding annually an average of 3,808,000 tons, valued at $60,790,000. All parts of the state have large acreages devoted to hay and the other forage crops. The state total of 3,645,000 acres for 1922 is more than 14 times that devoted to rye, nearly 20 times that devoted to barley, only 200,000 acres less than that devoted to oats, 22 times that devoted to spring wheat, 600,000 acres more than winter wheat, and more than one-third of the corn acreage.

Among the crops that go to make up this acreage are especially alfalfa, clover, timothy, and redtop. Each crop is subject to the attack of diseases which reduce either the yield, the value, or the quality of the crop to a greater or less extent.

Alfalfa

Leaf Spot

Caused by *Pseudopeziza medicaginis* (Lib.) Sacc.

This disease is the only important alfalfa disease occurring in Illinois. The first report of its presence in the state was made by Burrill in 1912, when it was found in Champaign, Edgar, and Union counties. Anderson reported it in Tazewell and Champaign counties in 1919. It is now known to occur in 67 counties widely distributed throughout the state, as shown on Map 34, but appears to be more general northward.

Plants infected with this disease lose their vigor, and a loss in hay through falling of the diseased leaves also occurs. Generally not more than one of a season's cuttings (usually the second) is seriously diseased, but the effect on that cutting may be very severe. An examination in 1922 of 61 fields distributed among 38 representative counties and including 349 acres indicated that 66.6 per cent of the plants were diseased and that 7.64 per cent of the leaves were spotted. Similar examinations made in 1923 in 36 fields distributed among 20 counties and including 261 acres indicated that 77.5 per cent of the plants were diseased and 3.85 per cent of the leaves spotted.

As a means of control, it is best to cut the infected crop as soon as it becomes apparent that the result of the infection is apt to be severe. If this is done the succeeding crop will usually be relatively free from the disease.

Rust

Caused by *Uromyces striatus* Schr.

This disease is said to be responsible for local losses in neighboring states. In Illinois it has been found in two counties, Edgar and Woodford. In neither case was the infection either abundant or severe.

Anthracnose

Caused by *Colletotrichum trifolii* Bain

This disease has been found in two counties, Putnam and Henry, but is not known to be of common occurrence or of a serious nature in our state.

Root-and-Crown-rot

Caused by *Fusarium* sp.

During three seasons past there have been incidental reports of a root-and-crown-rot of alfalfa apparently due to the attack of a species of Fusarium. The first instance of this was from Randolph county, and later reports and specimens have been received from Carroll county.

The disease is serious and destructive where it appears, but no specific control-measures can be recommended.

Sweet Clover

Leaf Spot

Caused by *Cercospora davisii* E. & E.

Leaf spot was found in Pike county near Barry in 1919 by H. W. Anderson.

Anthracnose

Caused by *Gloeosporium caulivorum* Kirch.

Anthracnose seems to be the one serious disease of sweet clover. It causes stem cankers and some reduction in yield.

The distribution of anthracnose as known at the present time appears limited, as shown on Map 35, to northern Illinois, where it is known to occur in 15 counties.

Red Clover

This crop is subject to the attack of five diseases.

Anthracnose

Caused by *Colletotrichum trifolii* Bain

Anthracnose has been found on red clover in the counties indicated on Map 36. Its distribution appears limited to the extreme northern part of the state. The fields in which it was found did not appear to be greatly injured, and the degree of infection was usually slight.

Caused by *Gloeosporium caulivorum* Kirch.

This disease has been found on red clover in Union, Ogle, DeKalb, Champaign, and Sangamon counties.

Powdery Mildew

Caused by *Erysiphe polygoni* DC.

Powdery mildew appeared throughout the eastern part of the United States as a serious disease of red clover in the fall of 1921. This outbreak spread rapidly westward, and in the spring of 1922 became very noticeable in Illinois.

Plants attacked by powdery mildew appear to have had their leaves dusted with flour. If diseased clover is allowed to stand after time for cutting, the quality of the hay is impaired, and the quality and quantity of yield from crops grown for seed is also impaired.

The distribution of this disease in Illinois is shown on Map 37.

No means of control are available, but much of the injury may be avoided by seeing that the cutting of the crop is not delayed.

Leaf Spot

Caused by *Polythrincium trifolii* Kuntze

Leaf spot has been found on red clover in McDonough, Carroll, Winnebago, Adams, Schuyler, Union, Saline, Coles, Pulaski, and Menard counties.

Rust

Caused by *Uromyces fallens* (Desm.) Kern.

Rust has been found on red clover in Kane, Putnam, Kendall, Union, DeKalb, Ogle, Vermilion, Edgar, Lake, Wayne, Bureau, Tazewell, and Menard counties.

Timothy

Stem Rust

Caused by *Puccinia graminis* Pers.

The commonest and most serious disease of timothy in Illinois is stem rust, but no early records of its occurrence are available. Its known distribution, shown on Map 38, includes 55 counties and indicates a widespread and common occurrence in northwestern and southern Illinois.

Leaf Smut

Caused by *Ustilago striaeformis* (Westd.) Niessl.

Smut has been found on timothy in Illinois, in three counties: Madison, Sangamon, and Moultrie. The infection in Moultrie county resulted in a 20 per cent crop-loss in one field. Other infections were not severe.

Redtop

Stem Rust

Caused by *Puccinia graminis* Pers.

The only important disease of redtop commonly found in Illinois is stem rust.

Its presence on this crop was recorded by A. B. Seymour in 1881. It is now known to occur in 26 counties as shown on Map 39. The distribution in these counties suggests that the disease is of state-wide occurrence, though possibly more abundant southward.

Diseases of Fruits

Apple

Among the fruits grown commercially in Illinois the apple is by far the most important. While production varies greatly from year to year, the value of the state's crop always runs into large figures. Since 1916 the lowest yield has been 2,381,000 bushels and the highest 9,720,000. The lowest valuation has been $5,575,000 and the highest $10,206,000. The commercial crop is much less than this, ranging since 1920 from 397,000 to 1,620,000 bushels, and from $2,977,000 to $6,845,000 in valuation.

The relative importance of apple-production in Illinois by counties for 1919 [1] is indicated on Map 40, from which it may be seen that the chief apple-producing section of the state lies southwest of a line drawn from the northern boundary of Hancock county to the northern boundary of Clark county. North of this line production is mostly incidental and comes chiefly from small farm orchards maintained for the convenience of the owners, only the surplus reaching the markets.

Scab

Caused by *Venturia inaequalis* (Cke.) Wint.

Scab is probably the most common apple disease occurring in Illinois. It has been known in the state at least since 1863, in which year it is mentioned in the Transactions of the Illinois Horticultural Society as occurring in Ogle county. During subsequent years its occurrence is noted in these Transactions in Carroll, Ogle, Bureau, Tazewell, Champaign, Adams, Pike, Cumberland, Madison, Marion, Jefferson, Richland, Union, and Johnson counties.

The distribution of scab in the state is shown on Map 41. In 10 counties only, of the 102 of the state, has its presence not been demonstrated, and even in these counties it is probably present.

This disease attacks the leaves, the flowering parts, and the fruit, and results in a reduction in the quantity of fruit set, in leaf injury and early defoliation, and in fruit-spotting. It also increases the number of windfalls. Crop reduction occasioned by this injury is great and has been estimated for a 5-year period ending with 1923, as recorded in Table 29, to have ranged from 3.5 per cent in 1923 to 12 per cent in 1921. In crop reductions these percentages are equivalent to 277,000 bushels valued at $318,000 in 1923, and to 387,000 bushels valued at $967,500 in 1921.

The seriousness of scab is illustrated in Table 30, which shows that in 18 counties in central and southern Illinois 23 representative orchards examined in 1923, including 1728 acres, had an average of 12.7 per cent

[1] U. S. Census Bulletin for 1920. Agriculture: Illinois. Statistics for the state and its counties.

of the trees infected and 9.4 per cent of the fruit noticeably marred by scab infection. Were it possible to include the much more severe infections commonly encountered in smaller orchards, these figures would be greatly increased.

Control of scab consists in the timely and thorough application of effective sprays. Infection takes place in spring from the overwintering spores, which are usually ready to begin their work between May 10 and May 20 in Illinois, when they take advantage of any moist period to produce infection. Application of sprays just previous to predicted rains during the middle fortnight of May should succeed in keeping the disease under control.

Blotch

Caused by *Phyllosticta solitaria* E. & E.

Blotch, next to scab the most serious apple disease found in Illinois, attacks twigs, stems, fruiting spurs, leaves, and fruit. Its chief damage, however, consists in the injury done to the fruit. On susceptible varieties it may kill fruit spurs and thus considerably reduce the yield.

The early history of blotch in Illinois is unknown. The disease first appeared in the United States about 1895, and its spread has been very rapid. Burrill reported blotch as occurring in 8 counties in 1911 and again in 5 counties in 1913. Its present distribution is shown on Map 42, which illustrates the southern distribution of the disease and its extension westward and northward with commercial apple-growing. It is known to occur in 63 of the 102 counties of the state.

The crop reductions from blotch attack have been estimated, as shown in Table 31, to have increased from 2 per cent in 1918 to 5.5 per cent in 1923.

The severity of this disease, when sprays are not applied, is illustrated in Table 32, which summarizes observations made during 1923 in 16 orchards distributed among 14 counties and including 131 acres. Practically 100 per cent of the trees were infected, and 90.4 per cent of the fruit was diseased. The effect of a thorough application of sprays is shown, on the other hand, by an examination made in the same year in 7 commercial orchards distributed among 5 representative counties. These orchards included 265 acres and showed only 25.2 per cent of the trees infected, with 2.5 per cent of the fruit diseased.

Fire-blight

Caused by *Bacillus amylovorus* (Burr.) Trev.

This disease, the oldest and best known of apple diseases in Illinois, attacks every above-ground part of the tree. Blossoms and leaves, when diseased, look as if scorched by fire and burned black. On branches and trunks cankers are formed, from which an exudate is given off.

Spread of the disease is accomplished by insects and to some extent by the wind.

The history of this disease in Illinois, as indicated by discussions in the Transactions of the Illinois Horticultural Society, is practically coextensive with apple-growing; and while the injury to apples is not so great as to pears and quinces, the loss to the state is larger because of the greater importance of the apple crop.

Damage done by this disease is often very severe. In 1914[1] it was placed at $500,000 for one county and at $1,500,000 for the state as a whole. For the period 1918-1923, inclusive, the crop reduction has varied, as shown in Table 33, from a trace in two seasons to 1.5 per cent in two other seasons. The equivalent reduction in bushels has ranged from 3,000 to 112,000 bushels and the valuation from $7,500 to $128,000.

The known distribution of fire-blight is shown on Map 43. There are only 13 counties in the state in which this disease is not known to occur.

There is no satisfactory means of control. Cutting out diseased parts with tools sterilized in a 1-1000 mercuric chloride solution is helpful in a new orchard, but in old orchards the only effective measure is the prompt eradication of blight cankers.

Rust

Caused by *Gymnosporangium juniperi-virginianae* Schw.

Rust is one of the very common apple diseases found in the state. Leaves and fruit are especially susceptible to attack. Leaf injury and defoliation, if severe over several seasons, markedly stunts the growth of trees. On the fruit, rust spots cause malformation or disfiguration, which prevents the fruit from being marketed as first-class produce.

According to Burrill,[2] rust has been present on apples in Illinois since 1881 or 1882. The earliest actual collection was made by a Mr. Snow in Perry county in 1896. G. P. Clinton made two collections in 1898, one in Washington county and one in Marion, and a further collection was made in Richland county in 1899 by a Mr. Woodworth.

In 1911 Burrill found the disease in 5 widely separated counties and in 1913 in 2 counties additional. The known distribution of apple rust at the present time is shown on Map 44.

The damage resulting from the attack of this disease is estimated by Anderson[3] to be over $25,000 annually. Estimates of crop reductions made for the years 1919-1923, inclusive, and reproduced in Table 34, range from a trace to 1.5 per cent, annually amounting to between

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[1] Pickett, B. S. The blight of apples, pears and quinces. Ill. Agr. Exper. Sta. Circ. 172. 1914.
[2] Parasitic fungi of Illinois. Bul. Ill. State Lab. Nat. Hist. 2: 240. 1885.
[3] Diseases of Illinois Fruits, Ill. Agr. Exper. Sta. Circ. 241: 37. 1920.

15,000 and 159,000 bushels, the valuation ranging from $21,000 to $166,000.

The seriousness of rust in apple orchards is indicated by an examination made in 1922 of 50 orchards distributed among 25 counties. An average of 58.6 per cent of the leaves and 3 per cent of the fruits were found diseased. Fruit infection was seen for the most part only in those orchards where extremely severe leaf infections occurred.

The fungus which causes apple rust is similar to the rust fungi of cereals in that it depends for its propagation upon the presence of a second host, which is, in this case, the common cedar (*Juniperus virginiana* L.). On the cedar the fungus causes the well-known "cedar apple." Spores borne upon these apples are transferred to near-by apple-trees on air currents, and the infection of the apple is accomplished.

There has been an attempt to secure the eradication of cedars in certain parts of Illinois as a preventive measure in the control of apple rust. On Map 45 is shown the distribution of cedar rust so far as it is now known. A comparison of the distribution here shown with that of the apple rust on Map 44, reveals a very striking correlation.

Control of apple rust may be accomplished more or less successfully by the application of Bordeaux mixture and lead arsenate or by lime-sulfur. More effective control can be had, however, by eradicating all red cedars within one mile of the orchard. Where cedars are too abundant for eradication, new orchards should include only resistant varieties, among which are especially the Grimes and the Liveland Raspberry.

Black Rot

Caused by *Physalospora cydoniae* Arn.

Black rot attacks the fruit, leaves, and twigs; but, as with blotch, the greatest loss comes from the injury done to the fruit.

Leaf infection, in the form of round spots, is commonly recognized under the name of "frog-eye". Twig and limb cankers are comparatively rare, but when cankers on old limbs have enlarged sufficiently they girdle the limb and bring about the death of all parts beyond them. The entrance of the fungus into the apple is dependent upon the presence of wounds—especially insect punctures. Besides the actual rotting of fruit, diseased apples drop early, and considerable rotting occurs in storage.

The earliest record of the occurrence of this disease in Illinois is 1879, but the exact location is not known. The present known distribution, as shown by the 1922 and 1923 survey, is indicated on Map 46. The disease has been found in orchards in 69 counties, and ranges in its distribution from the northern to the southern boundary of the state. There appear to be two general regions of occurrence: The first lies in the southeastern part of the state in the Ohio, Wabash, and lower Mississippi valleys; the second appears to conform to the upper Mississippi Valley north of the junction of that river and the Illinois. Northward.

this area spreads eastward so as to include the Rock River valley, the tributaries of the Illinois, and the watershed of Lake Michigan.

Losses from this disease are probably greater than is ordinarily suspected. Estimates of crop reductions for the years 1918-1923, inclusive, and reproduced in Table 35, vary from a trace to 2 per cent. When definite estimates have been made they have ranged from 33,000 to 199,000 bushels, and from $61,000 to $208,000 in valuation.

The seriousness of black-rot infection is indicated by an examination, made in 1922, of 22 orchards distributed among 18 counties and including 54 acres. Of the trees 91.2 per cent were infected, and the notes indictate that 27.3 per cent of the leaves and 0.92 per cent of the fruits were diseased.

To keep black rot under control it is necessary to cut out and burn all dead wood in the trees, to cut out all cankers with sterile tools, to keep fallen fruit picked up, and to apply an extra spray of Bordeaux in late July or early August.

Blister Canker

Caused by *Nummularia discreta* Tul.

Blister canker, also known as "Illinois canker" and as "nail-head," is one of Illinois' serious apple diseases. It was first reported in the state by Hasselbring in 1902. Since that time the disease appears to have been increasing and spreading steadily. This has been especially true because of the large proportion of Ben Davis apples grown; for this variety, more than any other, is susceptible to attack. Besides Ben Davis, Delicious, Gano, and Willow Twig are especially susceptible.

As usually seen in its advanced stages the blister canker is characterized by a covering of dead bark, often loose and shredding, through which project warts having the appearance of heads of nails driven into the tree.

The distribution of blister canker in Illinois is shown on Map 47. It reaches from the southern tip of the state, where infections have been found in Massac and Pope counties, to the northern boundary, where infections have been seen in Lake, McHenry, and Boone counties. The disease is known to be present in 66 of the 102 counties of the state, and in practically all of the important apple-growing counties. As we know it at present, the disease occupies a range of territory including, in southern Illinois, the tributaries of the Wabash and Ohio rivers and, in the extreme southwest, those of the Mississippi. Northward the disease is wide-spread in the valley of the Mississippi and Illinois rivers.

Injury by this disease results in the death of the wood. Girdling eventually occurs, and all the twigs or branches beyond the girdle die. Or, if the canker is on the main trunk, the whole tree dies.

Crop losses from blister canker are large, and the disease is especially serious, because the damage done to a tree in one season can not be repaired but continues to cause losses season after season. Anderson[1]

[1] Anderson, H. W. Diseases of Illinois Fruits. Ill. Agr. Exper. Sta. Circ. 241: 31. 1920.

estimates an average annual loss of 1 per cent of the apple crop, the valuation ranging from $25,000 to $30,000. For the 1922 and 1923 seasons estimated losses of 1 per cent were equivalent to 98,000 bushels valued at $102,000 and 74,000 bushels valued at $85,000.

The seriousness of this disease in our orchards is illustrated by the results, shown in Table 36, of an examination of 21 Ben Davis orchards distributed among 14 representative counties. The examinations were made during the summers of 1922 and 1923 and showed that 21.8 per cent of the trees were diseased.

How uncared-for infections may result was shown in 1922 by a special survey, with careful examination of trees in three Wayne county orchards. In orchard Number 1, which was about 50 years old, there were 400 trees, of which 95 per cent were diseased with blister canker; 100 trees had been killed and were being taken out; 100 other trees were dead or so nearly dead as to bear no crop; 150 trees were so severely diseased as to have their crop materially reduced; and only 50 trees were still in good bearing.

In orchard Number 2, which had 150 trees, 100 were dead or nearly so, and the remaining 50 were badly diseased and bearing small crops of inferior fruit.

Orchard Number 3 had about 300 trees, many of which were dead and many others dying. More than 80 per cent of the trees were diseased with blister canker, and the crop was poor in quantity and of inferior quality.

Control of this disease consists in carefully pruning out all infection as soon as it becomes apparent, and in the use, so far as practicable, of varieties relatively resistant to the disease.

Bitter Rot

Caused by *Glomerella cingulata* (Stonem.) S. & v. S.

Bitter rot, a disease which affects the fruit especially, though often causing stem cankers, is apparently limited to the extreme southern part of the state.

The past history of this disease in Illinois is not well known except for the serious outbreak of 1901 and 1902. At that time the disease was studied by Burrill, Blair, Clinton, von Schrenk, and Spaulding, and the loss in the state estimated at a very large figure. During subsequent years the disease appears to have become less and less severe until 1923, when another outbreak occurred. Bitter rot was seen in the counties indicated on Map 48, and the crop reduction due to its presence was estimated at 1 per cent or 74,000 bushels valued at $85,000.

Control of bitter rot demands careful attention to the application of sprays before the disease appears. When it does appear sprays should be supplemented by careful and thorough hand-picking of diseased fruits. Since the disease overwinters in the twig cankers, these should be cut out of the trees wherever they are found.

Brown Rot

Caused by *Sclerotinia cinerea* (Bon.) Schroet.

While very serious on peaches and plums, brown rot does not often become either abundant or severe on apples. Its occurrence in Illinois was noted by Clinton[1] in 1902 and by Conel,[2] in 1914. Very little damage has ever been attributed to it in our state, though in rainy seasons it may become very severe locally.

Its known occurrence in Illinois is shown on Map 49, which indicates a greater frequency of occurrence in the southwestern tip of the state, where its abundance is probably encouraged by the moisture present in the valley of the Ohio and the Mississippi.

The methods useful in controlling brown rot are outlined under peach brown-rot. (See p. 220.)

Powdery Mildew

Caused by *Podosphaera leucotricha* (E. & E.) Salm.

Powdery mildew of apple is not a common disease. It appears as a white, powdery coating on the under surface of the leaves, and occasionally upon the leaf stems and on young twigs.

The damage from this disease consists chiefly in a stunting of the leaves and an early leaf-fall.

Powdery mildew is apparently of rare occurrence in Illinois. Its distribution, as known at present, is shown on Map 50.

The usual spray schedule is sufficient, under ordinary circumstances, to keep it under control.

Sooty Blotch

Caused by *Gloeodes pomigena* (Schw.) Colby

This disease is very often found associated with the "fly-speck" disease on apples. It differs in appearance, however, being diffuse and causing a blotchy appearance over a considerable part of the surface of the fruit. The chief injury is a disfiguration of the fruit.

The distribution of sooty blotch in Illinois is shown on Map 51. It is known to occur, as the map indicates, in 19 counties, 17 of which are situated in the southern half of the state.

Varieties known to have been severely affected include especially Ben Davis and Grimes Golden. There is not, however, any apparent distinction between varieties as to susceptibility. The disease appears to develop commonly in damp situations or during moist seasons.

For control, the usual sprays in July and August are helpful. In orchards on low ground open pruning of the trees serves to keep the disease well controlled.

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[1] Clinton, G. P. Apple rots in Illinois. Ill. Agr. Exper. Sta. Bul. 69. 1902.

[2] Conel, J. L. A study of the brown rot fungus in the vicinity of Champaign and Urbana, Illinois. Phytopath. 4: 93. 1914.

Fly-speck

Caused by *Leptothyrium pomi* (Mont. & Fr.) Sacc.

Fly-speck appears to be of common occurrence within the state. The common name is descriptive of the disease, which appears as black specks, usually smaller than a pin-head, on the fruit. It may also occur on the twigs.

No actual damage is caused by this disease. Its only effect is, in serious cases, to mar the appearance of the fruit, thereby impairing its market value to a certain extent.

Distribution within the state is shown on Map 52.

According to Colby,[1] when infections are severe enough to mar the fruit, the specks can be removed by the use of Javelle water. This practice is probably advisable only in preparing the very finest fruit for the market.

Crown-gall

Caused by *Pseudomonas tumefaciens* E. F. S.

Crown-gall, known also under the names "crown knot," "hairy root," and "root knot," is common not only on apples, but on many other plants.

The disease is recognized in two common forms, as galls and as hairy root. It is most common and most serious in nurseries; but the rigid requirements of nursery inspection laws have prevented its serious spread into orchards.

Its known distribution in orchards is shown on Map 53. A very much wider distribution in nurseries would be evident were it possible to bring together proper reports. Distribution in orchards is apparent as a rule only when trees die and crown-gall is demonstrated upon their removal to have been the cause of death.

Serious losses in nurseries from this disease and the doubtful seriousness of its effects on older trees indicate a need for further investigation.

Cankers

Bark cankers of apple are frequently met with in orchards. Among those usually considered as diseases the following are known to occur in Illinois:

Valsa canker (*Valsa ambiens* Fr.) has been found in Pike and DeKalb counties.

European canker (*Nectria ditissima* Tul.) is reported from Stephenson county.

Myxosporium canker (*Myxosporium corticolum* Edg.) has been found in Champaign county.

These cankers can be cut out with sterilized tools when seen, and subsequent injury to the infected trees thereby avoided.

[1] Colby, A. S. Sooty blotch of pomaceous fruits. Trans. Ill. St. Acad. Sci. 13: 139-175. 1920.

Leaf Spots

There are numerous leaf spots of apple which are of relatively common occurrence but which usually do very little damage. Among those known to be present in Illinois is one caused by *Coniothyrium pyriana* (Sacc.) Shel., which has been found in Champaign and Ogle counties, and a second caused by *Phomopsis mali* Rob., found in Union county. The regular spray schedule is sufficient for their control.

Pear

Pear, so far as number of trees indicates, is the third most important fruit crop of Illinois. According to the census reports for 1920 there were within the state 54,585 pear trees of bearing age, distributed so as to include 21.3 per cent of the farms of the state. Pear culture is, however, on the decline—a fact which is due in no small degree to the serious effects of the diseases to which it is subject. The number of bearing trees in 1920 was nearly 14,000 less than in 1910.

Since 1912 the annual production has varied from 100,000 to 603,000 bushels valued at $270,000 to $735,000. The ten-year average from 1912 to 1921, inclusive, was 397,000 bushels, for which an average price of $1.24 is estimated, bringing the annual valuation of the crop up to $473,000 for that period.

The distribution of production, in bushels, according to the 1920 census, is indicated on Map 54. In general, production is massed in the southwestern half of the state, and here there appear to be three centers: (1) along the Mississippi north of its junction with the Illinois River, including especially Adams and Hancock counties; (2) in the extreme southwestern part of the state, along the Mississippi including especially St. Clair, Randolph, Jackson, Union, and Pulaski counties: and (3) an area of concentration practically confined to Marion county.

According to the data of the 1920 census the most important counties, mentioned in the order of their rank, are Union, Marion, Pulaski, St. Clair, Jackson, Adams, and Hancock.

Blight

Caused by *Bacillus amylovorus* (Burr.) Trev.

This disease is the same as the fire-blight of apple and quince.

The history of pear blight in Illinois is better known than that of any other disease. From discussions in the Transactions of the Illinois Horticultural Society in 1862 it appears that the disease had by that time become wide-spread, generally recognized, and universally feared. For years it was the subject of much discussion at horticultural meetings within the state, and the fear was often expressed that unless some means of control were discovered it would shortly wipe out every orchard in the state.

This disease is now so universally known that no description of it should be necessary. An enumeration of its various names, such as blight, pear-blight, fire-blight, blossom-blight, blight-canker, spur-blight, etc., will serve as an identification of the disease even to the inexperienced orchardist.

As the various names imply, pear blight attacks leaves, twigs, flowers, fruit, and even large branches and trunks. One reason for its extremely serious effects upon the pear tree is its ability to cause trunk-cankers which girdle trees and result in their death.

Losses from pear blight are great—so great that to term this disease the one limiting factor in the growing of pears in Illinois is not an exaggeration. Losses result annually in crop reductions, but the injury to trees is often so severe that its effects impair the quantity of the crop through many subsequent seasons. Anderson[1] estimates that losses from blight average annually in the United States 25 per cent of the potential bearing power of the trees. Pickett[2] places the loss from this disease on the fruits mentioned at $500,000 for 1 county and at $1,500,000 for the entire state, and reports that southern Illinois is more affected than northern.

Estimates of crop reductions caused by this disease in Illinois in 1922 and 1923 are shown in Table 37. In the former year the reduction of 5 per cent was equivalent to 26,800 bushels valued at $26,800, and in 1923 the crop reduction of 6 per cent was equivalent to 19,000 bushels valued at $17,800.

The distribution of pear blight in Illinois is shown on Map 55. It occurs from the northern to the southern and from the eastern to the western boundaries of the state and is known in all but 27 counties, the majority of which produce very small pear crops.

In Table 38 are shown the results of field examinations made in 28 orchards in 1922. These orchards were located in 25 counties. From the table it appears that 50 per cent of the trees showed infections involving 16.9 per cent of the branches on each tree. This is equivalent to 8.5 per cent of all the branches on all the trees, and represents the damage done to the trees in a single season of rather mild disease. It is not to be supposed that this injury was uniform on all branches, for injury to branches varies greatly. Such infections, however, usually involve a complete loss of the fruit which would have been produced, and give rise in many cases to cankers in the body of the tree, which may persist from year to year. Such "hold-over" cankers provide an abundance of material for bringing about new infections the following season. Moreover, the annual enlargement of these cankers usually results in the eventual death of large parts of the tree.

During the season of 1923 similar examinations, summarized in Table 39, were made in 16 orchards aggregating 131 acres, and distributed

[1] Anderson, H. W. Diseases of Illinois Fruits. Ill. Agr. Exper. Sta. Circ. 241 : 71. 1920.

[2] Pickett, B. S. The Blight of Apples, Pears and Quinces. Ill. Agr. Exper. Sta. Circ. 172. 1914.

among 9 counties. Practically 100 per cent of the trees were infected with blight, which involved an average of 43.1 per cent of the branches.

No satisfactory means of control is known but, as in the case of apple fire-blight, cutting out diseased twigs in young orchards and eliminating hold-over cankers in old orchards are helpful. A certain amount of freedom may be secured by planting relatively resistant varieties, such as Kieffer, Duchess, Koonce, Anjou, Seckel, Vermont Beauty, Garber, and Lincoln. However, even these varieties are so susceptible to attack that only the closest attention to the orchard will prevent extremely serious losses.

Leaf Blight

Caused by *Fabraea maculata* (Lev.) Atk.

This disease of the pear is second in importance to pear blight. Though common, it is not often sufficiently abundant to cause serious damage. It is limited for the most part to the leaves, where it causes circular spots, at first carmine-red, later developing a brown center bearing a single black spot. Similar spots are occasionally produced on the fruit and on the twigs. Severe infections result in serious defoliation.

As a rule the loss caused by this disease is small. Epidemics are rare, and fruit is seldom infected. The disease should not be confused, as the name indicates that it might be, with pear blight.

The earliest known occurrence of it in Illinois was in Union county in 1912. Its present known distribution is shown on Map 56.

The prevalence of leaf blight in orchards and its importance as a disease was illustrated by examinations made in 12 orchards in 1922. Among some 400 trees 33 per cent were infected and 49 per cent of the leaves were diseased.

Control of this disease is obtained by the use of the usual sprays.

Scab

Caused by *Venturia pyrina* Aderh.

Scab is not of common occurrence in Illinois. In appearance it is similar to the scab of apples and is caused by a similar fungus.

Its known occurrence in the state is shown on Map 57, which indicates a wide distribution. It has not appeared commonly, however, in the important pear-producing regions. The 8 counties in which it is known to occur are widely separated but, with the exception of Jackson county, lie outside of the areas of intensive culture.

Injury by this disease to leaves and fruit, as in the case of apple, constitutes its chief menace. Control is accomplished with the usual sprays.

Black Rot

Caused by *Physalospora cydoniae* Arn.

This disease is identical with the black rot of apples but it is not of such common occurrence, nor apparently so serious, on the pear.

It is known to occur, as shown on Map 58, in seven counties, four of which lie within the northern third of the state. Its occurrence in Randolph and Jackson counties, in the southwest, brings it within the intensive pear-producing region and indicates the possibility of severe loss under certain conditions.

Leaf Spot

Caused by *Mycosphaerella sentina* (Fr.) Schroet.

Leaf spot is a disease which is often confused with the leaf blight previously described. It is distinguishable, however, by its more angular spots, which are usually brownish, with, at later periods, grayish centers bearing several small black dots. It does not occur on the fruit or twigs. Leaf-spot attack results in the early falling of leaves; hence it is of importance in nurseries, where serious infections may materially interfere with the proper development of young trees.

The first report of this disease in Illinois was made by Burrill in 1912, when he recorded its occurrence in Union county. Its distribution as known at present is shown on Map 59, but it probably has a much wider occurrence than the map shows.

Control, when necessary, is gained by the use of the usual sprays.

Quince

This fruit is not grown commercially to any great extent in Illinois. For the most part single trees, or a few trees at the most, are maintained to supply the home table.

The diseases of the quince important in Illinois are few, and probably result in greater losses than would be the case were trees maintained in well-cared-for commercial plantings. The following are known to occur in Illinois.

Leaf Blight

Caused by *Fabraea maculata* (Lev.) Atk.

This disease is the same as the leaf blight of pear, but its effect on quince is much more marked and constitutes the chief cause of loss from disease. In appearance it is similar to pear leaf-blight, but it is much more commonly found on the fruit of quince, where severe infections cause marked distortion. On twigs the spots are elongated, and they frequently cause the death of the twigs by girdling.

Leaf blight is known to occur in Illinois in eleven counties, nine of which lie in the southern tip of the state, as shown on Map 60. The two central counties, indicate a possible northward extension of the disease under favorable conditions.

Control is had by the application of lime-sulfur spray, as for pears.

Fire-Blight

Caused by *Bacillus amylovorus* (Burr.) Trev.

Fire-blight of quince is caused by the same bacterium as fire-blight of apple and pear blight. It is usually fairly common, but is less severe on quince than on the other fruits.

Its presence in the state has been recorded from time to time, and its present known occurrence, as shown on Map 61, gives it a distribution practically co-extensive with the observed cultivation of the quince.

Injury to uncared-for trees may often be very serious, but a careful pruning-out of diseased parts as they appear will prevent its spread as will also the elimination of hold-over cankers.

Powdery Mildew

Caused by *Podosphaera oxyacanthae* (DC.) De Bary

Powdery mildew is one of two rather uncommon diseases of quince in Illinois. It appears as a whitish powder covering the upper side of the leaves and often extending down the leaf-stems. Under favoring circumstances the mildew may result in severe leaf-injury, accompanied by early and damaging leaf-fall.

The first collection of this disease was made by G. P. Clinton in September, 1894, presumably in Champaign county. It was found in 1922 in Coles and Edgar counties, where severe infections were seen on a few trees. Its present known distribution is small, as shown on Map 62.

Rust

Caused by *Gymnosporangium germinale* (Schw.) Kern

The rust of quince is similar in appearance to apple rust, and is caused by a similar fungus. It is not known to occur commonly in Illinois, but it is a much more serious disease than the apple rust because it attacks especially the fruits and twigs.

Quince rust was found in Hardin county in 1919, and this constitutes the only record of its occurrence in the state.

As with apple rust, control is to be had through the eradication of near-by cedars.

Miscellaneous Diseases

The quince, which is closely related to the apple and the pear, is subject to the attack of several diseases commonly found on those fruits. Among these should be noted especially black rot, bitter rot, brown rot, crown-gall, and bark cankers.

None of these have so far been found on quince in Illinois with the exception of a bark canker caused by the fungus *Valsa leucostoma* (Pers.) Fr., which was found in 1919 in Tazewell county.

Peach

Peaches constitute one of the most important fruit crops of Illinois. Though the production of large crops is dependent upon favorable weather, the average annual production is large and of considerable value.

Map 63 shows the status of peach-production in Illinois in 1919, as indicated in the Census Reports of 1920; Map 64 shows the distribution of peach trees in the state in 1923 according to later U. S. Census figures. The area of greatest production lies generally in the southern half of the state below a line drawn east and west along the northern boundary of Pike county. Within this region peach-production is intensified in certain areas. One such area is along the Mississippi from Pike county south through St. Clair county. A second includes especially Marion and Jefferson counties, and a third the three extreme southern tiers of counties. This last area is by far the most important, since it includes Union county, with its tremendously large production, and Jackson and Johnson counties. Union, Marion, and Jackson are the most important peach-producing counties in the state.

According to the 1920 census there were within the state a total of 1,851,037 peach trees, of which 1,011,325 were reported to be of bearing age. Many of the remaining 800,000 and upwards will have come into bearing since then, and it is probable that the regions of important production will have been altered so as to correspond more directly with tree distribution, as shown on Map 64. In general, the large commercial area remains the same, but with a marked northward extension along the Illinois River. The total number of trees is reported to be distributed over 55,968 farms or 23.6 per cent of the farms of the state.

During 1912-1921, inclusive, the peach-production of the state ranged from 76,000 bushels (valued at $281,000) in 1921 to 1,998,000 bushels (valued at $2,297,000) in 1913, the yearly average for the decade being estimated at 724,500 bushels, valued at $1,543,000.

Brown Rot

Caused by *Sclerotinia cinerea* (Bon.) Schroet.

This disease, though sometimes attacking pomaceous fruits, is primarily a disease of the stone fruits. It is by far the most serious peach disease in Illinois and is most injurious to the fruit, causing large losses not only in the orchard, but also when the fruit is in storage or in transit. Under favorable circumstances the brown-rot fungus may cause a blossom-blight and a twig-blight; and less frequently, cankers on limbs.

The early history of this disease in Illinois is not known. Probably it is coextensive with peach-growing. Burrill recorded its occurrence in 1911 in 3 counties, Champaign, Montgomery, and Union, with the note that there was little injury that season because of unfavorably dry weather.

The known distribution of brown rot of peaches in Illinois, is as shown on Map 65. It appears to be general over the southern tip of the state, including the counties important in commercial peach-production. Northward, distribution is more scattered, covering in a general way the territory between the Illinois and Mississippi Rivers. Toward the east, an irregular distribution occurs in six counties which lie along the tributaries of the Illinois and Wabash Rivers. It is probable that brown rot is even more wide-spread than has been recorded.

Estimates of crop reductions from brown rot for 1917-1923, and reproduced in Table 40, vary from none in 1918 to 12 per cent in 1917, equivalent to 50,000 bushels valued at $97,000. These amounts represent the loss in orchards, and do not include the tremendous losses which often occur between the harvesting of the crop and its ultimate disposal to the consumer.

An examination in 1922 of 32 orchards of varying size, scattered uniformly through 24 counties, indicated an average infection of 17 per cent of the trees and nearly 15 per cent of the fruit. Field notes of 1923 show that in 9 orchards the average of infected trees was slightly more than 62 per cent, with infected fruit averaging 26 per cent.

Control of brown rot is often difficult, since an outbreak may occur whenever sufficiently wet weather comes on. Twig and blossom blight is especially to be expected in damp springs and serious fruit infection may appear any time during the season during damp warm weather. The application of proper sprays should therefore be made with particular reference to predicted weather conditions. Assiduous adherence to such a schedule may reasonably be expected to do away with the considerable losses which might otherwise occur.

Leaf-curl

Caused by *Exoascus deformans* (Berk.) Fckl.

This disease is probably second to brown rot in destructiveness to peaches. It is confined to the current year's growth, affecting leaves, twigs, and blossoms. The leaves appear thickened along the veins, causing the blade to become folded, wrinkled, and puffed, and the edges to curl in on the under side. Ultimately the leaves turn yellow and fall from the tree.

The early history of this disease in Illinois is not known. It was reported by Burrill to have occurred in Champaign county in 1890 and in Champaign and Livingston counties in 1911. The extent of its prevalence as now known is shown on Map 66, which indicates its occurrence in 62 of the 102 counties of the state. The area of most common occurrence lies along the northern boundary of the region of commercial peach-production and this fact lends color to the belief that this is a northern disease. It should be remembered, however, that leaf-curl is very readily controlled and that its apparent common distribution on the northern edge of the commercial district may result from a more perfect control southward and also from the presence of an increasing number of private plantings northward in which disease-control is not practiced.

The abundance and severity of leaf-curl on peach may be illustrated by notes from the observations made in 1923.

"In Pike county, in a one-acre block of Lemon Clings all were infected and suffering considerable defoliation. A ten-acre tract of Belle of Georgia and Champion showed a large amount of infection, with defoliation of 10 to 15 per cent on the Belle of Georgia. In Edwards county a one-acre orchard of Elbertas showed 10 per cent of the leaves infected, and a two-acre tract of Hales 50 per cent of the leaves infected."

The use of resistant varieties is helpful in controlling this disease. At least, an effort should be made to avoid the planting of susceptible varieties, such as Lemon Cling and Belle of Georgia. Less susceptible, but still remarkably subject to infection, are the Elberta, the Hale, and the Carmen.

Further control is readily accomplished in most cases by the application of the customary dormant lime-sulfur spray, with especial attention given to thoroughly coating the buds.

Bacterial Shot-hole

Caused by *Pseudomonas pruni* E. F. S.

This constitutes the third important disease of peaches in Illinois. It affects both the fruit and twigs, but is especially noticeable on the leaves, where it appears as small spots, at first light colored but later becoming darker and eventually turning brown. Ultimately the spots separate from the leaves and fall out, giving the characteristic shot-hole appearance. Serious infection causes defoliation. On twigs spots are formed which turn dark and may kill the twig. Small purple spots, usually not more than 1/16 of an inch in diameter, are produced on the fruit, the skin cracks, the appearance of the fruit is marred, and it is made especially susceptible to attack by brown rot.

The history of the bacterial shot-hole as a serious peach disease in Illinois dates back only to 1915. According to Anderson[1] it was observed near Centralia in 1912. Since that time it has been widely observed, and is a disease needing careful attention for its control.

Its distribution as indicated by specimens collected in 1922 and 1923 is shown on Map 67, which indicates its occurrence in 82 counties

There appears to be no marked fluctuation in its severity from year to year. A crop reduction of 2 per cent was estimated for 1922 and 1923. In the first year this amounted to 22,000 bushels valued at $38,000 and in the second year to 14,000 bushels valued at $36,000.

Infection is very general where it has been observed to occur. In 20 orchards examined during 1923 in 12 representative counties and covering 1002 acres, 92.2 per cent of the trees were affected by this dis-

[1] Diseases of Illinois Fruits. Ill. Agr. Exper. Sta. Circ. 241: 90. 1920.

ease, diseased areas were found on an average of 31.4 per cent of the leaves, and the amount of infected fruit varied from 10 per cent to 45 per cent.

The fact that this disease is caused by a bacterium renders it difficult to control, and spraying seems to have little effect. Cultivation and the application of fertilizers, especially sodium nitrate, which tend to increase the vigor of the trees, are effective in holding it in check.

Scab

Caused by *Cladosporium carpophilum* Thuem.

Scab of peaches, also known as "freckle," is a very common disease in Illinois and is probably more disastrous in its effect than is usually supposed. While attacking leaves and twigs to a certain extent, it is primarily a disease of the fruit. Usually it appears on the exposed side of the fruit and is often considered as a natural reaction to sunshine—hence the name "freckle." Serious infection, however, results in misshaped, unevenly ripened fruit. Cracks often appear which reach to the stone of the peach. The fruit is thus rendered unsuitable for ready marketing and is also made more liable to brown-rot injury and internal breakdown.

The early history of this disease in Illinois is not well known. The earliest record of it is a specimen collected by F. S. Earle in Union county in 1881.

During 1922 and 1923 scab was found to occur in 46 counties, the distribution of which is shown on Map 68. It occurs most commonly in the south quarter of the state. Occurrence northward is much more scattered and irregular, and reaches only to Carroll and Ogle counties.

The prevalence of scab is illustrated by an examination, in 1923, of 12 orchards, distributed among six counties. Infection was found on 86.7 per cent of the trees and involved 79 per cent of the fruit produced in the 12 orchards. The apparent damage caused by fruit infection varied greatly in the several orchards and various expressions concerning its frequency occurred in the notes as follows: great, 5 times; much, 3 times; some, 2 times; little, twice. Of the 88 acres reported on, great damage was found on 54, much on 7, some on 23, and little on 4. In reports showing much to great injury to the crop, mention is made repeatedly of the quantity of fruit cracked and deformed. Where injury was less it consisted chiefly in a lesser degree of deformation and spotting of the fruit which detracts from its appearance and makes it unsalable as of the first class.

Control of peach scab consists partly in the use of resistant varieties and partly in the use of a well-applied spray. Early Crawford, Hiley, and Carmen are commonly thought to be most resistant, with Elberta, Hale, and Belle of Georgia next. These varieties, however, may not always be suitable to the needs of the grower, who must then depend upon his sprays for control. As infection begins when the petals have been off the tree about a month the first application of lime-sulfur spray should be made three to four weeks after petal-fall. Subsequent applications of this spray for the control of brown rot serve also to control scab.

Die-back

Caused by *Valsa leucostoma* (Pers.) Fr.

Of lesser importance than the preceding diseases is die-back. It occurs on the trunk and limbs but is especially a disease of the twigs.

Infection of buds, and of twigs through wounds, occurs during the growing season, and is followed by the death of the twigs, which, during the season following, may be killed-back for four inches or more.

The distribution of die-back of peaches in Illinois is indicated on Map 69, where it is shown to occur in 17 counties widely scattered through northern Illinois, and in one county in southern Illinois.

Spraying does not appear to control die-back satisfactorily, though it does lessen the amount of the disease. It is important to cut out carefully all parts showing evidence of infection.

Minor Diseases

Besides those previously noted, there occur in Illinois several peach diseases which do not materially affect either the welfare of the tree or the quantity or quality of the crop.

Leaf spot, caused by *Cercospora circumscissa* Sacc., has been found in Champaign and Marion counties. It is not known to be widely distributed, or common where it does occur.

Frosty mildew, caused by *Cercospora persica* Sacc., appears as a yellow leaf-spot, the under side of the spots having a frosty appearance from the spore-bearing hyphae of the fungus. This disease is reported to have been found in Illinois previous to 1885, by F. S. Earle,[1] and it was found in Union county in 1881 by A. B. Seymour. These early reports constitute all that is known of its occurrence in this state.

Apricot

The apricot is not grown extensively in Illinois. It is nevertheless subject to the attack of a number of diseases, several of which are the same as, or similar to, those affecting peach, plum, and cherry, and, in general, control is secured by the same means. Those known to occur on apricot in Illinois are the following:

Scab, caused by *Cladosporium carpophilum* Thuem., was found in Boone and Schuyler counties in 1922.

Bacterial shot-hole, caused by *Pseudomonas pruni* E. F. S. has been found in Coles, Monroe, Hardin, Edgar, Massac, Saline, and Ran-

[1] Ellis, J. B., and Everhart, B. M. Journ. Myc. I : 56. 1885.

dolph counties, all in the southern half of the state and most of them in its tip.

Brown rot, caused by *Sclerotinia cinerea* (Bon.) Schroet., has been found in Schuyler, Bond, and Fulton counties.

Plum

Although commercial production of this fruit is not practiced extensively in the state, most farms have one or more trees which supply the home table, and not infrequently small orchards which supply local markets.

Many of the diseases of the plum are the same as those attacking the peach. Others which attack plums attack cherries also.

Brown Rot

Caused by *Sclerotinia cinerea* (Bon.) Schroet.

Brown rot of plum is similar to the brown rot of peach, and is caused by the same fungus. It is the most important plum-disease occurring in the state, and for several years past has caused an average annual crop-loss estimated at five per cent.

Its distribution in Illinois is shown on Map 70. It is known to occur in 50 counties, distributed in all parts of the state.

Brown rot appears to be a disease more serious on plum than on peach. Its severity is illustrated by an examination of 395 trees made in 21 counties in 1922, where it was found on 43.9 per cent of the trees, and 8.8 per cent of the fruit. A similar examination in 1923 of 83 trees in 8 well distributed counties showed that an average of 94.4 per cent of the trees were infected and 50.5 per cent of the fruit diseased.

The fruit loss, however, is not the whole story for the brown-rot fungus causes a twig and blossom blight which does notable damage each year. In 1922, instances were common where from 10 to 30 per cent of the young twigs were killed.

Brown rot of plum is controlled like that of peach by the use of sprays, but owing to the unusual seriousness of the plum disease, extreme care must be taken to apply them thoroughly.

Leaf Blight

Caused by *Coccomyces prunophorae* Higg.

Leaf blight is, next to brown rot, the most common disease of plum in Illinois. Its injury appears limited to the leaves, on which it causes round, discolored spots, rather definitely limited in size. The spotted tissue eventually falls out of the leaf, giving it a "shot-hole" appearance, and serious defoliation often results.

The known occurrence of leaf blight in Illinois is shown on Map 71. It has been found in 56 counties widely distributed over the state.

Loss from this disease is difficult to estimate, but it was less than 1 per cent in 1922 and about 1 per cent in 1923. The field notes for 1923 indicate that of the plum trees examined in 9 counties 100 per cent were affected, each tree having more than 90 per cent of its leaves spotted by this disease.

Control of leaf blight is obtained by the use of the usual sprays, though in this case the addition of lead arsenate to the lime-sulfur increases its effectiveness, while a further addition of iron sulfate (1¼ pounds to 50 gallons of spray) lessens the injury to the foliage.

Black-knot

Caused by *Dibotryon morbosum* (Schw.) T. & S.

Unique among the diseases of stone fruits is the black-knot of plum, in that it is wholly confined to the woody part of the tree, and the injury which it causes is permanent.

It first appears on young branches, where it causes knots up to six inches in length and half an inch in diameter. The knots are usually on but one side of the twig, though they often completely encircle it. They are at first greenish and quite soft but later become black and hard.

The history of black-knot in Illinois, so far as known, dates from the year 1887, when it was found at Edgewood, Effingham county. In 1898 it was reported from Clark county, in 1899 from Marion and Stark counties, in 1900 from Cook and Madison counties, and in 1902 from Edgar county. The majority of these early collections were presumably from nurseries, as they are among the collections of the State Nursery Inspector. In 1911 Burrill reported the disease in Champaign, Clark, and Montgomery counties, with the notation that it was serious locally. In 1913 he added Bond, Coles, and Crawford counties to the list, saying that black-knot was common in the last two.

The distribution of black-knot as known at the present time is shown on Map 72. It is known to occur in only 21 counties, few of which are in the northern part of the state.

The best protection against the losses which black-knot causes, lies in the use of resistant varieties, among which the Wild Goose is preeminent. With other varieties constant watchfulness is necessary to insure cutting out all knots as soon as they are recognized. Badly affected trees are beyond hope and had better be cut down at once. Spraying is not effective.

Scab

Caused by *Cladosporium carpophilum* Thuem.

Plum scab is apparently of rare occurrence in Illinois. Up to the present time it has been found in only three counties along the northern boundary of the state—Jo Daviess, Stephenson, and Winnebago. The DeSoto variety appears to be most often diseased.

Bacterial Shot-hole

Caused by *Pseudomonas pruni* E. F. S.

This disease, which is the same as the bacterial shot-hole of peach, causes serious damage to both the leaves and the fruit, and produces cankers on the twigs. On the whole the disease appears to produce more serious effects on the plum than on the peach. It is not, however, so common or abundant on the plum, possibly because the more immune varieties, the Americana and Wild Goose, are among those most commonly grown. Japanese varieties are very susceptible.

The distribution of this disease appears at the present time to be limited to southern Illinois. It is known to occur in 13 counties as shown on Map 73.

Control measures are the same as for peach shot-hole (p. 222).

Leaf-curl

Caused by *Exoascus mirabilis* Atk.

Recently there has appeared in Illinois a disease of plum not previously known in the state, best described under the name of leaf-curl. Infection, which appears to take place in the bud or when the branch is still very young, results in a marked distortion of leaves, dwarfing and distortion of the twig, and eventual death of the part diseased.

The known occurrence of this disease in the state is shown on Map 74. It is not yet commonly distributed, but it has a wide range and the damage it causes is often serious. So far as observations go it appears to be rather definitely limited to the Wild Goose group of plums.

It can be controlled in some measure by means of the usual sprays, but their use should be supplemented by pruning out diseased parts, taking particular care to cut a considerable distance below the manifest injury and to have the tools thoroughly disinfected.

Cherry

Cherries like plums are not extensively cultivated in the state on a commercial scale but they are grown almost everywhere to supply home tables and local markets in season. On this account diseases of the cherry are the more common and serious for isolated trees or small orchards usually receive less care than commercial plantings.

Powdery Mildew

Caused by *Podosphaera oxyacanthae* (DC.) De Bary

Cherry is the only one of the Illinois fruits that is commonly subject to attack by a powdery mildew. Early in June, white, powdery spots appear on the under side of the leaves and rapidly increase in size and number thereafter until they cover the entire under surface. The leaves then begin to curl upward and inward and similar patches of powdery mold appear on the twigs.

The damage from this disease results from interference with the functioning of the leaves, and the injury done by the fungus causes early defoliation and a marked stunting of diseased twigs.

The history of powdery mildew on cherry in Illinois reaches back to 1881, when it was found in McHenry, Rock Island, and Piatt counties by A. B. Seymour. In 1882 Seymour found it in Adams and McLean counties. It was reported in Ogle county in 1888 and 1890, in Kankakee county in 1899, in Union county after 1880 by F. S. Earle, and in Champaign county in 1893, 1897, 1911, and 1919. These early reports show its occurrence in nine counties, eight of which lie within the northern half of the state.

As a result of the surveys made in 1921, 1922, and 1923 powdery mildew is now known to occur on the cherry in 65 counties as shown on Map 75. These counties may be roughly divided into two groups, lying respectively in the southern tip of the state and the northern half. Between these groups is a considerable area in which this disease has not yet been found.

Control of this disease is usually satisfactory if the ordinary lime-sulfur spray schedule is followed. If special control measures become necessary, it is best to use sulfur dust. Because powdery mildew is a superficial disease, dusting is effective even when begun after it has made its appearance.

Brown Rot

Caused by *Sclerotinia cinerea* (Bon.) Schroet.

The brown rot of cherry is the same as the brown rot of peach and plum. In Illinois, however, the abundance of sweet cherries explains the rare occurrence of the disease, since they are less susceptible to its attack than sour cherries.

It is known to occur in 14 counties, widely distributed over the state, as shown on Map 76. It is somewhat the most common in southern Illinois.

Leaf Blight

Caused by *Coccomyces hiemalis* Higg.

This leaf blight is similar to leaf blight of the plum and is caused by a similar fungus. It is, in Illinois, the most serious of the diseases to which the cherry is subject.

In late May or early June small, purplish, irregular or angular spots appear on the leaves, which, when badly spotted, turn yellow and fall off. Severe defoliation, which is by no means uncommon under Illinois conditions, results in a serious weakening of the tree.

Leaf blight of cherry is known to occur in 84 counties. Its distribution, as shown on Map 77, indicates a wide-spread and common occurrence in all parts of the state.

It was estimated to have causeed a 1 to 2 per cent crop-loss during the seasons of 1922 and 1923.

Its control is relatively easy, by the use of either lime-sulfur or Bordeaux mixture just after the petals fall and again about two weeks later. If lime-sulfur is used lead arsenate and iron-sulfate should be added.

The black cherry, *Prunus serotina* Ehrh., which has been commonly domesticated, is subject to a leaf blight very similar in appearance to the preceding and caused by a similar fungus *(Coccomyces lutescens* Higg.). Its known distribution in Illinois on black cherry is shown on Map 78.

Bacterial Shot-hole

Caused by *Pseudomonas pruni* E. F. S.

This disease is similar to the disease of the same name on peach and plum, and is caused by the same bacterium. It has been found on cherries in Saline county, in the southern part of the state, and in Knox county in the northern part.

Grape

Grape-growing on a commercial scale is not general in Illinois but it has been developed in more or less restricted areas. Nevertheless, there are to be found in the neighborhood of every town of any size one or more growers who cater to the local market, and it is unusual indeed to find a farm which does not have one or more vines producing grapes for home consumption. According to the 1920 census there were 1,642,527 grape-vines of bearing age in the state, yielding a crop of 10,339,018 pounds in 1919. In addition there were 180,172 vines not yet of bearing age. The distribution of these vines in the state is shown on Map 79.

Concentration of grape-production on a commercial basis occurs especially in territory adjacent to large cities; near Cairo in the south, St. Louis in the southwest, Springfield, Bloomington, and Peoria in central Illinois, La Salle and Chicago farther north, and Rock Island and Moline in the west. The region of greatest production in the state, is not, however, so related. This is the region surrounding Nauvoo, in Hancock county, where nearly 25 per cent of the vines of the state are located and where in 1919 more than 20 per cent of the entire crop of the state was grown.

Aside from the strictly commercial concentration of grape-growing in certain regions, production is more or less general over the entire state. There is no community in which the grape crop does not have some importance, and its total value is undoubtedly great.

Black Rot

Caused by *Guignardia bidwellii* (Ell.) V. & R.

Black rot is the most important grape disease in Illinois. While it attacks all above-ground parts of the vine, it is most commonly seen as a fruit rot and leaf spot.

On the fruit it first appears as a small white spot, which is soon surrounded by a brown ring. The fruit beneath the spot becomes rotten, and small black dots appear upon the surface of the spot. Eventually the entire fruit rots and shrivels to a small, dark mummy. The black-rot leaf-spot appears as a brown, more or less circular spot with a darker margin. In late summer it bears minute black dots on its surface. Stem lesions are charaterized by a dead brown area over which are scattered tiny black dots.

The history of this disease is extensive. It is reported to have been present in destructive amounts in Madison county as early as 1861, and references are made in the Transactions of the Illinois Horticultural Society to a grape disease, probably black rot, which appeared from time to time in Champaign, Hancock, and Madison counties.

Its present known occurrence in the state is shown on Map 80. The 63 counties are so distributed as to indicate that it has a state-wide distribution.

Control is secured in this and other diseases of grapes by the careful and thorough application of sprays.

Downy Mildew

Caused by *Plasmopara viticola* B. & C.

Downy mildew is probably second in seriousness among grape diseases occurring in Illinois. It is especially a leaf disease, but also attacks young stems, fruit, and leaf-stems. On the leaves it appears as white mildewed spots on the lower surface. The leaves first take on a slightly water-soaked appearance where the mildew occurs, and as the spots enlarge they curl upward and inward and are eventually killed. Diseased flowers do not set fruit; and fruit, when attacked, either shells off from the vine or dies and becomes mummified.

The history of this disease in Illinois dates back to 1882, when it was collected by A. B. Seymour at Fall Creek, Adams county. A later collection was made by G. P. Clinton at Urbana in 1892, and Burrill records its occurrence in Champaign county in 1912 and 1913.

Its present known distribution in the state is shown on Map 81. Its occurrence has been demonstrated in 30 counties, with a very irregular distribution suggesting a wide range of occurrence for the disease.

Control is accomplished through the usual sprays.

Anthracnose

Caused by *Gloeosporium ampelophagum* (Pass.) Sacc.

Anthracnose, a disease of lesser importance on grapes in Illinois, attacks all green parts of the vine, but especially the young shoots, berries, leaf stalks, and berry stems. On shoots and other stem parts it causes small reddish brown, somewhat sunken spots, which enlarge to an oval, with a gray and noticeably sunken center. Spots on berries first appear round and dark brown, but are later surrounded by a bright red ring, giving them a marked bird's-eye appearance. The attacked berries eventually rot.

Anthracnose has probably been present in Illinois ever since grapes have been grown in the state. Evidently, however, it has been confused with black rot, so that early reports found in the Transactions of the State Horticultural Society are not definite enough to be dependable.

The present known occurrence of anthracnose is shown on Map 82. Of the 18 counties in which it is known to occur all but three lie in the northern half of the state. The relatively unimportant nature of this disease to the commercial producer is apparent from the fact that, with the exception of the grape regions in Madison, Sangamon, and La Salle counties, anthracnose has not been found in the important grape-growing centers. Its known range in the state appears, from our present information, to be strikingly northern.

A partial explanation of the absence of anthracnose from commercial regions is to be found in the fact that the Concord grape, so commonly grown in Illinois, appears to be markedly resistant.

Where special effort is necessary to control this disease, the usual program of summer spraying, supplemented by a dormant spray (lime-sulfur, 1-8), will be found satisfactory.

Powdery Mildew

Caused by *Uncinula necator* (Schw.) Burr.

Powdery mildew, like the downy mildew, is chiefly a leaf disease, but differs in that it is caused by a fungus which is almost entirely superficial. All young parts of the vine are subject to attack. Whitish, powdery spots appear on the leaves. As the spots grow larger they cause a stunting of young leaves, and older leaves curl upward and eventually die. Mildewed blossoms fail to set fruit, and diseased berries either shell off or are badly deformed or cracked.

It is thought that powdery mildew shares with the downy mildew the place of second importance among grape diseases in Illinois, but observation on distribution and severity are not yet sufficient to show its relative importance clearly.

The earliest definite record of this disease is a collection made at Cobden, Union county, in 1881. Anderson collected it at Urbana, Champaign county, in 1921. Burrill[1] records its presence in Wabash, Union, and Champaign counties.

The present known occurrence of powdery mildew on cultivated grape is shown on Map 83 to include 8 counties, but it is probably much more widely distributed.

The usual sprays suffice for its control.

Brambles

The brambles include raspberries, blackberries, loganberries, and dewberries. Commercial production of these fruits, while of considerable importance for the state, is not scattered uniformly over the state, but appears to be localized in small areas of concentrated production.

All the brambles are subject to the same diseases, but one disease may commonly be severe on one bramble and mild on another. These diseases will, therefore, be discussed from the standpoint of the disease rather than the host, with appropriate notes on susceptibility under each.

Anthracnose

Caused by *Plectodiscella veneta* Burk.

Anthracnose is especially a disease of the raspberry, although blackberries, dewberries, and loganberries are subject to it; but besides the raspberry only the blackberry appears to suffer from it severely.

Anthracnose appears at first on the canes as small, purplish, slightly-raised spots which increase in size, their centers becoming cracked and dull gray. They are usually oval with a raised purplish border, but when numerous they grow together, forming large, irregular, grayish cracked areas on the canes. Similar spots occur on the petioles, leaf ribs, and berry-stems; and more rarely small purplish spots appear late in the season on leaves

Damage done by anthracnose is limited almost entirely to canes, but by direct injury to them the entire plant is weakened. Losses from this disease have been variously estimated. Anderson[2] reports that in 1908 the loss was 8 per cent of the crop. In 1923 it was estimated at 3 per cent.

The earliest Illinois record is in a collection made by Charles Wheeler[3] at Evanston, Cook county, in 1881. Another collection was made by F. S. Earle in Union county in 1884.

At the present time the disease is known to occur in 45 counties, most of which lie in the northern half of the state, as shown on Map 84. Anthracnose appears, however, to have an extensive distribution, including all parts of the state, and an examination of gardens would undoubtedly show its occurrence in every one of our 102 counties.

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[1] Bul. Ill. St. Lab. Nat. Hist. 2: 407. 1887.
[2] Ill. Agr. Exper. Circ. 211: 114. 1920.
[3] Ellis, J. B., and Everhart, B. M. Journ. Myc. 3: 129. 1887.

It is difficult to control, and measures must be thoroughly and conscientiously carried out if the desired results are to be obtained. Lime-sulfur is applied as a spray before growth starts (2½ gallons lime-sulfur to 50 gallons water) and again just before blossoming. New plants should be free from anthracnose when set. In the patch clean cultivation is essential, as the shade and moisture provided by rank weeds are extremely favorable to infection.

Cane Blight

Caused by *Leptosphaeria coniothyrium* Sacc.

Cane blight is known only on the raspberry. Both red and black varieties are subject to attack. This, like anthracnose, is primarily a disease of the canes. The first sign of its presence is a wilting of branches about the time the berries start to ripen. On the canes, below the wilted branches, there may be found at this time diseased areas usually several inches long in which the bark is light-colored and the wood dead and discolored. On diseased bark there appear small black dots, which are often surrounded by smoky halos.

Damage from this disease results first from its direct effect upon the fruit of wilted branches and second from its injurious effects upon the plant itself. The crop loss from it in Illinois is estimated at about 0.5 per cent annually.

The earliest report we have of cane blight in Illinois is one by Burrill, mentioning its occurrence during 1912 in Kane and Randolph counties. These two occurrences, one in the extreme north and one in the extreme south of the state, indicate that at that time it may have been much more widely distributed over the state than was supposed.

Its present known occurrence in the state is shown on Map 85. It has been found in 36 counties, and has a wide though irregular distribution, reaching both the southern and the northern borders of the state. Southward, its occurrence is only occasional, as shown by the few counties in which it has been found, and the limited number of times it has been seen. The northern third of the state appears to be an area of concentrated occurrence, from which more than 60 per cent of our specimens and reports have come.

Control of cane blight can be attained in some measure through the use of resistant varieties. The Columbian is reported to be very resistant, and the Cuthbert most susceptible. Sprays applied for other diseases are helpful but do not prove satisfactory alone. The nature of the disease and its life history suggest that new plants should be free from it when set, that old canes should be cut out and burned as soon as possible, and that care should be taken in cultivation to avoid injuring canes and thus providing points of entrance for the fungus.

Spur Blight

Caused by *Mycosphaerella rubina* (Pk.) Jacz.

Spur blight, or "gray bark," is a disease of the red raspberry. It appears on young canes as a brownish discoloration, located usually just below the leaf stems on the lower parts of the canes. It can be seen after about the middle of July. The diseased area then enlarges lengthwise of the stem for several inches above and below the nodes, and the bark becomes dry and brown, and splits longitudinally. Later, usually in September, tiny black spots appear on the diseased areas.

The damage done by this disease is of the same nature as that done by anthracnose and cane blight. Spur blight is, however, so uncommon that the actual loss in the state is slight.

The present known occurrence of spur blight in Illinois is shown on Map 86. It has been found in six counties only, all of which are in northern Illinois.

Control is not usually necessary, but where desirable may be attained by the application on young canes only of 3-2-50 Bordeaux mixture to which has been added two pounds of rosin-fish-oil soap. Four applications should be made, at two-week intervals, beginning when the canes are 8 to 12 inches high.

Leaf Spot

Caused by *Mycosphaerella rubi* Roark

Leaf spot, also known as Septoria leaf-spot, is the most common of the bramble diseases. Red raspberry and dewberry are most susceptible to it but it is unusually abundant on all the brambles. It begins to appear early in June as small purplish spots on the leaves. These enlarge somewhat, their centers turn gray or ash-color—on the blackberry tan or brown—with a definite purple border. Eventually minute black dots appear scattered over the spots.

Injury from this disease is usually limited to the leaves, but canes may sometimes be diseased. In favorable seasons infection may become so severe as to cause early and damaging defoliation.

The earliest record of this disease is a report of its occurrence in Illinois in 1887 by G. Martin[1] under the name of *Rhabdospora*. No specific locality is given. Under the name of *Septoria rubi* West., it was reported by Burrill in Champaign county in 1911 and in Champaign and Union counties in 1912.

It is now known to occur in Illinois as indicated on Map 87. It has been found in 35 counties widely distributed over the state. Its distribution is not uniform, however, and occurrence is rare northward. It increases in frequency southward, until in the southern third of the state it appears to be abundant everywhere.

[1] Journ. Myc. 3: 90. 1887.

It is rarely necessary to employ control measures against this disease. When necessary, either lime-sulfur or Bordeaux, made up according to the 3-2-50 formula to avoid injury from stronger mixtures, will be found satisfactory.

Orange Rust

Caused by *Gymnoconia interstitialis* (Schlecht) Lagerh.

Orange rust, the most conspicuous and one of the most serious of the bramble diseases, is in Illinois especially a blackberry disease. It is easily recognized by the striking orange color of the leaves of infected plants in spring.

In late April or early May small greenish-yellow spots appear on the under surface of the leaves of infected plants, and within a few weeks the leaf surface ruptures, exposing large patches of orange spores on the lower surface. The disease is systemic, and persists within the plants from year to year, dwarfing, deforming, and eventually killing them. All sprouts from runners of diseased plants are infected.

The history of bramble orange rust in Illinois dates back to 1850. Its present known distribution on economic hosts is shown on Map 88. It appears to be more common and more abundant southward, and is rather rare in the northern third of the state.

Control is to be had only by digging out and burning infected plants. The disease pervades all parts of the plant, persisting there until the plant dies. Infection may be prevented to some extent by planting resistant varieties, such as Snyder, and by taking care to eradicate all wild blackberries in the neighborhood.

Crown-gall

Caused by *Pseudomonas tumefaciens* E. F. S.

Crown-gall, while occurring on all the brambles, is in Illinois particularly destructive to red raspberries. Damage from this disease is extremely serious and is said to be the most important of the factors limiting raspberry production in the state at the present time.

Its known occurrence is shown on Map 89. It has been found in 28 counties widely scattered over the state, but appears to be less common southward.

Plants in the nursery suffer most from it, and it is there that most plants become infected. If the grower would avoid loss from this disease he must insist on plants absolutely free from infection.

Bramble-streak

The so-called bramble-streak is a disease affecting only the blackcap raspberry. In other states it is said to be extremely serious.

It was first found in Illinois by A. S. Colby near Peoria in 1922.

Observations during the season of 1923 have established its occurrence in 6 additional counties, distributed as shown on Map 90.

No definite cause is known for it, but it appears to be serious where seen and should receive prompt attention from growers. The only control known is to dig out and burn diseased plants.

Leaf Blight

Caused by *Cercospora bliti* Tharp

This bramble leaf blight, first described in Texas and said to be serious there, was found in 1922 in Jackson county, Illinois. It is caused by a fungus which makes large inroads upon leaf-tissue and may cause serious defoliation.

Powdery Mildew

Caused by *Sphaerotheca humuli* (DC.) Burr.

Powdery mildew is of rare occurrence in Illinois and causes no damage. It has been found in Champaign, Ogle, and Marion counties on blackberry; and on raspberry in Ogle county. On dewberry it has been found in Champaign county; and on the native wild blackberry, in Marion county.

Gooseberry and Currant

These two fruits are not grown to any great extent commercially in Illinois, but they are extremely common in the home gardens. As with the brambles, their diseases are so largely the same for both that they are discussed together.

Anthracnose

Caused by *Pseudopeziza ribis* Kleb.

Anthracnose is the most important disease of gooseberry and currant and occurs commonly on both. On leaves it has the form of dark or reddish brown, very small spots, scattered over the upper surface in greater or less numbers. These spots enlarge only slightly, and as they grow old develop a single black dot in their center. Seriously infected leaves become mottled, or turn yellow and fall early in the season.

Damage done by this disease results from the injurious effects of premature defoliation, from spotting of the fruit, which sometimes occurs, and from poor development of fruit, due to infection of the fruit stems.

The present known occurrence of the disease in Illinois is shown on Map 91. It has been found in 21 counties, widely distributed over the state.

Control is secured, when necessary, by the use of lime sulfur (1-50), making the first application as soon as the leaves appear, and following with additional treatments every fortnight until about the first of August.

Leaf Spot

Caused by *Mycosphaerella grossulariae* (Fr.) Lind.

The leaf spot of currant and gooseberry is, like anthracnose, chiefly a leaf disease. While both fruits are commonly subject to it, currants usually suffer the more severely.

It appears on the leaves as spots, more or less circular in outline, from one eighth to a quarter of an inch in diameter, and with a dark reddish or brownish margin, within which is an area of dead, brown leaf-tissue, over which a number of tiny black dots are scattered. Injury takes the form of a yellowing and dying of the leaf, followed by early defoliation.

The larger size of the spots, the central dead area, and the numerous tiny black dots serve to distinguish leaf spot from anthracnose.

Not many early reports of this disease in Illinois appear to have been made. At present it is known to occur in 30 counties, which are grouped in three districts, as shown on Map 92. In the north, leaf spot has been noted in 5 counties and a majority of the reports show that it occurred in this region especially on red currant. In central-eastern Illinois reports from 4 counties note its occurrence especially on the flowering currant. In the southern tip of the state leaf spot appears commonly prevalent and abundant through 20 counties. In this region gooseberries and currants are both commonly found diseased, though here there is again a majority of reports on currant.

For control of leaf spot, the same application as for anthracnose will be found effective.

Powdery Mildew

Caused by *Sphaerotheca mors-uvae* (Schw.) B. & C.

Powdery mildew is of less importance than leaf spot. Both currant and gooseberry are subject to its attack, but it is more frequent on gooseberry.

It appears, like other powdery mildews, as a white, powdery growth over the leaves. Berries and young shoots are often attacked. The injury consists in stunting the growth of leaves and shoots, and in disfiguring the berries to the extent of making them unsalable.

Powdery mildew has been known to occur in Illinois since 1881, when it was found in McLean county, and it has since been reported in La Salle, Pulaski, and Gallatin counties.

It can be controlled by the use of lime-sulfur (1-40) spray applied when the buds open and at 10-day intervals thereafter until 5 applications have been made. A better spray, since no injury to the fruit results from its use, is potassium sulphid, one ounce in 2 gallons of water.

Strawberry

Among the fruits raised for commercial sale in Illinois the strawberry occupies a leading position—second, it is said, only to the apple. That this is true may be understood if it be remembered that in addition to extensive areas of production for large-city markets there is usually one gardener at least near every town of any size who maintains a patch ranging from half an acre to five or more acres to supply the seasonal demands of the town.

According to the U. S. Census report for 1920 there were in the state 4958 acres given over to strawberry culture from which 6,901,199 quarts of berries were harvested. The regional distribution of commercial production corresponds to that of the acreage devoted to strawberry culture, which is shown on Map 93. There is a considerable concentration of strawberry production in western Illinois in Adams, Hancock, and McDonough counties; in northern Illinois in Winnebago county; in central Illinois in Macon and Sangamon counties; and southward in Williamson and Johnson counties. The greatest commercial production occurs, however, in Pulaski county (480 acres), Fayette county (330 acres), Union county (310 acres), and Marion county (160 acres).

According to the U. S. Bureau of Markets, commercial acreage during the years 1918-1923, inclusive, ranged from 3000 to 3590 acres, yielding from 48 to 79 crates of 24 quarts each, per acre. The total annual yield of the state for this period ranged from 383 to 566 cars of 400 crates each.

According to the same authority the crop of 1921—some 175,600 crates—sold for $3.77 per crate, making a total value of $662,245 for the commercial crop reported on. This statement includes only about three fourths of the acreage reported in the census tables, and a total value for the entire state of nearly $883,000 is a reasonable estimate.

Mycosphaerella Leaf-Spot

Caused by *Mycosphaerella fragariae* (Schw.) Lind.

Leaf spot is the one extremely important strawberry disease commonly occurring in Illinois. It is limited, for the most part, to the leaves, on which it produces spots which are at first minute, purplish red, and apparent only on the upper surface. Later they enlarge and show on both surfaces as circular spots with a small light-brown central area surrounded by a distinct purplish ring. An abundance of them on a leaf often causes its death.

Spots of similar appearance often occur on the leaf and on fruit stems, and when on the latter they may so weaken it as to reduce the size and quality of the fruit.

At the present time this disease is known to occur in 85 counties, the state-wide distribution of which is shown on Map 94. It is probably to be found everywhere throughout the state.

It is so common and so generally injurious that the reduction in yield has been estimated for several years past at between 10 and 12 per cent. In 1921 a reduction of 10 per cent would have meant a loss from the commercial crop of practically 17,300 crates or slightly more than 44 cars, equivalent to 6 crates per acre, or a reduction of the average acre yield from 60 crates to 54.

Control where necessary may be had by an application of Bordeaux mixture before the blossoms open and again at intervals after harvest. Cleaning off infected leaves when new plants are set also helps.

Dendrophoma Leaf-Spot

Caused by *Dendrophoma obscurans* (Ell.) And.

A second leaf-spot, less common than the preceding, but sometimes very injurious, produces rather large brown spots, surrounded by a diffused darker brown or purplish border of considerable width. If the attack is severe a large part of the leaf may be involved, considerably reducing its effective surface.

The first reports of this disease in Illinois were made by Anderson in 1920.[1] Since then it has been seen frequently, and its present known distribution is shown on Map 95. It is known to occur in 12 counties widely distributed over the state. The district of most frequent occurrence, so far as now known, lies in central Illinois, and it is in this region also that reports of greatest severity originate.

Leaf Scorch

Caused by *Mollisia earliana* (E. & E.) Sacc.

This is a leaf spot of strawberry of relatively infrequent occurrence. H. W. Anderson[2] first reported its occurrence in Illinois in Champaign county in 1921 on certain varieties imported from Michigan. It has not been reported from any other part of the state.

Control of Fruit Diseases

Diseases of fruits are chiefly controlled either by spraying with suitable preparations or by the cutting out of diseased parts. Other practices which are helpful have already been mentioned in connection with the diseases for which they are effective. A combination of sprays with insecticides is often useful as controlling the ravages of both diseases and insects.

[1] Anderson, H. W. Dendrophoma leaf blight of Strawberry. Ill. Agr. Exp. Sta. Bul. 229. 1920.

[2] Plant Disease Survey Bulletin. Supplement 20: 107. 1922.

Two sprays are in common use and have generally been found satisfactory. These are Bordeaux mixture and lime-sulfur, both of which are obtainable as commercial preparations or may be made up as needed. When small quantities are wanted, commercially prepared Bordeaux mixture is satisfactory; and when lime-sulfur is used, it is generally more convenient to use a ready-made material. Descriptions of these sprays, the methods of preparation, and the times of application are to be found in publications of the Illinois Agricultural Experiment Station, especially Circular No. 277, "Directions for spraying fruits in Illinois," published jointly by the Department of Horticulture and the Natural History Survey in February, 1924.

Diseases of Vegetable Crops

Potato

In the production of potatoes Illinois held in 1922 the sixteenth place, while in acreage it was twelfth. According to the Census reports for 1920 there were 86,384 acres devoted to potato-growing in the state. The distribution of the commercial acreage as reported in 1922 is shown on Map 96, each dot representing approximately 500 acres. From this map it appears that St. Clair county is the outstanding producer, with a noticeable extension of the industry into counties immediately to the north and south. A second area of intensive growing is found in northern Illinois, beginning in Rock Island county and running more or less continuously through the border counties of the state north, east, and then south to include Will county, with Whiteside and Cook counties leading in acreage.

The potato crop is estimated to have ranged from 5,200,000 bushels in 1919, valued at $10,192,000, to 9,568,000 bushels in 1923, valued at $8,420,000.

Early Blight

Caused by *Alternaria solani* (E. & M.) J. & G.

Early blight is the commonest potato disease in Illinois. It appears on the leaves as circular grayish to brownish spots, dry, dead, and concentrically marked. They first appear about the time the tubers begin to form, and gradually increase in size and number, coalescing and occupying large areas of leaf tissue. In severe cases all the leaves on the plants may be completely killed, leaving only the stem alive and green.

Burrill recorded the presence of this disease in Champaign county in 1911. During 1922 and 1923 it was found in 15 counties, the distribution of which is shown on Map 97. It appears from this map that it is more common in the southern half of the state than northward.

Crop reductions from early blight have been estimated at 1 per cent in 1922 and 1.5 per cent in 1923, equivalent to 68,000 bushels valued at $61,200 and 145,000 bushels valued at $127,600 for the years mentioned.

Late Blight

Caused by *Phytophthora infestans* (Mont.) De Bary

In most of the states where potato growing is important, the most dreaded disease is late blight. In Illinois it was first reported in 1882 by A. B. Seymour, who collected specimens August 7 at Camp Point, Adams county, and at Freeport, Stephenson county, September 13. A collection by Burrill, without date or place, is reported by G. W. Wilson.[1]

These are the only records of the occurrence of late blight in Illinois. It is noteworthy that in all the examinations of potato fields made by our Survey during the past three seasons no instance of late blight has been found. It has never been known to cause serious loss in Illinois.

Scab

Caused by *Actinomyces scabies* (Thax.) Güss.

Scab is a very common tuber disease of the potato in Illinois. It is characterized by roughening and pitting of the tuber. It first appears on the surface of the tuber as a tiny reddish or brownish spot, which increases in size, deepens in color, and eventually develops the rough, corky incrustation so commonly seen.

It has not been widely reported in Illinois. It was reported present in Champaign and Coles counties in 1911, and in Champaign county in 1912 by Burrill. It is now known to occur in 16 counties, the distribution of which is shown on Map 98. This indicates a wide range over the state, and it is probable that further search will prove the disease to be much more general than it now appears to be. Observations made in 1923 indicated an injury equivalent to a crop reduction of approximately 1 per cent. In terms of the 1923 yield, this is equivalent to 96,000 bushels valued at $84,400.

Control of scab is difficult, since the disease infests soil in which it has once occurred. Rotation of crops on infected soil, treatment of infected seed-potatoes with formalin or mercuric chloride, and withholding fertilizers which favor scab development serve to keep the disease in check.

Black Leg

Caused by *Bacillus astrosepticus* van H.

This is a bacterial disease which causes a stunting of the plants and a rotting of the stem below the ground, later resulting in the death of the plant. It was present, but not seriously abundant, in 1923 in three counties, Logan, Lawrence, and Monroe. It is seed borne, and prevention demands careful selection and treatment of seed tubers.

[1] Bul. Torr. Bot. Club. 34: 392. 1907.

Black Scurf

Caused by *Rhizoctonia* sp.

This disease, which results in blackened, rotted stems, the wilting and dying of young shoots, and aerial tubers, has been found but once in Illinois, in July, 1922, near Ryder, Jefferson county.

Infection arises from diseased tubers and from soil infection. Preventive measures include use of clean seed, crop rotation, and general sanitary practices in field cultivation.

Wilt

Caused by *Fusarium* sp.

The wilt disease results in wilting and stunting of the tops, death of roots, and serious storage rots. It was found in 1923 in Lawrence county. In a small field of Irish Cobber practically all the plants were diseased, and it appeared that the loss would be severe. As a preventive measure, the use of infected tubers for seed should be avoided.

Curly Dwarf, or Mosaic

This disease, of unknown cause, results in stunted and variously deformed plants, mottled coloring of the leaves, and noticeably reduced yields. It is probable that it is wide-spread in the state, but it has been noticed thus far only in Carroll county, where it was found in several fields in 1923. Its history there indicated that it had been present for several years. It is seed borne, and tubers for seed should be selected from fields free from disease.

Tomato

The tomato is an important crop in Illinois. In 1921 there were only 9 states having a greater acreage, and in the same year the total commercial crop was exceeded by only 8 states. During the years 1918-1921 the tomato acreage in the state varied from 7,064 to 9,355 acres; and the yield, from 24,724 tons to 59,584 tons. This crop is used for local consumption, for immediate distribution and sale, and for canning and the manufacture of tomato products.

In addition to the commercial crop of the state, growers maintain small patches in the neighborhood of towns, from which the local seasonal market is supplied.

The tomato is subject to a variety of diseases, several of which are similar to those of the potato.

Early Blight

Caused by *Alternaria solani* (E. & M.) J. & G.

Early blight is one of the commonest and most wide-spread of tomato diseases in Illinois. It causes numerous small, more or less angular, concentrically-marked spots upon the leaves, and when serious infection occurs the leaves dry up and die.

As shown on Map 99, it has been found in 17 counties.

The severity of the disease, as indicated by field observations, indicates an injury equivalent to a 4 per cent reduction in the crop for each of the years 1921, 1922, and 1923. Such a percentage, when applied to the commercial product of 1921, the last year for which published figures are available, represents a reduction in yield of 1,030 tons, equivalent to the yield of 294 acres.

Control is readily obtained by spraying with Bordeaux mixture, beginning at the first sign of the disease and continuing the application every 3 to 10 days through wet weather.

Wilt

Caused by *Fusarium lycopersici* Sacc.

Wilt, the most destructive of the tomato diseases in Illinois, gains entrance through the roots and penetrates the water-conducting tissues, plugging them and causing a wilting, and finally the death of the plant. A characteristic feature of the disease is the fact that besides causing the plants to wilt it turns the sap vessels brown or black. Usually the disease does not become evident until after the fruit has set.

This disease is known to have been in Illinois since 1911, in which year Burrill reported that it was becoming very serious. Presumably he referred to its occurrence in Union county. The following year he reported it as wide-spread in southern Illinois, and according to C. E. Durst probably 50 per cent of the crop was destroyed in Union county.

Tomato wilt is now known to occur in 22 counties, the distribution of which is shown on Map 100. It appears to be limited to the southern two-thirds of the state, and is most common in the southern third.

Field observations made in 1922 and 1923 indicated an injury equivalent to a crop loss of 10 and 12 per cent respectively. If the average of these figures be applied to the 1921 production it would mean a crop reduction of 3,055 tons, equivalent to the yield from some 870 additional acres.

The fungus causing tomato wilt persists in the soil after it is once introduced, and control can be secured only through a rotation of crops, whereby tomatoes are kept off the infected ground for several years.

Leaf Spot

Caused by *Septoria lycopersici* Speg.

Tomato leaf spot is wholly a disease of the leaves. It starts on the lower part of the plant and eventually involves all the leaves. Those severely spotted turn brown and appear blighted, and when the disease is severe throughout a patch serious damage results.

In 1911 leaf spot was reported by Burrill in Champaign county and in a group of 8 counties in southern Illinois; but in 1912 in Champaign county only.

At present leaf spot is known to occur in 26 counties, the distribution of which is shown on Map 101. It appears to be wide-spread over the state, but in northern Illinois it is only occasional, while in southern Illinois it is apparently common.

Loss from this disease is not usually great, but may at any time become so. Control is readily obtained with Bordeaux mixture.

Sweet Potato

According to the 1920 census, there were 8,003 acres in Illinois devoted in 1919 to the raising of sweet potatoes, with a yield of 668,845 bushels. According to the reports of the State Agricultural Statistician the acreage since 1919 has been about 9,000 acres, yielding between 850,000 and 990,000 bushels, valued at from $890,000 to $1,179,000.

Only 8 counties are reported to have no commercial acreage in 1922. For the most part the county acreage is small, running from 3 to 90 acres. Union county is an outstanding producer, with an acreage of 1,974. Johnson and Pulaski counties each has over 500 acres and Williamson over 400. The acreage of important counties is indicated on Map 102. The principal sweet potato region lies, therefore, in southern Illinois, with a considerable acreage also in Adams and Cass counties.

Illinois shares fifteenth rank in acreage with Delaware and Maryland. In yield per acre it ranked seventh in 1921, and in total production in the same year it ranked sixteenth.

Two diseases appear to be common in Illinois.

Black Rot

Caused by *Sphaeronema fimbriatum* (E. & H.) Sacc.

Black rot is the most serious disease of sweet potato in Illinois. Dark brown to black spots appear on the surface of the potato and extend in all directions, finally involving the entire root. In storage the rot is also extremely destructive.

This disease is known to occur in Illinois in the six counties indicated on Map 103. They are widely distributed over the state but include only two counties—Pulaski and Cass—with a large sweet potato acreage.

For a control of this disease the use of disease-free roots in starting cuttings, the maintenance of seed beds free from the disease, and the cultural practices used for all soil-infecting diseases are essential.

Wilt

Caused by *Fusarium* sp.

Sweet potato wilt, known also as stem-rot, is caused by a species of Fusarium which grows within the plant, killing and rotting the roots and causing the wilting and death of the tops.

It is known to occur in 8 Illinois counties, rather widely separated, as shown on Map 104. Three of the 8 counties have important commercial acreages. Where the disease has been seen it has been severe in the extreme. The loss in Cass county, on the Nancy Hall variety, ranged from 5 to 10 per cent, in two Union county fields from 5 to 10 per cent, and elsewhere from 1 to 10 per cent.

Control involves the use of healthy seed, clean soil in the seed-bed, and a consistent rotation of crops on infected land.

Cantaloupe

During the years 1918-1921 the commercial cantaloupe acreage in Illinois varied from 865 to 883 acres, the state ranking 14th in acreage of this crop. The yield per acre varied from 142 to 200 standard crates of 45 melons each, and the total yield varied from 356 cars (350 crates per car) in 1918 to 505 cars in 1921.

In addition to this commercial crop there is probably an equal production by local growers who supply the small-town seasonal markets.

The commercial production of cantaloupes, while carried on more or less generally over the state, is usually confined locally to a relatively small area, where suitable soil conditions exist.

Diseases of the cantaloupe, while not numerous, may often be severe.

Wilt

Caused by *Bacillus tracheiphilus* E. F. S.

Wilt is a bacterial disease which causes the vine to wilt and die. It has probably been present in Illinois for years but it has not been often reported. Burrill found it in Union county in 1912, and it was seen in 1922 in the Poag Station melon-district in Madison county, and was more widely observed in 1923.

At present it is known to occur on cantaloupe and muskmelon in 18 counties, the distribution of which is shown on Map 105. It appears wide-spread in the state, with none of the larger areas of production free from it.

Losses due to it as observed in the field during 1923 especially, varied usually from 1 to 10 per cent; more rarely, from 20 to 30 per cent.

Control is obtained by pulling and burning diseased plants, by crop rotation, and by spraying to prevent its spread by insects.

Anthracnose

Caused by *Colletotrichum lagenarium* (Pers.) E. & H.

Anthracnose is a fungus disease which attacks leaves, stems, and fruit of cantaloupe doing serious damage, especially to the fruit under favoring weather conditions. It has not been frequently reported in Illinois, but is known to occur in 8 counties so widely scattered over the state as to indicate its rather general prevalence. Counties in which it has been seen are Carroll, Rock Island, Henderson, Knox, Pike, Lawrence, Gallatin, and Union. The infections seen in Knox, Lawrence, and Gallatin counties were generally severe, while those occurring elsewhere were, for the most part, light.

This disease is controlled by treatment of the seed and by the application of Bordeaux spray (4-4-50) later in the season.

Mosaic

The mosaic disease of cantaloupes, the cause of which is not known, results in a stunting of vines and a poorer crop. It has not been frequently reported. At present it is known to occur in Whiteside, Sangamon, Christian, and Union counties. Rocky Ford melons in Christian county showed 30 per cent of the plants diseased and in Whiteside county Tip-top melons showed infection, while Osage and Rocky Ford plants were free from it.

Milkweeds are said to be subject to the disease, which is carried by insects from them to the cantaloupe.

Watermelon

The acreage devoted to watermelons in Illinois for commercial production varied from 1,100 acres in 1918 to more than 3000 acres in 1919 and 1921 and to nearly 3000 acres in 1920. The yield is said to run from 274 to 615 melons per acre, the latter figure being the average yield in 1921. Total production in 1920 was 1,014 cars of 1000 melons each, and in 1921 it was 1,894 cars. Production for local markets adds considerably to this acreage and yield.

The watermelon is subject to several diseases, some of which are also common to the cantaloupe and cucumber.

Wilt

Caused by *Fusarium niveum* E. F. S.

Wilt, undoubtedly the most serious watermelon disease in Illinois, results in a drooping and wilting of the leaves, and eventually in the death of the plant. The fungus which causes it lives in the soil, gains entrance through the root, and at first plugs the water vessels, later bringing about the death of the parts attacked. Cutting across the main root near the crown of the plant shows an abnormal yellow color in the woody parts.

First reports of this disease in Illinois were made in 1921 by Anderson, who found it serious locally. In 1922 it was so severe where seen, as to cause a general loss of 25 per cent of the crop. In 1923 wilt appeared less severe but was thought to have resulted in about a 20 per cent crop reduction.

It is now known to occur in 21 counties, widely distributed, as indicated on Map 106, and representative to a marked degree of the regions in which melon culture is important, thus suggesting that wilt is widespread and common in Illinois.

Its seriousness may be illustrated by a summary of some of the 1923 field notes. In Cass county in a 10-acre field of melons, largely Irish Gray, more than 90 per cent of the vines of that variety were dead by September first. In a two-acre field in Mason county more than 50 per cent of the vines were dead by August 31. In Henderson county some 20 acres devoted to melons, especially Irish Gray and Excel, showed 80 to 90 per cent of the vines dead before the melons ripened. It is reported that in White county, where there is a large melon acreage, the wilt completely destroys the crop in many individual fields. In Johnson county 50 to 100 per cent loss is reported. In Gallatin county 5 to 15 per cent loss commonly occurs, but in a 7-acre field of Tom Watson melons 85 per cent of the plants were dead by August 6. In Lawrence county the variety Excel suffered to the extent of 20 to 60 per cent. These notes, while not representing the condition of infection in the average field, are certainly illustrative of the damage this disease can cause.

To escape these tremendous losses, it is necessary to understand that the fungus which causes the disease inhabits the soil and that when soil has once become infected it may remain so for years, producing the disease in every watermelon crop planted on the land. If watermelons are cropped on the same land year after year it is to be expected that within a few years it will be impossible to grow melons profitably on that land. This soil infection is commonly noticed by growers, and there is much doubt whether land once infected with wilt can ever be profitably used again for melons. One grower reports severe wilt on land not cropped to melons for eleven years; another reports bad wilt after 23 years; another, who practices a 3-year rotation, finds he has large losses; and another, after an 8-year rotation, found his crop severely diseased. Certainly it is not safe to crop wilt-infected land to melons short of a 10-year lapse in such cropping. Additionaly care must be taken to grow crops which will not be likely to spread the infection to the manure heap, and thence to all parts of the farm.

The ultimate solution of the problem of wilt control will probably be found in the development of wilt-resistant varieties. This task has been undertaken and is already yielding promising results.

Anthracnose

Caused by *Colletotrichum lagenarium* (Pers.) E. & H.

Anthracnose of watermelons is usually less severe in Illinois than wilt. However, during the 1923 season unusual weather so favored its development that in many places it resulted in damage so severe as to obscure completely the effects of wilt. Anthracnose causes severe spotting of the leaves and, in serious cases, death of the vine. Sunken diseased spots are produced on the melons which mar their appearance and furnish points of entrance for rot-producing fungi.

This disease has not been reported often in Illinois in years past. The first known outbreak of a serious character occurred in 1923 in the four counties indicated on Map 107. Perhaps it is merely a coincidence that the counties in which anthracnose was found lie in approximately the same latitude. In Mason county certain fields were seen in which 80 per cent of the melons showed anthracnose spots; and in Clark county many fields were a total loss.

Control of anthracnose may be had by treating the seed with mercuric chloride (1-1000) before planting and by the application of Bordeaux about picking-time. Seed treatment alone may result in a great reduction of disease, as was illustrated in one case in 1923, where only 3 per cent of the crop from treated seed was lost, while neighboring fields grown from untreated seed were complete failures.

Cucumber

The production of cucumbers in Illinois, aside from those raised by local gardeners to supply local markets, appears to be largely limited to production for canning and manufacturing purposes. Available figures indicate a rather steady reduction in acreage, yet the state is still among the important producers, and there are sections of it in which cucumbers are an important crop. Estimates indicate a commercial acreage varying from 1700 acres in 1918 to 844 acres in 1921, with an annual production ranging from 90,600 bushels in 1918 to 67,500 bushels in 1921. The average yield per acre for both years was 51 bushels.

In general the cucumber is subject to the same diseases as are cantaloupe and watermelon, though their relative importance is less in the case of the cucumber.

Wilt

Caused by *Bacillus tracheiphilus* E. F. S.

Cucumber wilt is a bacterial disease caused by the same organism that causes the wilt of cantaloupe, and its appearance is practically the same on both.

It has not been reported often in Illinois, and the infections that have been seen have usually been mild. In 1922 it was reported in 6 counties and in 1923 in 11 counties additional, making a total known occurrence in 17 counties. They are widely distributed over the southern two-thirds of the state, as shown on Map 108, suggesting a wide-spread occurrence of the disease in that section of the state.

Its seriousness in 1923 is indicated by some of the field notes. In Sangamon county certain patches showed from 10 to 40 per cent of the plants infected; in Effingham county we have a record of a 10 per cent infection, and a similar record for two patches in Warren county; in Lawrence county 60 per cent infection was recorded; from Union and Alexander counties there were several reports of 1 to 2 per cent, one from Alexander of 5 per cent; and another from Clinton county of 20 per cent; and in Union county in some of the larger fields 20 to 100 per cent of the plants were infected.

Control in this case is the same as that outlined under cantaloupe. (See p. 244.)

Anthracnose

Caused by *Colletotrichum lagenarium* (Pers.) E. & H.

Anthracnose of cucumber is similar to that of watermelon and cantaloupe and is caused by the same fungus.

Doolittle's report of it in Illinois in 1922 is the first record of its presence in the state. In 1923 it was found in Union county, where in many instances it appeared to be a troublesome disease. It was especially prominent near Dongola and Balcom, where the percentage of infected vines varied from 20 to 100. Observations made on about 6 acres in this region indicated the probability of considerable damage resulting from the attack.

Control is to be had through seed treatment and spraying, as indicated for watermelon anthracnose (p. 247).

Mosaic

Mosaic, next to wilt, is probably the most important disease cucumber growers have to contend with in Illinois. While the cause of it is unknown, its appearance is familiar to most growers, who know it not only as mosaic, but also as "leaf-mottle" and "white-pickle."

Bierbaum reported the disease in Union county in 1922, and in 1923 it was found in Union, Sangamon, and Macon counties. Wherever found it has been serious. In Macon county 30 per cent of the plants seen were diseased. In Union county in many fields from 50 to 75 per cent of the plants were diseased, and in one instance 80 per cent of the cucumbers picked for pickling showed its presence. In Sangamon county the percentage of infected plants varied from 15 to 70 per cent.

Control consists in keeping in check such insects as spread the disease from plant to plant, and in eradicating wild cucumbers and milkweed plants from the neighborhood of the field since both of these are subject to the disease and serve to introduce it into the cropped fields.

Downy Mildew

Caused by *Pseudoperonospora cubensis* (B. & C.) Rostow

The downy mildew disease appears as a leaf spot, which may be very destructive under favoring conditions. It was reported by Burrill to have occurred in Union and Effingham counties in 1911, and this is our only report of its presence in the state.

Angular Leaf-spot

Caused by *Pseudomonas lachrymans* E. F. S. and Bryan

The angular leaf-spot of cucumber, caused by a bacterium, is not known to have occurred in Illinois previous to 1923. During that season, it was seen occasionally in Union county and once in Pulaski county. In a 5-acre field in Alexander county practically all the plants were diseased, but the infection was light and little damage resulted.

Asparagus

The land devoted to asparagus-growing in Illinois averages annually nearly 2000 acres for commercial production, and the annual yields per acre is above 95 crates. The annual yield of the state for commercial purposes is about 332 cars of 600 crates each. Illinois ranks either second or third in commercial production, and California is the only state which greatly exceeds it.

Asparagus is subject to two diseases in Illinois, both important, not only to the commercial grower, but to the many gardeners who cater to local markets, and in the home garden.

Rust

Caused by *Puccinia asparagi* DC.

Asparagus rust is widely distributed and often serious in its effects. It has the appearance of the rust described on other plants.

It is not known how long this disease has been present in Illinois, but it was probably first recorded here in 1899. Since that time it has been frequently seen and reported.

It is now known in 30 counties, distributed over the state as shown on Map 109. It appears prevalent in two sections of the state—one in southern and one in northern Illinois, and its presence in Champaign, Edgar, and Coles counties probably indicates a wider distribution.

Its control lies in the use of varieties not susceptible to rust. Among these are the Palmetto varieties and resistant strains of Washington asparagus. Additional control may be gained by dusting with sulfur or spraying with sulfur-soda-soap.

Anthracnose

Caused by *Colletotrichum* sp.

Anthracnose of asparagus has not been often reported. It produces on the stem a light-colored spot of considerable size which becomes covered by black dots, composed of the reproductive structures of the fungus.

Its only known occurrence in Illinois was at Polo, Ogle county, in 1922 and it was not serious there.

Beet and Swiss Chard

Beet and Swiss chard are among the commonest of the garden vegetables. It is seldom that a garden, no matter how small, does not have at least its row of beets, and local gardeners usually grow a considerable quantity for sale in season at their local markets. There is one disease common to both plants.

Leaf Spot

Caused by *Cercospora beticola* Sacc.

Leaf spot is the only serious disease of these vegetables known in Illinois. It appears as roundish gray-brown spots with purple borders, often so numerous as to destroy the leaf, resulting in smaller roots, and spoiling the leaves for use as greens.

It has been known in Illinois at least since 1888, when it was found in Champaign county by M. B. Waite. It is known at the present time in 67 counties, the distribution of which is shown on Map 110. It is evidently wide-spread and common in the state.

Cabbage

Beginning with 1919, Illinois has ranked among the states growing important cabbage crops. An acreage of from 1300 to 1600 acres, with an annual yield per acre of from 5 to 8 tons and a total production for commercial purposes of from 530 to 1040 cars of 12.5 tons each, places the state high in the list as to cabbage production. If the diseases of this crop were under control the yield per acre might equal or exceed that of Wisconsin and Michigan.

Yellows

Caused by *Fusarium conglutinans* Woll.

Cabbage yellows stands out pre-eminently as the limiting factor in cabbage production in Illinois. It is commonly known as "yellows," "yellow-sides," and "dry-rot." Its first symptom is a yellowish color of the lower leaves, often restricted to one side of the plant or even to one side of the leaf, which first appears from two to four weeks after trans-planting. The yellow leaves are eventually shed, and the plant may die, or, if it continues to live, it produces a long leafless stem capped by a small and worthless head.

How long this disease has been present in Illinois is not known. Burrill reported it in Cook county in 1911, with the note that it was doing considerable injury. In the following year he reported it from Madison and St. Clair counties, as causing there a 50 per cent loss, estimated at $35,000.

It is at present known in 22 Illinois counties as shown on Map 111, which may be taken to indicate in a measure its abundance in the state. It is commonest and most severe southward; but toward the north, while still extremely severe, it is confined rather noticeably to commercial or local-garden plantings. Late crops appear to be most severely injured.

Control of this disease requires either a soil not infected with its fungus, or the use of resistant varieties, among which are certain selected strains known as the Wisconsin Hollander. It may possibly be carried by the seed, and seed disinfection is advisable to prevent its introduction. Rotation is essential to check its injurious development after it has been introduced.

Black Rot

Caused by *Pseudomonas campestris* (Pam.) E. F. S.

Black rot is second in importance among cabbage diseases in Illinois. Infection starts in the water pores at the leaf margin, travels down the veins, killing the leaf tissue as it goes, and finally enters the stem, where the bacteria clog the sap-carrying tissues and pass to other parts of the plant.

Black rot is widely prevalent in the state. It is known in 41 counties, as shown on Map 112. It seems to be most general in southeastern Illinois, but its prevalence elsewhere is shown by the widely scattered counties in which it occurs. Losses from this disease in Illinois have been estimated to range from 1 to 4 per cent of the annual crop.

Control consists in seed treatment, in crop rotation, and in avoiding the replanting of land to related crops, such as radishes and cauliflower.

Club-Root

Caused by *Plasmodiophora brassicae* Wor.

Club-root, a malformation disease of the cabbage, produces large knots or galls on the roots changing their structure so as to interfere with their normal function, and the plant becomes sickly, grows slowly, and often fails to head.

The only reliable early record of club-root in Illinois is a report by Burrill of its presence in 1911 in Cook county, where it was doing only a small amount of damage. In 1923 it was again found in Cook county, on only a few plants in a 1-acre field.

Club-root is controlled by growing the young plants in beds not infected and in using a rotation without crucifers other than cabbage.

Black Mold

Caused by *Alternaria brassicae* (Berk.) Sacc.

Black mold, or black leaf-spot, appears chiefly as round black spots often marked with concentric brown rings on the lower leaves of the plant.

This disease is not often serious in the field. It was reported by the Bureau of Markets to have caused some damage to cabbage heads shipped from Illinois in 1921. It has been found on field cabbage in Knox, Marion, Pulaski, and Alexander counties, which indicates a wide range over the state. Northern infections appear less severe than southern.

Miscellaneous Diseases

Two leaf diseases of cabbage which are of minor importance have been found in Illinois. One, commonly called "ring spot", caused by *Mycosphaerella brassicicola* (Duby) Lindau, was found in Pope county in 1922; the other, a leaf spot caused by *Cercospora bloxami* B. & Br., was found in Pope county in 1922 and in Alexander county in 1923.

Cauliflower

The growing of cauliflower is of some importance in the trucking areas of the state. In general, this crop is subject to the same diseases as is cabbage, though in Illinois black rot is the only one thus far seen. It has been found in Peoria county, where from 5 to 30 per cent of the plants were infected, and in Cook county in the south Halsted district, where from 1 to 10 per cent of the plants were infected.

Measures of control are described under cabbage.

Bean

In trucking areas bean-growing is of some importance, and local gardeners usually cater to the needs of markets.

Anthracnose

Caused by *Colletotrichum lindemuthianum* (S. & M.) B. & C.

Anthracnose of bean is especially destructive. It appears as a spot on the leaves, stems, and pods. It is most injurious on the pods, where it forms a round, sunken, rust-colored spot with a reddish border.

The first report of this disease in Illinois was made by C. E. Durst, who found it in 1912 injuring 20 per cent of the crop near Anna, Union county. In 1922 and 1923 it was found in Jackson and Peoria counties, where it appeared to injure from 1 to 5 per cent of the crop.

Blight

Caused by *Pseudomonas phaseoli* E. F. S.

Blight is a bacterial disease. It may be severe on the leaves and pods, where it causes dark, water-soaked spots. It is known in 8 widely scattered Illinois counties, the distribution of which is shown on Map 113.

Rust

Caused by *Uromyces appendiculatus* (Pers.) Lev.

Rust of the bean is especially a disease of the leaves, although it occasionally attacks stems and pods. It appears as rusty spots or blisters, which eventually break open, exposing a mass of rusty powder.

It is known to have been present in Illinois since 1881, in which year it was found by A. B. Seymour in Union county.

It is now known in 6 counties, the distribution of which is shown on Map 114. Apparently it is widely distributed, but is most common in southern Illinois.

Onion

Approximately 1000 acres are devoted annually to the growing of onions for commercial purposes in Illinois. The yield varies from 200 to over 400 bushels per acre, and the total production varies from 400 to 800 cars of 12.5 tons each per annum. It is estimated that of the 442 cars produced in 1921, 44 were sold in home markets and 398 were shipped outside the state.

Smut

Caused by *Urocystis cepulae* Frost

The one onion disease of importance in the field in Illinois is smut. It is carried over in the soil from year to year, from which it attacks only the seedling plants, causing dark stripes on the leaves, dwarfing, death of the tops, and death of the bulbs.

This disease was first reported in Illinois in 1918, when it was said to have caused a 25 per cent crop injury accompanied by a 10 to 15 per cent crop loss. Presumably the report was made by J. C. Walker and had to do with the Cook county onion district. The disease is now known to occur in Cook and Peoria counties.

Treatment for prevention consists in spraying the seeds with a formaldehyde solution as they are being planted.

Lettuce

This crop, so commonly grown in home gardens, by local truckers for their markets, and to some extent in greenhouses for winter-consumption, and southward for supplying the early demand of northern markets, is subject to several diseases, of which only one appears common in Illinois.

Leaf Blight

Caused by *Septoria lactucae* Pass.

The blight of lettuce attacks the outer leaves, though rarely causing much damage. It has been in Illinois at least since 1887 according to Martin,[1] and is now known in 19 counties, distributed as shown on Map 115. Its range apparently extends from northern Illinois to the southern tip of the state, and it is most general in the extreme south.

Its control requires merely the practice of sanitary cultivation.

Rhubarb

Rhubarb is not subject to many diseases in Illinois, but at least one of them is extremely serious.

Crown and Stalk Rot

Caused by *Phytophthora* sp.

Crown and stalk rot is the most serious disease of rhubarb in Illinois. How long it has been present in the state is not known, but it certainly has been destructive since 1919. At present it seems to be confined to southern Illinois. It is of especial concern in Union county and has been found in Pulaski county also.

Some idea of the seriousness of the disease may be conveyed by two field notes made in 1923: Near Alto Pass, in Union county, a new field of about 5 acres showed a large percentage of infected plants, and along one side a third of the plants were already dead. In spots in a half-acre field in Pulaski, from 10 per cent to 40 per cent were infected and many were dead.

This disease has not been studied, and control measures can not be recommended.

Leaf Spot

Caused by *Phyllosticta straminella* Bres.

Leaf spot of rhubarb is common in Illinois and at times destructive. Stevens reported the disease as injurious in 1918 in Kankakee and Champaign counties.

During 1923 it was found in 16 counties as shown on Map 116. It is evidently wide-spread and appears not to be limited to any one part of the state.

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[1] Journ. Myc. 3: 63. 1887.

Anthracnose

Caused by *Colletotrichum erumpens* Sacc.

This disease is reported by Stevens as causing a serious rot of the leaf stalks in many Illinois localities.

Radish

The radish is commonly grown by local gardeners for sale at local markets and early in the season is to some extent shipped to more northern markets. It is subject to several diseases, which are, however, rarely severe in Illinois.

White Rust

Caused by *Albugo candida* (Pers.) Kze.

White rust is a fungous disease which results in excessive growth and distortion of the flowers and seed pods. For the most part it is injurious only to plants grown for seed.

The earliest reported occurrence of it in Illinois was in Champaign county in 1882. It is now known in 17 counties widely distributed over the state, as shown on Map 117. The area of most general occurrence appears, however, to lie within the northern third of the state.

Other Diseases

Downy mildew, caused by *Peronospora parasitica* (Pers.) De Bary, was found in Ogle county in 1922; and a leaf spot, caused by *Cercospora cruciferarum* E. & E., was found in Champaign county by Clinton in 1896 but has not been reported from Illinois since then.

Horseradish

This crop is commonly grown in home gardens, and local gardeners often grow it in quantity and prepare the roots for sale at their local markets and to manufacturers of condiments.

Leaf Spot

Caused by *Cercospora armoraciae* Sacc.

The one disease of horseradish known to occur in Illinois is a leaf spot, round and light-colored. Often the dead spots fall out and severe infection may result in considerable leaf injury.

This disease was first found in Illinois by Clinton, who collected leaves infected by it in Champaign county in 1896. It was also found in 1898.

This leaf spot is now known to occur in 24 Illinois counties, as shown on Map 118. They are widely scattered over the state and indicate a state-wide distribution for the disease.

Diseases of Ornamental Plants

The diseases of ornamental plants affect the appearance of the plants and often check growth and flowering.

Rose

Many kinds of roses, are grown in Illinois—Rugosas, Ramblers, Climbers, and Teas for outdoor decoration, and an endless variety under glass for cut flowers. The distribution of the diseases here reported is limited mainly to those found on outdoor plants.

Powdery Mildew

Caused by *Sphaerotheca pannosa* (Wallr.) Lev.

Powdery mildew covers rose leaves with a white, powdery, fungous growth. When present in abundance it attacks the young shoots and leaves, and causes their dwarfing, curling, and malformation. It is often serious on cuttings in the greenhouse.

It was first reported in Illinois by Seymour, who collected a specimen at Camp Point, Adams county, in July 1879 and at Villa Ridge, Pulaski county, in 1881, and again in Cook county in the same year.

At present powdery mildew on roses is known to occur in 68 counties, the distribution of which is shown on Map 119. It appears generally distributed over the state, and is especially common in both the extreme north and the extreme south. Something of its general occurrence may be inferred from the fact that the Survey herbarium now contains more than 200 specimens of mildew, collected on cultivated roses, including practically every type grown for outdoor decoration. The Ramblers and Climbing roses seem to be most severely attacked.

Mildew is readily controlled either indoors or out, by dusting the plants thoroughly with a mixture of 90 parts sulfur and 10 parts lead arsenate.

Black Spot

Caused by *Diplocarpon rosae* Wolf

Black spot of the rose is a leaf disease, producing irregularly circular black spots on the upper surfaces of mature leaves. Those diseased usually fall prematurely, and serious infections may prove destructive.

At present, black spot is known to occur in 51 counties, distributed as indicated on Map 120. It is wide-spread in the state and appears to be commonest and most general in the southern tip and in the northwest corner of the state.

Many reports indicate that black spot is injurious to potted roses in greenhouses, and this has been found to be true especially in Christian and Logan counties.

It may be controlled by the application of ammoniacal copper carbonate, lime-sulfur, or Bordeaux.

Leaf Spot

Caused by *Phyllosticta rosae* Desm.

Leaf spot of rose is of less common occurrence than black spot and is not often serious.

It is known to occur in 18 counties, as shown on Map 121. With this, as with the black-spot disease, there appear to be two regions of most common occurrence, one in the southern tip of the state, and one in the extreme northwest.

It may be controlled, when necessary, by application of any of the standard fungicides.

Lilac

The lilac, with its several cultivated varieties, is of large importance in the decorative plantings of the state, and is also of considerable value to the nurseryman. In Illinois it is subject to only one serious disease.

Powdery Mildew

Caused by *Microsphaera alni* (Wall.) Salm.

Powdery mildew of lilac appears, as a rule, late in summer, covering the leaves with a whitish powder, which presently becomes gray and dirty. When the season favors, it may cause severe and early defoliation.

This very common disease has the distinction of being the first one definitely recorded in Illinois. It was collected in McLean county in 1872 and again in 1879 by Seymour. Further collections were made in 1881 and 1882 in 9 counties—Jo Daviess, McHenry, Lake, Cook, Rock Island, La Salle, McLean, Jackson, and Union—indicating a widespread occurrence over the state at that time.

At present, powdery mildew is known in 59 counties, the distribution of which is shown on Map 122. The commonness of the disease where it has been found may be illustrated by the fact that there are in the Survey herbarium 190 specimens of this mildew.

Carnation

The carnation, grown in greenhouses for cut flowers and in many varieties in gardens for decoration and for flowers, suffers from a single common disease, the "carnation rust."

Rust

Caused by *Uromyces caryophyllinus* (Schw.) Wint.

This rust appears as small, reddish-brown, more or less circular spots upon the leaves and stems, the plant tissue for some distance around usually taking on a sickly, yellowish color.

This disease is a pest in greenhouses especially, where it may be quite destructive. It is known in 19 counties in Illinois, as shown on Map 123, indicating its wide-spread occurrence over practically the whole state.

Control measures consist, first of all, in the selection of cuttings which are not infected. Free ventilation, and watering of the soil only, with a periodical spraying with copper sulfate, one pound to 25 gallons of water, are very helpful in preventing the spread of the disease in greenhouses.

Virginia Creeper

The Virginia creeper, commonly used as a decorative vine, is subject to two diseases, which are of some importance in that they may impair the appearance of the vine and may reduce the growth of the plant in the nursery.

Leaf spot

Caused by *Guignardia bidwellii* (Ell.) V. & R.

The leaf spot is identical with the black-rot disease of grapes and has, on the leaves, essentially the same appearance.

It is known to occur in 21 counties, as shown on Map 124. It appears to be especially abundant in southern Illinois, with only occasiona occurrence northward.

Powdery mildew

Caused by *Uncinula necator* (Schw.) Burr.

Powdery mildew is identical in appearance with the powdery mildew of grapes.

It is known to occur in 9 counties as shown on Map 125. It is apparently widely distributed in Illinois, with a most frequent occurrence in the northern part of the state.

This and the preceding disease of the Virginia creeper are controlled by the same means as on grapes.

Snapdragon

The snapdragon, grown extensively in greenhouses for cut flowers and in gardens for decoration, is subject in Illinois to one common disease, the snapdragon rust.

Rust

Caused by *Puccinia antirrhini* Diet. & Holw.

Rust is evident on the snapdragon as reddish-brown pustules about the size of a large pin-head upon the leaves. These spots, if numerous, may seriously detract from the appearance of the plant, limit its growth, and check flower production.

Snapdragon rust is known to occur in Illinois in 7 counties, whose distribution, as shown on Map 126, indicates a very wide range of this disease in the state, with the commonest occurrence probably northward.

It is controlled in greenhouses by so directing the watering of the flats and benches as to avoid splashing or dropping of the water from leaf to leaf.

Conclusion

The preceding pages contain an account of 165 of the plant diseases occurring in Illinois. They attack 44 of our crops and, according to the classification given in Table 41, 115 of them are serious either continuously or in years favorable to them while 50 are commonly of less significance. These are not all the diseases attacking crops in this state, yet the number is large enough to suggest that their presence is a continual menace to successful production and that they are, because of their widespread distribution and common occurrence, the cause of a not inconsiderable yearly reduction in the crop yield of the state.

How great the yearly loss is may be inferred from the estimates summarized in Table 42 from the more detailed estimates previously given. Five diseases of wheat are estimated to have caused a loss averaging annually 7,712,800 bushels valued at $11,837,000; two diseases of oats have caused an average annual loss of 12,820,000 bushels valued at $6,479,000; and two diseases of corn have caused a similar loss of 35,013,000 bushels valued at $24,840,000. Among the fruits, six apple diseases reduce the crop annually by 814,980 bushels valued at $1,240,500; one pear disease causes a yearly loss of 22,900 bushels valued at $22,300; and one peach disease, a yearly loss of 13,850 bushels valued at $31,220. These 16 diseases attacking 6 of our chief crops are responsible for a reduction in yield averaging annually 56,398,900 bushels valued at $44,452,000. If it were possible to state in concrete terms the losses resulting from the remaining 99 serious diseases and the damage done by the 50 less serious ones, these figures would undoubtedly be multiplied many times; but such a statement would only serve to make more impressive the facts already emphasized—that many diseases are widely distributed, that most of them are serious, and that the infection of crop plants can result only in costly reductions in yield.

Losses can be largely avoided by using the approved methods of prevention and control which are given briefly in this bulletin for nearly all the important diseases. This is a subject, however, which deserves a more detailed treatment than is consistent with the scope and object of this preliminary report.

TABLES OF CROP REDUCTION AND LOSSES.

TABLE 1.—ESTIMATED WHEAT LOSSES FROM LEAF RUST, 1919–1923

Year	Crop reduction, bushels	Crop reduction, per cent	Value lost
1919	708,000	1.0	$1,486,000
1920	221,000	0.5	355,000
1921	500,000	1.0	500,000
1922	5,543,000	10.0	5,931,000
1923	1,803,000	3.0	1,604,000

TABLE 2.—SEASONAL VARIATION IN AMOUNT OF LEAF-RUST INFECTION OF WHEAT

Year	Acres examined	Per cent of stalks infected	Per cent of diseased leaf-tissue on infected plants	Average per cent of leaf-tissue diseased
1918*	350	83	12	10
1922	310	98	57	55.8
1923	1833	86.8	36.6	31.76

TABLE 3.—COMPARISON OF LOSS IN WHEAT FROM LEAF RUST WITH NUMBER OF INFECTED PLANTS AND AMOUNT OF DISEASED LEAF-TISSUE

Year	Estimated crop-loss in per cent	Average per cent of diseased leaf-tissue per stalk	Per cent of infected plants
1918	1.0	8.3	83
1922	10.	55.8	98
1923	3.	31.76	86.8

* U. S. Dept. Agr. Plant Disease Survey Bulletin. Supplement 4 131. 1919.

TABLE 4.—Estimates of Wheat Losses from Leaf Rust resulting from the 1922 Epidemic

County	Acreage	Loss per acre, bushels	Total loss, bushels
Adams	59,250	1.20	71,100
Clinton	61,700	1.64	101,188
Christian	80,000	0.25	20,000
Jersey	60,000	0.60	36,000
Madison	122,000	2.00	244,000
Mason	50,000	0.05	2,500
Monroe	60,900	5.00	304,500
Montgomery	69,000	5.00	345,000
Morgan	95,000	0.15	14,250
Randolph	82,500	2.00	165,000
Sangamon	99,000	0.05	4,950
St. Clair	130,200	0.50	65,100
Total	969,550		1,373,588

TABLE 5.—Estimated Wheat Losses from Stem Rust in Illinois, 1918–1923

Year	Per cent loss	Crop reduction bushels	Value per bushel	Money loss
1918	trace	trace	$2.08	trace
1919	1	842,000	2.10	$1,768,200
1920	0.5	221,000	1.61	355,000
1921	0.5	250,000	1.00	250,000
1922	trace	trace	1.07	trace
1923	1.5	901,800	.92	829,600

TABLE 6.—Comparison of Observations on the Amount of Stem-Rust Infection in Wheat Fields and Estimated Crop Losses

Year	Fields examined	Acres examined	Per cent of infected stalks	Average per cent of diseased tissue per plant	Estimated crop-loss in per cent
1918	51	....	....	2.9	trace
1919	..	....	1–100	....	1.
1920	92		trace–75	0.62	0.5
1921	..	....	....	....	0.5
1922	31	760	3.4	17.	trace
1923	64	1208	41	40.	1.5

TABLE 7.—Field Observations on Susceptibility of Wheat Types to Stem-Rust Infection

Variety	Acres examined	Per cent of stalks infected	Per cent of diseased tissue
Soft Wheats:			
Fultz	102	75	22.5
Red Cross	80	61.5	47.5
Red Wave	45	92.5	37.5
Salzer's Advance	48	100.0	60.0
Hard Wheats:			
Turkeys	837	49.2	21.
Kanred	2	30.0	10.

TABLE 8.—Susceptibility of Soft Wheats to Stem-Rust Infection

Variety	Per cent of stalks infected
Fulcaster	44.2
Fultz	42.0
Indian Swamp	24.2
Mediterranean	50.0
Red Chaff	61.7
Red Cross	35.0
Red Wave	92.5

TABLE 9.—Estimated Wheat Losses from Stinking-Smut Infection

Year	Per cent of crop lost	Crop reduction, bushels	Money loss
1917	3.0	940,000	$1,889,400
1918	1.9	1,181,300	2,357,104
1919	0.3	197,600	414,960
1920	trace	trace	trace
1921	trace	trace	trace
1922	2.0	1,082,000	1,157,740
1923	6.0	3,934,000	3,619,280

TABLE 10.—Stinking-Smut Infections found in Wheat Fields in 1923

County	No. of acres examined	Per cent of heads infected		
		Average	Highest	Lowest
Cass	30	3.0	3.0	3.0
Christian	50	18.1	40.0	0.5
Crawford	40	1.0	1.0	1.0
Douglas	280	3.0	15.0	+
Ford	35	0.2	1.0	+
Franklin	10	0.5	0.5	0.5
Hamilton	60	2.0	2.0	2.0
Iroquois	30	10.0	10.0	10.0
Jo Daviess	10	0.2	0.2	0.2
Kankakee	40	0.5	0.5	0.5
La Salle	15	0.1	0.1	0.1
Lawrence	20	2.0	2.0	2.0
Livingston	80	10.0	18.0	0.1
Macoupin	35	25.0	30.0	20.0
Madison	80	2.9	10.0	+
McLean	40	2.7	5.5	0.01
Menard	20	0.5	0.5	0.5
Monroe	100	6.7	25.0	+
Morgan	45	0.1	0.1	0.1
Moultrie	20	0.5	0.5	0.5
Piatt	35	0.2	0.5	0.1
Sangamon	65	0.6	1.5	0.1
Total	1140	Av., 4.08		

TABLE 11.—CASH DOCKAGE ON STINKING-SMUT-INFESTED WHEAT, 1922-CROP

County	Total wheat marketed bushels	Bushels smutted	Dockage per bu.	Total dockage
Bureau	16,000	0		
Champaign	49,400	2000	$ 0.05	$100.00
		622	0.04	24.88
Douglas	58,000	1500	0.05	75.00
Ford	650	0		
Greene	65,000	1000	0.02	20.00
Henry	....	200*	1.00	200.00
Iroquois	1,300	0		
Kane	5,000	0		
Kankakee	16,000	5333	0.06	319.98
Knox	55,600	0		
La Salle	35,000	200	0.02	4.00
Lee	....	360*	1.00	360.00
Macon	72,000	0		
McLean	61,000	3550	0.05	177.50
		2000	0.035	70.00
		1300	0.10	130.00
Mercer	10,000	0		
Monroe	40,000	1200	0.10	120.00
Montgomery	40,300	100	0.03	3.00
Peoria	10,000	2000	0.06	120.00
Piatt	22,000	2000	0.035	70.00
		500	0.06	30.00
Putnam	30,000	2000	0.05	100.00
Randolph	48,135	0		
Tazewell	140,000	0		
Vermilion	36,350	0		
Wabash	60,000	0		
Washington	191,178	0		
Whiteside	20,000	0		
Total	1,082,913	25,865	Av., $0.0744	Total, $1924.36

* Purchase refused because of smut.

TABLE 12.—DOCKAGE ON STINKING-SMUT-INFESTED WHEAT, 1923-CROP

County	Total wheat marketed bushels	Bushels smutted	Smutted bushels docked	Dockage per bu.	Total dockage
Adams	67,000	0			
Bureau	59,000	0			
Champaign	127,214	1,150	150	$0.05	$ 7.50
Christian	60,000	850	850	0.05	42.50
Clinton	100,000	5,000	5,000	0.05	250.00
Coles	35,000	450	450	0.05	22.50
Douglas	30,000	2,000	2,000	0.10	200.00
Edgar	15,000	0			
Ford	9,250	2,500	2,500	0.01	25.00
Greene	40,000	3,000	3,000	0.02	60.00
Grundy	40,000	0			
Henry	6,750	0			
Iroquois	43,100	8,180	180	0.03	5.40
			1,750	0.10	175.00
Kankakee	100,000	5,360	5,000	0.05	250.00
Kane	1,300	0			
Knox	42,000	2,000	2,000	0.04	80.00
La Salle	44,582	1,300	500	0.03	15.00
			800	0.05	40.00
Livingston	132,092	15,821	1,781	0.02	35.62
			1,390	0.035	48.65
			150	0.075	11.25
			10,000	0.04	400.00
Logan	146,300	400	400	0.025	10.00
Macon	80,000	0			
Mason	38,490	0			
McDonough	61,000	0			
McLean	123,670	9,250	2,250	0.02	45.00
			7,000	0.05	350.00
Mercer	3,000	0			
Monroe	40,000	2,000	2,000	0.10	200.00
Morgan	40,000	5,800	1,800	total loss	......
Montgomery	30,000	423	423	0.05	21.15
Peoria	34,848	650	500	0.01	5.00
Piatt	294,000	25,950	4,000	0.03	120.00
			4,200	0.035	147.00
			9,500	0.05	475.00
			6,000	0.07	420.00
			500	0.10	50.00
Putnam	40,000	2,000	2,000	0.04	80.00
Randolph	11,171	+	0		
Sangamon	149,000	28,200	2,100	0.02	42.00
			7,000	0.03	210.00
St. Clair	158,100	10,900	6,200	0.11	682.00
			2,200	0.06	132.00
Stark	3,000	0			
Tazewell	150,000	0			
Vermilion	60,036	1,000	1,000	0.05	50.00
Wabash	130,000	0			
Washington	17,000	1,000	500	0.03	15.00
			500	0.15	75.00

TABLE 12—Concluded.

County	Total wheat marketed bushels	Bushels smutted	Smutted bushels docked	Dockage per bu.	Total dockage
Warren	55,500	8,000	8,000	0.045	360.00
Woodford	1,350	0			
White	280,000	0			
Whiteside	10,000	0			
Will	93,770	Some	Some	0.05	Some
Total	3,002,523	143,184	105,574	Av. $0.0488	$5,157.57
		4.4%	3,51%		

TABLE 13.—OBSERVATIONS ON THE STINKING-SMUT INFECTION OF WHEAT VARIETIES COMMONLY GROWN IN THE FIELD

Variety	Acres examined	Per cent of heads smutted
Black Hull	20	0.5
Fulcaster	40	1.0
Fultz	325	5.2
Indian Swamp	15	0.37
Red Cross	100	4.7
Red Wave	125	4.6
Turkey	440	2.26

TABLE 14.—ESTIMATED WHEAT LOSSES FROM LOOSE-SMUT INFECTION

Year	Per cent lost	Crop reduction, bushels	Cash loss
1917	3.0	941,000	$1,891,400
1918	1.5	929,000	1,932,300
1919	2.0	1,684,000	3,536,400
1920	3.0	1,326,000	2,134,800
1921	3.0	1,499,000	1,499,000
1922	3.0	1,644,000	961,000
1923	1.56	899,000	845,000

TABLE 15.—Loose-Smut Infections found in Wheat Fields in 1922

County	Fields examined	Acres examined	Per cent of heads smutted
Adams	1	20	+
Bond	3	60	6.3
Calhoun	3	41	0.9
Chistian	3	60	+
Clay	1	20	14.0
Clinton	4	80	+
Edwards	2	40	1.2
Effingham	3	93	10.2
Fayette	2	90	10.7
Fulton	2	30	2.0
Hamilton	2	40	1.2
Jefferson	2	40	1.0
Lawrence	6	120	+
Madison	5	130	+
Marion	2	40	+
Menard	4	76	0.8
Pike	8	203	0.6
Scott	2	40	+
Shelby	2	40	+
Schuyler	7	137	3.6
St. Clair	3	60	1.0
Tazewell	4	120	0.5
Wabash	2	40	0.5
Washington	2	40	+
Wayne	2	35	1.0
White	4	61	0.9
Total	81	1756	Acre av., 2.13

TABLE 16.—LOOSE-SMUT INFECTIONS IN WHEAT FIELDS IN 1923

County	Fields examined	Acres examined	Per cent of heads smutted
Bond	2	110	1.7
Calhoun	1	18	0.7
Cass	1	30	0.6
Christian	2	35	7.0
Coles	12	332	0.4
Crawford	10	200	2.5
Douglas	5	240	0.5
Edwards	12	240	5.0
Fayette	1	40	0.37
Ford	4	65	1.5
Franklin	8	110	3.4
Hamilton	3	55	3.9
Hancock	1	20	0.37
Iroquois	1	40	2.0
Jackson	5	65	5.3
Jo Daviess	1	15	2.0
Kankakee	1	15	1.0
Knox	1	47	+
La Salle	1	15	0.7
Lawrence	2	40	3.0
Macon	7	295	0.1
Macoupin	1	5	0.37
Madison	4	120	0.8
Marion	2	40	1.3
McDonough	1	40	1.0
McLean	1	20	1.0
Menard	1	35	2.0
Monroe	13	156	0.5
Montgomery	3	50	4.0
Perry	7	70	0.25
Piatt	2	35	1.0
Pope	15	310	5.0
Randolph	10	119	0.4
Richland	10	200	2.0
Saline	60	60	0.4
Sangamon	1	20	0.3
St. Clair	4	80	0.7
Wabash	10	200	2.7
Washington	10	297	0.25
White	18	965	0.9
Total	254	4849	Acre av., 1.56

TABLE 17.—ESTIMATED WHEAT LOSSES FROM SCAB IN ILLINOIS

Year	Per cent of crop lost	Crop reduction, bushels	Money lost
1917	7	2,288,000	$ 4,598,000
1918	1	616,000	1,281,000
1919	18	15,156,000	31,827,000
1920	2	884,000	1,423,000
1921	4	1,999,000	1,999,000
1922	2	1,131,000	1,210,000
1923	2.2	791,000	727,000

TABLE 18.—FIELD OBSERVATIONS ON THE INFECTION OF WHEAT VARIETIES WITH SCAB IN 1923

Variety	Number of acres examined.	Per cent of heads infected	Per cent of spikelets per head infected	Actual per cent of infection
Fulcaster	110	0.87	54.00	0.469
Fultz	927	1.53	49.29	0.754
New Columbia	230	0.44	56.5	0.248
Red Cross	20	9.5	66.6	6.327
Red Wave	360	1.625	28.43	0.4619
Stoddard Co. Pride	80	5.5	52.5	2.8875
Turkey 10-110	87	1.61	44.9	0.82289
Turkey Red	85	13.1	49.1	6.4321
	Average per cent for all varieties			2.300

TABLE 19.—DEPARTURES OF WHEAT VARIETIES FROM THE AVERAGE SCAB INFECTION OF 2.3 PER CENT IN 1923

Variety	Per cent of infection	Departure of all varieties from average
Fulcaster	0.469	—1.831%
Fultz	0.754	—1.546
New Columbia	0.248	—2.052
Red Wave	0.461	—1.839
Turkey 10-110	0.822	—1.478
Red Cross	6.327	+4.027
Stoddard Co. Pride	2.887	+0.587
Turkey Red	6.432	+4.132

TABLE 20.—Speckled Leaf-Blotch Infections seen on Wheat in 1923

County	Per cent of diseased plants	Per cent of leaves infected per diseased plant
Madison	75	25
Jackson	75	30
Franklin	100	30
Hamilton	100	50
Saline	100	38
White	97	33
Coles	66	34
Macon	85	25
Fayette	100	50
Marion	100	50
Washington	100	50
Perry	100	30
Randolph	100	50
Monroe	100	35
St. Clair	55	20
Macoupin	100	10
Menard	100	10
Sangamon	100	10
Morgan	90	15
Hancock	100	18
Piatt	100	25
McLean	90	50
La Salle	25	5
Average	89.4	32.2

TABLE 21.—Varietal Differences in the Speckled Leaf-Blotch Infection of Wheat in 1923

Variety	Acres examined	Per cent of diseased plants	Per cent of leaves infected per diseased plant	Average per cent of infection
Black Hull	50	87.4	26	22.7
Fulcaster	60	100	50	50
Fultz	1147	89.3	35.1	31.3
New Columbia	240	100	32.9	32.9
Red Cross	80	77.5	27.5	21.31
Red Wave	100	52.4	22.5	11.79
Stoddard Co. Pride	80	100	30	30.00
Turkey 10-110	60	90.1	33.3	30.0
Turkey Red	682	83.4	22.6	18.84

TABLE 22.—Estimated Crop Reduction from Crown Rust of Oats

Year	Reduction, per cent	Reduction, bushels	Money loss
1919	1	1,323,000	$ 962,000
1920	1	1,820,000	782,000
1921	3	4,454,000	1,291,000
1922	4	4,583,000	1,787,000
1923	2.5	3,464,000	1,350,000

TABLE 23.—Comparison of Variation in Crown-Rust Infection of Oats and Estimated Crop Reductions in 1922 and 1923

Year	Acres examined	Per cent of diseased plants	Per cent of diseased tissue per plant	Estimated crop reduction
1922	538	91.038	58.05	4.0%
1923	1226	90.850	36.94	2.5%

TABLE 24.—Estimated Crop Reductions from Loose Smut of Oats

Year	Reduction, per cent	Reduction, bushels	Money loss
1917	7	18,395,000	$11,956,750
1918	6	12,661,000	8,382,870
1919	5	6,616,000	4,631,200
1920	5	9,098,000	3,912,000
1921	5	7,423,000	2,512,000
1922	5	5,790,000	2,258,000
1923	5.5	7,862,000	3,065,580

TABLE 25.—Estimated Crop Reductions from Corn Diseases

Year	Reduction, per cent	Reduction, bushels	Cash loss
1917	2*	8,531,000	$ 9,384,000
1918	4.5	16,222,000	19,466,000
1919	7.0	22,656,000	29,453,000
1920	6.0	18,777,000	11,078,000
1921	13.5	47,752,000	18,145,000
1922	4.0	12,044,000	7,226,000
1923	20.5	86,980,000	56,537,000

* In 1917 smut alone was estimated, but ear-rots and root-rots were reported as doing damage.

TABLE 26.—Estimated Crop Reductions from Root-, Stalk-, and Ear Rots of Corn

Year	Reduction, per cent	Reduction, bushels	Cash loss
1918	3	10,870,000	$13,044,000
1919	5	16,183,000	21,037,000
1920	4	12,518,000	7,385,000
1921	10	35,372,000	13,442,000
1923	15	59,525,000	38,691,000

TABLE 27.—Estimated Crop Reductions from the Smut of Corn

Year	Reduction, per cent	Reduction, bushels	Cash loss
1917	2.0	8,531,000	$9,384,000
1918	1.5	5,352,000	6,422,000
1919	2.0	6,473,000	8,414,000
1920	2.0	6,259,000	3,692,000
1921	3.5	12,380,000	3,704,000
1922	2.5	7,412,000	4,447,000
1923	3.0	10,432,000	6,780,000

TABLE 28.—Field Observations on the Susceptibility of Corn Varieties to Brown-Spot

Variety	Acres examined	Per cent of stalks infected
Boone County White	100	100
Reed's Yellow Dent	20	100
Democrat	25	88
Yellow Dent	181	86

TABLE 29.—Estimated Crop Reductions from Apple Scab

Year	Reduction, per cent	Reduction, bushels	Cash loss
1918	4	134,000	$247,900
1919	6	342,000	786,600
1920	8	604,000	845,600
1921	12	387,000	967,500
1922	4	405,000	425,250
1923	3.5	277,000	318,000

TABLE 30.—PREVALENCE OF APPLE-SCAB INFECTIONS IN ORCHARDS DURING 1923

County	Orchards examined	Acres	Per cent of trees infected	Per cent of fruit infected
Edwards	1	5	100	75
Jackson	1	5	100	50
Hamilton	1	½	100	75
Macon	1	½	100	10
Morgan	1	½	100	10
Greene	2	1420	few	trace
Tazewell	1	½	100	50
Logan	2	5	100	75
Montgomery	1	6	100	75
Jackson	1	50	75	60
Johnson	1	20	100	35
Pope	2	80	100	100
	1	20	trace	trace
Marshall	1	20	80	55
Bureau	2	40	30	trace
Douglas	1	½	100	10
Fulton	1	10	75	16
Crawford	1	40	10	5
Pike	1	5	80	20
Total	23	1728	Acre av., 12.7%	Acre av., 9.4%

TABLE 31.—ESTIMATED CROP REDUCTIONS FROM APPLE BLOTCH

Year	Reduction, per cent	Reduction, bushels	Cash loss
1918	2	66,000	$122,000
1919	3	171,000	393,000
1920	4	302,000	422,000
1921	7	226,000	566,000
1922	5	511,000	536,000
1923	5.5	428,000	492,000

TABLE 32.—PREVALENCE OF BLOTCH IN UNSPRAYED APPLE ORCHARDS IN 1923

County	Orchards examined	Acres	Per cent of trees infected	Per cent of fruit infected
Hamilton	1	1	100	65
Saline	1	1	100	75
White	1	1	100	50
Randolph	1	2	100	100
Christian	1	2	100	100
Shelby	1	1	100	100
Bond	1	5	100	100
Clinton	1	5	100	70
Union	1	5	100	100
Alexander	1	5	100	100
Johnson	1	10	100	100
Williamson	1	3	100	100
Jasper	1	40	100	75
Effingham	3	50	100	100
Total	16	131	Acre av., 100%	Acre av., 90.4%

TABLE 33.—ESTIMATED CROP REDUCTIONS FROM FIRE-BLIGHT OF APPLE

Year	Per cent lost	Bushels lost	Cash lost
1918	1.5	49,000	$ 90,650
1919	trace	+	+
1920	trace	+	+
1921	0.1	3,000	7,500
1922	1.0	98,000	102,900
1923	1.5	112,000	128,000

TAPLE 34.—ESTIMATED CROP REDUCTIONS FROM APPLE RUST

Year	Per cent lost	Bushels lost	Cash lost
1919	0.3	17,000	$ 39,100
1920	0.2	15,000	21,000
1921	trace	+	+
1922	1.5	159,000	166,000
1923	1.0	74,000	85,000

TABLE 35.—Estimated Crop Reductions from Black Rot of Apple

Year	Per cent lost	Bushels lost	Cash lost
1918	1	33,000	$61,000
1919	trace	+	+
1920	1	75,000	105,000
1921	2	64,000	160,000
1922	2	199,000	208,000
1923	1	74,000	85,000

TABLE 36.—Blister Canker Infection found in Ben Davis Orchards, 1922 and 1923

County	Orchards examined	Acres	Per cent of trees infected
Hancock	1	2	20
	1	2	20
	1	1	100
Edwards	1	+	trace
Mercer	1	1	40
Schuyler	1	1	100
	1	5	25
Henderson	1	3	30
McLean	1	2	16
	1	1	20
Wayne	1	10	50
	1	20	95
Henderson	1	2	50
	1	100	8
Pike	1	1	90
Jefferson	2	40	2
Ogle	1	2	25
Lake	1	1	100
Boone	1	2	5
Livingston	1	6	25
Total	21	203	Acre av., 21.8%

TABLE 37.—Estimated Crop Reductions from Pear Blight

Year	Per cent lost	Bushels lost	Cash loss
1922	5	26,800	$26,800
1923	6	19,000	17,800

TABLE 38.—ABUNDANCE OF PEAR-BLIGHT INFECTION IN 1922

County	Orchards	Per cent of trees infected	Per cent of diseased branches on infected trees
Clay	1	100	10
Lake	1	100	0.5
White	1	+	45.
Hancock	1	trace	trace
	1	100	50
Mercer	1	100	+
McHenry	1	100	20
Putnam	1	2	1
Schuyler	1	100	10
Washington	1	+	40
Massac	1	+	50
	1	+	35
Kane	1	90	3
Kankakee	1	100	1
	1	75	5
Edgar	1	+	40
Wabash	1	+	40
Marshall	1	100	2
Stephenson	1	100	10
Kendall	1	100	5
Will	1	15	5
Jackson	1	+	30
Williamson	1	+	30
La Salle	1	100	2
White	1	+	35
Carroll	1	25	trace
Grundy	1	100	1
Pulaski	1	+	5
	28	Acre av., 50.25%	Acre av., 16.9%

TABLE 39.—ABUNDANCE OF PEAR-BLIGHT INFECTION IN 1923

County	Orchards	Acres	Per cent of trees infected	Per cent of infected branches on infected trees
Clay	2	18	100	25
	1	20	100	45
Marion	2	20	100	25
	1	30	100	40
Randolph	1	1	100	30
	1	10	100	20
Adams	1	+	100	40
Macon	1	+	100	60
Christian	1	1	100	50
Shelby	1	1	100	60
	1	5	100	40
Clinton	1	10	100	25
Richland	1	5	100	20
	1	10	100	60
	16	131	100	43.1

TABLE 40.—ESTIMATED CROP REDUCTIONS FROM PEACH BROWN-ROT

Year	Per cent reduction	Reduction, bushels	Money loss
1917	12	50,000	$97,500
1918	0	0	0
1919	1	8,000	21,600
1920	1	14,000	44,300
1921	..	......	......
1922	1	11,000	19,200
1923	2	14,000	36,000

TABLE 41.—Tabulation of Diseases Discussed in the Text

Crop	Serious diseases	Less serious diseases	Total
Cereals and Forage			
Wheat	5	8	13
Oat	2	1	3
Corn	2	5	7
Rye	3	2	5
Barley	3	2	5
Alfalfa	1	3	4
Sweet Clover	1	1	2
Red Clover	2	3	5
Timothy	1	1	2
Redtop	1	0	1
Fruits, including Small Fruits			
Apple	8	9	17
Pear	4	1	5
Quince	2	3	5
Peach	4	3	7
Apricot	3	0	3
Plum	6	0	6
Cherry	4	0	4
Grape	4	0	4
Brambles (Blackberry, etc.)	8	1	9
Currant and Gooseberry	3	0	3
Strawberry	3	0	3
Vegetable and Field Crops			
Potato	7	0	7
Tomato	3	0	3
Sweet Potato	2	0	2
Cantaloupe	3	0	3
Watermelon	2	0	2
Cucumber	5	0	5
Asparagus	1	1	2
Beet	1	0	1
Cabbage	4	2	6
Cauliflower	1	0	1
Bean	3	0	3
Onion	1	0	1
Lettuce	1	0	1
Rhubarb	2	1	3
Radish	1	2	3
Horseradish	1	0	1
Ornamental plants			
Rose	2	1	3
Lilac	1	0	1
Virginia Creeper	2	0	2
Snapdragon	1	0	1
Carnation	1	0	1
Total for the 44 crops	115	50	165

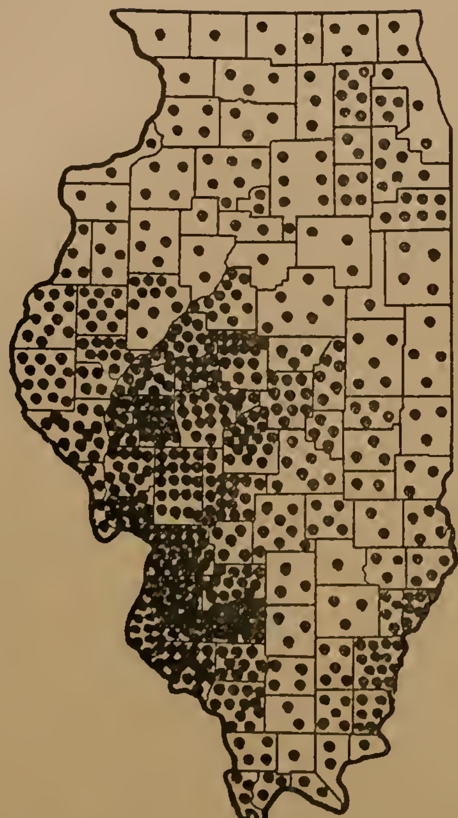
TABLE 42.—AVERAGE ANNUAL ESTIMATED CROP REDUCTIONS AND MONEY LOSSES RESULTING FROM DISEASE ATTACK

Crop and disease	Average annual reduction, bushels	Average annual money loss	Period of record
Wheat			
Leaf rust	1,755,000	$1,975,200	5 years
Stem rust	369,100	533,800	6 "
Stinking smut	1,047,800	1,348,300	7 "
Loose smut	1,274,500	1,828,500	7 "
Scab	3,266,400	6,152,100	7 "
Oat			
Crown rust	3,128,800	1,234,400	5 "
Loose smut	9,692,142	5,245,485	7 "
Corn			
Root-, Stalk-, and Ear-rots	26,893,600	18,719,800	5 "
Smut	8,119,857	6,120,428	7 "
Apple			
Scab	358,160	598,470	6 "
Blotch	286,000	421,830	6 "
Fire-blight	43,660	54,840	6 "
Rust	53,000	62,220	5 "
Blackrot	74,160	103,160	6 "
Peach			
Brownrot	13,850	31,220	7 "
Pear			
Blight	22,900	22,300	2 "
Total	56,398,929	$44,452,053	

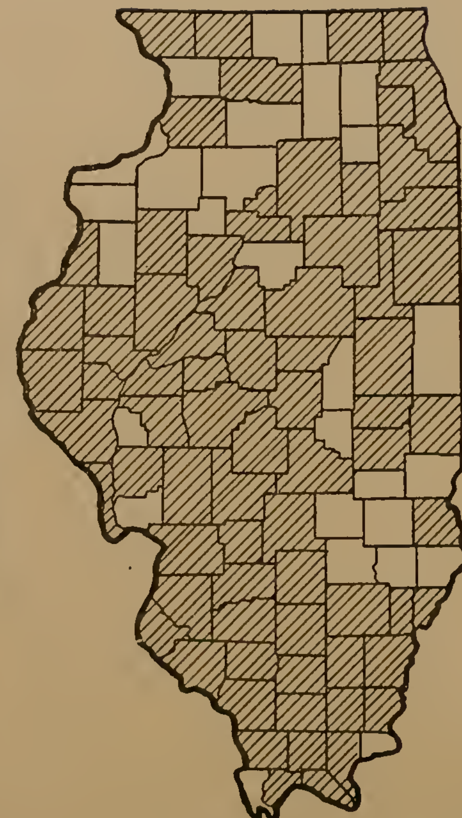
MAPS

Illustrating the distribution of the diseases
discussed in the text.

Map of Illinois, with county names for comparison with the following maps.

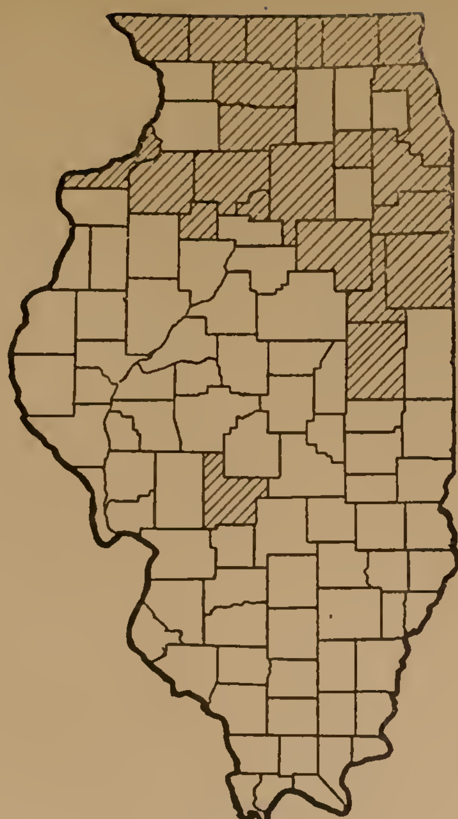


Map 1.—Distribution of wheat acreage in Illinois in 1922. One dot represents 1,000 acres.



Map 2.—Distribution of leaf rust of wheat.

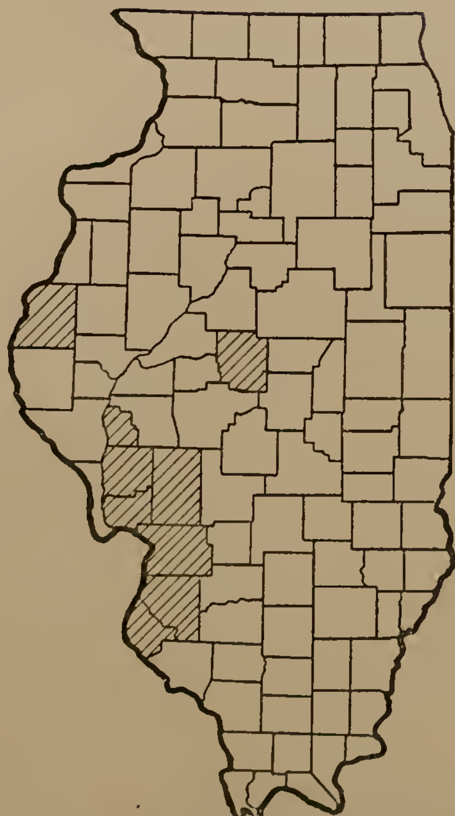
Map 3.—Distribution of stem rust of wheat.



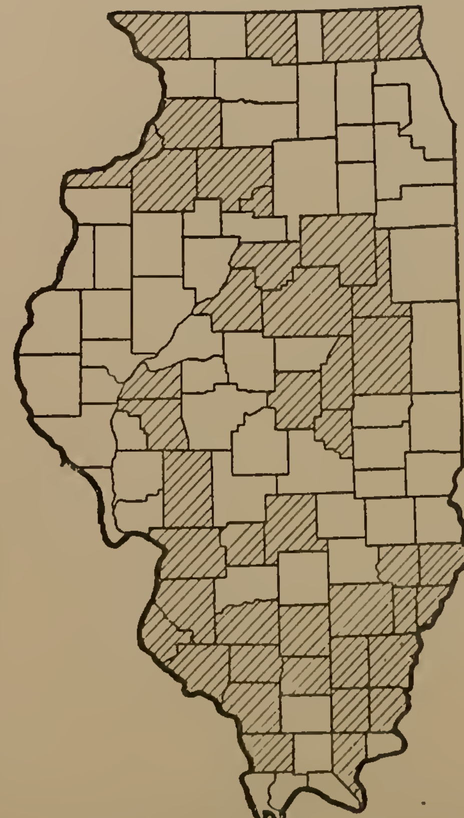
Map 4.—Distribution of stem rust on the common barberry.

Map 5.—Distribution of stinking smut of wheat.

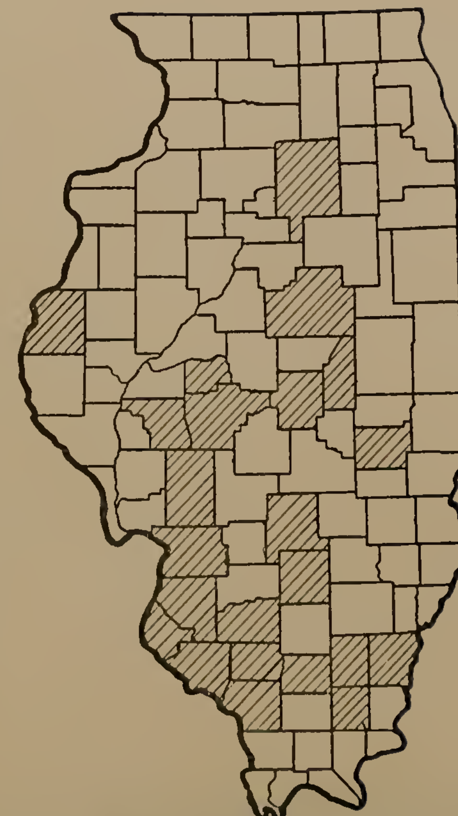
Map 6.—Distribution of loose-smut of wheat.



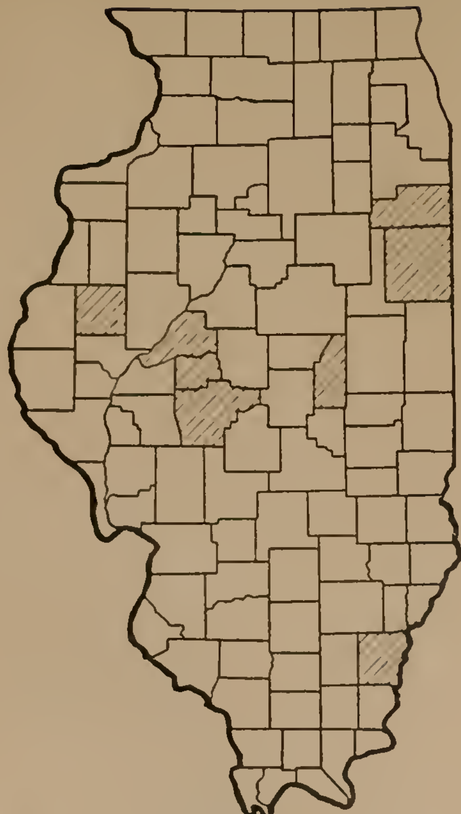
Map 7.—Distribution of flag smut of wheat.



Map 8.—Distribution of wheat scab.



Map 9.—Distribution of the speckled leaf-blotch of wheat.

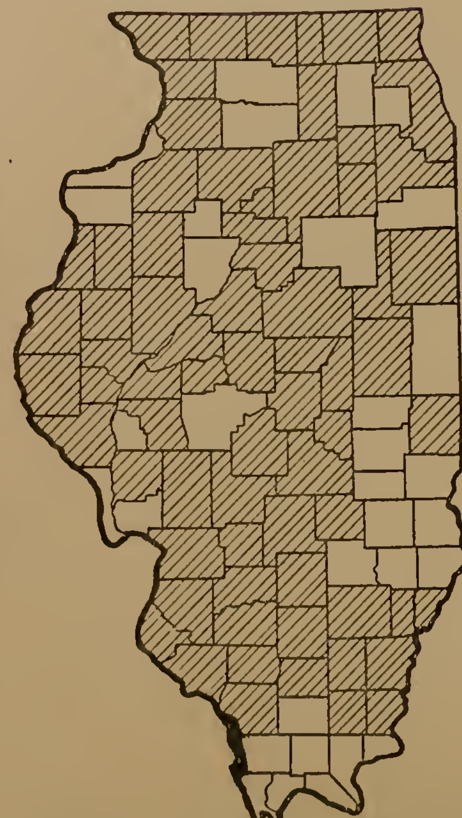


Map 10.—Distribution of wheat anthracnose.

Map 11.—Distribution of wheat foot-root.

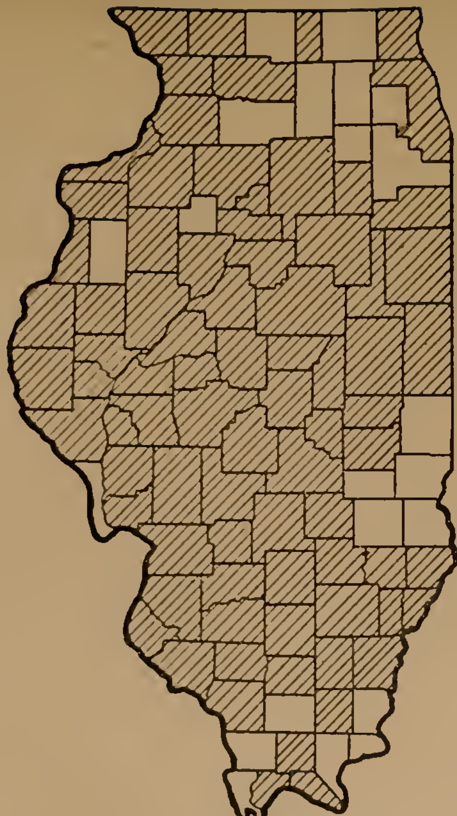
Map 12.—Known occurrence of the black-chaff disease of wheat.

MAP 13.—Distribution of oat acreage in 1922. One dot represents 10,000 acres.

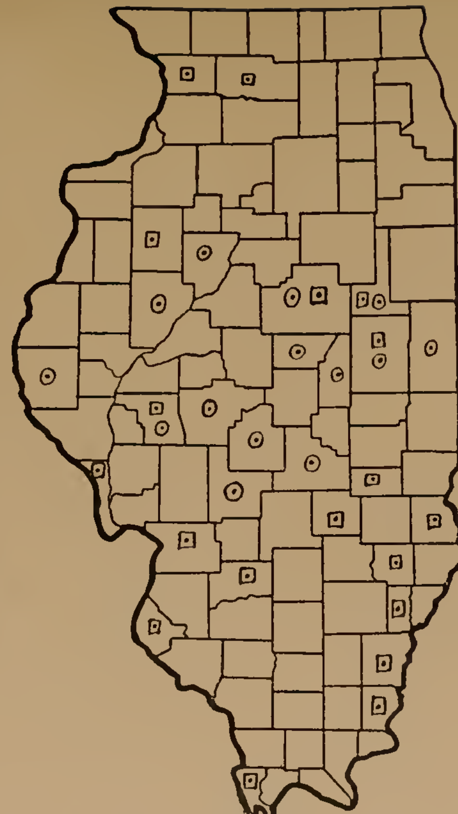


MAP 14.—Distribution of crown rust of oats.

MAP 15.—Distribution of stem rust of oats.



MAP 16.—Distribution of loose-smut of oats.

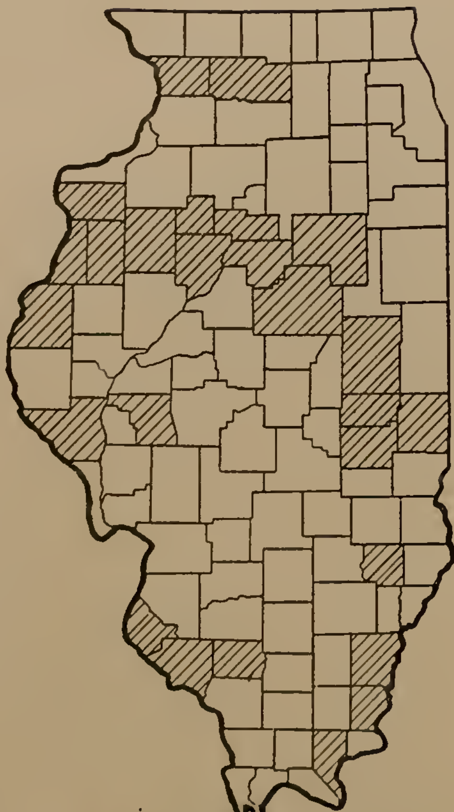


MAP 17.—Distribution of root-, stalk-, and ear-rots of corn.

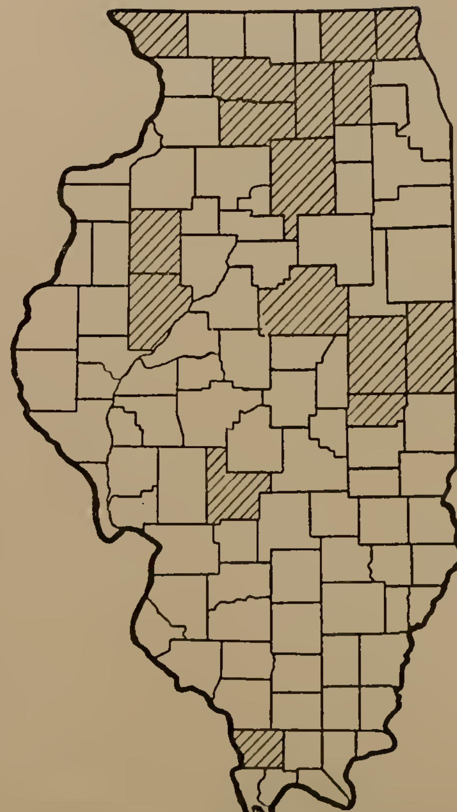
Dot in circle equals Diplodia rots.

Dot in square equals Gibberella and Fusarium rots.

MAP 18.—Distribution of corn smut.

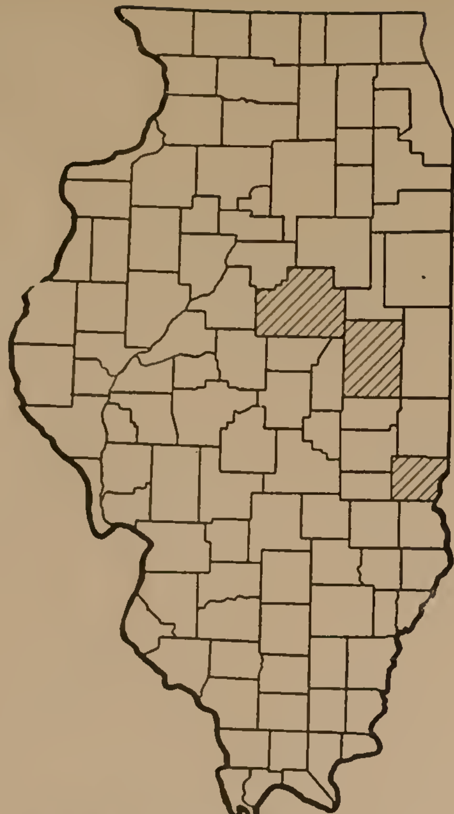


Map 19.—Distribution of brown-spot of corn.

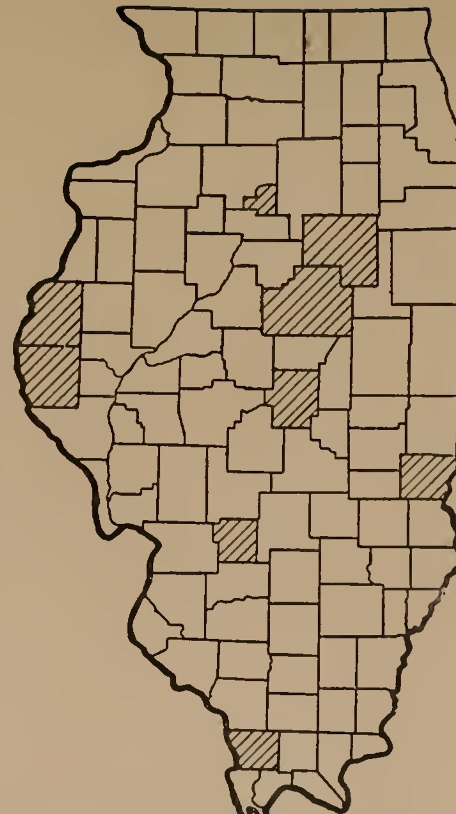


Map 20.—Distribution of corn rust.

Map 21.—Distribution of Rosen's disease of corn.

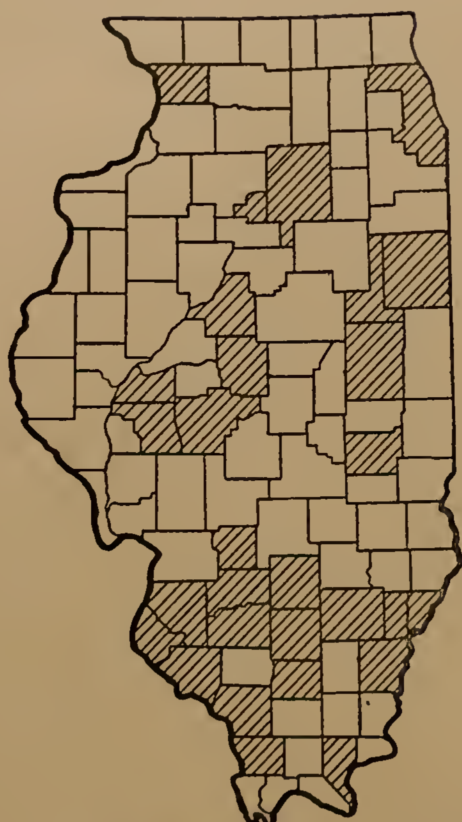


MAP 22.—Distribution of the black-bundle disease of corn.



MAP 23.—Distribution of Stewart's disease of corn.

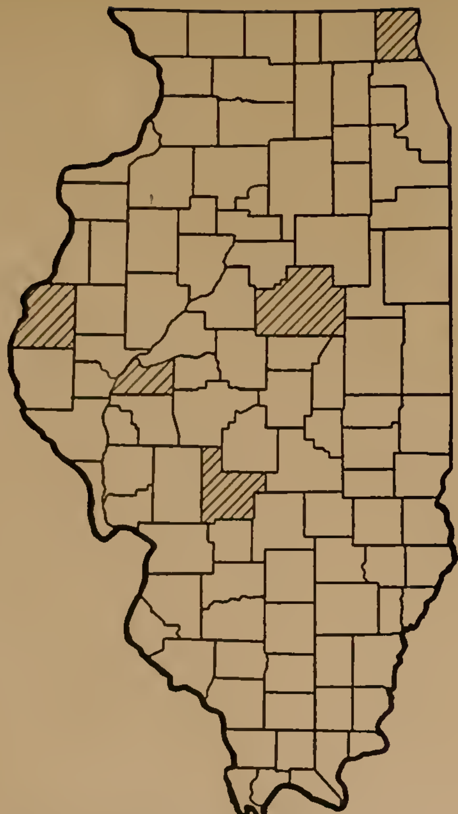
MAP 24.—Rye average in 1922. Each dot represents 500 acres.



Map 25.—Distribution of the brown rust of rye.

Map 26.—Distribution of stém rust of rye.

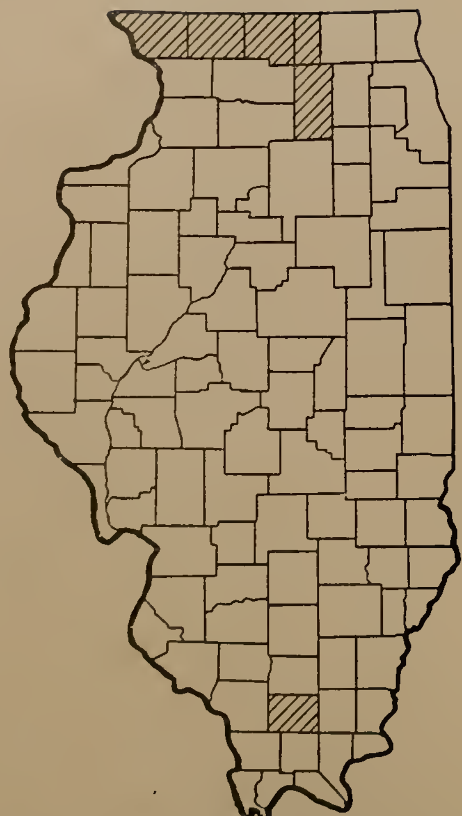
Map 27.—Distribution of ergot of rye.



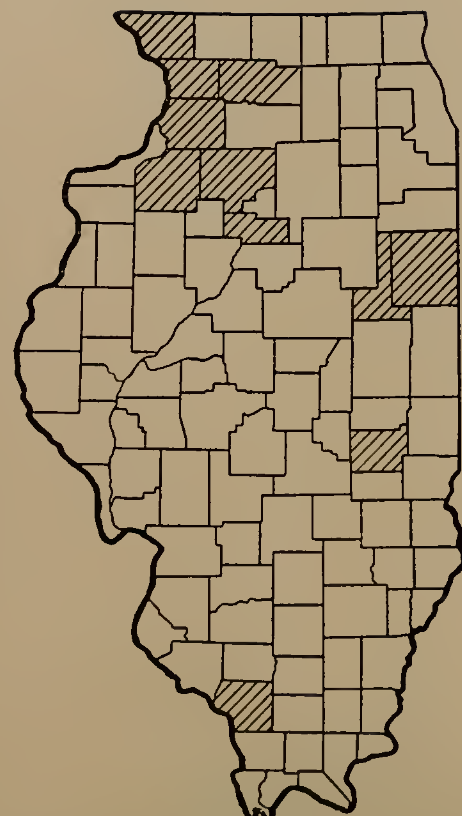
Map 28.—Distribution of leaf smut of rye.

Map 29.—Barley acreage in 1922. Each dot represents 500 acres.

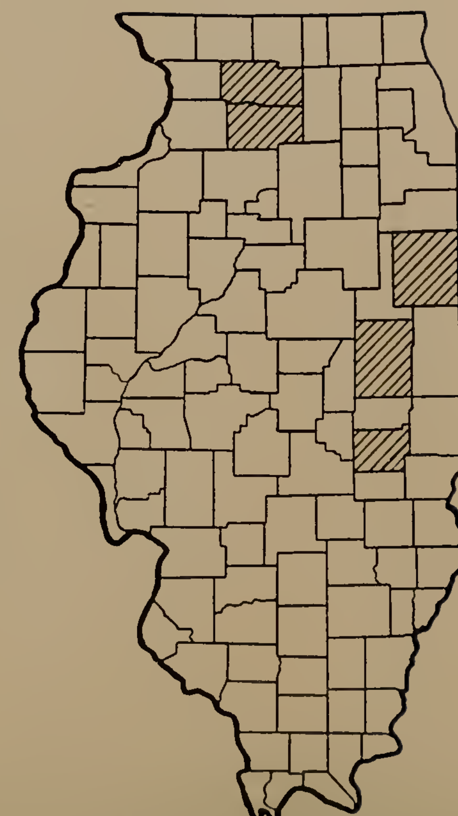
Map 30.—Distribution of leaf rust of barley.



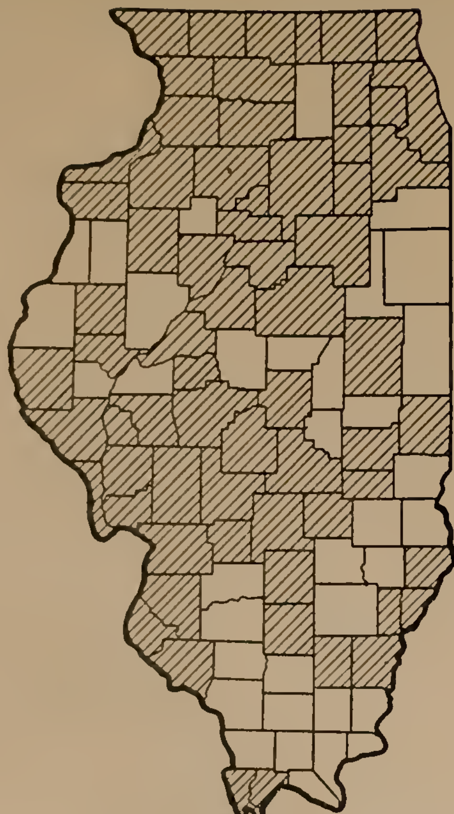
Map 31.—Distribution of stem rust of barley.



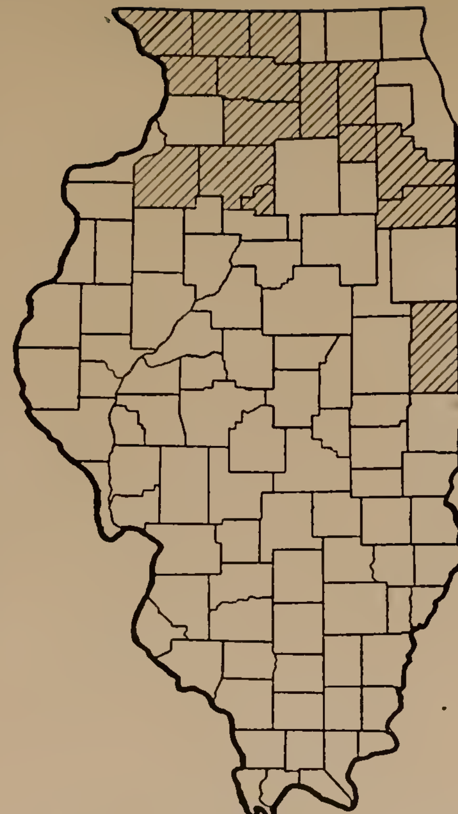
Map 32.—Distribution of loose-smut disease of barley.



Map 33.—Distribution of barley stripe.



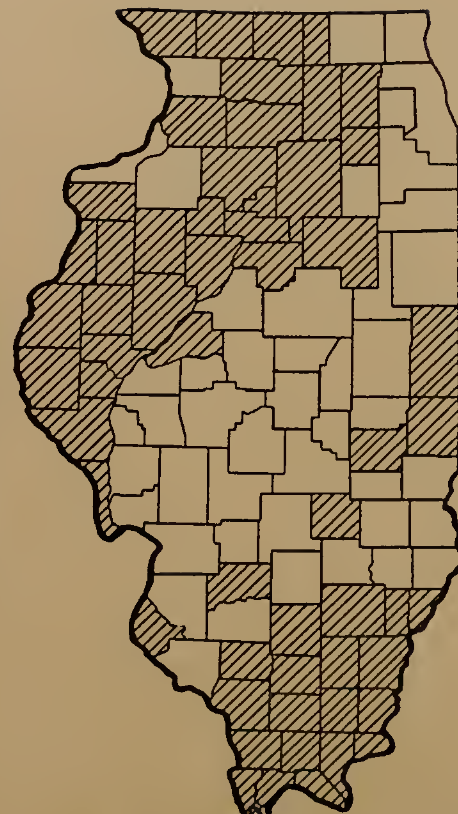
Map 34.—Distribution of alfalfa leaf-spot.



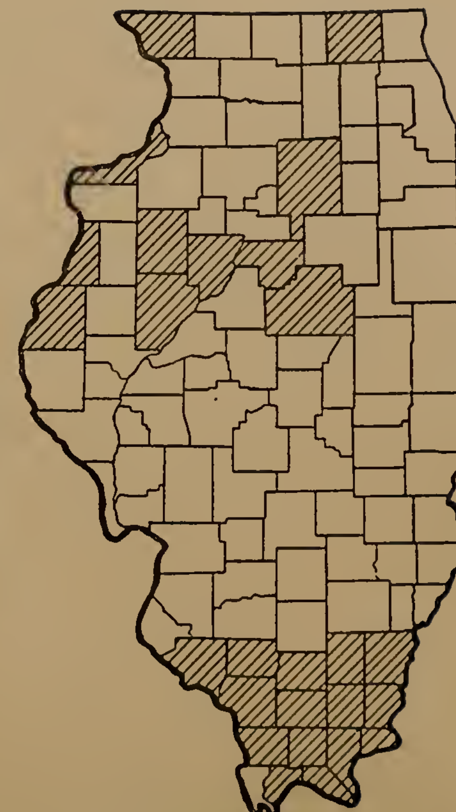
Map 35.—Distribution of sweet clover anthracnose.

Map 36.—Distribution of red clover anthracnose.

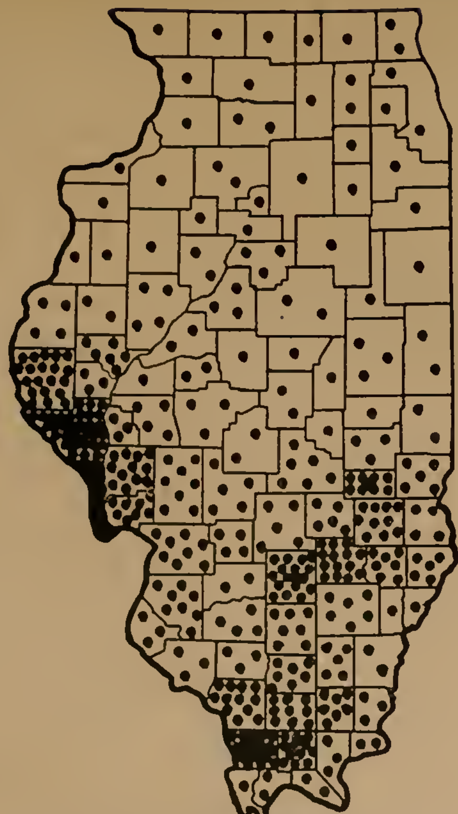
Map 37.—Distribution of powdery mildew of red clover.



Map 38.—Distribution of stem rust of timothy.



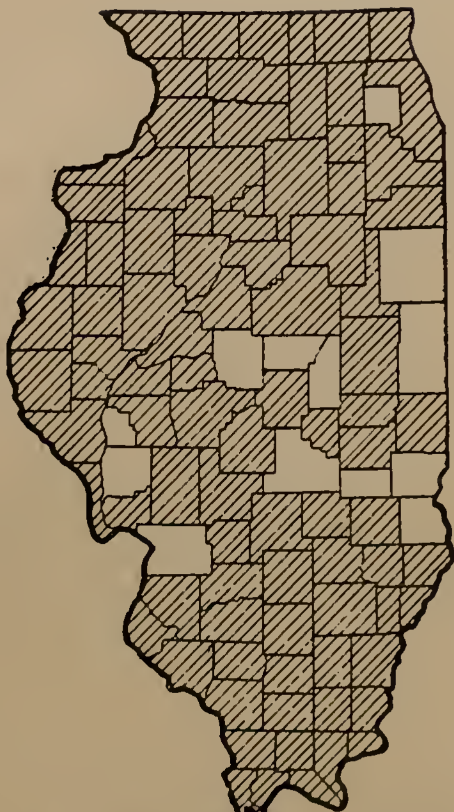
Map 39.—Distribution of stem rust of redtop.



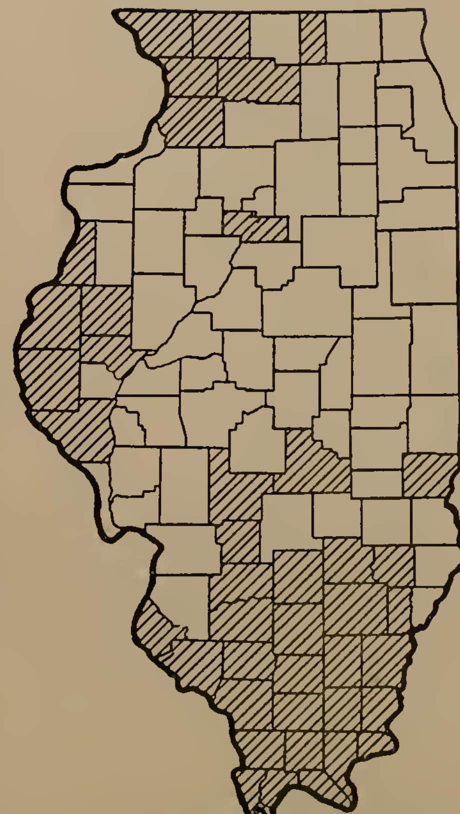
Map 40.—Apple production. One dot represents 10,000 bushels harvested in 1919.

Map 41.—Distribution of apple scab.

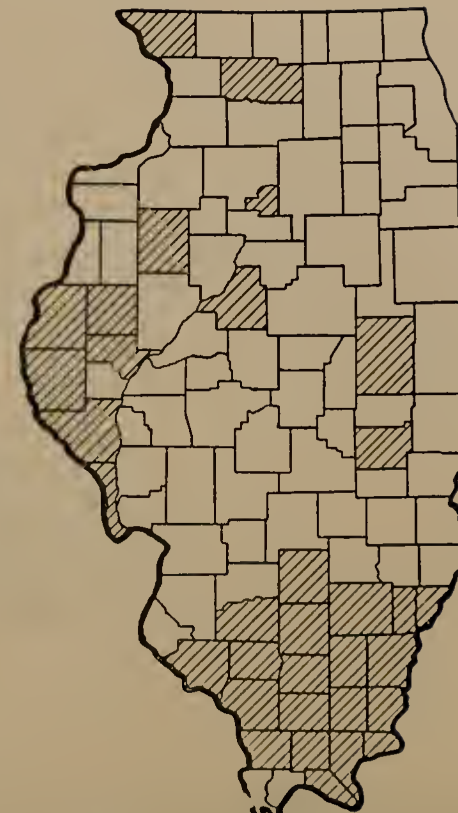
Map 42.—Distribution of apple blotch.



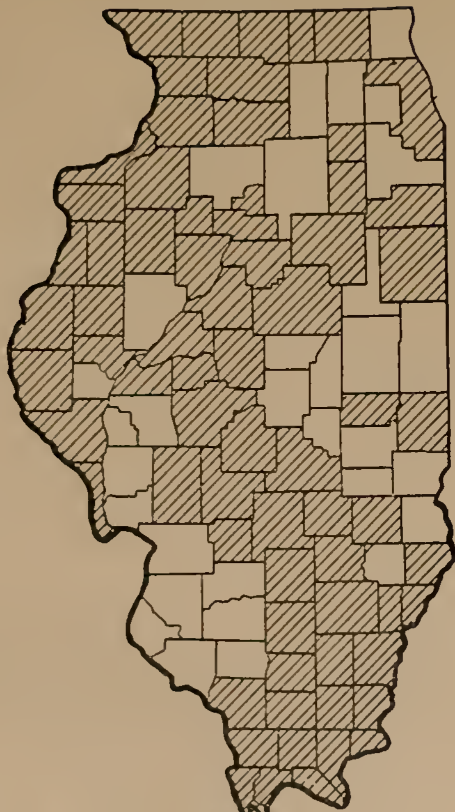
MAP 43.—Distribution of fire-blight of apple.



MAP 44.—Distribution of apple rust.



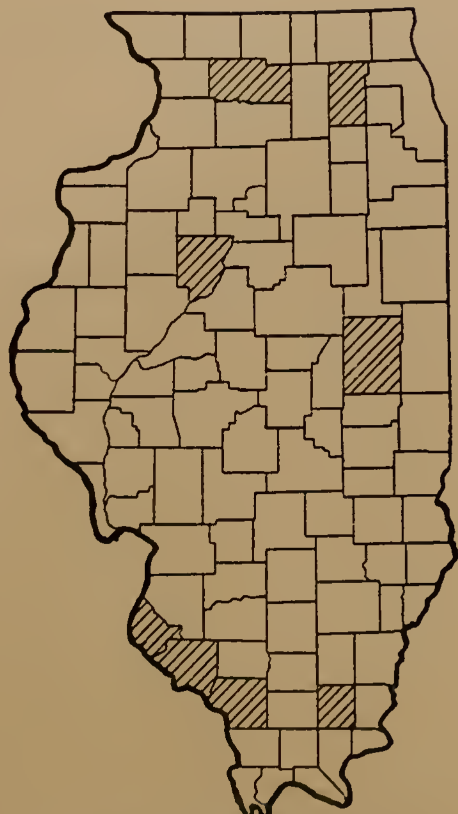
MAP 45.—Distribution of cedar rust, the alternate stage of the apple rust.



Map 46.—Distribution of black rot of apple.

Map 47.—Distribution of the blister canker of apple.

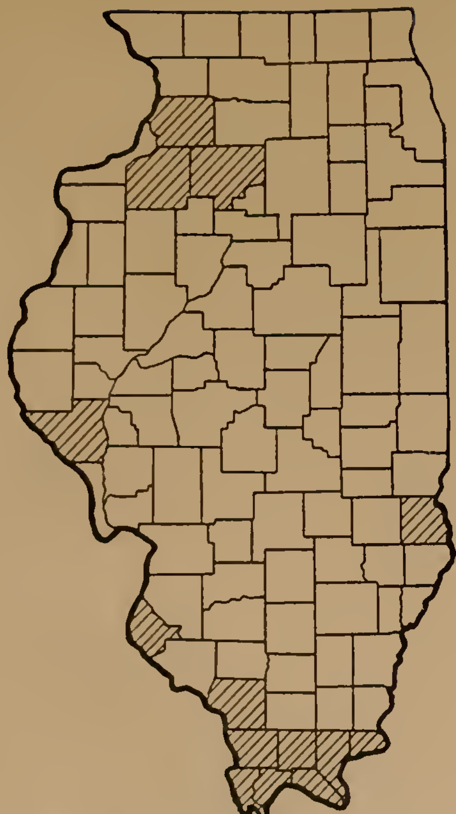
Map 48.—Distribution of the bitter-rot of apple.



Map 49.—Distribution of brown rot of apple.

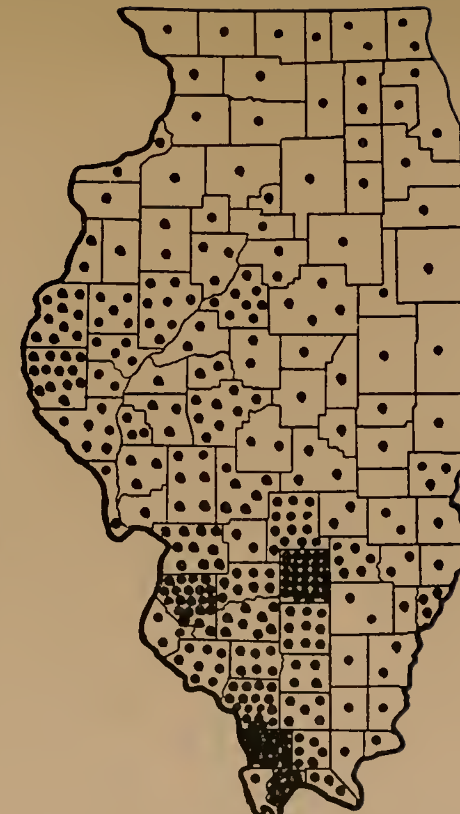
Map 50.—Distribution of the powdery mildew of apple.

Map 51.—Distribution of sooty blotch of apple.

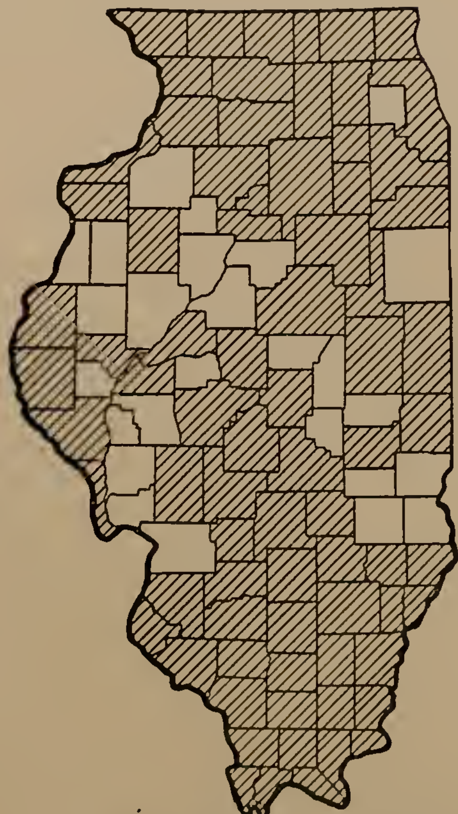


Map 52.—Distribution of fly-speck of apple.

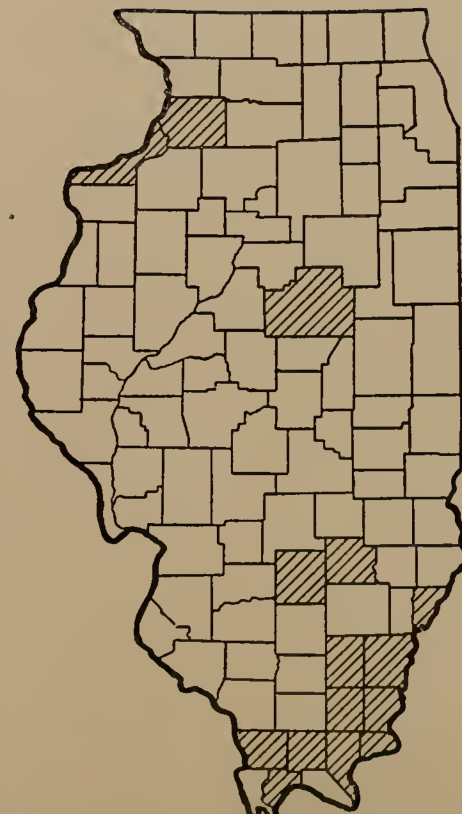
Map 53.—Distribution of crown-gall of apple in orchards.



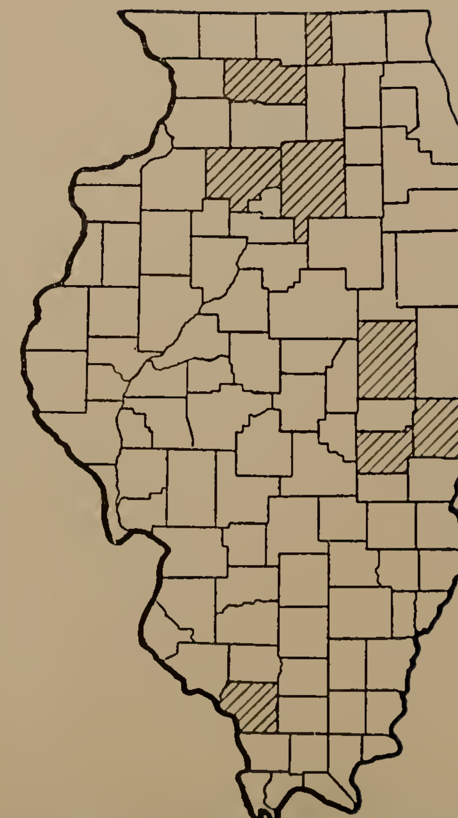
Map 54.—Pear production. One dot represents 1,000 bushels, harvest of 1919.



Map 55.—Distribution of pear blight.

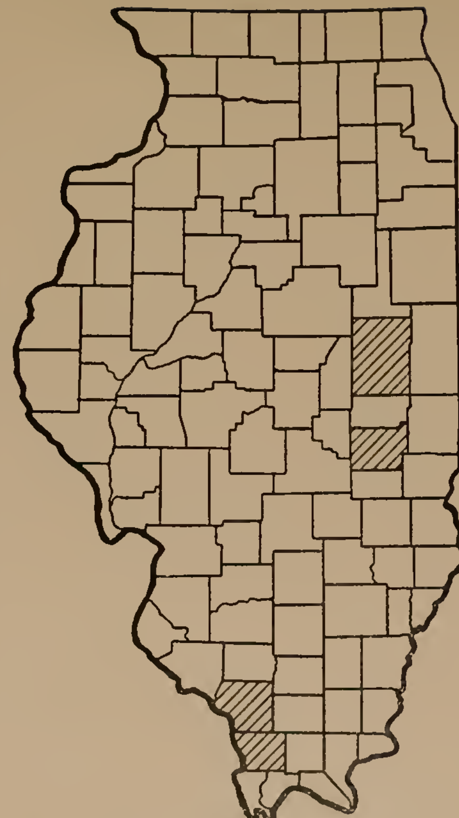


Map 56.—Distribution of leaf blight of pear.



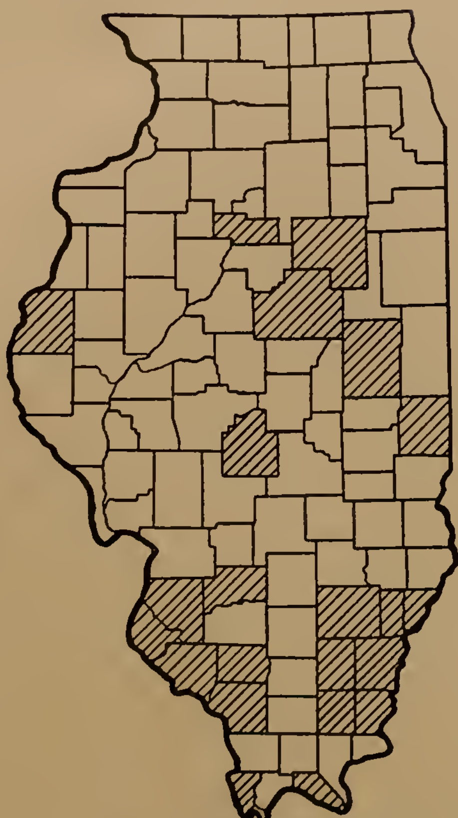
Map 57.—Distribution of pear scab.

Map 58.—Distribution of black rot of pear.



Map 59.—Distribution of pear leaf-spot.

Map 60.—Distribution of leaf blight of quince.

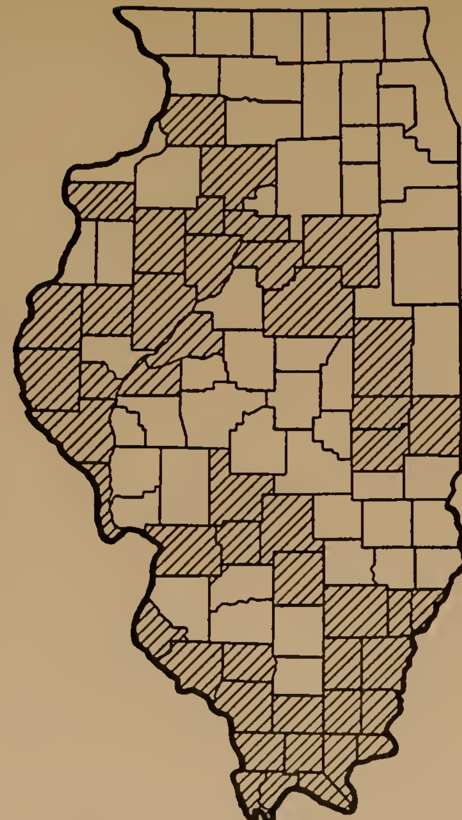


Map 61.—Distribution of fire-blight of quince.

Map 62.—Distribution of powdery mildew of quince.

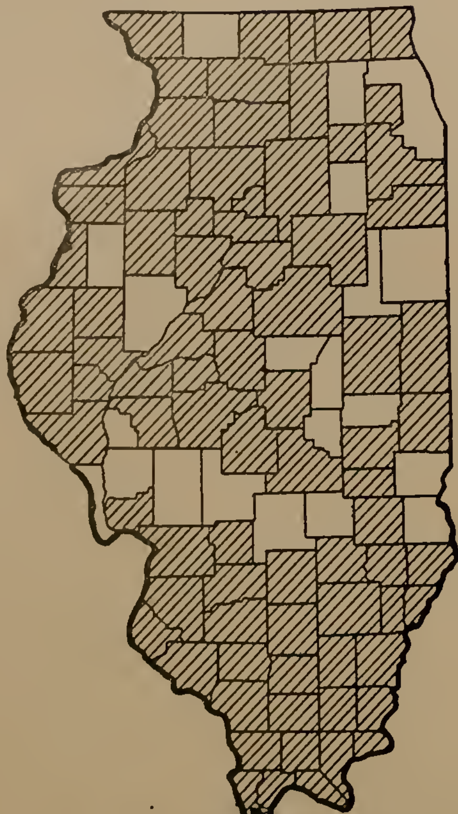
Map 63.—Peach production. One dot represents 1,000 bushels—harvest of 1919.

MAP 64.—Distribution of peach trees in 1923. One dot represents 2,000 trees.

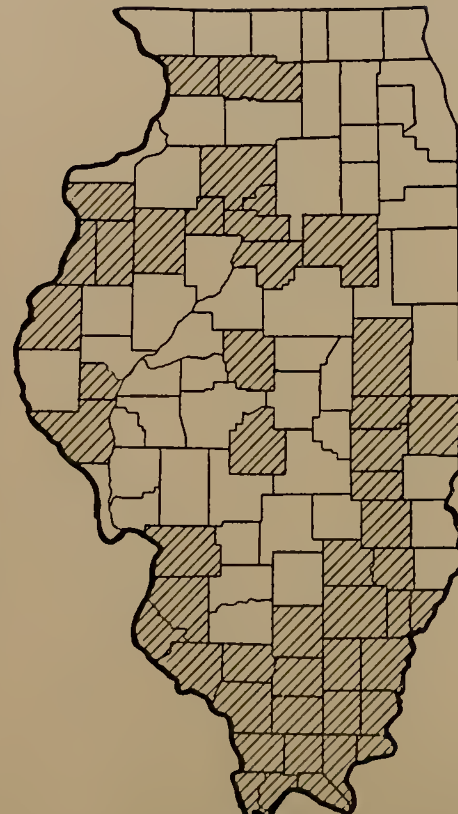


MAP 65.—Distribution of brown rot of peach.

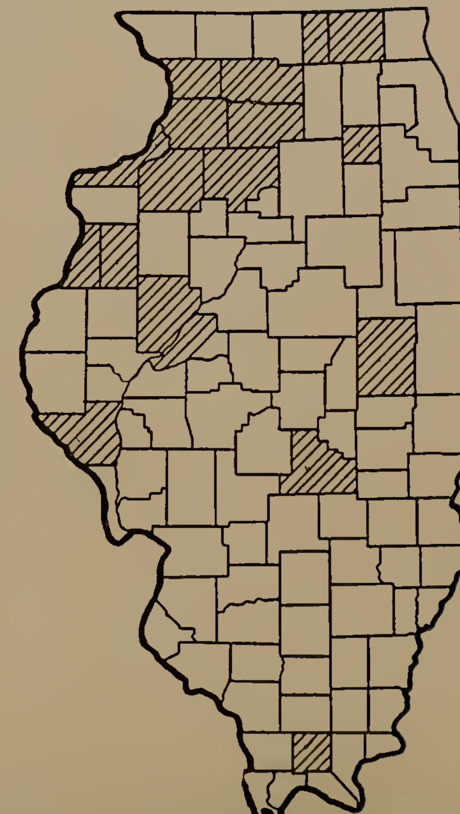
MAP 66.—Distribution of peach leaf-curl.



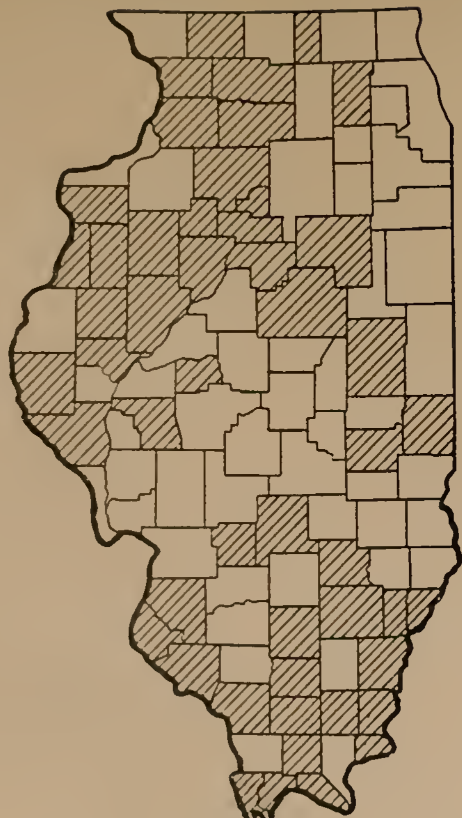
MAP 67.—Distribution of bacterial shot-hole of peach.



MAP 68.—Distribution of peach scab.



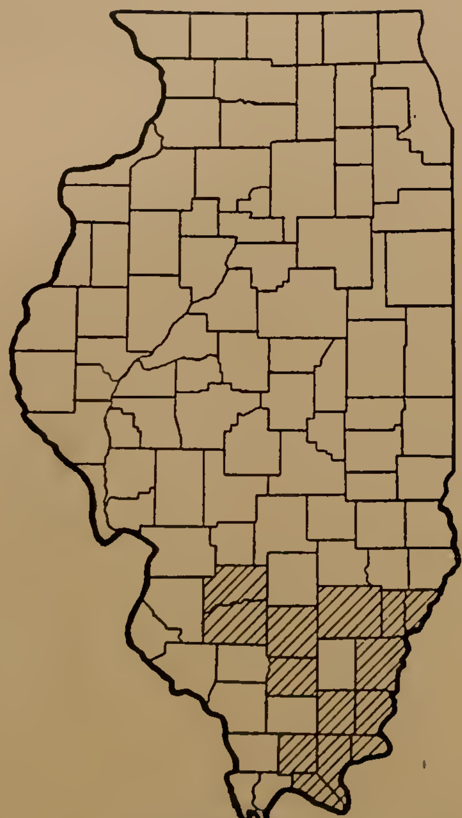
MAP 69.—Distribution of peach die-back.



MAP 70.—Distribution of brown rot of plum.

MAP 71.—Distribution of leaf blight of plum.

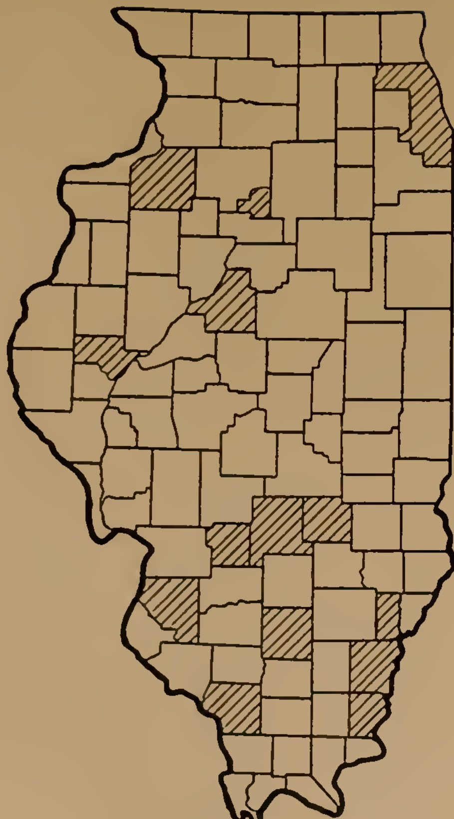
MAP 72.—Distribution of black-knot of plum.



Map 73.—Distribution of the bacterial shot-hole of plum.

Map 74.—Distribution of leaf-curl of plum.

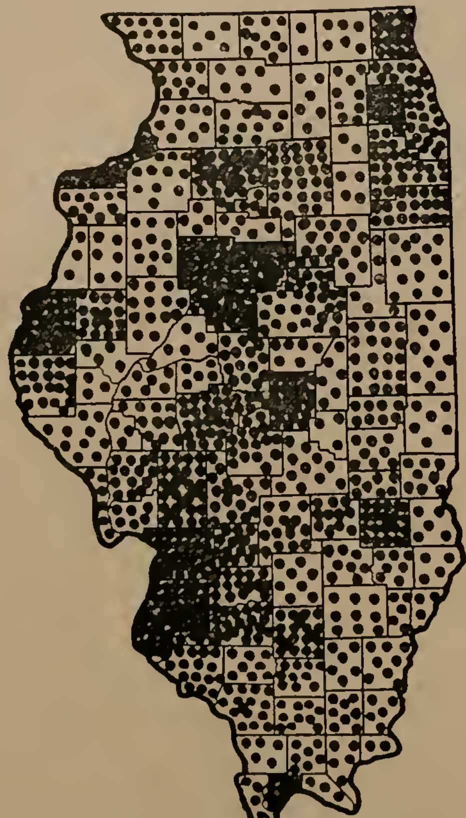
Map 75.—Distribution of powdery mildew of cherry.



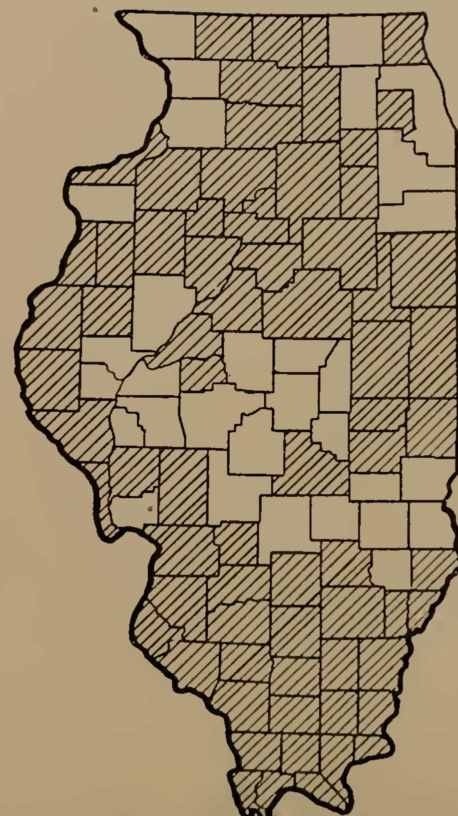
Map 76.—Distribution of brown rot of cherry.

Map 77.—Distribution of cherry leaf-blight.

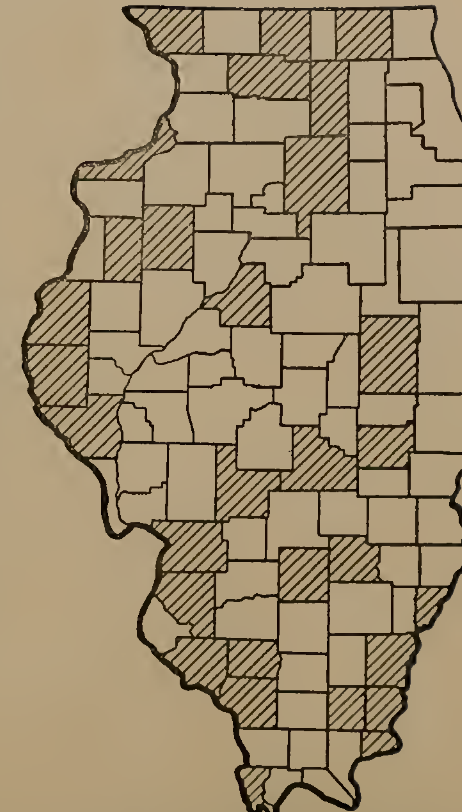
Map 78.—Distribution of the leaf blight of black cherry.



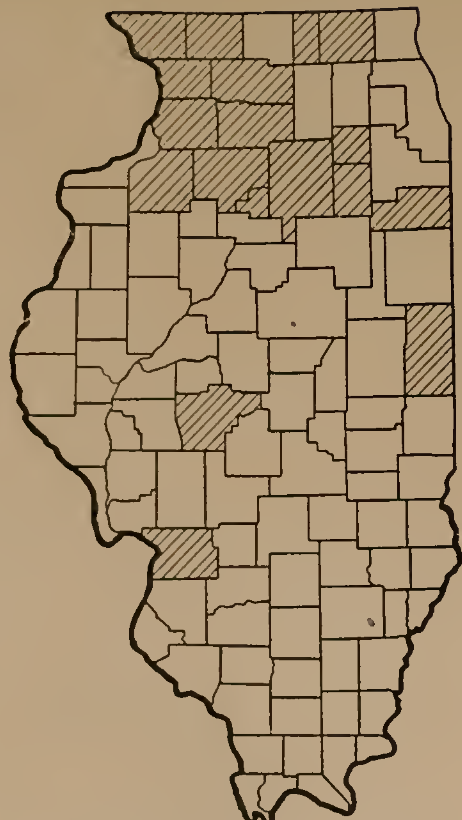
Map 79.—Grape production. One dot represents 1,000 vines.



Map 80.—Distribution of black rot of grape.



Map 81.—Distribution of downy mildew of grape.



Map 82.—Distribution of grape anthracnose.

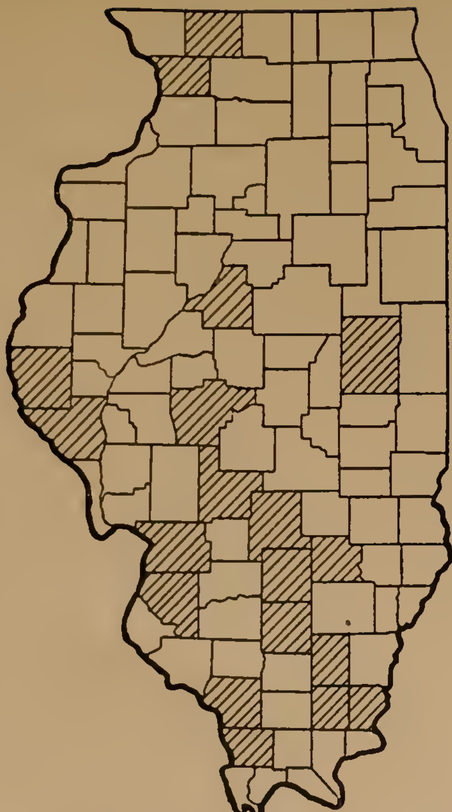
Map 83.—Distribution of powdery mildew of grape.

Map 84.—Distribution of anthracnose of blackberry and raspberry.

MAP 85. — Distribution of raspberry cane-blight.

MAP 86. — Distribution of raspberry spur-blight.

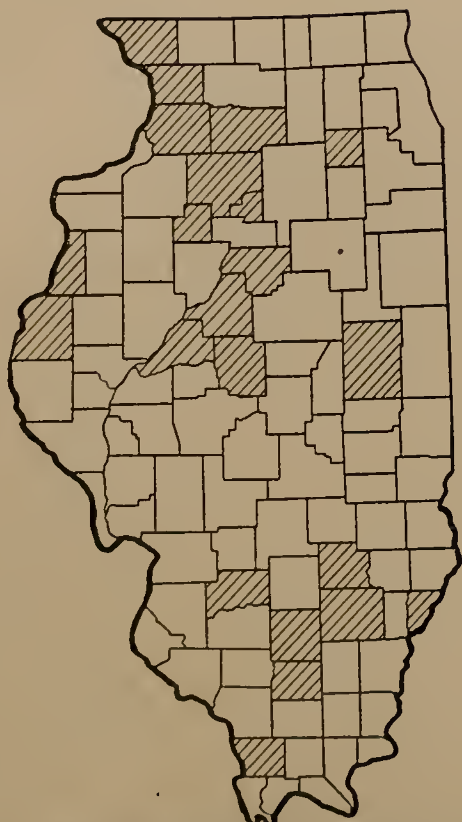
MAP 87.—Distribution of leaf spot of raspberry and blackberry.



Map 88.—Distribution of orange rust of brambles.

Map 89.—Distribution of crown-gall of brambles.

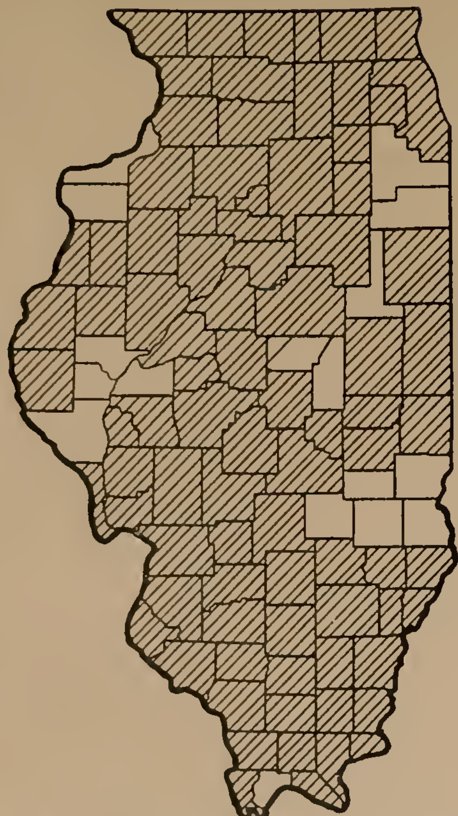
Map 90.—Distribution of bramble-streak of black-cap raspberry.



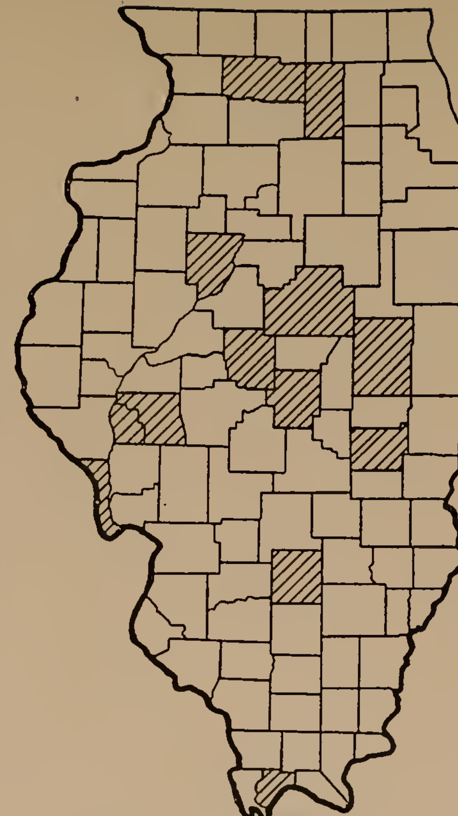
Map 91.—Distribution of anthracnose of currant and gooseberry.

Map 92.—Distribution of currant and gooseberry leaf-spot.

Map 93.—Distribution of strawberry acreage. One dot represents 10 acres.



Map 94.—Distribution of the Mycosphaerella leaf-spot of strawberry.



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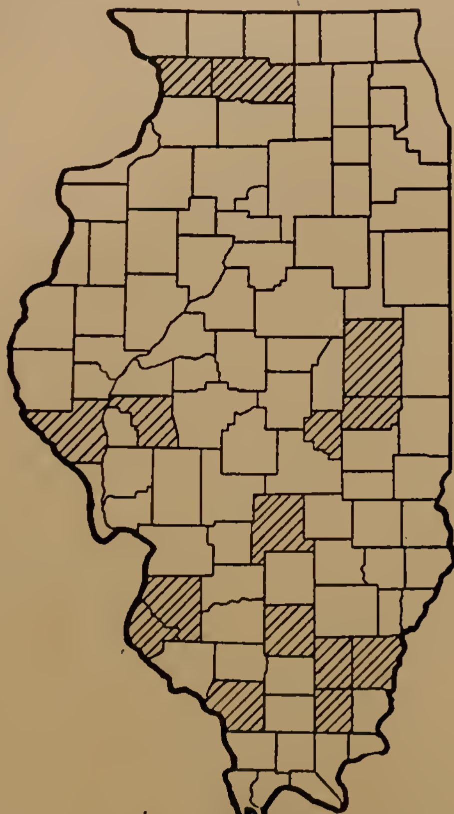
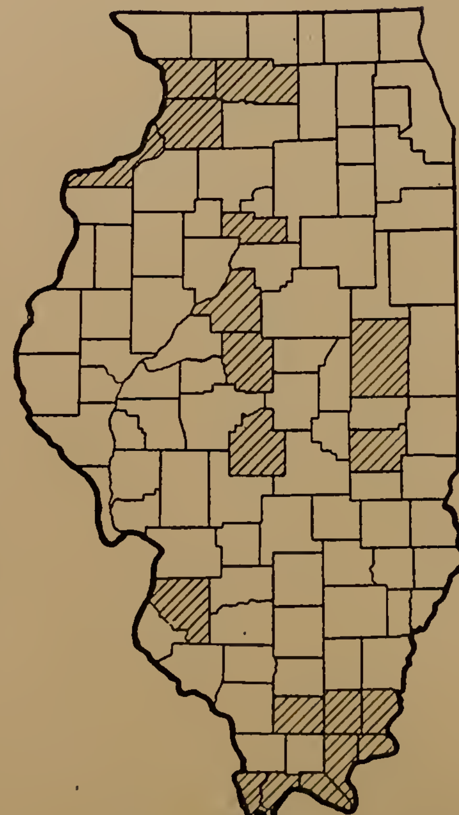
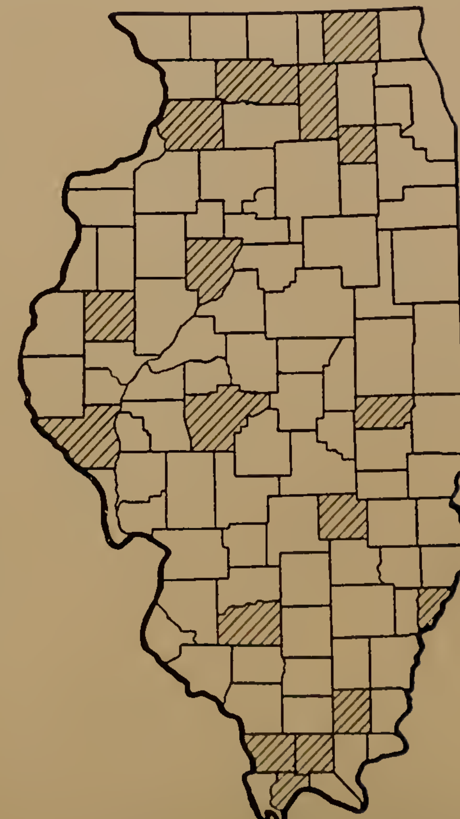


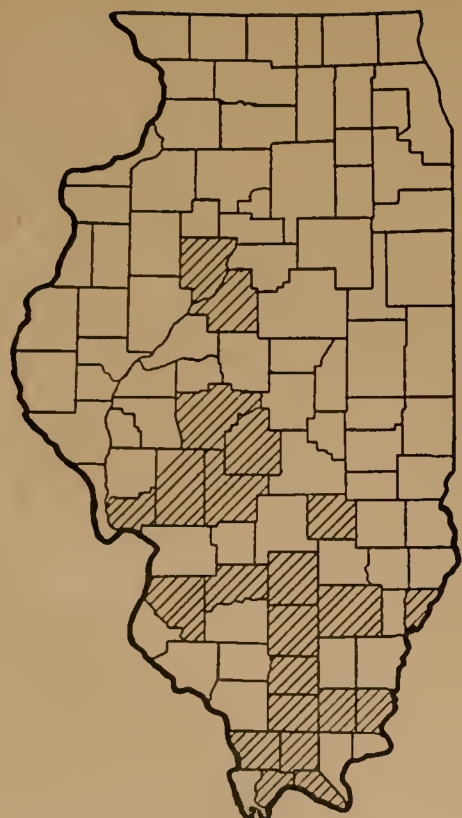
Map 97.—Distribution of early blight of potato.



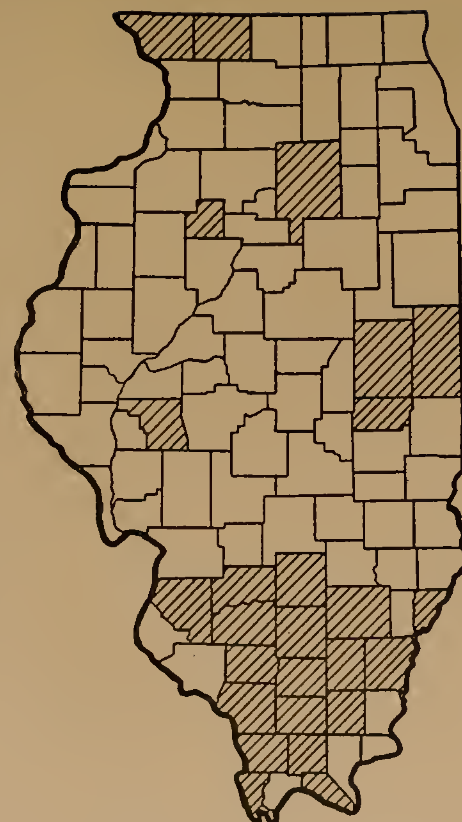
Map 98.—Distribution of potato scab.



Map 99.—Distribution of early blight of tomato.

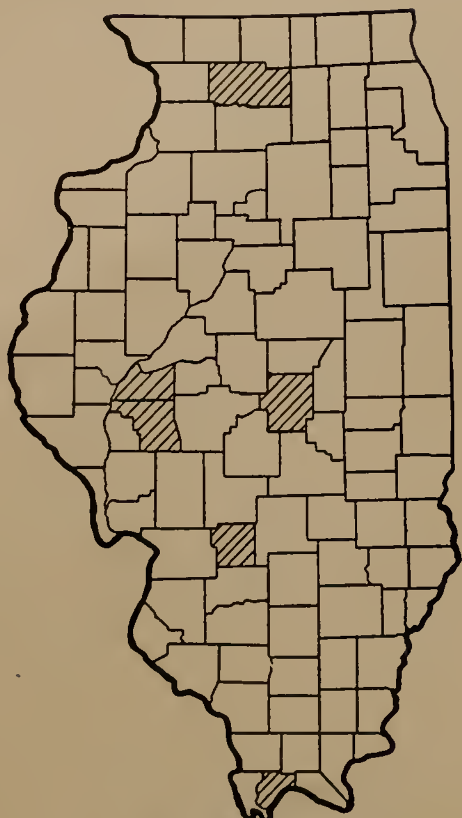


Map 100.—Distribution of tomato wilt.

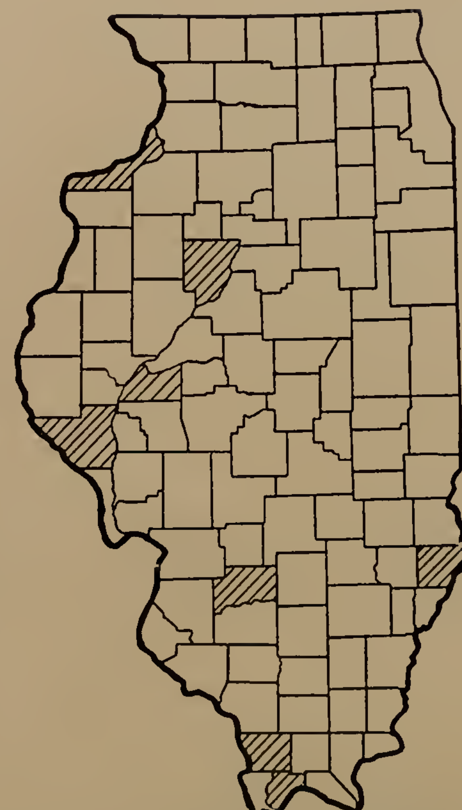


Map 101.—Distribution of tomato leaf-spot.

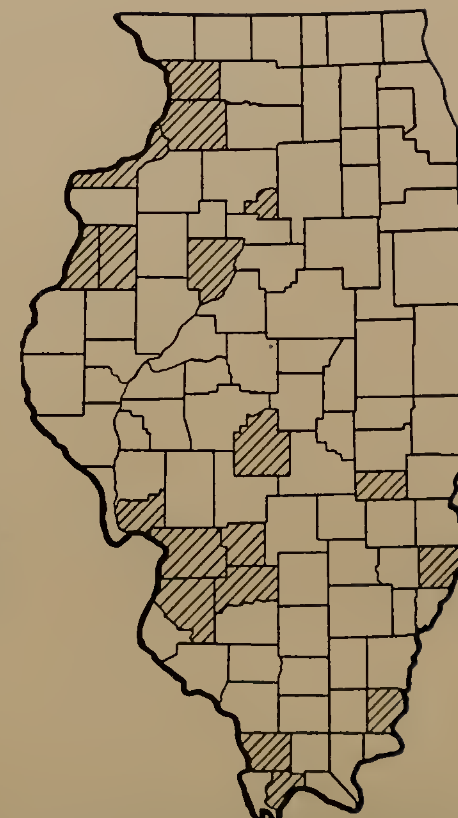
Map 102.—Distribution of sweet-potato acreage. One dot represents 50 acres.



Map 103.—Distribution of the black rot of sweet potato.



Map 104.—Distribution of sweet-potato wilt.



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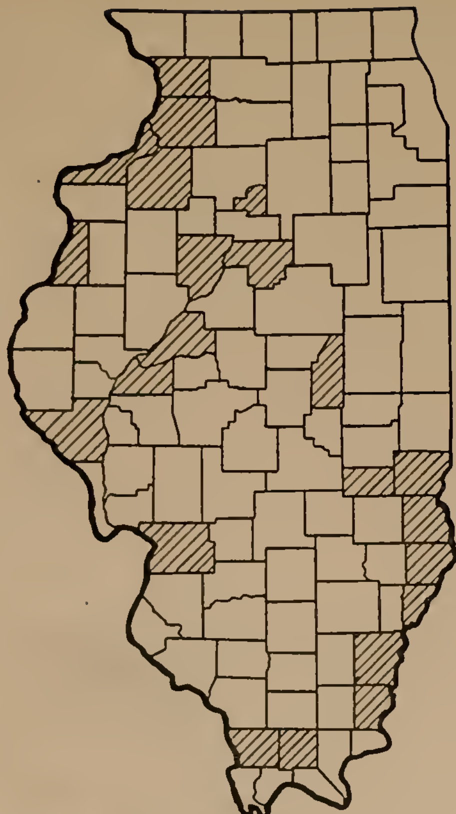
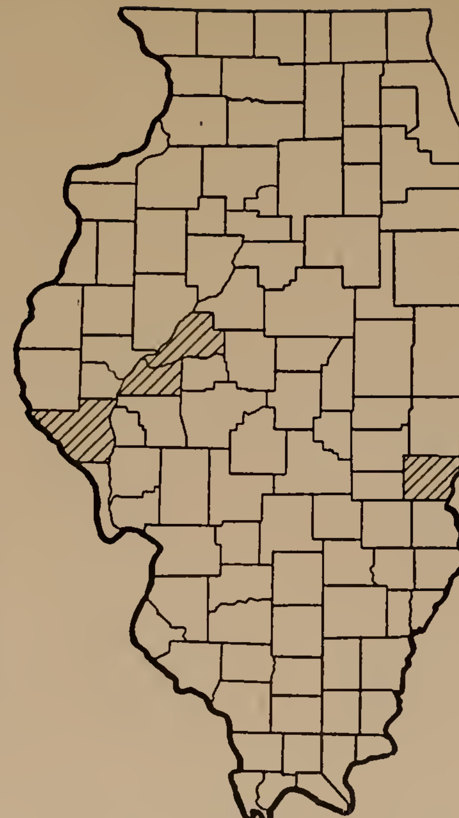
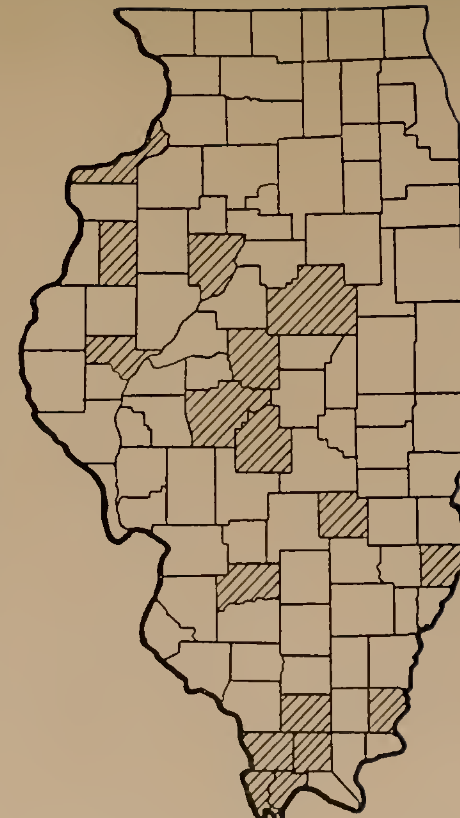


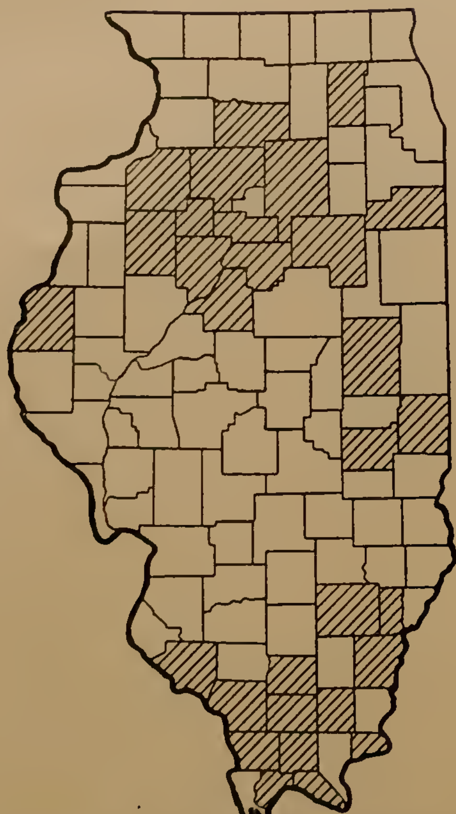
Map 106.—Distribution of watermelon wilt.



Map 107.—Distribution of watermelon anthracnose.



Map 108.—Distribution of cucumber wilt.



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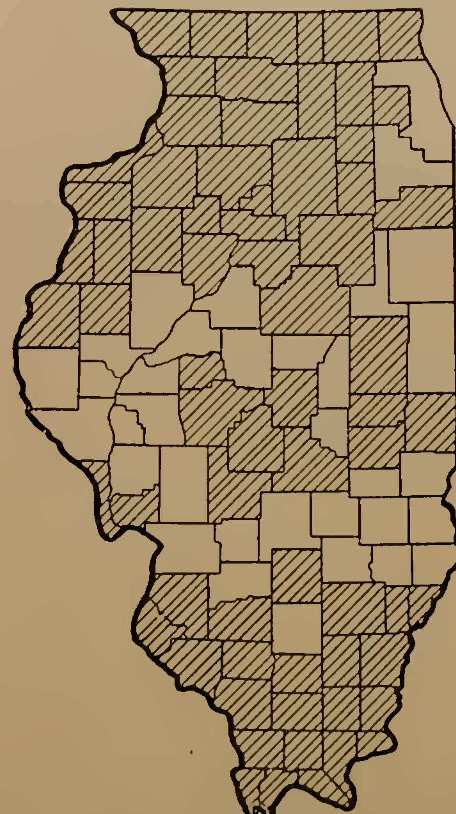

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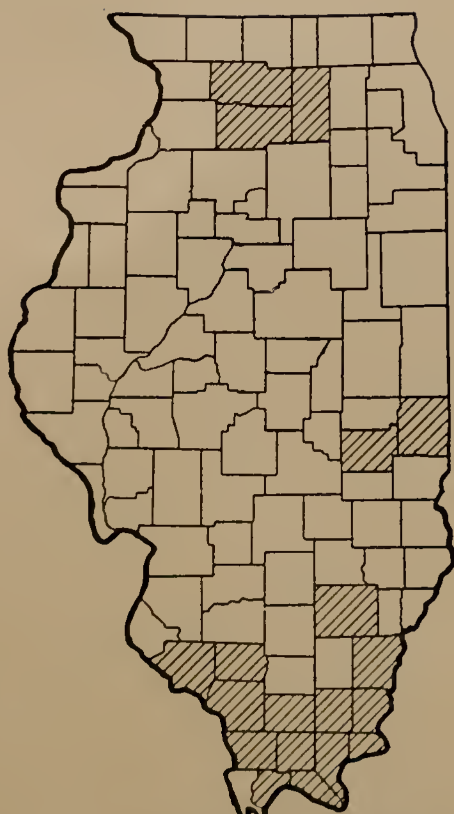
MAP 112.—Distribution of black rot of cabbage..

MAP 113.—Distribution of bean blight.

MAP 114.—Distribution of bean rust.



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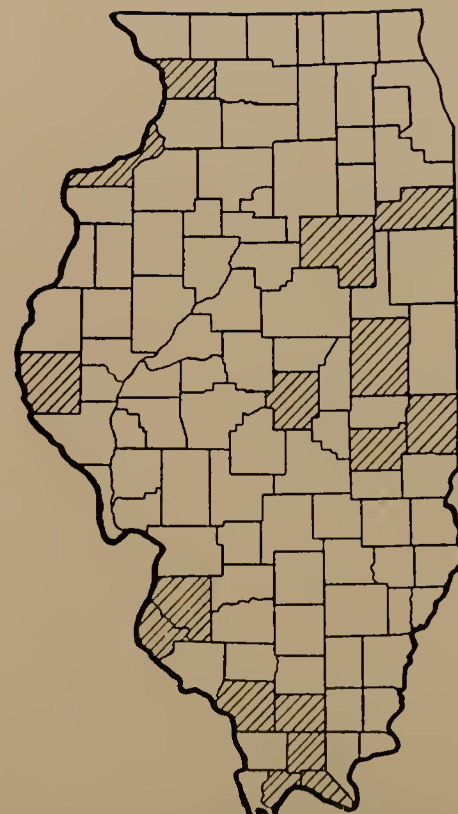

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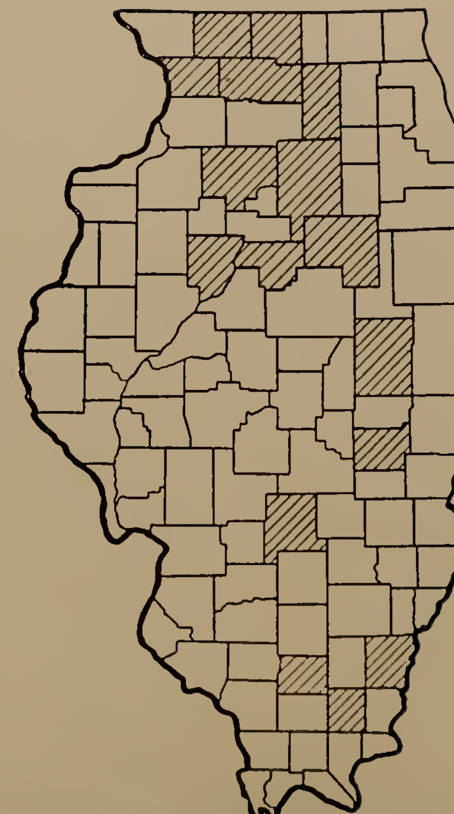
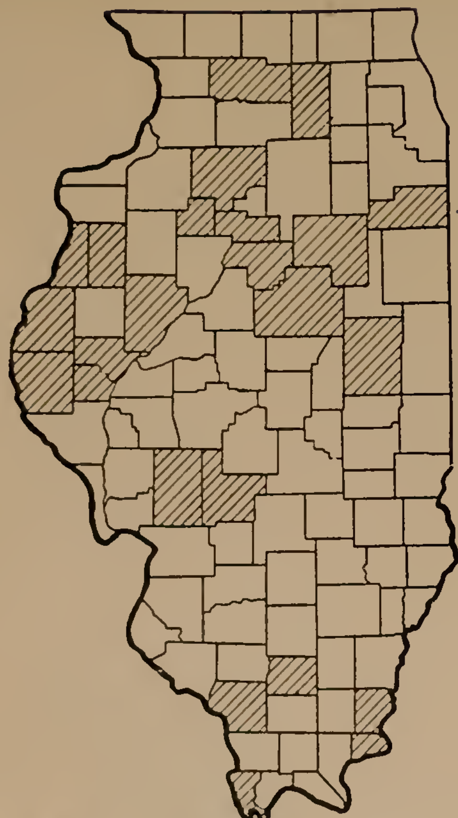


Map 117.—Distribution of white rust of radish



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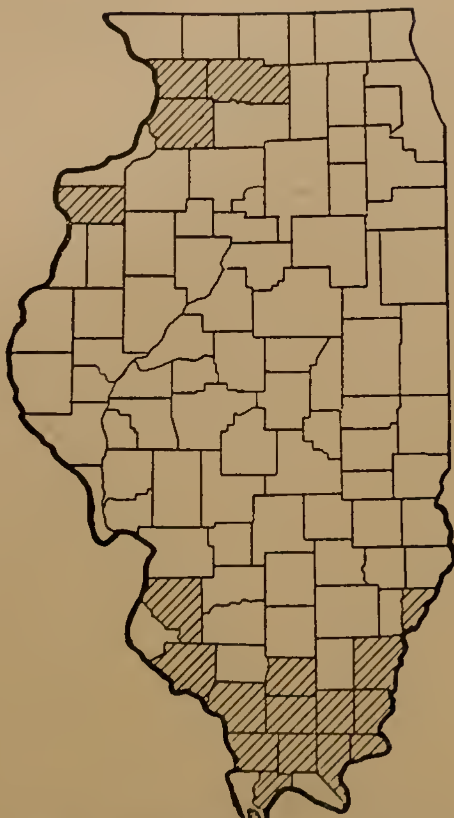
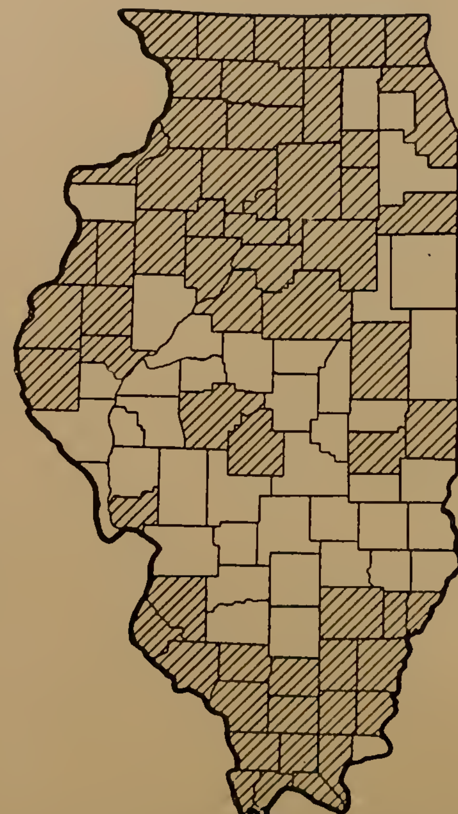


Map 121.—Distribution of rose leaf-spot.



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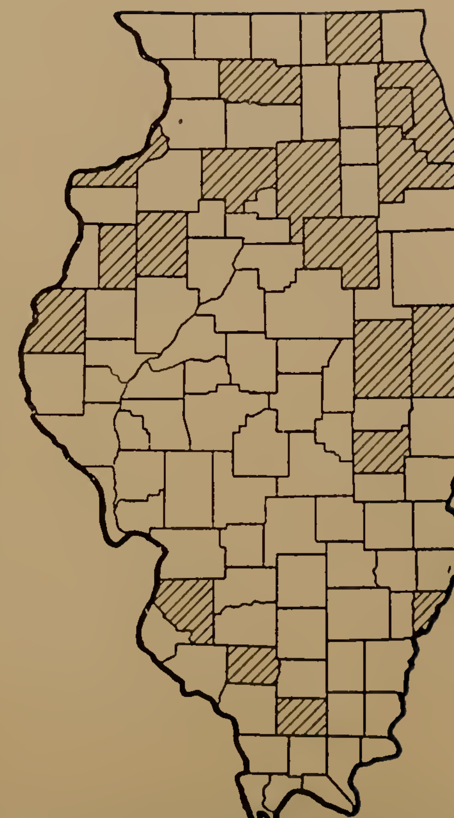
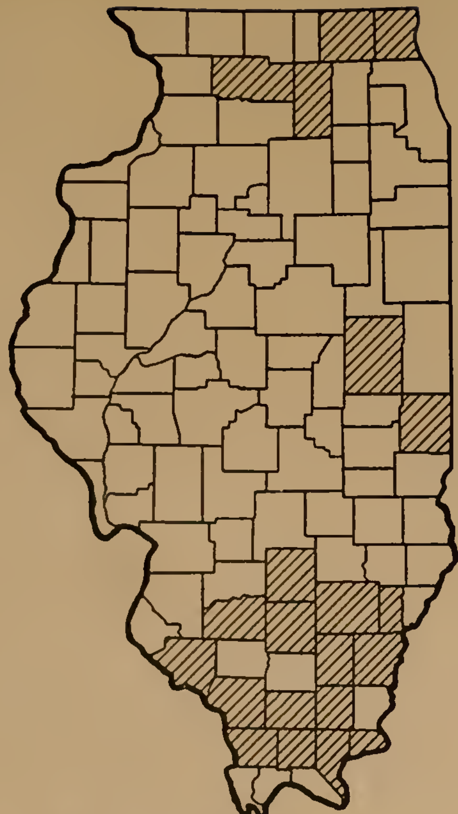


Map 123.—Distribution of carnation rust.



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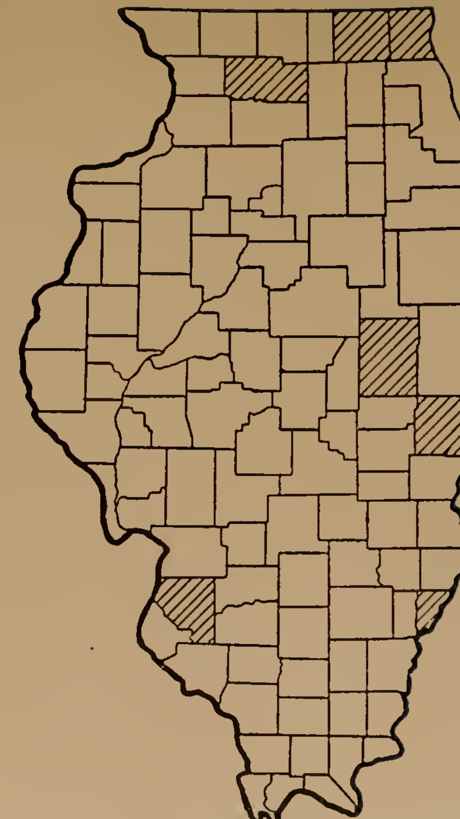

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STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE
NATURAL HISTORY SURVEY
STEPHEN A. FORBES, *Chief*

Vol. XV. BULLETIN Article V.

Changes in the Small Bottom Fauna of Peoria Lake, 1920 to 1922

BY

ROBERT E. RICHARDSON

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ARTICLE V.—*Changes in the Small Bottom Fauna of Peoria Lake, 1920 to 1922.* BY ROBERT E. RICHARDSON.

INTRODUCTION

Early in July 1922 the cooperative program of chemical and biological investigations of the middle Illinois River and Peoria Lake begun in the summer of 1920 by the State Natural History Survey and the State Water Survey was again taken up after an interval of two years. The summer's work included, as one item among several others, between the date of opening and the middle of September, quantitative bottom dredgings at seventy-one stations in the channel and wide waters of Peoria Lake and contiguous river between Chillicothe and the Peoria and Pekin Union Railway Bridge opposite the lower part of the city of Peoria. The dredging stations were distributed over approximately the area covered by the thirty-five stations worked in Peoria Lake in the summer of 1920, and covered a linear distance of 19.9 miles. Collections were made and handled as in 1920. Assistance was furnished by Dr. C. P. Alexander in determining the larval Chironomidae (midges), by Mr. F. C. Baker and by Dr. V. Sterki on snails of the family Sphaeriidae, and by Prof. Frank Smith and Dr. J. P. Moore on the worms and leeches. The nitrogen data on which the 1921 curve of per cent free ammonia is based have been furnished in advance of publication by the U. S. Public Health Service.

DESTRUCTION OF THE OLD BOTTOM FAUNA

In a paper* published in December, 1921, on the changes in the bottom and shore fauna of the middle Illinois River, it was shown that between the period 1913-1915 and the summer of 1920, there had been an almost complete extermination of the older normal bottom population over a stretch of around 90 miles of river, including Peoria Lake, extending from Chillicothe to Beardstown. The same period also saw

* Bul. Ill. Nat. Hist. Surv., Vol. XIV, Art. 4, pp. 33-75.

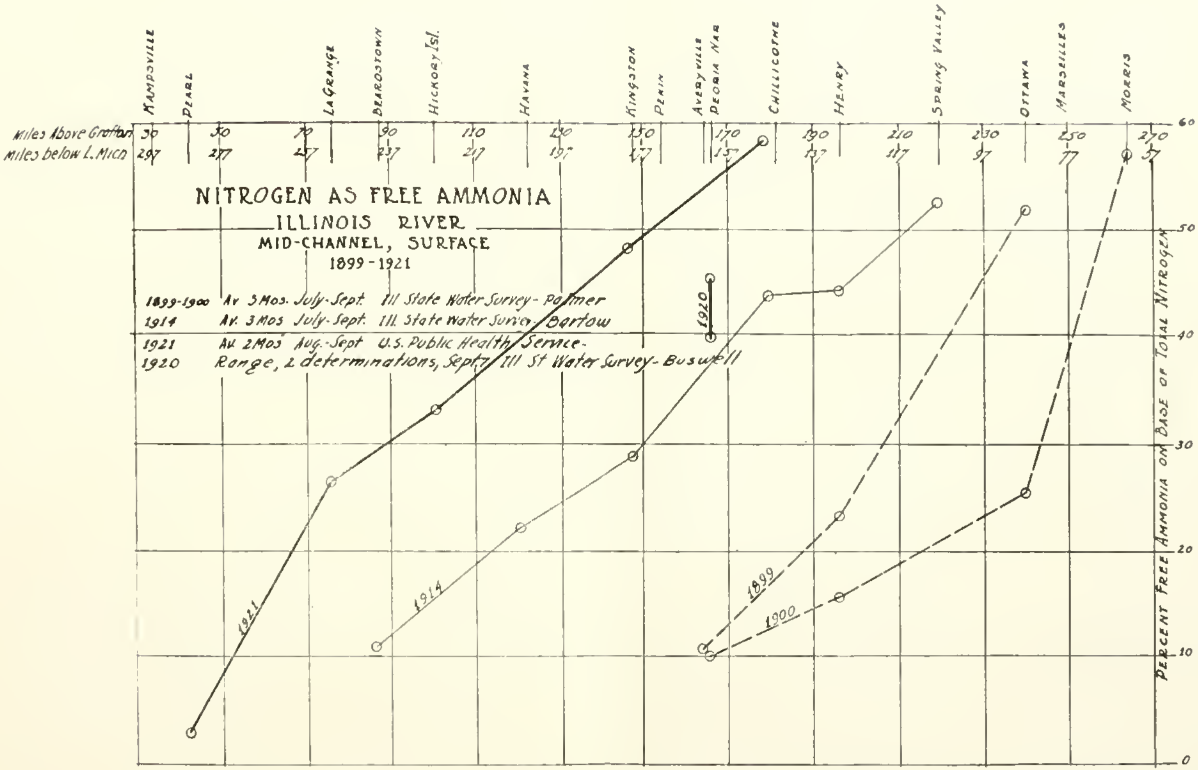
the point of practically complete oxygen exhaustion, a foot below the surface, in midsummer, move 83 miles down stream, from Morris, 63.5 miles below Chicago, to Chillicothe, 146.5 miles below; and saw the surface dissolved oxygen at the same time of year fall from around 4 p. p. m. to as low as 1 p. p. m. at Havana, 207 miles below Chicago. During the same five or six years, also, the zone of high free ammonia, with the ratio (per cent) on the base of the total nitrogen between 40 and 60 per cent, moved down the river more than 50 miles, or from Spring Valley, 108.6 miles below Chicago, to Peoria Narrows, 160.9 miles below; while the upper limits of the zone of well clarified effluent, with free ammonia around or under 10 per cent of the total nitrogen, receded from Beardstown to Kampsville, a distance of about 57 miles, or to within about 30 miles of the mouth of the 327 mile continuous waterway to Grafton. See charts following.

Between 1914 and 1918 the total weight of animals slaughtered at the Chicago stockyards (Tables, pp. 331 and 332) had increased at a rate more than eight times as fast as the estimated normal rate of increase of human population; and there had been large increase in the rates of operation of the Corn Products Refining plants both at Argo and Pekin; while the average dilution employed in the Chicago Sanitary Canal was changed in an amount relatively small.

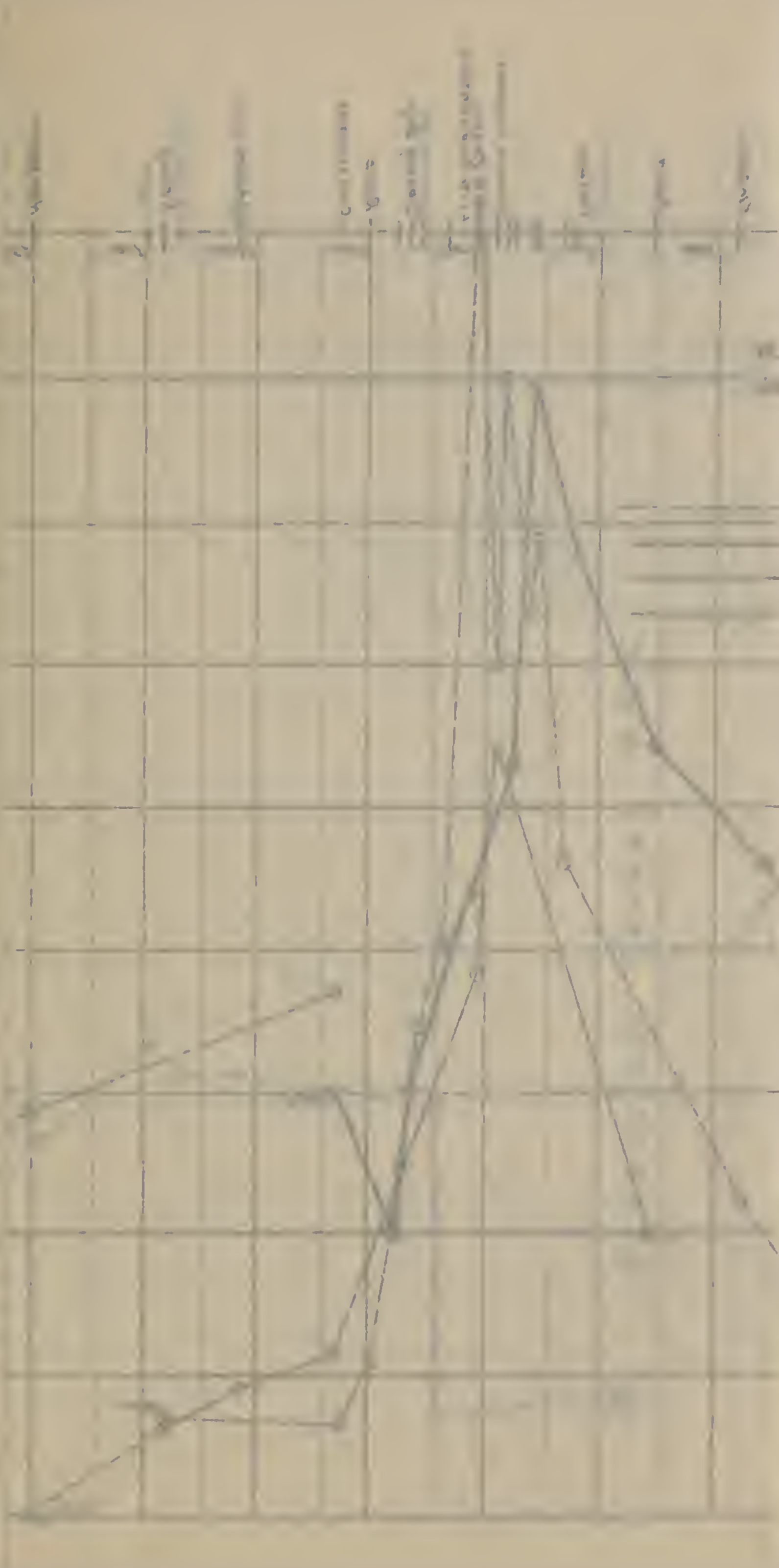
The years 1911 to 1914 inclusive had been rather quiescent years for the packing industry, the total weight of animals slaughtered dropping off gradually during that time from about 3,383 million pounds in 1911 to 3,040 million pounds in 1914. From the 1914 low figure the weight of slaughterings climbed rapidly, with only a slight recession during 1917, to a peak of 4,870 million pounds in 1918, representing an increase of fully 60 per cent over the 1914 yearly rate (Table, p. 332); and about 50 per cent over the average rate of 3,258 million pounds for the four years 1911-1914.

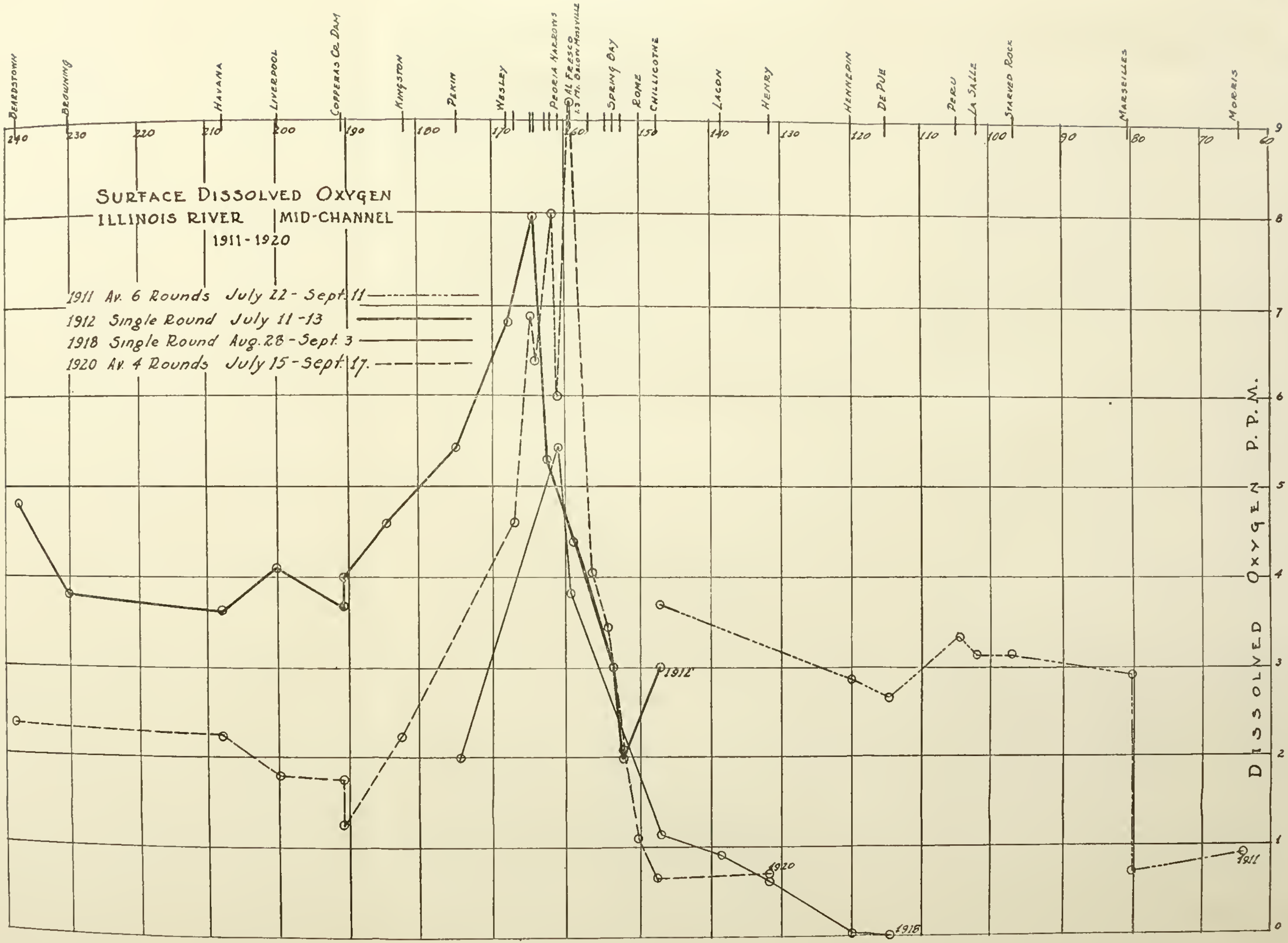
The increase in the Packingtown wastes entering the sanitary canal in the four years 1914 to 1918 amounted in population equivalent on the basis of the Sanitary District's own figures* to more than 523,000 persons, or almost treble the estimated actual increase in human population during the period; or to more than the total 1920 population of the city of Buffalo, New York. During peak weeks of 1916,

* Packingtown Report II, 1921, pp. 8, 14, 231, etc.



NITROGEN AS FREE AMMONIA
ILLINOIS RIVER
MID-CHANNEL, SURFACE
1899 - 1921
1899-1900 Av 3 Mos. July-Sept. Ill State Water Survey - Palmer
1914 Av. 3 Mos July-Sept. Ill. State Water Survey - Bartow
1921 Av. 2 Mos Aug.-Sept U.S. Public Health Service.
1920 Range, 2 determinations, Sept 7, Ill St Water Survey - Buswell
Miles Above Grafton
Miles below L. Mich
Kampsville
Pearl
La Grange
Beardstown
Hickory Isl.
Havana
Kingston
Pekin
Averyville
Peoria Nar
Chillicothe
Henry
Spring Valley
Ottawa
Marseilles
Morris
Percent Free Ammonia on Base of Total Nitrogen
1921
1914
1920
1899
1900





SURFACE DISSOLVED OXYGEN
ILLINOIS RIVER MID-CHANNEL
1911-1920
1911 Av. 6 Rounds July 22 - Sept. 11
1912 Single Round July 11-13
1918 Single Round Aug. 28 - Sept. 3
1920 Av. 4 Rounds July 15 - Sept. 17.
BEARDSTOWN
BROWNING
HAVANA
LIVERPOOL
COPPERAS CR. DAM
KINGSTON
PEKIN
WESLEY
PEORIA NARROWS
AL FRESCO
MOSSVILLE
SPRING BAY
ROME
CHILLICOTHE
LACON
HENRY
HENNEPIN
DE PUE
PERU
LA SALLE
STARVED ROCK
MARSEILLES
MORRIS
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
DISSOLVED OXYGEN P.P.M.
9
8
7
6
5
4
3
2
1
0
1912
1920
1918
1911

1917, and 1918 the weekly rate of killings ran for weeks at a time at more than double the average weekly rate of 1914; and in November and December, 1918, particularly, at rates representing increases of 110 to 145 per cent over the average weekly rate five years earlier. These weekly peaks were in the late fall or early winter, when it is presumed that a large portion of the wastes would settle to the bottom, not far away from their source, ready to be washed out, still to a considerable extent undecomposed, with the first heavy rains of spring.

Heavy mortality among the snails was noted at points all the way from Spring Valley to Havana during and following summer floods in 1917. In August of that year dead snails acres in extent were seen floating down the Illinois past Peoria and Havana; and in places were from one to two feet deep along the water-front at Peoria. In late summer 1918, while in the field with chemists of the State Water Survey, it was noted that all snails except one species of Musculium and one Campeloma of unusual hardiness seemed already to have been killed both at Lacon and Chillicothe. During the five weeks July 22 to August 31 that year we got our first records of surface dissolved oxygen under one part per million south of Spring Valley—finding them then extending as far south as Lacon*.

After 1918, up to the end of 1921, there was a long-sustained recession in the packing industry, which carried the slaughtering figures off more than a billion and a third pounds from the 1918 peak, or to within 443 million pounds of the 1914 rate (only 14.5 per cent above the 1914 figure).

Between 1921 and 1922 the slaughtering rate moved up 400 million pounds to a year total for 1922 of 3,975 million, and this was accomplished without seeming to exert any further seriously unfavorable influence on chemical or biological conditions; except as it was possibly reflected in increase in numbers of the sludge or mud worms (Tubificidae).

The present paper compares the condition of the bottom fauna of Peoria Lake as found in July-September, 1922, with that of the summer of 1920, which was probably very close to its point of low condition following the mortality of 1917-1918, just referred to; with the result, in general, of indicating an essentially slight though measurable improvement in the two years.

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* Third Annual Report, State Div. Waterways, 1919-1920, pp. 28-32.

Since 1922 there has continued a gradual rise in the Packingtown slaughterings, which brought them at the end of 1923 to a year total of 4,461 million pounds, or to a point again only 8.4 per cent under the 1918 peak of 4,870 billion pounds.

TOTAL WEIGHT OF ANIMALS SLAUGHTERED AND POPULATION EQUIVALENT 1911-1924

	Million pounds	Population equivalent.[3]	
1911	3,380[1]	967,000	
1912	3,330[1]	952,000	[4]
1913	3,250[1]	929,000	
1914	3,040[1]	869.000	
1915	3,700[1]	1,058,000	
1916	4,000[1]	1,144,000	
1917	3,830[1]	1,096.000[5]	
1918	4,870[1]	1,393.000[6]	
1919	4,420[1]	1,264,000	
1920	3,638[2]	1,040,000	
1921	3,483[2]	994.000	
1922	3,975[2]	1,137,000	
1923	4,461[2]	1,276.000	
1924	4,332[2]	1,239,000	

[1] From Chart, Packingtown Rep. II, 1921, p. 32, yrs. 1911-1919, inclusive.
[2] Own calculations from Drover's Journal Year Books, 1920-1924 inclusive.
[3] Rate of 286.1 persons for each million pounds killed. See reference 1, above p. 14.
[4] Av. 4 years, 1911-1914, 929.825.
[5] Basic figure. See Packingtown Rep. II, p. 14.
[6] War-time peak.

Weight of Animals Slaughtered—Cattle, Sheep, and Hogs only

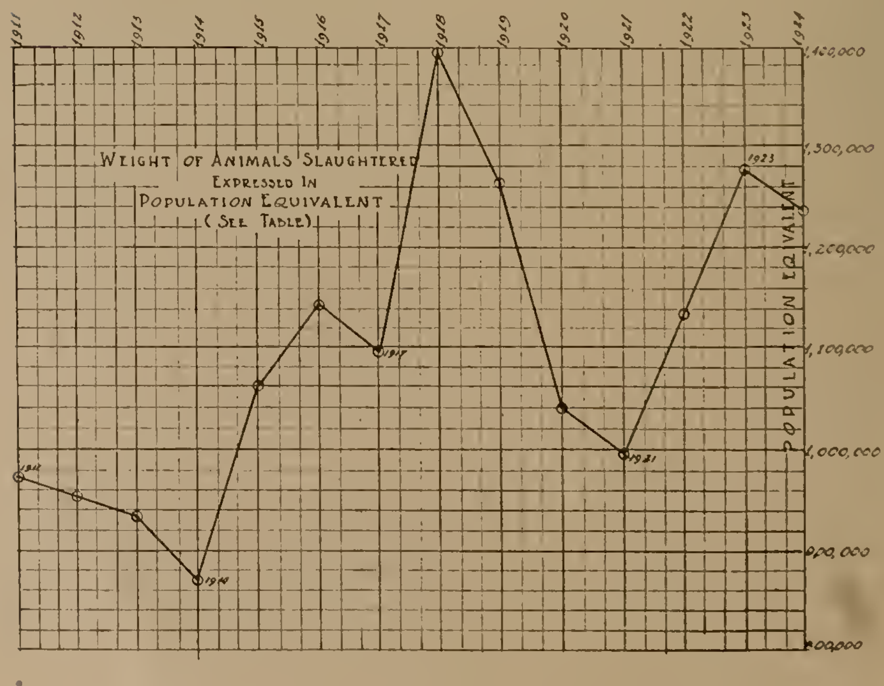
weekly rate, pounds

	1914	1918
Year Av.	57,380,000	90,200,000
Hot season		
July Av., weekly	49,330,000	88,350,000
Aug. Av., "	43,950,000	71,020,000
Sept. Av., "	52,830,000	90,270,000
Peak weeks ending:		
Jan. 26	———	124,425,000
Feb. 9	———	107,206,000
Mar. 23	———	105,109,000
Nov. 23	———	131,698,000
Nov. 30	———	121,513,000
Dec. 7	———	140,621,000
Dec. 14	———	129,962,000
Dec. 21	———	128,030,000

Changes in Chicago Population (Est.) and Packingtown Equivalent, 1914 to 1918

	Population	Total weight of animals killed Million lbs.	Population equivalent of animals killed	Sum of human population and population equiv.	Av. discharge san. canal, ft. per sec.
1914	2,437,526*	3,040	869,744	3,307,270	7,193‡
1918	2,613,647†	4,870	1,393,307	4,006,954	8,000¶
Increase	+176,121	+1,830	+523,556	+699,684	+807
Per cent. increase	+7.2	+60.0		+21.1	+11.2

* Chicago *Daily News* Almanac, from federal and school census reports.
† The 1914 figures plus 4 times the average yearly increase, 1914-1920.
‡ Alvord and Burdick, 1914 Report on Illinois River Bottomlands.
¶ Packingtown Report II, 1921, p. 8.



Terminology with Reference to Degree of Pollution and Tolerance

The terms used in the present paper to describe the varying degrees of tolerance exhibited by the small bottom animals do not differ essentially from those used by Forbes and Richardson, 1913: i. e., *septic, pollutional, contaminate,* and *clean-water,* in order of decreasing pollution. For the purpose of greater flexibility and at the same time better suitability of application to the animals themselves, I have substituted the word *tolerant,* with qualifying adjectives, for the word *contaminate* as used in the 1913 paper. After the comparatively few cases of species in the present bottom fauna with authentic previous records of pollutional or unusually tolerant habit*, the tests of tolerance used have been (1) survival under conditions of much lower than normal oxygen supply; (2) association with other authentic pollutional or unusually tolerant species; or (3) survival in areas where species of known cleaner preferences have wholly succumbed. It can not be too strongly urged that at the best we do not find in the actual field habitats the hard and fast lines perhaps too easily suggested by the use of these and other group terms by authors. The great flexibility called for in classifications of the kind is particularly well illustrated in the recent species lists from the bottom muds of Peoria Lake, which may be said to have been neither septic at the worst nor clean at the best, either in 1920 or 1922; by the occurrence there side by side in both years of tubificid worms and midge larvae characteristic of the septic zones of the upper Illinois, and of a number of species of sphaeriid snails thought of usually heretofore as of clean-water habit, though now shown to have more than the ordinary amount of tolerance.

The approximate position of the various subdivisions of Peoria Lake in the zonal system above recognized may be outlined as follows, basing conclusions on the chemical, plankton, and bottom-fauna data of 1920 and 1922.

1. Pollutional Zone:—Chillicothe to lower End of Upper Peoria Lake. Distance 7.5 miles

The dissolved oxygen in midsummer both in 1920 and 1922 ranged here normally between 0.5 and under 3 p. p. m. Though below the septic zone, in the most proper sense, this is still the zone of vast num-

* Includes *Tubifex tubifex; Chironomus plumosus,* and a very few others.

bers of Tubificidae, including Tubifex and several species of Limnodrilus; as well as of *Chironomus plumosus*. Practically the only snails surviving here recently are those that are more than ordinarily tolerant —the list including several species of Sphaeriidae, but only one member of the family Viviparidae (*Campeloma subsolidum*). On the plankton side this is the zone of blue-green algae, these organisms, both filamentous and non-filamentous types, giving a blackish blue color to the plankton samples, easily visible to the unaided eye immediately after treatment with alcohol-formalin preservative, in the case of collections made either in July, August, or September, and as far south as Spring Bay Narrows or even the upper end of the middle lake. *Rotifer tardus* was common in the plankton in the summer of 1920, while shelled rotifers were rare.

2. Sub-pollutional or Contaminate Zone; or Zone of Tolerant Bottom Animals:—Head or Center of Middle Peoria Lake to foot of Lower Peoria Lake Distance about 12 miles

The dissolved oxygen ranged usually from around 2.5 to more than 5 p. p. m. through the summer season, both 1920 and 1922. The blackish blue color given the upper lake plankton by the blue-greens begins to disappear rapidly at or just below Mossville; the blue-green organisms thereafter giving way to great increase in chlamydomonads and other chlorophyll-bearing forms. Shelled types of rotifers of the family Brachionidae increase rapidly down the middle lake and *Rotifer tardus* tapers out almost altogether at Peoria Narrows. In the bottom fauna, sphaeriid snails increase in variety in the middle lake, but the Viviparidae and Amnicolidae remain absent, both there and in the lower lake. In the lower lake, areas or zones of heavy local pollution and of unusually fast current cause mixed conditions; and there are otherwise in this portion of the river more or less insensible gradations between conditions nearly clean, contaminate, and pollutional.

Hydrographical Subdivision

The bottom collections made in the summer of 1922 were all made under substantially average low water conditions. Although we went several times within between 50 and 100 feet from shore with the dredge, few depths under five feet were found even at that distance;

while traces of vegetation worth mentioning were found at only two stations in all three lakes all summer. The collections of 1922 are thus practically altogether open-lake dredgings, from areas where the bottom animals are subject to the full influence of low oxygen when it occurs, and where they receive a minimum of aid from the reaerating or freshening effects of shore vegetation and spring water. Noting the very wide extent to which the largely deaerated waters of the river spread out in the upper lake wide-waters opposite Rome—where the bottom dissolved oxygen was under 1 p. p. m. for fully a half mile to the eastward of the mid-channel line on August 9, 1922—it has seemed best to emphasize distance from mid-channel rather than depth in the zonal subdivision of the wide waters. Thus in all cross-sections in 1922 in the lake proper we had first a mid-channel stop, in an imaginary channel some 700 feet wide, the approximate width of the main channel at Chillicothe; next a first wide-water zone embracing several collections in which the first haul was usually taken 400 to 600 feet to either side of the mid-channel line; and last a second wide-water zone extending from 1800 to 4500 feet eastward or westward of the mid-channel line, depending upon the width of the lake in the area crossed.

A table of distances down stream between stations at which cross-sections were made, follows.

TABLE OF MILE NUMBERS AND DISTANCES, PEORIA LAKE, 1922

	Miles below Lake Michigan	Distance below next station above	Distance below Chillicothe
*Chillicothe	146.5	——	——
Upper Lake			
*Rome	149.3	2.8	2.8
*1.5 miles above Spring Bay	151.7	2.4	5.2
Spring Bay	153.2	1.5	6.7
Foot of S. Bay Narrows	154.2	1.0	7.7
Middle Lake			
*Mossville	154.9	0.7	8.4
*Foot of Horshor Island	157.4	2.5	10.9
*Al Fresco Park	159.3	1.9	12.8
Lower Lake			
*Peoria Narrows, below bridge	161.0	1.7	14.5
*Workhouse Point	162.7	1.7	16.2
*Fulton Street	164.2	1.5	17.7
*P. P. U. R. R. Bridge	166.4	2.2	19.9

* Petersen dredge cross-section, 1922.

SUMMARY

1. Improvement in both the upper and middle lake since 1920 is indicated by the close to doubling of the species lists of both lakes in the two years ending summer 1922; but the increase in kinds was almost wholly confined to the group of tolerant sphaeriid snails, which seem to have survived the mortality (between 1915 and 1918) that destroyed practically all the other snail families, and between 1920 and 1922 to have again spread sufficiently over their old range to appear more frequently than in the first-named year in dredge hauls.

2. The extension of range of the surviving Sphaeriidae between 1920 and 1922 went hand in hand with large expansion (following the lull due to business depression of 1921) in the Packingtown slaughterings at Chicago, and with tremendous increase in numbers of tubificid worms in the muds of the upper lake and the river at Chillicothe; and suggests perhaps a progressive immunization of the already tolerant sphaeriid snails to conditions which a few years earlier might have gone harder with them.

3. Both in the upper and the middle lake in 1922 improvement in the condition of the muds is indicated by increase in variety of the species lists (1) as we proceed down stream; and (2) as we proceed outward from mid-channel stations into the wide waters.

4. In the lower lake there are various evidences of mixed conditions on the bottom, partly due, in the wide waters, to wind-blown local pollution; and so far as suitable situations for a few cleaner-preference forms are provided, apparently due to the much greater current that prevails in the lower lake channel, or in the narrows (in our results included as lake stations) immediately above or below it.

5. Species that have definitely disappeared from Peoria Lake since 1913-1915 include all but three or four kinds out of a total of more than forty kinds of fresh-water mussels; all of the snails of the family Amnicolidae; all but one species of the formerly important and especially conspicuous snail family Viviparidae; and a varied weed fauna.

6. From the rather restricted list of small bottom invertebrates that seem to have been exterminated in Peoria Lake since 1913-1915, compared with the decidedly larger lists from the vicinity of Havana*, it is suggested that upper and middle Peoria Lake may have been subjected to a measurable amount of injury from up-river pollution prior to 1915.

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* See Article VI of this volume, on 1923 fauna.

Upper Peoria Lake and the Illinois River, Chillicothe to Spring Bay. (Mile 146.5—153.2 below Lake Michigan)

Hydrography

The three cross-sections in the upper lake district in 1922 began with one in the river proper at Chillicothe, which is only a half mile above the present low-water head of the upper lake, 6.7 miles above its approximate foot at Spring Bay, and 14.5 miles above the head of the lower lake at Peoria Narrows. The two cross-sections through the lake proper included one at Rome, 2.8 miles below Chillicothe, where the extreme width at recent summer low water has been in the neighborhood of 4,800 feet; and one on a line a mile and a half above Spring Bay, 5.2 miles below Chillicothe, where low water widths have recently been somewhat more than 6,000 feet. Mid-channel depths at Chillicothe in August 1922 were around 22 feet, but were only 13 or 14 feet opposite Rome and Spring Bay, at the first of which places considerable filling has evidently occurred since 1901. The soundings made in the east wide-waters opposite Rome were not over 6.5 feet in the first 1,500 feet; and did not exceed 5 feet in the next 2,000. A mile and a half above Spring Bay depths in the open lake were much greater, nine- to more than ten-foot soundings continuing for 3,500 feet beyond the mid-channel line on the east or widest side. The bottom in the river at Chillicothe was deep mud; and throughout the upper lake was uniformly soft black mud at the stations visited, except on the far west side above Spring Bay, where harder mixed mud and gravel bottom reaches out a hundred feet or more from the bank at low water.

Though the odors of the bottom sediments in the upper lake showed striking differences between 1915 and 1920, as described in a previous paper, it was not always an easy matter to make out really definite differences between the summers of 1920 and 1922. While some average improvement evidently occurred in the two years, it was clear also that there was still abundant room for more. Summarizing the records from this portion of the lake for the summer of 1922, it is found that we noted abundant bubbling at all stations; distinctly foul odors at seven stations out of the total of twenty-three; mildly bad odors at nine out of the twenty-three stations; and had no record or records of uncertain value at seven stations. This exhibit compares with bad odors at all stations in the summer of 1920, but is qualified in value by the feature that worse odors were noted in the summer of 1922 well to the east and west of the main channel than within it, both opposite Rome and just above Spring Bay; and rather milder ones in the river channel at Chillicothe than at the worst stations in the wide-water cross-sections three to five miles farther south. The possibility that the very unusual flood of January-April 1922 flushed out the channel at the same time that it brought in a new load of putrescible sediment to the wide waters suggests itself as a plausible explanation of some of these changes, as also of the fact that the spongy gas-filled mud noted in the summer of 1920 at several upper lake stations in or near the steamboat channel did not appear in any of our 1922 dredge hauls.

Toward the west bank below Rome some spreading of Potamogeton occurred between 1920 and 1922; and in September 1922 mats of Lemnaceae were found here, and also in the brushy southwest corner of the upper lake opposite Spring Bay. The total area supplied with vegetation is, however, insignificant compared with that of the low-water period between 1910 and 1915, on gages little if any lower. No living vegetation at all was encountered at any of the stations actually dredged in the summer of 1922.

Dissolved Oxygen

The dissolved oxygen one foot from the bottom in mid-channel at Chillicothe fell as low as 0.3 p. p. m. in July 1922, and to 0.2 p. p. m. in August. The bottom oxygen during the same period in mid-channel opposite Rome dropped to 0.2 p. p. m. on July 3, 1922; rose to 2.0 p. p. m. on July 27; fell to 0.5 on August 9; and rose again to 1.6 on August 29. On August 9, when the bottom oxygen in the channel at Rome was 0.5 p. p. m., bottom figures under one part per million were recorded at six wide-water stations east of the steamboat channel in the Rome cross-section, averaging more than 600 feet apart and extending altogether more than 3600 feet eastward of the mid-channel station.

At points between a mile and a half above Spring Bay and the foot of the upper lake at Spring Bay Narrows, which is 7.7 miles below Chillicothe, the bottom dissolved oxygen in July and August 1922 ranged between 1.4 and 3.9 parts per million. The bottom figure on July 28, 1922, at Spring Bay Narrows (1.4 p. p. m.) was lower than the figure at Rome the day before; but both on July 3, 1922 (when it was 3.3 at Spring Bay Narrows), and on August 29, 1922 (when it was 3.9), a relatively large improvement had taken place in the approximate five-miles distance between Rome and the foot of the lake. The variation in the gage at Peoria during the period July 3 to August 29 was a little less than two feet. The lowest bottom dissolved oxygen figures at Chillicothe were recorded on July 3, August 9, and August 29, on gages 11.3, 10.4, and 9.8 feet corresponding; and the highest on a gage of 10.7 feet on July 27. The lowest bottom figures at Rome occurred on July 3 at a gage of 11.3 feet Peoria, and on August 9 at gage 10.4; while the high figures (1.6 to 2.0 p. p. m.) came on July 27 and August 29 on gages 10.7 and 9.8 feet.

Bottom oxygen figures slightly lower than any of these were recorded at Chillicothe and Rome and in the vicinity of Spring Bay in the summer of 1920. A table comparing the channel figures from the upper lake and Chillicothe for 1922 and 1920 follows.

BOTTOM DISSOLVED OXYGEN, MID-CHANNEL, UPPER PEORIA LAKE, 1920-1922
MIDSUMMER FIGURES, PARTS PER MILLION

Peo. gage ft.	Chillicothe Mile 146.5*		Rome Mile 149.3		1.5 miles above Spring Bay Mile 151.7		Spring Bay Narrows Mile 154.2		
	1922	1920	1922	1920	1922	1920	1922	1920	Dates
11.3	0.3	....	0.2	....	4.5	....	3.3	....	July 3
10.7	0.9	0.3	2.0	0.4	3.8	0.7	1.4	....	July 15–28
10.6	....	....	....	....	....	0.7	....	1.4	July 16
10.4	0.7	....	0.5	....	....	....	....	4.1	July 21–August 9
9.8	0.2	0.0	1.6	0.0	....	0.4	3.9	0.7	August 4–Aug. 29
9.7	....	0.3	....	....	....	....	....	1.2	Aug. 23–28

* Miles below Lake Michigan. Chillicothe is a river station just above the present upper low-water boundary of the Peoria Lake wide-waters.

Small Bottom Animals

Nineteen species of small bottom invertebrates were recorded from twenty-three dredging stations between Chillicothe and a mile and a half above Spring Bay, near the lower end of upper Peoria Lake, in the summer of 1922 (Table, p. 342). This increased number compares with eleven or twelve kinds taken at eight stations in very nearly the same area in the corresponding months of 1920. That the increase may to some extent be due to the greater number of stations visited, particularly in the wide waters, in 1922, has not been allowed to escape our notice. More probable explanations, however, include the increase in the worm list (+2) due to a more thorough study of that group in 1922, and the evident increase, mostly in the wide waters, of the less tolerant snails (+5), that seem to have escaped total destruction between 1915 and 1920, but that had not had time by 1920 to extend again over their old range sufficiently to make the chance good of getting them in collections. It will be noted, also, in ensuing pages, that other equally important changes were apparent at the end of the two year interval that could have no possible connection with an increase in the number of stations.

Both in 1922 and 1920 the majority of the species taken in the upper lake, whether in channel or wide waters, belonged to the more distinctly pollutional or tolerant groups of small bottom animals; that is, small annelid worms (Tubificidae), leeches, midge larvae, and tolerant snails. The more sensitive varieties of the old snail, insect, crustacean, and other small bottom population of 1915 and before were in 1922 as in 1920 wholly absent from all hauls taken in the upper lake more than 50 feet from shore. There was, however, to be set down fairly definitely on the side of improvement during the two years following 1920 the noticeable increase in the number of kinds and abundance of the tolerant snails, already mentioned; and, more qualifiedly, because they may have merely been washed out by the violent flood of the spring of 1922, the decrease in both numbers and kinds of more pollutional midge larvae. Suggesting caution, on the other hand, in accepting at face value these apparent evidences of improvement, was the remarkable increase in abundance at all stations in the upper lake in 1922 of the small oligochaete worms, which were present in numbers exceeding any that we have before recorded from anywhere in the Illinois River.

As will be seen in the tables that follow, there was noticeable a sharp difference between the rates of increase in the species lists in mid-channel and in the open lake from 1920 to 1922. In fact, substantially no favorable change in number seems to have occurred in the two years in the channel, where decrease in kinds of midges was balanced by increase in worms, leeches, and tolerant snails; and where, in 1922, the number of all species taken decreased instead of increasing as we proceeded down the lake from Chillicothe. In the wide waters, on the other hand, there was an increase in the list of species in the two years from 11+ to 18+; and the increase was almost all due to the multiplication in variety of the less tolerant kinds of snails and midges, (see Table below). Further evidence of improvement in the extra-channel zones is seen as we go down stream (see Table on following page) ; as also in the near to more than doubling of the species lists in size, both in the Rome and the Spring Bay cross-section, as we move outward from the channel into the wide waters (Table on p. 344).

Summary of Bottom Species Lists, Upper Peoria Lake, Summer 1922

1. comparison with 1920. number of kinds taken

	Channel		Combined wide-water zones		All zones	
	1922	1920	1922	1920	1922	1920
Worms	4+*	3	5+	3	5	3+
Leeches	1	0	1	1	2	1
Pollutional midges	0	2	1	3	1	3
Other midges	0	2	4+	2+	4+	2+
Very tolerant snails	1	1	1	1	1	1
Less tolerant snails	2	0	5	1	5	1
Other snails	0	0	1	0	1	0
Total	8+	8	18+	11+	19+	11+

* The + after figures in this and other tables indicates a residue of undetermined material, definite returns on which might add one or more to the number of species given.

SUMMARY OF BOTTOM SPECIES LISTS, UPPER PEORIA LAKE, SUMMER 1922

2. CHANGES DOWN STREAM. NUMBER OF KINDS TAKEN

	Worms	Leeches	Pollutional midges*	Other midges*	Very tolerant snails	Less tolerant snails	Other snails	All snails	Total
Mid-channel									
Chillicothe Mile 146.5	3+	1	0	0	1	0	0	1	5+
Rome Mile 149.3	3+	0	0	0	1	2	0	3	6+
1.5 miles above Spring Bay Mile 151.7	2	0	0	0	1	0	0	1	3+
Combined wide-water zones									
Chillicothe Mile 146.5	4+	0	1	0	1	0	0	1	6+
Rome Mile 149.3	4+	0	0	4+	1	3	0	4	12+
1.5 miles above Spring Bay Mile 151.7	4+	1	1	1+	1	4	1	6	13+

* Larvae.

Summary of Bottom Species Lists, Upper Peoria Lake, Summer 1922

3. CHANGES FROM MID-CHANNEL OUTWARD INTO WIDE WATERS
NUMBER OF KINDS TAKEN

	Mid-channel	First 1500 ft.	1800–4500 ft.	All extra-channel
Rome Mile 149.3				
Worms	3+	4+	4+	4+
Leeches	0	0	0	0
Pollutional midges*	0	1	0	1
Other midges*	0	1	3+	4+
Very tolerant snails	1	1	1	1
Less tolerant snails	2	2	3	3
Other snails	0	0	0	0
Total	6+	9+	11+	13+
1.5 miles above Spring Bay Mile 151.7				
Worms	2	4+	3+	4+
Leeches	0	0	1	1
Pollutional midges*	0	1	0	1
Other midges*	0	0	2	2
Very tolerant snails	1	1	1	1
Less tolerant snails	0	1	4	4
Other snails	0	0	1	1
Total	3+	7+	12+	14+

Larvae.

WORMS

The tube-worms (Tubificidae) and other small annelids recorded from upper Peoria Lake in 1922 included not less than five kinds, and were, along with one of the unusually tolerant snails, the conspicuous feature from the point of view of abundance, of the muds in all cross-sections. Three of the species belonged to the genus Limnodrilus, viz., *L. hoffmeisteri* Claparède; an unidentified species similar to *L. claparedeianus* Ratzel; and a species believed by Professor Frank Smith, who determined the specimens, to be new. The genus Tubifex, usually thought of as the common one in septic or polluted muds, was represented by a single species, referred with question, because of slight differences, to the European *Tubifex tubifex* (Müller). The related family of free living worms known as Naididae was represented by small numbers of one or more undetermined species.

The species of the genera Tubifex and Limnodrilus live in tubes or burrows in the soft top ooze of stream bottoms, from which they protrude the posterior end, waving it constantly when undisturbed, as an accessory act in respiration. When very abundant these worms literally carpet the bottom with a living nap of reddish brown or deep red. This fact is the more easily visualized by those who have not seen them when it is known that they occurred in numbers as high as 60,000 per square yard in upper Peoria Lake in the summer of 1922. Such numbers amount to nearly 250 rows of 250 each in such a space, and call for a separation between individuals amounting to less than fifteen-hundredths of an inch in each direction.

The several times recorded occurrence of *Tubifex tubifex* in unusually septic situations in recent years by European writers, as about the edges of septic tanks and very near the sources of the pollution in sewage-fouled streams, seems to have led to the entire group being referred to rather indiscriminately by local authors la ely as "slime worms" or "sludge worms," with little or no reference at all to the possible varying preferences or the identity of individual species. This has been no doubt largely a result of the difficult and time-consuming technique necessary in the determination of species in this group, and the extreme rarity of specialists competent to render an opinion upon them. Some of them occur quite frequently, however, in ordinary clean bottom in our inland lakes and streams; and extensive carpets of them have been observed near the edges of deep reservoirs thought clean enough to be a part of the source of a city's water supply. Even *Tubifex tubifex* has recently been reported by Muttkowski (1918) from the bottom muds of Lake Mendota; and was found, as represented by the American form as here understood, to be commonly present in the comparatively clean muds of the Illinois River at and near Havana in the early days of operations at the Illinois Biological Station.

Of the Tubificidae taken in upper Peoria Lake in 1922 far the most abundant one was not *T. tubifex* as might have been expected on the basis of recent American and European records, but *Limnodrilus hoffmeisteri*. This worm occurred at twenty-one out of twenty-three of the collecting stations in the upper lake, including all cross-sections, and like *T. tubifex* and the undescribed species of Limnodrilus was most abundant in the two upper cross-sections, opposite Chillicothe and Rome, at the latter of which the dissolved oxygen one foot above bottom was under one part per million at stations embracing over a mile of lake-width early in August. The species was also taken, however, at a large proportion of the stations in the upper part of the middle lake and at a few in the lower.

The undescribed species of Limnodrilus had a distribution in the summer of 1922 very much like that of *L. hoffmeisteri,* being taken at nineteen out of the twenty-three upper lake stations, embracing three cross-sections; and was also taken in scattered hauls both in the middle and the lower lake. *Tubifex tubifex,* on the other hand, was taken in or just above the upper lake in 1922 only in the Chillicothe and Rome cross-sections, where it occurred at only six out of twelve stations; was not recorded at all from the eleven stations in the Spring Bay cross-section; and was recorded only once each from the middle and lower lakes.

The distinct tendency toward confinement of *Tubifex tubifex,* as here understood, to the Chillicothe and Roman cross-sections may be accepted as further confirmation of the value of that species as an indicator of bad bottom; though it is believed that the facts of outside distribution before mentioned suggest that great caution be used before basing conclusions as to the cleanness of muds upon mere occurrence, either of this or other species.

When the totals of all Tubificidae are tabulated, it is suggested that numbers may be quite as important as specific identity when we are seeking an index of the condition of the bottom muds in the small annelids. Averaging 22,400 at Chillicothe, and averaging 29,000 and ranging as high as 69,000 opposite Rome in early August, 1922, the total of all worms dropped to only 2,100 per square yard in the next 2.4 miles (cross-section 1.5 miles above Spring Bay); and to a figure of only 420 per square yard in the first cross-section in the middle lake, another 4.5 miles south. The sharp decline in the 2.4 miles between Rome and the next cross-section southward corresponded to a rise of less than two parts per million in the bottom dissolved oxygen on the round of August 9, 1922, and was proportionately more emphatic than the oxygen figures in suggesting the rapidity of improvement in the water and the muds after they spread out into the upper lake wide-waters just above Rome.

CHANGES IN ABUNDANCE OF COMMONEST SMALL BOTTOM ANIMALS IN PEORIA LAKE, 1920 TO 1922

AVERAGE NUMBERS PER SQUARE YARD

	Miles below Lake Michigan	Mud worms Tubificidae				Unusually tolerant snail Musculium transversun				Midge larvae Chironomidae				Collections averaged			
		Channel		Wide waters		Channel		Wide waters		Channel		Wide waters		Channel		Wide waters	
		1922	1920	1922	1920	1922	1920	1922	1920	1922	1920	1922	1920	1922	1920	1922	1920
Upper Lake																	
Chillicothe	146.5	14,400	4,800	27,400	960	28,800	240	63,300	0	0	2,400	216	960	1	1	2	1
Rome	149.3	48,000	480	26,910	1.200	49,200	·96	38,475	16	0	1,200	438	224	1	1	8	3
1.5 mi. above Spr. Bay	151.7	2,800	9,600	2,090	240	5,760	0	7,936	24	0	48	58	0	1	1	10	1
Middle Lake																	
Mossville	154.9	48	480	468	348	768	0	1,478	3	48	48	36	42	1	1	8	4
Foot Horshor Isl.	157.4	1,560	—*	847	—	9,600	—	1,326	—	648	—	402	—	1	—	6	—
Al Fresco Park	159.3	0	480	0	24	1,500	0	583	0	24	24	51	360	1	1	13	2
Lower Lake																	
Peoria Narrows	161.0	48	0	504	0	120	0.5	24	6	72	40	36	108	1	1	2	2
Strawboard Works	161.7	—	0	—	210	—	0	—	0	—	144	—	270	—	1	—	4
Workhouse Point	162.7	72	—	36	—	0	—	16	—	0	—	108	—	1	—	6	—
Green Street	163.9	—	24	—	0	—	0	—	0	—	120	—	219	—	1	—	4
Fulton Street	164.2—	124	—	96	—	0	—	18	—	0	—	243	—	1	—	4	—
Liberty Street	164.2+	—	0	—	120	—	0	—	2	—	156	—	402	—	1	—	4
P. P U. Bridge	166.4	0	0	0	1	0	0	0	0	0	0	0	3	1	1	2	2

* The dash means no collection.

The reasons for the much greater abundance of these worms in the summer of 1922 than in the summer of 1920, when the average oxygen supply was somewhat less at the lowest than in 1922 at upper lake stations, are not clear unless we assume that the increase followed, as it might quite naturally, the bringing in with the very unusual flood of the winter and spring of 1922 of a new load of rich sediments, along with a richer bottom bacterial flora, than were present in the summer of 1920, following a more quiescent spring season. In fact, these worms do not seem to be bound to their habitat so much by a qualitative as by a quantitative food relation, deriving their sustenance as they do, without apparent selection, from the bacteria and other living and dead organic matter in the soft bottom-sediments, which they first swallow *en masse*. So far as a low oxygen supply is concerned, they seem merely able to tolerate it by virtue of their ability to store haemoglobin and to effect a mechanical aeration of their immediate surroundings, rather than to be in any true sense partial or obligate to it.

LEECHES

Two species of leeches were taken in the upper lake in the summer of 1922: the first, *Erpobdella punctata* (Leidy), in the channel opposite Chillicothe; the second, *Helobdella nepheloidea* (Graf), in the wide waters 3,600 feet eastward of mid-channel in the cross-section a mile and a half above Spring Bay. The first species mentioned was taken also in 1922 in the river at the P. P. U. Railway Bridge opposite the lower part of the city of Peoria where the pretty well aerated waters of the lower lake are being mixed with the discharge from the main sewers. *Erpobdella punctata* was noted by Baker (1922) as common at stations in the Big Vermilion River in 1918-1920 where gas bubbling was continuous in warm weather and where the mussels were dead; and by Weston and Turner (1917) as common at the upper and worst polluted stations in the Coweeset below Brockton, Massachusetts. Muttkowski (1918), on the other hand, reported *Erpobdella punctata* to be common along clean gravelly shores of Lake Mendota.

Helobdella nepheloidea, in addition to its occurrence in the upper lake above Spring Bay at stations where distinctly bad odors were recorded, was also taken in the wide waters of the middle lake opposite Mossville; in the steamboat channel and the wide waters of the lower lake opposite Fulton Street, Peoria; and, in company with *Erpobdella* *punctata*, below the outlet of the lower lake at the P. P. U. Railway Bridge. We have found no definite outside records of habitats of this species. The conclusion is evidently to be drawn, with respect both to this and the other species named, that they are of rather indifferent value as an index of the condition of muds in the Illinois River.

MIDGE LARVAE

Larvae of midges occurred in our 1922 dredge-hauls from upper Peoria Lake at only eight out of the total of twenty-three stations, and failed altogether to appear at any of the channel stations. The total number of identified kinds was the same as in the summer of 1920, but three of the more pollutional species of that year were not taken at all in 1922, and the single 1922 species known to be unusually tolerant (*C. plumosus* Linn., var.) occurred only at three extra-channel upper lake stations, one each in the Chillicothe, Rome, and Spring Bay cross-sections. Undetermined species of Chironomus, Procladius, and Tanypus were taken at a few open lake stations well eastward of the channel opposite Rome and Spring Bay; and a few specimens of *Tanypus monilis* Linn., in the past reported only from cleaner situations, were taken toward the west side opposite Rome, in a haul in which tubificid worms exceeded 7,000 per square yard and unusually foul odors were noted.

In the summer of 1920 all channel hauls contained midge larvae, though the recognized more tolerant kinds then as in 1922 came from the stations outside the channel. In the middle lake and in the lower in 1922 larval Chironomidae occurred at a much larger proportion of all stations than in the upper lake, although no important increase in numbers was noted at the stations southward.

With the exception of *C. plumosus* or its varieties, and of two other pollutional species (*C. decorus* Johannsen and *Tanypus dyari* Coquillett) taken rather frequently in the summer of 1920, neither in 1922 or 1920 did numbers of chironomid larvae attain importance in Peoria Lake (Table, p. 347). The first-named species does, however, seem to bear an unusually distinct relation to pollution; as has been noted since some years ago in studies of its sister forms in Europe, where variation in the length of its ventral blood-gills has been observed to coincide more or less definitely with differences in the oxygen supply. The recent Illinois River and Peoria Lake specimens which we have referred to this species do not seem to differ very materially except in that respect from the abundant larva formerly referred to *C. tentans* in our work of ten years or so ago at and above Havana—a form which seems to have wholly disappeared from this section of the Illinois River since some time before 1920. The practical confinement of the more pollutional kinds of midge larvae recently to the lake zones outside the channel, while to an extent perhaps a result of habitat preference unconnected with pollution, places them conveniently in those areas where the bottom receives the largest fresh supplies of rich sediment as the gage recedes after floods.

UNUSUALLY TOLERANT SNAILS

One of the most surprising facts that came out of the study of the bottom dredgings from upper Peoria Lake was the enormous multiplication at Chillicothe and in the lake opposite Rome between 1920 and 1922 of the little sphaeriid snail, *Musculium transversum* Linsley. Numbers of this small bivalve, familiar to local hunters and fishermen under the name of "duck shell", reached a hundred thousand per square yard in parts of the upper portion of the upper lake in the summer of 1922. Average numbers for all stations in cross-sections passed 51,000 at Chillicothe and 39,000 opposite Rome, these figures representing equivalents of weight valuations between 19,000 and 25,000 pounds per acre over limited areas, on the supposition that all the young and half grown lived to become adult. The distribution of the largest hauls of this little snail agreed closely with the location of the largest catches of mud worms, and also an equally abrupt average decline in the Musculium figures corresponded to the drop in worm figures already mentioned as having taken place in the two miles between the Rome cross-section and the next one south. This decline was followed by further decrease or showed little recovery in the areas sampled in the middle and lower lakes. (Table, p. 347.)

The ability of this snail to withstand low oxygen is well supported by previous evidence from the Illinois River, where it occurred in small numbers near the banks as far north as Marseilles in the summers of 1911 and 1912. Its recent extremely rapid multiplication in the worst instead of the best portion of its old range in Peoria Lake, amounting to from 50 to more than 2,000 times numbers as of the summer of 1920, may be supposed, however, to reflect quite probably some other factor than those involved in the original habitat preferences of the species. Perhaps it is true that an important consideration has been that this snail has recently met almost no hindrance to multiplication from its greatest predatory enemy, the carp, in this poorly aerated section of Peoria Lake. The supposition that its recent distribution and abundance has been in substance inverse to that of the coarse bottom-feeding fishes is borne out by such information as we have concerning the location of the most profitable seine hauls recently above Peoria Narrows. It may also be the case that there has recently been some increase in an already relatively strong immunity in this species to the ill effects of low oxygen.

LESS TOLERANT SNAILS

It was in the group of less tolerant snails that the greatest increase in variety of the small bottom fauna of the upper lake occurred in the two years following 1920. The species included under this designation are all evidently less tolerant than *Musculium transversum*, as shown both by their greater rarity in upper Peoria Lake in 1922, and by the fact that none of them occurred quite so far north in the Illinois River in 1912 as that very tolerant species. Though less tolerant than that unusually hardy form, they are all evidently considerably more so than several other snail species (particularly *Vivipara contectoides* Binney, *V. subpurpurea* Say, *Lioplax subcarinatus* Say, and *Amnicola emarginata* Küster), all of which were common in Peoria Lake up to 1915 but have not since appeared in collections from either the upper, middle, or lower lake. Though no representative of this group could be called abundant at any upper lake station in 1922, we took then, in all, five species, all but one belonging to the Sphaeriidae, compared with a single species in 1920. The channel collections contributed two species, *Musculium truncatum* Linsley and *Pisidium compressum* Prime, against none at all in 1920; and the collections from the open lake five kinds, *M. truncatum*, *P. compressum*, *P. pauperculum* var. *crystalense* Sterki, a species of Pisidium near *P. complanatum* Sterki, and *Campeloma subsolidum* Anthony, as against the last species alone in the summer of 1920.

Of these five snails, only one, the large viviparid, *C. subsolidum*, has been previously known through published records, so far as we know, to be much more than ordinarily resistant to pollution or low oxygen. This snail was taken by us in the Illinois River in 1912 as far north as Starved Rock, or farther north than any other snail except *Musculium transversum;* and was recently reported by Miss Jewell

(1922) from the acid waters of the Big Muddy. The distribution of *Campeloma subsolidum* in upper Peoria Lake in 1922, was confined to two stations in the far east wide-waters a mile and a half above Spring Bay. Bad odors and abundant bubbling were noted at both of these stations, and the bottom dissolved oxygen was under three parts per million in July, and considerably lower in August.

While *Musculium truncatum* did not appear at all in 1920 collections from any part of Peoria Lake, in August 1922 we found it at seven out of the nine stations in the Rome cross-section, including the channel, and at one station in the upper portion of the middle lake. Numbers in the Rome cross-section ran as high as 700 per square yard, and the species was associated with Tubificidae at stations where they exceeded forty thousand. This species was found in the Illinois River channel in 1912 as far north as De Pue and Spring Valley, and seems to possess not far from as high a degree of tolerance as its more prolific coingener, *M. transversum*. It seems, in fact, to differ from it mainly at the present time in Peoria Lake as it did in the past in the cleaner waters of the Illinois, in a lesser aptitude for multiplying and occupying the capacity of its range.

Of the three species of Pisidium taken in the upper lake in 1922, *P. compressum* had much the widest distribution, occurring at six out of the total of 23 stations, compared with no records at all in 1920. It was present at three stations in the Rome cross-section, including the mid-channel station, and was associated there with Tubificidae and other annelid worms whose combined numbers exceeded 45,000 per square yard. This little shell also occurred in the upper lake in 1922 at three stations toward the west end of the Spring Bay cross-section, and extended southward into the middle lake and the upper portion of the lower. In 1912 it was taken in the channel of the Illinois at Spring Valley, De Pue, Henry, and Chillicothe.

Pisidium pauperculum, var. *crystalense* Sterki occurred in the upper lake in 1922 at only two stations, both west of the main channel in the cross-section a mile and half above Spring Bay. At one of these two hauls unusually bad odors were noted and Tubificidae and other small annelids passed 5,000 per square yard. The species was not taken in the Illinois River above Henry in the summer of 1912, and is apparently to be graded as somewhat less tolerant than *P. compressum*.

A third species of Pisidium, close to *P. complanatum* Sterki, was taken twice in the summer of 1922 in the far east wide-waters of the upper lake, once in the Rome and once in the Spring Bay cross-section. Tubificidae exceeded 6,000 per square yard at one of these stations and especially bad odors were recorded at both.

It may be mentioned here that Miss Emmeline Moore (information by correspondence) found *Pisidium compressum* and also an unnamed species near *P. abditum* Haldeman in waters of the Skaneateles outlet, New York, recently, under conditions that suggested a high degree of tolerance. It is also of interest in the present connection to recall that Juday (1908) took a species of this genus (*P. idahoense* Roper) in the deeper waters of the glacial lakes of Wisconsin, at depths where for more than two months in the year there was nearly if not complete oxygen exhaustion. These specimens were found to be quiescent under those conditions, but to revive upon being placed in well-aerated water.

Belonging to a group of snails and other bottom species still less tolerant than the Pisidia, is the little *Valvata tricarinata* Say, which we took in small numbers in August 1922 about a hundred feet from the west bank opposite Spring Bay. Here there was somewhat solider bottom than farther out in the lake, though no vegetation; and no especially bad odor was recorded. As this species is more frequently than not a shore form and more than ordinarily partial to vegetation, the question of the amount of tolerance possessed by it does not affect any conclusions already or later drawn as to the condition of the bottom muds of the great portion of upper Peoria Lake.

Middle Peoria Lake, Mossville to Al Fresco Park (Mile 154.9—159.3 below Lake Michigan)

Hydrography

The three bottom fauna cross-sections through the middle lake in the summer of 1922 began at Mossville, 3.2 miles below the last section in the upper lake, and were approximately two miles apart in all cases. The one at Mossville was 8.4 miles below Chillicothe, the one at the foot of Horshor Island 10.9 miles below, and the one opposite Al Fresco Park 12.8 miles below the first cross-section taken in 1922. The width of Peoria Lake at Mossville in August 1922 was around 4,500 feet; but had rapidly expanded to about 7,000 opposite the foot of Horshor Island; and declined again to about 3,500 at Al Fresco Park. Mid-channel depths in the first two cross-sections were not over 13 feet, but were 18 feet opposite Al Frésco Park, where the lake is beginning to taper to the lower narrows and the current is noticeably stronger than farther northward. Extra-channel depths in the middle lake cross-sections were nearly all over seven feet, and depths of nine to ten feet were met in all three throughout a total width sweep of 2,500 to 3,000 feet. Soft mud bottom was found everywhere except in the last hundred feet next the west bank, where there was some sand or gravel.

A more readily recognizable change for the better since 1920 could be perceived in the bottom sediments of the middle lake in the summer of 1922 than was the case in the upper. Although bubbling was abundant at nearly all stations, and mild bad odors at a majority of them, no very foul odors such as were encountered in or near the channel as far south as Al Fresco Park in 1920 were noticed anywhere in the middle lake in the summer of 1922. Improvement between Mossville and Al Fresco Park, a distance of about four and a half miles, was clearly evidenced by the entire absence of foul odors and the fewness of bubbles at a number of the wide-waters stations opposite the latter place.

Replacement of vegetation does not seem to have progressed so far in the two years since 1920 in the middle as in the upper lake, a circumstance possibly having some connection with the fact that the middle lake is regularly seined. Sparse patches of Potamogeton and Vallisneria were visible near the west bank in late August and early September 1922 in the lower half of the lake, but the great weed-beds that formerly covered hundreds of acres in the upper half of the lake were as absent from the landscape as they were in 1920.

Dissolved Oxygen

There was a plentiful supply of dissolved oxygen over the greater part of the middle lake in July 1922, when on gages between 11.3 and 10.7 feet more than five parts per million were found a foot from the bottom a mile below Mossville, and nearly or more than six parts per million opposite Al Fresco Park in mid-channel samples. But before the end of the first two weeks of August, on a gage down to 10.3 feet, the mid-channel figure a mile below Mossville had dropped to 2.2 p. p. m., and was only 3.4 p. p. m. a mile and a half above the foot of the lake. Similar mid-channel figures (2.8 p. p. m. one foot from bottom) were obtained a mile below Mossville late in August (gage 9.8 feet) ; and on September 13, after a slight rise, when the low figure for 1922, 1.7 p. p. m., was recorded. At Al Fresco Park on the last two dates mid-channel bottom oxygen was 5.3 and 4 p. p. m.

In the wide waters a mile below Mossville the bottom oxygen rose rapidly toward the west bank in late July 1922, topping 10.2 p. p. m., or about a part and a half above saturation, about a hundred feet from shore on July 28. But in the far east wide-waters on the same date the figures obtained a foot from the bottom ranged between 3.1 and 3.4 p. p. m., or a part to more than that lower than the channel figures. However, at this time, in the wide waters as in the channel, bottom oxygen figures rose rapidly as we proceeded down the lake, ranging between four and six parts per million opposite the foot of Horshor Island and six to more than seven opposite Al Fresco Park. On August 9, 1922, bottom figures were under 1 p. p. m. in the open lake at three stations in the cross-section a mile below Mossville, and were as high as 3 p. p. m. only at distances more than 3,000 feet east or 2,000 west of mid-channel (it will be noted that the lake is some 2,000 feet wider at low water here than directly opposite Mossville). On the same date open lake figures opposite Al Fresco Park were under 4 p. p. m. as far as 1,300 feet east of the mid-channel line, but had risen to 6.7 p. p. m. within a total of 2,000 feet.

In August 1920 appreciably lower bottom dissolved oxygen figures than any of those obtained in the summer of 1920 were recorded from the middle lake, both in its upper portion in the vicinity of Mossville and toward the lower end opposite Al Fresco Park. Then, as in 1922, there was sometimes quite rapid improvement from the channel outward into the wide waters, particularly in the lower portion. But in the second week of August 1920, figures under 1 p. p. m. were found more than 2,500 feet to the east of the mid-channel line at Al Fresco Park. Neither in 1920 nor 1922 did these extreme low figures have a very extended duration in the open lake, but were likely to be succeeded within a week or two, coincidently with a sudden increase in the green microplankton, by figures four to five parts per million higher. Even bottom dissolved oxygen figures above saturation were recorded once in 1920 from a middle lake wide-water station, late in August, though this was in the lower part of the lake, and not above the middle as in the latter part of July 1922.

Bottom Dissolved Oxygen, Mid-channel, Middle Peoria Lake. 1920-1922
Midsummer Figures, Parts per Million

Peoria gage ft.	Mossville Mile 154.9*		1.3 miles below Mossville Mile 156.2		Foot of Horshor Island Mile 157.4		Al Fresco Park Mile 159.3		
	1922	1920	1922	1920	1922	1920	1922	1920	Dates
11.3	...	...	5.2	...	...	...	6.4	...	July 3
10.7	...	...	5.2	...	4.9	...	5.8	...	July 28
10.4	...	...	...	3.0	...	...	...	1.5	July 21-22
10.3	...	...	2.2		...	...	3.4	...	Aug. 9
10.2	...	...	1.7	...	...	...	4.0	...	Sept. 13
9.8	...	...	...	2.3	...	...	...	3.4	Aug. 6
9.8	...	...	2.8	...	...	...	5.3	...	Aug. 29
9.5	...	...	...	...	...	1.9	...	2.2; 1.5	Aug. 10-11
9.5	...	1.3	...	2.1	...	2.7	...	4.8	Aug. 25-26
9.5	...	1.2	...	...	...	1.8	...	3.7; 4.0	Aug. 27-28

* Miles below Lake Michigan.

Small Bottom Animals

The all-zone list of small bottom animals from the middle lake contained 23 species in 1922 compared with 19 from the upper lake the same season (Table 1, p. 358). Though variety of species was least both in the middle and the upper lake at the channel stations, it was there that the greatest relative increase occurred: i. e., from 8 species in the upper to 11 species in the middle lake in the same period. In the wide waters the 1922 hauls yielded in all 21 species compared with 18 from the upper lake. The increases over the upper lake lists were largely due both in the channel and in the wide waters to increased variety of the less tolerant snails and midge larvae, the first of these two groups rising to a total of 10 species for the middle lake as a whole in the summer of 1922.

Compared with 1920, there was substantially a doubling in variety of the 1922 lists, whether in channel, wide waters, or all zones combined (Table 2, p. 358). The increases over 1920 were principally due to multiplication of kinds of the less tolerant snails, which rose in the two years from one to ten species; and to the less tolerant kinds of larval midges, which increased from two kinds to five. Both the snails and the less tolerant midges showed the greatest gain in the wide waters, at the same time that the more pollutional kinds of midges fell off in representation in the extra-channel areas as compared with 1920.

The changes in the species lists of the middle lake from its upper to its lower end in 1922 were irregular in the channel, the Al Fresco Park stations showing scarcely better than those opposite Mossville, four and a half miles above (Table on p. 359). The largest variety of channel species was found in the intermediate cross-section, opposite the foot of Horshor Island, and about half way between the head and the foot of the lake. In the wide waters there was a more regular showing of improvement southward from Mossville, both the Horshor Island and the Al Fresco cross-sections yielding nearly or quite twice as many of the less tolerant snails and from three to four times as many of the less tolerant midges as were taken opposite the Mossville station.

In all three of the middle lake cross-sections of 1922 there was marked increase in variety of species as we proceeded outward into the wide waters from the steamboat channel (Table on p. 360). This improvement was mainly due in all three cross-sections to the increase in number of kinds of less tolerant snails; which rose in the Mossville section from none in the channel to three kinds in the wide waters; in the Horshor Island section from three kinds in the channel to six kinds in the wide waters; and in the Al Fresco Park section from one kind in the channel to five kinds at the extra-channel stations.

Summary of Bottom Species Lists, Middle Peoria Lake, Summer of 1922

1. comparison with upper lake. number of kinds taken

	Worms	Leeches	Pollutional midges	Other midges	Very tolerant snails	Less tolerant snails	Other snails	All snails	Total
Mid-channel									
Upper lake......	4+	1	0	0	1	2	0	3	8+
Middle lake.....	4+	0	1	1	1	4	0	5	11+
Extra-channel or wide waters									
Upper lake......	5+	1	1	4+	1	5	1	7	18+
Middle lake.....	3+	2	1	5+	1	9	0	10	21+
All zones.........									
Upper lake......	5+	2	1	4+	1	5	1	7	19+
Middle lake.....	4+	2	1	5+	1	10	0	11	23+

Summary of Bottom Species Lists, Middle Peoria Lake, Summer of 1922

2. comparison with 1920. number of kinds taken

	Channel		Combined wide-water zones		All zones	
	1922	1920	1922	1920	1922	1920
Worms...............	4	3	3	3	4	3+
Leeches..............	0	0	2	1	2	1
Pollutional midges....	1	1	1	3	1	3
Other midges.........	1	1	5+	2+	5+	2+
Very tolerant snails...	1	0	1	1	1	1
Less tolerant snails...	4	0	9	1	10	1
Other snails..........	0	0	0	0	0	0
Less tolerant associated group........	0	0	0	0	0	0
Total............	11	5	21+	11+	23+	11+

Summary of Bottom Species Lists, Middle Peoria Lake, Summer of 1922

3. CHANGES DOWN STREAM. NUMBER OF KINDS TAKEN

	Worms	Leeches	Pollutional midges*	Other midges*	Very tolerant snails	Less tolerant snails	Other snails	All snails	Total
Mid-channel									
Mossville Mile 154.8	1	0	0	1	1	0	0	1	3
Foot of Horshor Island Mile 157.3	4+	0	1	0	1	3	0	4	9+
Al Fresco Park Mile 159.3	0	0	1	0	1	1	0	2	3
Combined Wide-water zones									
Mossville Mile 154.8	2	1	0	1	1	3	0	4	8
Foot of Horshor Island Mile 157.3	3+	0	1	3	1	6	0	7	14+
Al Fresco Park Mile 159.3	0	1	1	4+	1	5	0	6	12+

* Larvae.

SUMMARY OF BOTTOM SPECIES LISTS. MIDDLE PEORIA LAKE, SUMMER 1922
4. CHANGES FROM MID-CHANNEL OUTWARD INTO WIDE WATERS
NUMBERS OF KINDS TAKEN

	Mid-channel	First 1500 ft.	1800-4500 ft.	All extra-channel
Mossville				
Mile 154.8				
Worms	1	2	2	2
Leeches	0	1	0	1
Pollutional midges*	0	0	0	0
Other midges*	1	0	1	1
Very tolerant snails	1	1	1	1
Less tolerant snails				
1st and 2d groups				
combined	0	3	3	3
Other snails	0	0	0	0
Total	3	7	7	8
Foot of Horshor Island				
Mile 157.3				
Worms	4+	3+	2	4+
Leeches	0	0	0	0
Pollutional midges	1	1	1	1
Other midges	0	3+	2	3+
Very tolerant snails	1	1	1	1
Less tolerant snails				
1st and 2d groups				
combined	3	5	2	6
Other snails	0	0	0	0
Total	9+	13+	8+	15+
Al Fresco Park				
Mile 159.3				
Worms	0	0	0	0
Leeches	0	1	0	1
Pollutional midges	1	1	1	1
Other midges	0	2	3	4
Very tolerant snails	1	1	1	1
Less tolerant snails				
1st and 2d groups		1		
combined	1	4	4	5
Other snails	0	0	0	0
Total	3	9	9+	12+

* Larvae.

WORMS

Except for the irregular continuation of the decline in numbers already noticed in the upper lake, and their failure to appear at all in the collections opposite Al Fresco Park, the tubificid worms presented little of interest in the middle lake in the summer of 1922. Substantially the same list of species was found as in the upper lake, though in all cases in much smaller average numbers and with more scattered distribution. The various species of Limnodrilus, rather than *Tubifex tubifex*, led as in the upper lake in frequency; while the local form of *Tubifex tubifex* was found at only a single station in the channel opposite the foot of Horshor Island.

The absence of small annelids from the Al Fresco Park hauls is not to be taken as conclusive evidence that they were not there although noticeably improved conditions on the bottom were visible also in other respects. It is more probable that if we had increased the fraction of the Petersen dredge sample sieved for them at least small numbers of some of the species would have been found.

LEECHES

Leeches were represented in the 1922 middle lake hauls by two species, the same number as in the upper lake. One of them, *Helobdella nephcloidea* (Graf), occurred in the wide waters of the Mossville cross-section, and was also recorded in 1922 from the wide waters of the upper lake above Spring Bay. The second, *Helobdella stagnalis* (Linnaeus), although it occurred in the middle lake in 1922 only in the lower or Al Fresco Park cross-section, was one of the two commonest leeches at the more heavily polluted stations of the Coweeset just below Brockton, Massachusetts, in 1914 (Weston and Turner 1917). *Erpobdella punctata* (Leidy), which was taken in the channel at Chillicothe in 1922 and was the other common leech at the upper Coweeset hauls in 1914, was not found in middle Peoria Lake collections in the season of 1922.

MIDGE LARVAE

While a total of six species of immature midges were recorded from the middle lake in the summer of 1922, compared with five in 1920, the more distinctly tolerant or pollutional kinds were reduced in 1922 in the middle as in the upper lake from three to only one. The one, a variety of *Chironomus plumosus* Linnaeus or a species very closely allied to it, occurred at fourteen of the thirty stations covered in the middle lake in 1922. It was, however, absent in all collections in the upper or Mossville cross-section, and reached its highest average numbers in the cross-section opposite the foot of Horshor Island, or through almost the exact center of the lake.

Chironomids of more uncertain status were represented in the middle lake hauls of the summer of 1922 by not less than five species. Of these, *Chironomus digitatus* Malloch has not before to our knowledge been recorded from any but ordinarily clean bottom. The others included a species very near *C. maturus* Johannsen, which was taken in foul muds in the lower lake both in 1922 and 1920; and an uncertain number of unidentified kinds of Chironomus, Tanypus, and Procladius.

UNUSUALLY TOLERANT SNAILS

While the snails were easily led in abundance in the middle lake as in the upper in the summer of 1922 by the unusually tolerant *Musculium transversum* Say, the figures for that species were small compared with the numbers reached by it the same season in the upper lake. The largest all-station average of a single cross-section amounted only to a little over 2,500 per square yard, or about a fifteenth of the average of the nine 1922 stations in the best upper lake cross-section (opposite Rome); and the smallest to only one sixtieth of the nine-station average of the same cross-section. Though so small compared with upper lake figures, those of the middle lake represented valuation equivalents between 200 and nearly 500 pounds per acre and made up the largest single item by weight of the whole 1922 middle lake bottom fauna.

LESS TOLERANT SNAILS

Ten other kinds of snails, all presumed to be of lesser tolerance than *Musculium transversum* but more tolerant than several species of the old fauna that have not appeared in any part of the open waters of Peoria Lake since before 1920, and all but one belonging to the Sphaeriidae, were taken in the middle lake in the summer of 1922. Numbers were small in all cases, and all recorded occurrences were at stations well away from the channel and toward the east or west margins of the lake, or, if widely distributed, in its lower portion. This number of species is just double that of the less tolerant group of snails listed from the upper lake in 1922, and compares with a single snail species besides *M. transversum* from the middle lake in 1920. Five of these species were the same as the five already listed from the upper lake on a preceding page. This group, distinguished from the other five by the fact of occurrence above the middle lake in 1922, included one sphaeriid of the genus Musculium, one viviparid, and three species of the sphaeriid genus Pisidium, sometimes called pea-clams in the literature. The five new entrants in the 1922 lists, embracing snails whose farthest northward occurrence in 1922 was the middle lake, included three additional species of Pisidium not taken in the upper lake in 1922 or in any part of either the upper, middle, or lower lakes in 1920, and two species of Sphaerium, also not taken in the upper lake in the summer of 1922, but one of them recorded from the lower lake in 1920.

The distinction between these two groups of the less tolerant snails and their relation, in the matter of tolerance to pollution, to the other recent snail groups and to the Viviparidae and Amnicolidae apparently exterminated between 1915 and 1920 is shown in the table that follows.

COMMONER SNAILS OF PEORIA LAKE, 1913–1922

	Full list of species, 1922													Commoner species of 1913–1915 that have not since appeared in collections					
	Unusually tolerant species	Less tolerant, first group, taken in both upper and middle lakes in 1922					Less tolerant, second group, not taken above the middle lake in 1922					Current-loving species, taken only in swifter current in lower lake							
Figures indicate No. of collections in which each species occurred	Musculium transversum	Musculium truncatum	Pisidium compressum	P. pauperculum, var. crystalense	Pisidium sp. near complanatum	Campeloma subsolidum	Pisidium pauperculum	Pisidium species	Pisidium species	Sphaerium stamineum	S. striatinum, var. lilycashense	Pleurocera elevatum var. lewisii	Goniobasis livescens	Vivipara contectoides	Vivipara subpurpurea	Lioplax subcarinatus	Amnicola emarginata	Amnicola limosa	Somatogyrus subglobosus
Upper lake 23 colls.	23	7	6	2	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Middle lake 30 colls.	23	1	16	1	2	9	4	1	1	5	3	—	—	—	—	—	—	—	—
Lower lake* 18 colls.	8	—	4	1	—	3	—	—	—	2	—	—	2	—	—	—	—	—	—

* Includes Peoria Narrows and P. P. U. Bridge.

Lower Peoria Lake and Illinois River, Peoria Narrows to Peoria and Pekin Union Railway Bridge (Mile 161.0—166.4 below Lake Michigan)

Hydrography

In or adjacent to lower Peoria Lake in the summer of 1922 bottom dredgings were made at eighteen stations in four cross-sections. Collections began at the foot of Peoria Narrows, which is just above the head of the lower lake wide-waters and is not far from a quarter of a mile wide at recent low water, and ended at the P. P. U. Railway Bridge across the Illinois River about a mile and a half below the foot, which lies slightly below the center of the city of Peoria. The two intermediate cross-sections through the lake proper were opposite Workhouse Point, a little less than two miles below the Narrows; and opposite the foot of Fulton Street, a mile and a half below the first open lake cross-section and less than a mile above the lake's foot. The full width of the lake was somewhat more than a mile at the Point and considerably less than a mile opposite Fulton Street, though appreciably wider in between, during the summer months of 1922.

Though a good deal smaller, as measured either by length or width, than the upper or the middle lake, being only about three and a half miles long as compared with nearly six for the middle lake and more than six for the upper, the lower lake with its immediately contiguous areas, as here regarded, presents a visibly greater variety of habitats than either of the others, and differs from them also in several other main features. Its entire lower half is narrowed to an effectual width of much less than a mile by a long submerged but formerly wooded island on the east side, whose outside edge is only about three quarters of a mile from the Peoria water-front opposite. The effect of this is that throughout the central and lower portion of the lower lake, where our main cross-sections were made both in 1922 and 1920, the great body of moving water passes through a relatively narrow and deep prism, with depths between twelve and fourteen feet prevailing over a total width of nearly half a mile, and with, as a consequence, a greater average current everywhere in the open portion than in corresponding sections of the upper or middle lake.

The west littoral of the lower lake receives the discharge from most of the main sewers and industrial drains of a city of nearly 100,000 people, but although this is true, during the summer season the prevailing direction of the winds and the current together seem to keep this soiling material largely confined between the channel and the bank as far as the foot of the lake, where the first extensive mixing of lake water and local sewage appears ordinarily to take place. The general orientation of both the channel and the adjacent wide-waters is such, however, that in the fall of the year and occasionally during the summer season, north or slightly north of west winds may cause much more mixing of the sewage with the lake water eastward.

Soft mud bottom was met at all stations in the lower lake proper. Harder mud and shell bottom was found in midstream at the Narrows, and nearly clean sand at the P. P. U. Bridge, where the current is four to five times that in the channel opposite Workhouse Point and six to seven times midstream current measured near the middle of the middle lake in the summer of 1920.

Since the first cross-section in the lake proper was above most of the main sewers, and we confined our collecting below that place to the channel and the open lake eastward of it, no especial foul odors were recorded at any of the lower lake stations in the 1922 summer season. Bubbling was observed in abundance at most stations opposite Workhouse Point, as also at the farthest eastward stations opposite Fulton Street, but in the middle of the main channel and at most open lake stations opposite Fulton Street neither bubbles nor unusually bad odors were noted.

Little restoration of the killed-out vegetation in the southeastern part of the lower lake had occurred in the two years since 1920, the thin Potamogeton patch on the east side facing Liberty Street looking about as it did in the summer of 1920. Traces of Vallisneria were brought up by the dredge at the station nearest the west shore off Workhouse Point, but no vegetation was encountered in any other hauls.

Dissolved Oxygen

Both in the summer of 1922 and of 1920 the supply of dissolved oxygen a foot from the bottom in mid-channel at the foot of Peoria Narrows ranged between 50 and 75 per cent of saturation, numerous samples taken between the middle of July and the middle of September 1920 averaging 5.1 to 6.4 parts per million, and eight samples taken in September 1922 averaging 4.8, with a range from 3.6 to 6.2 p. p. m. Soon after the middle of July 1920 almost as high or higher figures than at the Narrows continued in mid-channel to and below the foot of the lake. But in the first week of August 1920 the bottom oxygen dropped sharply below the Narrows from a high figure for the season of 6.4 p. p. m. to only 3.4 a mile below, and to 2.0 p. p. m. opposite Green Street, which is a mile above the foot of the lake. On the same dates a rapid rise in bottom oxygen figures from the channel eastward into the wide waters was noted a mile below the Narrows; but opposite Green Street samples showed between three and two parts per million for two fifths of a mile eastward into the open lake.

Bottom Dissolved Oxygen, Mid-Channel, Lower Peoria Lake, 1920–1922
Midsummer Figures, Parts per Million—Averages

Peoria gage ft.	Peoria Narrows Mile 161.0*		Strawboard works Mile 161.7		Green street Mile 163.9		Liberty street Mile 164.2		Dates
	1922	1920	1922	1920	1922	1920	1922	1920	
10.4	..	5.5	..	6.2	..	..	..	4.7	July 17–22
9.8	..	6.4	..	3.4	..	2.0	..	3.1	August 6
9.5	..	6.1	..	..	..	..	..	..	Aug. 24–28
9.5	..	5.1	..	..	..	..	..	..	Sept. 13
9.6	4.8	..	..	..	..	..	..	..	Sept. 1

* Miles below Lake Michigan.

Small Bottom Animals

In the two lower lake cross-sections of 1922 and those in the river immediately adjoining, there were taken in all 28 species of small bottom invertebrates, or 5 more than the total taken in the middle lake the same season and 9 more than the total from the upper. Worms, leeches, midges, and *Musculium transversum* accounted for 17 of the total of 28 species; the remaining 11 being distributed between the less tolerant snails, in the lower lake reduced to four kinds; and a miscellaneous group of seven species of Bryozoa, sponges, snails, insects, and Crustacea, all of which had their first occurrence both in 1922 and 1920 in or below Peoria Narrows.

The two main features distinguishing the 1922 lower lake fauna from that of the middle lake (Table on p. 369) were the reduction in number from ten kinds to only four kinds of the less tolerant snails, at the same time with the first appearance below Chillicothe of seven miscellaneous small bottom animals of presumably lesser tolerance than any of the groups taken either in 1922 or 1920 in the middle or the upper lake.

The comparison of 1922 collections from the lower lake with those of 1920 (Table on p. 370) showed less dicerence than appeared either in the upper or middle lake, and suggests that this section of the lake, with its greater average current, and its long history of local pollution, has at the present time a small bottom population somewhat better adjusted to the prevailing conditions than has been the case recently in the portions of the lake above Peoria Narrows.

As we would expect from the heavy local pollution adjacent to the channel on the east side, there was a greater increase in variety in the species lists from the channel outward into the wide waters (from 2 kinds to 12 kinds in the Workhouse Point cross-section; and from 8 kinds to 17 kinds in the Fulton Street section) than either in the middle or the upper lake (Table on p. 372). This was despite the fact that the corrective action of the more rapid current in and also well outside of the channel here permits the existence of several current-loving forms that have not been found since 1915 above the lower lake; and that wind- or wave-carried local pollution has apparently reduced the number of kinds of the less tolerant Sphaeriidae in the wide waters.

The changes in the lower lake species lists down stream (Table on p. 371) were irregular and of no special significance.

SUMMARY OF BOTTOM SPECIES LISTS

LOWER PEORIA LAKE, SUMMER OF 1922

1. COMPARISON WITH MIDDLE LAKE. NUMBER OF KINDS TAKEN

	Worms	Leeches	Pollutional midges	Other midges	Very tolerant snails	Less tolerant snails	Less tolerant associated group						Combined less toler. associated group	Grand total
							Mussels	Snails	Bryozoa	Sponges	Crustacea	Other insects		
Mid-channel														
Middle lake	4+	0	1	1	1	4	0	0	0	0	0	0	0	11+
Lower lake	3+	3	0	1	1	2	1	0	1	0	1	0	3	13+
Extra-channel or Wide waters														
Middle lake	3+	2	1	5+	1	9	0	0	0	0	0	0	0	21+
Lower lake	4+	4	3	5+	1	4	0	1	1	1	1	2	6	27+
All zones														
Middle lake	4+	2	1	5+	1	10	0	0	0	0	0	0	0	23+
Lower lake	4+	4	3	5+	1	4	1	1	1	1	1	2	7	28+

Summary of Bottom Species Lists, Lower Peoria Lake, Summer of 1922
2. comparison with 1920. number of kinds taken

	Channel		Combined wide-water zones		All zones	
	1922	1920	1922	1920	1922	1920
Worms	3	3	4+	2	4+	3
Leeches	3	0	4	2	4	2
Pollutional midges	0	4	3	4	3	4
Other midges	1	3+	5+	3+	5+	4+
Very tolerant snails	1	1	1	1	1	1
Less tolerant snails	2	2	4	3	4	3
Other snails	0	1	1	2	1	2
Less tolerant assoc. group	3	0	5	5	6	5
Total	13	14+	27+	22+	28+	24+

Summary of Bottom Species Lists, Lower Peoria Lake, Summer 1922
3. Changes down stream. Number of kinds taken

	Worms	Leeches	Pollutional midges*	Other midges*	Very tolerant snails	Less tolerant snails	Less tolerant associated group	Total
Mid-channel								
Workhouse Point Mile 161.7	1	0	0	0	0	1	0	2
Fulton Street Mile 164.2	2	3	0	0	0	0	3	8
First Wide-water zone								
Workhouse Point Mile 161.7	1	0	2	3+	1	3	0	10+
Fulton Street Mile 164.2	2	2	1	2+	1	0	3	11+
Second Wide-water zone								
Workhouse Point Mile 161.7	1	0	0	3	0	0	0	4
Fulton Street Mile 164.2	2	3	2	3	0	0	0	10

* Larvae.

SUMMARY OF BOTTOM SPECIES LISTS, LOWER PEORIA LAKE, SUMMER 1922
4. CHANGES FROM MID-CHANNEL OUTWARD INTO WIDE WATERS.
NUMBER OF KINDS TAKEN

	Mid-channel	First 1500 ft.	1800–4500 ft.	All extra-channel
Workhouse Point Mile 161.7				
Worms	1	1	1	2
Leeches	0	0	0	0
Pollutional midges*	0	2	0	2
Other midges*	0	3+	3	4+
Very tolerant snails	0	1	0	1
Less tolerant snails	1	3	0	3
Less tolerant associated group	0	0	0	0
Total	2	10	4	12
Fulton Street Mile 164.2				
Worms	2	2	2	3
Leeches	3	2	3	3
Pollutional midges	0	1	2	2
Other midges	0	2	3	5
Very tolerant snails	0	1	0	1
Less tolerant snails	0	0	0	0
Less tolerant associated group	3	3	0	3
Total	8	11	10	17

* Larvae.

WORMS

Though tubificid worms occurred at eleven out of the total of eighteen stations in the lower lake in 1922, and included four species, one of which was *Tubifex tubifex*, their numbers were generally so small as to be of no especial consequence. The commoner kinds were species of Limnodrilus, as in the upper and middle lakes, and *T. tubifex* occurred only at a single station. The comparison with the middle and upper lake figures and with the lower lake figures for 1920, which for unknown reasons averaged even less than those of 1922, is shown in the table on page 347 preceding.

LEECHES

Four species of leeches were taken in the lower lake in the summer of 1922, which was more than were found in either the middle or upper lake in 1922 or in the lower in 1920. These four species included *Erpobdella punctata* and *Helobdella stagnalis*, both of which have been recently listed from outside of Illinois in polluted bottom; *Helobdella nephcloidea*, which was taken in the upper lake above Spring Bay in 1922 where odors were bad and bubbles were abundant; and *Dina parva*, of which we have no local or outside records from foul bottom. *Erpobdella punctata* was found only in the mixture of local sewage and lake water at the P. P. U. Bridge, below the foot of the lake, that and the occurrence in mid-channel at Chillicothe being the only records obtained anywhere in the summer of 1922. With a single exception, occurrences of the other three species were limited to the Fulton Street cross-section, where leeches were especially common in the summer of 1922 both in channel and extra-channel collections.

MIDGE LARVAE

Though average abundance of midge larvae did not go as high in the lower lake as in the upper and middle lakes in the summer of 1922, both the total number of species identified and the number known to be more than usually tolerant was greater. The three pollutional forms included the common one from the upper and middle lakes, *Chironomus plumosus*, var. as well as also typical *C. plumosus,* which was taken once opposite Fulton Street; and *C. maturus* Johannsen, which was taken at two hauls in the cross-section opposite Workhouse Point. In addition there were upwards of five or six kinds of Chironomidae of more or less doubtful position, two of them apparently less tolerant than the three above mentioned. These two were *Chironomus digitatus* Malloch, which was also taken in the middle cross-section in the middle lake in 1922, and which occurred in clean muds in Lake Mendota, studied by Muttkowski in 1918; and *Tanypus monilis* Linnaeus, found once in the Fulton Street cross-section, well to the eastward, and except for its occurrence not far from mid-channel opposite Rome in August 1922, not known to us to favor bad bottom.

UNUSUALLY TOLERANT SNAILS

Musculium transversum, the leader of the water-breathing snails in enduring low oxygen and other effects of pollution in upper Peoria Lake, continued in the lower lake to still lower levels the decline begun between Rome and Spring Bay in the summer of 1922 and showed no increase worth mentioning over 1920 abundance (Table, p. 347). The lower lake has recently had ordinarily a sufficient supply of oxygen at levels well above the bottom for the coarser commercial fishes, and is subject to little or no seining as a consequence of the almost entire absence of good landing places. Perhaps the little-restricted fish foraging may account in part for the small numbers recently found not only of this species but also of others, including mud worms and midge larvae, in the lower lake. A second circumstance that may have bearing on the recent scarcity of this snail in lower Peoria Lake is that in the period between 1913 and 1915, when bottom conditions were more nearly normal in this part of the Illinois River, the upper lake was, as in 1922, its principal stronghold. In those years the lower lake snail fauna was largely made up of species of Viviparidae and Pleuroceridae, though *M. transversum* was also taken in some hauls in moderate or small numbers.

LESS TOLERANT SNAILS

The less tolerant snails from lower lake hauls in the summer of 1922 were of only four kinds, as against ten kinds from the middle lake the same season, but no more than three from the lower lake in the summer of 1920. Three of these, *Pisidium compressum*, *P. pauperculum*, var. *crystalense*, and *Campeloma subsolidum* were present both in upper and middle lake collections in 1922, while the fourth, *Sphaerium stamineum*, had its farthest northward 1922 occurrence in the middle lake. All four of them were found in the Peoria Narrows hauls, and three of them, or all excepting the variety of *P. pauperculum*, were taken on the west beach side in the Workhouse Point cross-section. Only the two of them least reputed previously for sensitiveness, *P. compressum* and *Campeloma subsolidum*, were found in the channel or eastward of it below Peoria Narrows; and none of them was taken at stations more than 500 feet to the eastward of the mid-channel line or south of the upper and cleaner third of the lower lake. Numbers per collection or per unit of bottom area were small and relatively unimportant in all cases.

While the comparison with variety and abundance in the same group in the middle lake in 1922 was distinctly unfavorable, that with the lower lake in the summer two years before, particularly in the case of the Pisidia, was less so, and suggests moderate improvement within the limited area of best conditions in the two years. Besides taking in 1922 one more species than we did in 1920, one or the other of the two species of that genus was found at five in all of the total of eighteen stations visited in 1922; whereas in the summer of 1920 only a single species of the genus (*P. compressum*) was taken, and it was confined to a single station in the Peoria Narrows cross-section.

No explanation of the reduction in variety in this group between the middle and lower lakes recently is furnished by the comparison with our 1913 and 1915 data. In those years we took as many kinds and as great average numbers of Pisidium in the lower as in the middle lake, and more kinds of Sphaerium in the lower lake than in either the middle or upper; and found as well species of both genera at the wide-water stations in the lower half of the lower lake, where they were not taken at all either in 1922 or 1920. In view of these facts, though based in some cases on few collections, it is difficult to avoid the conclusion that local pollution has been injurious to this group in lower Peoria Lake recently.

LESS TOLERANT ASSOCIATED GROUP

A group of seven miscellaneous species having at first sight no characteristics in common except the fact that none of them was taken above the lower lake either in 1922 or 1920 completes the list of lower lake bottom animals taken by us in the season of 1922. Of this group three appeared in 1922 that were not found in collections in 1920, and three in1920 that were absent in 1922, giving us seven representatives of the lot in each summer's collections. The list included, as taken either in 1922 or 1920, the following species, embracing insects other than Chironomidae; young mussels; pleurocerid snails; sponges; bryozoans; and Crustacea:

1922 only.

Corixa species.—Peoria Narrows, in strong current.

Leptocerid (caddis) larva.—Peoria Narrows, in strong current.

Anodonta imbecillis Say.—Mid-channel, opposite Fulton Street, Peoria, in current.

1922 and 1920.

Goniobasis livescens Menke.—P. P. U. Bridge, in strong current.

Sponge species.—Peoria Narrows, in strong current, 1920; opposite Fulton Street, Peoria, 1922, 600 feet east of mid-channel, in current greater than that outside of channel in middle or upper lake.

Hyalella knickerbockeri (Bate).—In or near channel, several stations, both 1922 and 1920, in current; once in far wide-waters, 1920, near edge of smartweed bed.

Plumatella princeps var. *fruticosa* Kraepelin.—Peoria Narrows and P. P. U. Bridge in strong curent, and just outside of channel opposite Liberty Street, 1920; mid-channel and 600 feet east, opposite Fulton Street, 1922.

1920 only.

Quadrula plicata Say, *young.*—Peoria Narrows only, in strong current.

Pleurocera elevatum var. *lewisii* Lea.—Peoria Narrows and P. P. U. Bridge, in strong current.

Hydropsyche species.—Peoria Narrows and P. P. U. Bridge, a strong current.

Evidently an important consideration about this otherwise motley group is that all but one of them were confined both in 1922 and 1920 either to the swifter water at Peoria Narrows or the P. P. U. Railway Bridge, slightly above and below the lake proper; or were confined if taken in open lake cross-sections to the first 600 feet eastward of the mid-channel line, where also the current is appreciably greater than in corresponding locations in the upper and middle lakes. Besides this, the little fresh-water shrimp, Hyalella, which was found once in the east wide-waters near the edge of a smartweed bed, as also the species of Corixa, are really not bottom forms in the strict sense, being both free swimmers to a considerable extent and, in the case of the corixids, coming to the surface occasionally for air.

In favor, on the other hand, of a higher degree of tolerance in all members of this group than that possessed by the recently exterminated mussels, snails, and other bottom species of all three lakes is the fact that they have survived in recent years where so many other species have perished. Such a supposition receives support from our records from the polluted waters of the upper Illinois River obtained in the years 1911 and 1912 (Forbes and Richardson, 1913). At that time the identical species in the case of five of the 1920-1922 list

(*Quadrula plicata*, *Pleurocera elevatum*, var. *lewisii*, *Goniobasis livescens*, *Hyalella knickerbockeri*, *Plumatella princeps*, var. *fruticosa**, and species closely allied in three other cases) were taken at stations in the polluted sections of the upper Illinois where surface dissolved oxygen ranged between 1.4 and 2.7 parts per million, and where the great bulk of the normal bottom population had already been destroyed. One of the snails, also, *Pleurocera elevatum*, was one of the only two snails taken by Jewell in the acid waters of the Big Muddy River in southern Illinois in 1919 (Jewell, 1922).

Comparison of the Recent Small Invertebrate Bottom and Weed Fauna of Peoria Lake with that of 1913-1915.

GENERAL COMPARISON

Pre-1920 records of the bottom fauna, including the mussels, from the section of the Illinois River covered in the present paper were made by us at Chillicothe in the autumn of 1911 and the summer of 1912; and collections of the smaller bottom species only were made in a series of cross-sections between Chillicothe and the foot of lower Peoria Lake in the summers of 1913 and 1914 (Forbes and Richardson, 1913; Richardson, 1921). In addition to this earlier work of our own, the United States Bureau of Fisheries made a survey of the mussel resources of Peoria Lake, in connection with one of the entire Illinois River, during the years 1911 and 1912 (Danglade, 1914).

In making comparisons with these earlier records it is not possible always to be as exact as one could wish, because determinations were not carried out in as much detail in the earlier period as has been the case with more recent collections. For this reason, and also because of the necessarily very small fraction of the total bottom area covered by dredge hauls, neither our lists of the earlier nor the more recent bottom species of the lake are assumed to be as complete as they might have been with heavier programs of dredgings. Previous experience in dredging in the Illinois River and in other waters in Illinois has shown, however, that the number of bottom species that may be expected in single hauls is never very large, apparently as a consequence of a general rule that one or two or at the best a few species tend to predominate, usually with great distinctness, in a given range.

* At that time incorrectly identified.

In view of this fact, added to the generally rational and therefore explicable nature of the results, it seems not unreasonable to suppose that in the total of one hundred and fifty-two hauls in Peoria Lake between 1913 and 1922 (46 in 1913-1915, as a part of a total of 387 for the entire river; and 106 in 1920-1922) we probably obtained in both periods examples of at least most of the commoner species insofar as these are present during the summer season.

As all subdivisions of Peoria Lake were well supplied with coarse aquatic vegetation over a large portion of their area up to 1915, in order to obtain fair comparison with our 1920 and 1922 records, which were made after the old weed-beds had been destroyed, it has been necessary to exclude a good many of the less distinctly bottom forms of the pre-1920 lists. The exclusions cover a sizable assortment of free-swimming, weed-dwelling, and air-breathing species, not belonging in a proper sense to the bottom, which formerly entered in considerable numbers into bottom collections made in the shallower areas where there was more or less vegetation. Most of the excluded forms, it may be noted, have also disappeared since nine or ten years ago, along with the vegetation, over practically the entire area of Peoria Lake.

Having regard at present, then, only to the more exclusively bottom-species, both in the case of the earlier and the more recent records, we find that we took as nearly as may be calculated a total of 22 or more kinds in the upper lake in 1913-1915, of which at least 8 have since disappeared; 26 or more species in the middle lake, of which 12 have since dropped out; 43 or more species from the lower lake, of which 19 have disappeared; and from the bottom muds of all three lakes combined no less than 61 species, of which at least 23 are missing in recent collections, although recent hauls have been more than double the number of the earlier ones.

In evident contrast with the reduction of representation in the lists of more sensitive species, the tabulation (p. 383) indicates good-sized additions in all three lakes to the totals of more tolerant kinds since 1915. While a part of these apparent additions in the pollutional or tolerant column have undoubtedly taken place, especially in the Tubificidae and Chironomidae, it is probable that the more complete identification of the more recent material accounts for a part of them. It is, however, quite certain that there has been large increase in *numerical abundance* since 1915 of some of the more pollutional forms.

Of interest also is the apparent indication of a larger variety of bottom species in the lower lake than in the upper or middle lake before 1920, and a correspondingly greater loss of kinds in the lower lake species lists between 1915 and 1922. It is quite posisble that the upper and middle lakes may have been injured to a minor extent by sanitary canal pollution before 1915 and in advance of serious injury to the lower lake from the same or local causes. But this can not now be proven, and the continued existence of a healthy and varied mussel fauna (see page 385) between Peoria Narrows and Chillicothe as late as 1915, is against assuming that there had by that time been any very serious change, at least in the channel, in or quite near to which the mussel beds have always been located.

The greater variety of habitats furnished by the lower lake and its connections, already mentioned, may account for a good deal of the difference shown; and some of it may result from the greater number of lower lake bottom collections in the earlier period, including fuller special studies on the Chironomidae there than elsewhere, in the course of short visits by Malloch to Peoria in 1913 and 1914 (Malloch, 1915). But as special evidence suggesting earlier injury, particularly to the wide waters of both the upper and middle lakes, where sedimentation after the spring floods is particularly heavy, may be mentioned the noticeable absence or extreme rarity in the 1913-1915 collections of several groups of insects; such as the commoner aquatic Coleoptera; various Odonata; and from the upper lake in particular, the common May-fly nymph of the genus Hexagenia, as well as other Ephemeridae. The limited amount of collecting in the vegetation zones before 1920 also showed much poorer results than were easily to be obtained at that time with the same amount of effort in the lakes possessing similar aquatic vegetation near Havana.

COMMONER SMALL BOTTOM ANIMALS THAT HAVE DISAPPEARED SINCE 1915

While reviewing the missing members of the old fauna, it will be recalled that the species obtained in Peoria Lake in 1922 and 1920 have already been arranged, in this and earlier papers in a descending order of tolerance without so far disclosing any that seem to have a clear title as clean bottom species. The subjoined lists may be supposed, on the contrary, to include a considerable number of kinds that fall fairly under that designation, so far as they are applicable at all to the inhabitants of the bottom muds of our larger streams under present-day conditions.

PLANARIANS

Various unidentified species of planarians, attached to shells, bits of bark, leaves, etc., were not uncommon in Peoria Lake bottom hauls in years previous to 1920. These did not appear in any of our 1920 or 1922 bottom dredgings, or on any of a quite large number of dead mussel shells examined in the summer of 1920, although a few were noted in sediment samples caught in the relatively fast current at Peoria Narrows in August 1922 by a machine set about eighteen inches above the bottom.

BRYOZOA

While only a single species of bryozoan, *Plumatella princeps*, var. *fruticosa*, was found in Peoria Lake bottom collections in 1920 or 1922, two other species, *Paludicella ehrenbergii* Van Beneden and *Urnatella gracilis* Leidy, were common on live or dead shells in the deeper water everywhere below Chillicothe up to the summer of 1915. On many of the mussel shells examined in the summer of 1920 there were marks apparently left by the attachment of former colonies of these species.

SNAILS

The list of snails missing since 1915 includes two conspicuous cases of large and abundant kinds which were formerly so common in collections nearly everywhere in the lake that they gave their character largely to the majority of hauls made between Chillicothe and Peoria in 1913 and 1915. These were *Vivipara contectoides* W. G. Binney and *Lioplax subcarinatus* Say.

Species of snails that occurred in smaller numbers, but which seem to be of scarcely less importance as index organisms, include a second large species of Vivipara, *V. subpurpurea* Say, which was taken several times in the earlier collections, only in the middle and lower lakes, and principally in the lower. Notable also, up to 1915, was the little *Amnicola emarginata* Küster, which, although not widely distributed, occurred before 1920 in fairly large numbers over limited areas in both the middle and lower lake.

Two species of Valvata, *V. tricarinata* Say and *V. bicarinata* Lea, were formerly not far from equally common in the wide waters of the first two of the lakes. The first one was taken in a single haul also in the summer of 1922 within less than a hundred feet of the bank at the lower end of the upper lake, but the other appeared in none of our collections from anywhere between Chillicothe and Peoria in 1920 and 1922. These two species, while evidently partial to shallow weedy waters, also habitually spread far from shore in our local bottomland lakes; occurring in lakes near Havana in 1914 and 1915 in six to nine feet of water on plain mud bottom, and in the four to seven foot depth zone in upper Peoria Lake before 1920. A species of *Amnicola* near *A. limosa* Say, partaking of the habit of the Valvatas just described, of becoming bottom or weed species at will, was taken in the shallower areas of the upper and middle lakes before 1920.

Other bottom-dwelling snails taken in Peoria Lake in 1913 and 1915 collections but since then not seen, included one or more species of the little limpet-like Ancylus, which was formerly common on shells and sticks in the deeper water near the channel; a species of Pleurocera, *P. subulare* Lea, which occurred less commonly than its more abundant congener, *P. elevatum lewisii,* which latter species still persists in small numbers in the more rapid current in the lower lake; and the comparatively large amnicolid *Somatogyrus subglobosus* Say, which was taken in small numbers only in the upper lake.

INSECTS

Among larvae and nymphs of insects which have recently disappeared entirely from open-water dredgings in all three lakes the most important are members of the family Ephemeridae, or May-flies; of several families of Odonata, or dragon-flies; and of the commonest of the midge families locally, the Chironomidae.

In 1913 and 1915 the common May-fly, *Hexagenia variabilis* Eaton, was occasional in collections from both the middle and lower lakes, but has not since been taken in the Illinois River above Havana. Specimens of two other genera of May-flies that have since failed to appear, Callibaetis and Caenis, were also taken several times in the course of the dredging before 1920 in the two lower lakes.

The principal Chironomidae that have disappeared include *Chironomus tentans* Fabricius, formerly one of the most generally distributed and abundant, and because of its large size most conspicuous of the midge larvae of Peoria Lake and other middle Illinois River situations during the summer season. Other larval midges definitely missing recently, include *Chironomus nigricans* Johannsen; one or more species of the genus Cricotopus; and a species of the genus Orthocladius.

Several unidentified species of at least three families of dragonflies, whose nymphs have no green or other bright color*, are for the present admitted to the list of bottom forms that have disappeared from Peoria Lake since eight or ten years ago although some members of this group have recently been found to be unusually tolerant. Stickney (1922) found *Libellula pulchella* Drury very tolerant to conditions of low oxygen in recent experiments at Urbana; and Baker (1922) took the same species in the comparatively foul muds of the Big Vermilion at St. Joseph, where all the mussels had been killed. The writer took *Chromagrion conditum* Hagen and *Platythemis lydia* Drury in the Kishwaukee River below De Kalb in February 1922 in water polluted by acid wastes from steel mills to such an extent that most of the normal bottom fauna had been driven out or destroyed. The disappearance of nymphs of this group recently in the Peoria district may have been more in the nature of an indirect effect of the destruction of the vegetation, which served as headquarters for the adults, than evidence in all cases of unusual sensitiveness.

* Some green nymphs of the family Agrionidae have been excluded, as weed species, from the present comparison.

Number of Species of Small Bottom Animals Taken in Peoria Lake, 1913-1915 to 1920-1922. All Zones Combined; Accidental Weed and Surface Forms Excluded; no Duplications

	No. of collections	Species taken both in 1922–1920 and 1913–1915, or added, as unusually tolerant, since the earlier period			Total
		Group I Variously pollutional or tolerant worms, leeches, midge larvae, and snails	Group II Less tolerant associated group, as recognized in preceding pages	Group III Cleaner water group of 1913–1915, missing in all 1922–1920 collections.	
Upper lake					
1913–1915	17	9	5	8	22
1920	8	11	0	0	11
1922	23	19	1*	0	19
Middle lake					
1913–1915	13	11	3	12	26
1920	8	11	0	0	11
1922	30	23	0	0	23
Lower lake					
1913–1915	16	16	8	19	43
1920	19	17	7	0	24
1922	18	21	7	0	28
Three lakes combined					
1913–1915	46	28	10	23	61
1920–1922	106	32	10	0	42

* *Valvata tricarinata.*

ALMOST COMPLETE EXTINCTION OF AN ABUNDANT AND VARIED MUSSEL FAUNA SINCE 1913-1915

If we add to the list of exterminated small bottom animals the most of the mussels found by Danglade (1914) in Peoria Lake in 1911 and 1912, and now apparently all gone but an inconsequential number of the hardier species in the lower lake, this addition raises the total of missing bottom species from more than twenty to more than sixty kinds. Danglade listed in all, from the three lakes, a total of forty-one species, of which twenty came from Chillicothe and thirty from the middle lake. The number of kinds taken in the lower lake was not stated. The location of the most important commercial mussel beds as described by Danglade as they existed in 1911-1912, included beds above and below Rome; a mile above Spring Bay and in Spring Bay Narrows; below Mossville; and between Al Fresco Park and Peoria Narrows. The continued existence in good condition of the Mossville and Al Fresco Park beds, and of a vast bed of bluepoints. (*Quadrula plicata*) more than two miles long in the lower lake, extending from the center of the channel eastward, was verified by sketch maps furnished us as late as November 1915 by Havana pearl-hunters who spent the summer and fall of 1915 in Peoria Lake.

In the summer of 1920 and of 1922 we took with the Petersen dredge a single specimen each in the lower lake of two species, but no trace of live mussels of any kind in the waters above Peoria Narrows. We also, in July 1920, went carefully over a small boatload of mussel shells taken with a dip-net the same day by a Peoria musseler who we thought must have a market for dead shells to justify the otherwise unproductive work that he was doing. The number of shells we found alive was extremely few and all belonged to one or the other of two species, the bluepoint, *Quadrula plicata;* or the warty-back, *Quadrula pustulosa.* It is significant that both of these species were taken by us farther north in the polluted upper Illinois River in the summer of 1912 than any other mussels with the exception of one species (*Symphynota complanata*); the first having been taken at Starved Rock in company with *S. complanata;* and the second at Spring Valley.

The list of Peoria Lake mussels as of 1911-1912 that follows is as presented by Danglade (1914), except for the starring of the two unusually tolerant species of Quadrula above noted, and of the apparently hardy dwarf species of Anodonta which we took with the Petersen dredge in the lower lake in the summer of 1922. The fact that the full Danglade list for Peoria Lake, inclusive of Chillicothe, of forty-one species, was only eight short of his complete list of forty-nine kinds for the entire Illinois River in 1911-1912 does not suggest that the channel areas of Peoria Lake had been seriously injured up to that time, although the Chillicothe list had already apparently suffered some reduction.

Mussels Reported by Danglade (1914) from Peoria Lake, Inclusive of Chillicothe, in 1911-1912, but which Appear to have Since been Completely Exterminated above Peoria Narrows, and to have Nearly All Perished in the Lower Lake

The three species of which we obtained records in the lower lake in 1920 and 1922 are starred; those taken or seen by Danglade both at Chillicothe and in the lake below there, or at Chillicothe only, are marked with a C. No. 16 was taken at Chillicothe only.

1. Quadrula granifera. C
2. Quadrula ebena. C.
3. Quadrula plena
4. Quadrula solida
5. Quadrula coccinea
6. Quadrula obliqua
7. Quadrula trigona. C
8. Quadrula rubiginosa
*9. Quadrula pustulosa. C
10. Quadrula fragosa
11. Quadrula lachrymosa. C
12. Quadrula metanevra
13. Quadrula heros. C
14. Quadrula undulata. C
*15. Quadrula plicata. C
16. Unio crassidens. C
17. Unio gibbosus. C
18. Symphynota complanata
19. Arcidens confragosus. C
20. Anodonta corpulenta
21. Anodonta suborbiculata
*22. Anodonta imbecilis
23. Strophitus edentulus
24. Obliquaria reflexa. C
25. Tritigonia tuberculata
26. Plagiola donaciformis
27. Plagiola elegans
28. Plagiola securis. C
29. Obovaria ellipsis
30. Lampsilis laevissima
31. Lampsilis gracilis. C
32. Lampsilis alata
33. Lampsilis parva
34. Lampsilis recta, C
35. Lampsilis fallaciosa. C
36. Lampsilis anodontoides
37. Lampsilis higginsi. C
38. Lampsilis orbiculata. C
39. Lampsilis ligamentina. C
40. Lampsilis luteola. C
41. Lampsilis ventricosa

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Comparison of 1922 and 1920 Species Lists, Detail

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URBANA, ILLINOIS
October, 1925

COMPARISON OF SPECIES LISTS; UPPER PEORIA LAKE

All Zones

1922: 23 stations; 3 cross-sections	1920: 8 stations; 3 cross-sections
POLLUTIONAL, MORE TOLERANT, OR DOUBTFUL	
Worms (Tubificidae and Naididae)	
Limnodrilus hoffmeisteri Claparède Limnodrilus n. sp.* Tubifex tubifex (Müller)? or var. Limnodrilus sp. like L. claparedeianus Ratzel Naididae, unidentified	At least 3 or 4 spp., unidentified
5	3+
Leeches	
Erpobdella punctata (Leidy) Helobdella nepheloidea (Graf)	One unidentified species
2	1
Pollutional or more tolerant midge larvae	
Chironomus plumosus Linnaeus, var.	Chironomus plumosus Linnaeus Chironomus decorus Johannsen Tanypus dyari Coquillett
1	3
Midge larvae of doubtful status	
Chironomus sp. or spp. Procladius sp. or spp. Tanypus sp. or spp. Tanypus monilis Linnaeus	Chironomus sp. or spp. Tanypus sp. or spp.
4+	2+
Unusually tolerant snails	
Musculium transversum Say	Musculium transversum Say
1	1
LESS TOLERANT GROUP (SNAILS ONLY)	
Less tolerant snails, first group, (upper lake, farthest northward occurrence, 1922)	
Musculium truncatum Linsley Pisidium compressum Prime Pisidium pauperculum, var. crystalense Sterki Pisidium sp. near complanatum Sterki Campeloma subsolidum Anthony	Campeloma subsolidum Anthony
5	1
CLEANER WATER OR LESS TOLERANT ASSOCIATED GROUP	
Mussels 0	*Mussels* 0
Snails Valvata tricarinata (Say) 1	*Snails* 0
Bryozoa 0	*Bryozoa* 0
Sponges 0	*Sponges* 0
Crustacea 0	*Crustacea* 0
Other insects than midges 0	*Other insects than midges* 0
Total 19+	Total 11+

* To be described by Professor Frank Smith.

Wide Waters

1922: 20 stations; 3 cross-sections	1920: 5 stations; 3 cross-sections
POLLUTIONAL, MORE TOLERANT, OR DOUBTFUL	
Worms (Tubificidae and Naididae)	
Limnodrilus hoffmeisteri Claparède Limnodrilus n. sp. Tubifex tubifex (Müller)? or var. Limnodrilus sp. like L. claparedeianus Ratzel Naididae, unidentified	At least 3 unidentified spp.
5+	3
Leeches	
Helobdella nepheloidea (Graf)	Unidentified sp.
1	1
Pollutional or more tolerant midge larvae	
Chironomus plumosus Linnaeus, var.	Chironomus plumosus Linnaeus Chironomus decorus Johannsen Tanypus dyari Coquillett
1	3
Midge larvae of doubtful status	
Chironomus sp. or spp. Procladius sp. or spp. Tanypus sp. or spp. Tanypus monilis Linnaeus	Chironomus sp. or spp. Tanypus sp. or spp.
4+	2+
Unusually tolerant snails	
Musculium transversum Say	Musculium transversum Say
1	1
LESS TOLERANT GROUP (SNAILS ONLY)	
Less tolerant snails, first group, (upper lake, farthest northward occurrence, 1922)	
Musculium truncatum Linsley Pisidium compressum Prime Pisidium pauperculum, var. crystalense Sterki Pisidium sp. near complanatum Sterki Campeloma subsolidum Anthony	Campeloma subsolidum Anthony
5	1
CLEANER WATER OR LESS TOLERANT ASSOCIATED GROUP	
Mussels 0	*Mussels* 0
Snails Valvata tricarinata Say 1	*Snails* 0
Bryozoa 0	*Bryozoa* 0
Sponges 0	*Sponges* 0
Crustacea 0	*Crustacea* 0
Other insects than midges 0	*Other insects than midges* 0
Total 18+	Total 11+

Channel

1922: 3 stations; 3 cross-sections	1920: 3 stations; 3 cross-sections
POLLUTIONAL, MORE TOLERANT, OR DOUBTFUL	
Worms (Tubificidae and Naididae)	
Limnodrilus hoffmeisteri Claparède Limnodrilus n. sp. Tubifex tubifex (Müller)? or var. Naididae, unidentified	At least 3 unidentified spp.
4+	3
Leeches	
Erpobdella punctata (Leidy)	
1	0
Pollutional or more tolerant midge larvae	
	Chironomus decorus Johannsen Tanypus dyari Coquillett
0	2
Midge larvae of doubtful status	
	Chironomus sp. or spp. Tanypus sp. or spp.
0	2+
Unusually tolerant snails	
Musculium transversum Say	Musculium transversum Say
1	1
LESS TOLERANT GROUP (SNAILS ONLY)	
Less tolerant snails, first group, (upper lake, farthest northward occurrence, 1922)	
Musculium truncatum Linsley Pisidium compressum Prime	
2	0
CLEANER WATER OR LESS TOLERANT ASSOCIATED GROUP	
Mussels 0	*Mussels* 0
Snails 0	*Snails* 0
Bryozoa 0	*Bryozoa* 0
Sponges 0	*Sponges* 0
Crustacea 0	*Crustacea* 0
Other insects than midges 0	*Other insects than midges* 0
Total 8+	Total 8+

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URBANA, ILLINOIS
October, 1925

COMPARISON OF SPECIES LISTS; MIDDLE PEORIA LAKE

All Zones

1922: 30 stations; 3 cross-sections	1920: 8 stations; 2 cross-sections
POLLUTIONAL, MORE TOLERANT, OR DOUBTFUL	
Worms (Tubificidae and Naididae)	
Limnodrilus hoffmeisteri Claparède Limnodrilus n. sp. Tubifex tubifex (Muller)? or var. Naididae, unidentified Other unidentified, immature	At least 3 or 4 spp., unidentified
4+	3+
Leeches	
Helobdella nepheloidea (Graf) Helobdella stagnalis (Linnaeus)	Unidentified species
2	1
Pollutional or more tolerant midge larvae	
Chironomus plumosus Linnaeus, var.	Chironomus plumosus Linnaeus Chironomus plumosus Linnaeus, var. Tanypus dyari Coquillett
1	3
Midge larvae of doubtful status	
Chironomus sp. near C. maturus Johannsen Chironomus digitatus Malloch Chironomus sp. or spp. Procladius sp. or spp. Tanypus sp. or spp.	Chironomus sp. or spp. Tanypus sp. or spp.
5+	2+
Unusually tolerant snails	
Musculium transversum Say	Musculium transcersum Say
1	1
LESS TOLERANT GROUP (SNAILS ONLY)	
Less tolerant snails, first group, (upper lake, farthest northward occurrence, 1922)	
Musculium truncatum Linsley Pisidium compressum Prime Pisidium pauperculum, var. crystalense Sterki Pisidium sp. near P. complanatum Sterki Campeloma subsolidum Anthony	Campeloma subsolidum Anthony
5	1
Less tolerant snails, second group, (middle lake, farthest northward occurrence, 1922)	
Pisidium pauperculum Sterki Pisidium sp. like P. sp. from L. Winnebago, Sterki Pisidium sp. unidentified, Sterki Sphaerium stamineum Conrad Sphaerium striatinum, var. lilycashense Baker	——— ——— ———
5	0
CLEANER WATER OR LESS TOLERANT ASSOCIATED GROUP	
Mussels 0	*Mussels* 0
Snails 0	*Snails* 0
Bryozoa 0	*Bryozoa* 0
Sponges 0	*Sponges* 0
Crustacea 0	*Crustacea* 0
Other insects than midges 0	*Other insects than midges* 0
Total 23+	Total 11+

Wide Waters

1922: 27 stations; 3 cross-sections	1920: 6 stations; 2 cross-sections
POLLUTIONAL, MORE TOLERANT, OR DOUBTFUL	
Worms (Tubificidae and Naididae)	
Limnodrilus hoffmeisteri Claparède Limnodrilus n. sp. Naididae, unidentified Other unidentified, immature	At least 3 unidentified spp.
3+	3
Leeches	
Helobdella nepheloidea (Graf) Helobdella stagnalis (Linnaeus)	Unidentified species
2	1
Pollutional or more tolerant midge larvae	
Chironomus plumosus Linnaeus, var.	Chironomus plumosus Linnaeus Chironomus plumosus Linnaeus, var. Tanypus dyari Coquillett
1	3
Midge larvae of doubtful status	
Chironomus sp. near C. maturus Johannsen Chironomus digitatus Malloch Chironomus sp. or spp. Procladius sp. or spp. Tanypus sp. or spp.	Chironomus sp. or spp. Tanypus sp. or spp.
5+	2+
Unusually tolerant snails	
Musculium transversum Say	Musculium transversum Say
1	1
LESS TOLERANT GROUP (SNAILS ONLY)	
Less tolerant snails, first group, (upper lake, farthest northward occurrence, 1922)	
Musculium truncatum Linsley Pisidium compressum Prime Pisidium pauperculum, var. crystalense Sterki Pisidium sp. near P. complanatum Starki Campeloma subsolidum Anthony	Campeloma subsolidum Anthony
5	1
Less tolerant snails, second group, (middle lake, farthest northward occurrence, 1922)	
Pisidium pauperculum Sterki Pisidium sp. unidentified, Sterki Sphaerium stamineum Conrad Sphaerium striatinum, var. lilycashense Baker	——— ——— ———
4	0
LESS TOLERANT ASSOCIATED GROUP	
Mussels 0	*Mussels* 0
Snails 0	*Snails* 0
Bryozoa 0	*Bryozoa* 0
Sponges 0	*Sponges* 0
Crustacea 0	*Crustacea* 0
Other insects than midges 0	*Other insects than midges* 0
Total 21+	Total 11+

Channel

1922: 3 stations; 3 cross-sections	1920: 2 stations; 2 cross-sections
POLLUTIONAL, MORE TOLERANT, OR DOUBTFUL	
Worms (Tubificidae and Naididae)	
Limnodrilus hoffmeisteri Claparède Limnodrilus n. sp. Tubifex tubifex (Müller) or var.? Naididae, unidentified	At least 3 unidentified spp.
4	3
Leeches	
Leeches 0	*Leeches* 0
Pollutional or more tolerant midge larvae	
Chironomus plumosus Linnaeus, var.	Tanypus dyari Coquillett
1	1
Midge larvae of doubtful status	
Chironomus sp. or spp.	Chironomus sp. or spp.
1	1
Unusually tolerant snails	
Musculium transversum Say	——— ——— ———
1	0
LESS TOLERANT GROUP (SNAILS ONLY)	
Less tolerant snails, first group, (upper lake, farthest northward occurrence, 1922)	
Pisidium compressum Prime Pisidium sp. near P. complanatum Sterki	——— ——— ———
2	0
Less tolerant snails, second group, (middle lake, farthest northward occurrence, 1922)	
Pisidium sp. like P. sp. from L. Winnebago, Sterki Sphaerium striatinum, var. lilycashense Baker	——— ——— ———
2	0
CLEANER WATER OR LESS TOLERANT ASSOCIATED GROUP	
Mussels 0	*Mussels* 0
Snails 0	*Snails* 0
Bryozoa 0	*Bryozoa* 0
Sponges 0	*Sponges* 0
Crustacea 0	*Crustacea* 0
Other insects than midges 0	*Other insects than midges* 0
Total 11+	Total 5+

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URBANA, ILLINOIS
October, 1925

COMPARISON OF SPECIES LISTS; LOWER PEORIA LAKE

All Zones

1922: 18 stations; 3 cross-sections	1920: 19 stations; 5 cross-sections
POLLUTIONAL, MORE TOLERANT, OR DOUBTFUL	
Worms (Tubificidae and Naididae)	
Limnodrilus hoffmeisteri Claparède Limnodrilus n. sp. Tubifex tubifex (Müller) or var.? New genus Other unidentified, immature 4+	At least 3 unidentified spp. 3
Leeches	
Erpobdella punctata (Leidy) Helobdella stagnalis (Linnaeus) Helobdella nepheloidea (Graf) Dina parva Moore 4	Erpobdella punctata (Leidy) Helobdella stagnalis (Linnaeus) 2
Pollutional or more tolerant midge larvae	
Chironomus plumosus Linnaeus Chironomus plumosus Linnaeus, var. Chironomus maturus Johannsen 3	Chironomus plumosus Linnaeus Chironomus plumosus Linnaeus, var. Chironomus maturus Johannsen Chironomus frequens Johannsen 4
Midge larvae of doubtful status	
Chironomus digitatus Malloch Tanypus monilis Linnaeus Chironomus sp. or spp. Procladius sp. or spp. Tanypus sp. or spp. 5+	Chironomus crassicaudatus Malloch Palpomyia longipennis Loew? Chironomus sp. or spp. Tanypus sp. or spp. 4+
Unusually tolerant snails	
Musculium transversum Say 1	Musculium transversum Say 1
LESS TOLERANT GROUP (SNAILS ONLY)	
Less tolerant snails, first group, (upper lake, farthest northward occurrence, 1922)	
Pisidium compressum Prime Pisidium pauperculum, var. crystalense Sterki Campeloma subsolidum Anthony 3	Pisidium compressum Prime Campeloma subsolidum Anthony 2
Less tolerant snails, second group, (middle lake, farthest northward occurrence, 1922)	
Sphaerium stamineum Conrad 1	Sphaerium stamineum Conrad 1
CLEANER WATER OR LESS TOLERANT ASSOCIATED GROUP	
Mussels	
Anodonta imbecillis Say 1	Quadrula plicata Say 1
Snails	
Goniobasis livescens Menke 1	Goniobasis livescens Menke Pleurocera elevatum, var. lewisii Lea 2
Bryozoa	
Plumatella princeps, var. fruticosa Kraepelin 1	Plumatella princeps, var. fruticosa Kraepelin 1
Sponges	
Unidentified species 1	Unidentified species 1
Crustacea	
Hyalella knickerbockeri (Bate) 1	Hyalella knickerbockeri (Bate) 1
Other insects than midges	
Caddis larva (Leptoceridae) Corixid nymph 2	Hydropsyche sp. 1
Total 28+	Total 24+

Wide Waters

1922: 14 stations; 4 cross-sections	1920: 14 stations; 5 cross-sections
POLLUTIONAL, MORE TOLERANT, OR DOUBTFUL	
Worms (Tubificidae and Naididae)	
Limnodrilus hoffmeisteri Claparède Limnodrilus n. sp. Tubifex tubifex (Müller) or var.? New genus Other unidentified, immature 4+	At least two unidentified spp. 2
Leeches	
Erpobdella punctata (Leidy) Helobdella stagnalis (Linnaeus) Helobdella nepheloidea (Graf) Dina parva Moore 4	Erpobdella punctata (Leidy) Helobdella stagnalis (Linnaeus) 2
Pollutional or more tolerant midges	
Chironomus plumosus Linnaeus, var. Chironomus maturus Johannsen Chironomus plumosus Linnaeus 3	Chironomus plumosus Linnaeus Chironomus plumosus Linnaeus, var. Chironomus maturus Johannsen Chironomus frequens Johannsen 4
Midge larvae of doubtful status	
Chironomus digitatus Malloch Tanypus monilis Linnaeus Chironomus sp. or spp. Procladius sp. or spp. Tanypus sp. or spp. 5+	Chironomus crassicaudatus Malloch Palpomyia longipennis Loew? Chironomus sp. or spp. 3+
Unusually tolerant snails	
Musculium transversum Say 1	Musculium transversum Say 1
LESS TOLERANT GROUP (SNAILS ONLY)	
Less tolerant snails, first group, (upper lake, farthest northward occurrence, 1922)	
Pisidium compressum Prime Pisidium pauperculum, var. crystalense Sterki Campeloma subsolidum Anthony 3	Pisidium compressum Prime Campeloma subsolidum Anthony 2
Less tolerant snails, second group, (middle lake, farthest northward occurrence, 1922)	
Sphaerium stamineum Conrad 1	Sphaerium stamineum Conrad 1
CLEANER WATER OR LESS TOLERANT ASSOCIATED GROUP	
Mussels	
——— ——— ——— 0	Quadrula plicata Say 1
Snails	
Goniobasis livescens Menke 1	Goniobasis livescens Menke Pleurocera elevatum, var. lewisii Lea 2
Bryozoa	
Plumatella princeps, var. fruticosa Kraepelin 1	Plumatella princeps, var. fruticosa Kraepelin 1
Sponges	
Unidentified species 1	Unidentified species 1
Crustacea	
Hyalella knickerbockeri (Bate) 1	Hyalella knickerbockeri (Bate) 1
Other insects than midges	
Caddis larva (Leptoceridae) Corixid nymph 2	Hydropsyche sp. 1
Total 27+	Total 22+

Channel

1922: 4 stations; 4 cross-sections	1920: 5 stations; 5 cross-sections
POLLUTIONAL, MORE TOLERANT, OR DOUBTFUL	
Worms (Tubificidae and Naididae)	
Limnodrilus hoffmeisteri Claparède Limnodrilus n. sp. Unidentified 3	At least 3 unidentified spp. 3
Leeches	
Helobdella stagnalis (Linnaeus) Helobdella nepheloidea (Graf) Dina parva Moore 3	——— ——— ——— 0
Pollutional or more tolerant midges	
——— ——— ——— 0	Chironomus plumosus Linnaeus Chironomus plumosus Linnaeus, var. Chironomus maturus Johannsen Chironomus frequens Johannsen 4
Midge larvae of doubtful status	
Chironomus sp. or spp. 1	Chironomus sp. or spp. Tanypus sp. or spp. Chironomus crassicaudatus Malloch 3+
Unusually tolerant snails	
Musculium transversum Say 1	Musculium transversum Say 1
LESS TOLERANT GROUP (SNAILS ONLY)	
Less tolerant snails, first group, (upper lake, farthest northward occurrence, 1922)	
Pisidium compressum Prime Campeloma subsolidum Anthony 2	Campeloma subsolidum Anthony 1
Less tolerant snails, second group, (middle lake, farthest northward occurrence, 1922)	
——— ——— ——— 0	Sphaerium stamineum Conrad 1
CLEANER WATER OR LESS TOLERANT ASSOCIATED GROUP	
Mussels Anodonta imbecillis Say 1	*Mussels* 0
Snails ——— ——— ——— 0	*Snails* Pleurocera elevatum, var. lewisii 1
Bryozoa Plumatella princeps, var. fruticosa Kraepelin 1	*Bryozoa* 0
Sponges 0	*Sponges* 0
Crustacea Hyalella knickerbockeri (Bate) 1	*Crustacea* 0
Other insects than midges 0	*Other insects than midges* 0
Total 13+	Total 14+

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE
NATURAL HISTORY SURVEY
STEPHEN A. FORBES, *Chief*

Vol. XV. BULLETIN Article VI.

Illinois River Bottom Fauna in 1923

BY

ROBERT E. RICHARDSON

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URBANA, ILLINOIS
October, 1925

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October, 1925

STATE OF ILLINOIS

DEPARTMENT OF REGISTRATION AND EDUCATION

A. M. SHELTON, *Director*

THE NATURAL HISTORY SURVEY DIVISION

STEPHEN A. FORBES, *Chief*

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Article VI.—*The Illinois River Bottom Fauna in 1923.* By Robert E. Richardson.

The present paper is based on one hundred and fifty Petersen sampler collections taken in the Illinois River and Peoria Lake between June and September 1923; including 26 taken between La Salle and the head of Peoria Lake; 75 in the lake or its entrance, outlet, or connecting-"narrows"; and 49 below the lake and between Peoria and Beardstown.

The subdivision of the river and lake into zones follows that in the article on the 1922 bottom fauna as respects Peoria Lake, emphasizing distance from the channel center rather than depth, and recognizing three subdivisions as follows: (1) a central, imaginary, channel zone of about 700 feet average total width; (2) to either side and adjacent to this an intermediate zone extending outward to the 1500 foot line, on either side of the channel center; and outside of this, where the width permits, (3) an outer zone extending anywhere from somewhat more than 1500 to more than 4800 feet beyond the mid-channel line at recent summer levels with normal rainfall. In the river the so-called intermediate and outer zones correspond for the most part, except where the river is very shallow, to the zones of 4 to 7 and 1 to 3 feet as used in preceding papers, reference being to recent normal summer levels.

The subdivision of the species on the basis of degree of tolerance also follows in main features that of the 1922 paper, which recognizes, in general, three greater groups, as follows:

Group I. Pollutional or more or less tolerant species, including all recent tubificid worms, leeches, and midge larvae of Peoria Lake; and a number of more than ordinarily tolerant snails belonging chiefly to the sphaeriid genera Musculium and Pisidium. The basis of inclusion in this group has been chiefly the fact of survival in Peoria Lake through 1920, a short time before which year a sizable list of the more sensitive of the members of the old bottom population seem to have been wholly exterminated. For the distinction between the words pollutional and tolerant as used above and elsewhere in this paper, and the general alignment of terminoolgy with that of our 1913 paper on the biology of the Upper Illinois*, see the paper on changes in the bottom fauna of Peoria Lake, 1920 to 1922†.

Group II. Cleaner preference species, including principally current-loving forms of snails, Bryozoa, insects, and Crustacea, that have persisted in Peoria Lake or in the river shortly southward through and.

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* Bul. Ill. State Lab. Nat. Hist., Vol. IX, Art. 10, June, 1913.
† Bul. Ill. State Nat. Hist. Surv., Vol. XV, Art. V, 1925.

since 1920, usually near shore or in unusually good current, but where all of the species in Group III have disappeared.

Group III. Missing members of the old bottom fauna, as of our lists of 1913-1915, including snails of the families Viviparidae and Amnicolidae, chiefly; insects or insect larvae or nymphs of the orders Ephemerida, Odonata, Hemiptera, Neuroptera, and Coleoptera; and various other small bottom animals.

The word pollutional as here used corresponds roughly to Kolkwitz's term "mesosaprobic" and to Forbes and Richardson's term "pollutional", as used in the 1913 paper on the Illinois River. Both in its use and in that of the word "tolerant" (rather than "contaminate") it has been my purpose to attain greater flexibility than might be expected with the customary restricted use of these or similar terms; and by the use of the latter term, more especially, to express better the breadth of range, merging preferences, and adaptability of the not inconsiderable group of species which find their true position, quite unbounded by hard and fast lines, almost anywhere between pollutional and strictly clean-water forms.

Summary

In the 44 miles of the Illinois River above Peoria Lake examined in the summer of 1923 all of the bottom organisms taken belonged to the more strictly pollutional or unusually tolerant kinds; the most of them being small worms, at least one variety of which has previously both in Illinois and elsewhere been found to be characteristic of septic sludge. In this portion of the river the "sludge worms" were found to be most abundant outside the channel, where there is greatest sedimentation after floods.

The small bottom animals taken in 1923 in the broadly expanded 20-mile section of river between Chillicothe and the foot of Peoria Lake were with a few exceptions pollutional or more or less tolerant forms, in variety, abundance, and dispersal, showing no essential change since the summer of 1922.

Toward shore on the west or sand bluff side of the first 14 miles of this 20-mile section, and in the faster current of the upper and lower "narrows" or adjacent waters several less tolerant to fairly clean preference species were taken, as they were also in 1920 and 1922; and these showed some evidence of increase both in variety and numbers within their recent range as thus localized.

In about 71.5 miles of river below Peoria studied in 1923 enumerations showed a clear though irregular decline in abundance of the tubificid worms as compared with numbers above Peoria, as well as a decrease in variety of other pollutional or unusually tolerant species. But when the distribution of the collecting stations is taken into account this can not be believed to signify much if anything more than that the most of this section of river has too hard a bottom or too sharp local gradients to furnish good lodgment and a "settled suspended" food supply for these

types of organisms. This view receives support also from the fact that in this portion of the river such cleaner preference bottom species as are represented at all occur on the average in less variety than do similar forms in the lower part of Peoria Lake.

In respect to the number of species of the old 1913-1915 bottom fauna that have apparently been exterminated by the sewage since somewhat less than 10 years ago, the various reaches below the head of Peoria Lake examined in 1923 compare as follows: Peoria Lake, twelve species exterminated; Wesley to Copperas Creek Dam, thirteen species; Spring Lake Canal to Havana, 68-69 species; Matanzas to Beardstown, 24-25 species.

It is particularly noteworthy that the greatest injury since 1913-1915 seems to have been done in the short but formerly exceedingly rich section just above Havana; where current is slackest and sedimentation most abundant after floods; or where, in other words, there was at the same time most danger and the most that was capable of being destroyed.

The similarity of its hydrographical conditions to those of the one-time rich Liverpool-Havana section, and the fact that the list of species known to be missing from Peoria Lake since 1913-1915 is so small in comparison strongly suggests that at least the portion of Peoria Lake above the lower narrows had been to some extent injured by Chicago sewage previous to 1915.

Evidence that the lower section of Peoria Lake, below the lower narrows and opposite the city, has for several years been receiving serious injury from wind and wave-borne local pollution is seen in the fact that the improvement noted both in 1920, 1922, and 1923 as we proceed southward through the "upper" and "middle" lakes is wholly discontinued in the "lower lake", when we properly discount the occurrences of a few current-loving cleaner preference forms restricted to areas of unusual current.

The bottom animals covered above and in the following pages include only the smaller kinds, and are wholly exclusive of adult commercial mussels, which have been largely exterminated recently in Peoria Lake and in the river as far south as Havana.

Illinois River above Peoria Lake, La Salle—Chillicothe, 44 Miles

With the exception of the single occurrence of the little shrimp *Hyalella knickerbockeri* in swift water near the shore below the dam at Henry—an insignificant circumstance—all of the small bottom species taken in 1923 in the river between La Salle and the head of Peoria Lake belonged to the more strictly pollutional or tolerant groups, including only: upwards of half a dozen varieties of Tubificidae, small worms some of which are characteristic of septic sludge; two or three varieties of leeches; a similar number of kinds of chironomid larvae, of which one, *Chironomus decorus,* has a previous definite record of pollutional habit; and three species of sphaeriid snails, of which one, *Musculium transversum,* has previously been found in company with tubificid worms where their numbers exceeded 40,000 per square yard. Both in the channel and the outer zones of the river between La Salle and Henry, in the first 28.5 miles of the section dredged in 1923, nothing at all but tubificid worms were taken. *Musculium transversum* was taken at most stations between the Henry dam and Chillicothe (15.5 miles); the few kinds of midge larvae and leeches not until Lacon or below; and the two less tolerant Sphaeriidae only at or within two or three miles of Chillicothe.

The bulk of the tubificid worms taken in the more polluted reaches, as in upper Peoria Lake in 1922 and 1923, were not identified as *Tubifex tubifex,* the common pollutional form recorded in Europe, but as species of the genus Limnodrilus.

The largest numbers of all tubificid worms combined, and of *Tubifex tubifex* and the two principal species of Limnodrilus taken singly, per unit of bottom area, did not occur in the river channel, but in the shallower water close to or outside the 3-foot line, where conditions favor the greatest sedimentation.

Peoria Lake, Chillicothe—P. P. U. Bridge*, 20 Miles

In Peoria Lake in 1923 rather rapid increase is visible in the variety of the small bottom fauna as we proceed southward, as well as increase of the less tolerant forms in identical areas as compared with 1920 and 1922. But it is equally clear that the increases in kinds and in abundance of the less tolerant groups are greatest, and that they in fact show a strong tendency to be localized, either (1) quite close to shore; (2) in the faster current of Peoria Narrows or other essentially river situations included in the comparisons; or (3) in the rather limited area represented by the southwest third or less of the lower lake that lies between Long Shore Beach and Al Fresco Park. Except at a few stations in swifter current*, also, numbers and bulk of the species with greatest preference for clean bottom are uniformly much smaller per unit of bottom area than are the numbers and volume of the tubificid worms and others of the pollutional or more tolerant groups taken alongside of them.

* Where bulky growths of sponge or Bryozoa occurred.

PEORIA LAKE, 1922–1923, INCREASE OR DECREASE IN NUMBER OF SPECIES OF SMALL BOTTOM INVERTEBRATES*

	Channel				Intermed. zone				Outer zone				All zones combined			
	Group I†		Group II‡		Group I		Group II		Group I		Group II		Group I		Group II	
	'22	'23	'22	'23	'22	'23	'22	'23	'22	'23	'22	'23	'22	'23	'22	'23
Upper lake Inclusive of Chillicothe Goose Pond Spr. Bay Nar.	8	19	0	2	10	9	0	2	14	16	1	1	18	.24-25	1	5
Middle lake	11	18	0	1	21	18	0	5	15	21	0	3	23	29-30	0	7
Lower lake Inclusive of Peoria Nar. McK. Bridge P. P. U. Br.	10	16	3	12	19	2	6	0	12	19	0	4	21	24	7	14
Lower lake Exclusive of Peoria Nar. McK. Bridge P. P. U. Br.	7	12	3	1	14	—¶	3	—	12	15	0	1	19	18	4	2
Peoria Narrows McKinley Br. P. P. U. Bridge	5	14	1	12	12	2	3	0	—	13	—	4	13	20	4	14

* For comparison of number of collections these two years see separate table on p. 403.

† Group I = pollutional and more or less tolerant forms; viz., tubified worms, leeches, midge larvae, *Musculium transversum*, several other less tolerant Sphaeriidae, and *Campeloma subsolidum*.

‡ Group II = the less tolerant associated group including other snails than those in Group I, mussels, and various insects, Crustacea, sponges, Bryozoa, etc.

¶ Dashes indicate no collection.

PEORIA LAKE, 1923. AV. NOS. PER SQ. YD.

	Channel	No. of colls.	Group I						Group II	
			Worms Tubific.	Leeches	Poll. midges	Other midges	Very tol. snails	Less tol. snails	Other snails	Less tol. assoc. group
Upper lake	Chillicothe	2	925			84	444	6		
	Rome, incl. Goose Pond	3	15,848	16			312	48		
	Spring Bay, incl. S. B. Nar.	7	1,409	133	27	58	1,621	65		7
Middle lake	Mossville	1	8,592				1,296	168		
	Maple Point	2	2,208		120		2,112	60		
	Long Shore Beach	2	192		48	24	168	24		
	Towhead	1	5,580	72	1,004	24	2,352	288		
	Al Fresco	4	222	66	1,074	36	876	336	6	
Lower lake	Peoria Narrows	4	168	18	12	2,757	12	24	6	306
	U. S. Slips	3	1,552		720	96	16			
	Main St.	3	560	104	456	40	104			8
	McKinley Bridge	4	3	93		63	51	9	9	251
	P. P. U. Bridge	0	No coll.							

PEORIA LAKE, 1923. AV. NOS. PER SQ. YD.

	Intermediate zone	No. of colls.	Group I: Worms Tubific.	Group I: Leeches	Group I: Poll. midges	Group I: Other midges	Group I: Very tol. snails	Group I: Less tol. snails	Group II: Other snails	Group II: Less tol. assoc. group
Upper lake	Chillicothe	0	No coll.							
	Rome, incl. Goose Pond	3	2,664	32			8,773	24	32	
	Spring Bay, incl. S. B. Nar.	1	3,168	48			1,536			
Middle lake	Mossville	1	3,264	48	72	72	5,304	312		
	Maple Point	1	48	72	72	24		2,928		
	Long Shore Beach	2	1,476	6	72	12	366	222		18
	Towhead	1		120	48	48	1,512	648		48
	Al Fresco	1	144	624	96	1,968	72	384		72
Lower lake	Peoria Narrows	1	2,160							
	U. S. Slips	0	No coll.							
	Main St.	0	No coll.							
	McKinley Bridge	0	No coll.							
	P. P. U. Bridge	0	No coll.							

PEORIA LAKE, 1923. AV. NOS. PER SQ. YD.

	Outer zone	No. of colls.	Group I						Group II	
			Worms Tubific.	Leeches	Poll. midges	Other midges	Very tol. snails	Less tol. snails	Other snails	Less tol. assoc. group
Upper lake	Chillicothe	0	No coll.							
	Rome, incl. Goose Pond	3	1,664		20	68	16	32		4
	Spring Bay, incl. S. B. Nar.	2	810	12	156	174	42	822		
Middle lake	Mossville	6	2,152	32	104	104	856	336	4	32
	Maple Point	2	502	12	36	24	72	36		
	Long Shore Beach	3	168		160	560	24	55		
	Towhead	1	96	48						
	Al Fresco	2	228	72	1,140	30	84			
Lower lake	Peoria Narrows	2	804	24	324	60	36	90		126
	U. S. Slips	4	48	18	36	36	24	114		3
	Main St.	1	96		120	24				
	McKinley Bridge	1		36			24	12		
	P. P. U. Bridge	1	144	12		152				648

It is noted both of *Tubifex tubifex* and of the more abundant species of Limnodrilus that, quite contrary to the findings in the river above Chillicothe in 1923, their numbers in upper and middle Peoria Lake ran about as high if not higher in the channel than in either of the outer zones. This is, however, in agreement with such information as we have about velocities, which evidently permit much more sedimentation in the lake channel during flood recessions than can ordinarily take place in average river above the lake.

The sludge worms as a whole showed an irregular decline southward of the upper lake in 1923, both in the channel and in the outer zones, with exception of some upturn in the figures at Peoria Narrows and the U. S. Slips, which are unexplained. Unworked out specific differences might be concerned here. It is at least known that not all species of Limnodrilus, or even Tubifex, for that matter, are equally tolerant of or partial to polluted bottom.

Compared with 1922, both the Tubificidae and the very tolerant sphaeriid snail (*M. transversum*) showed conspicuous decline in numbers in the upper lake in 1923 collections. This was true in all zones in the upper lake and should, it would seem, mean improvement. In the middle lake, however, numbers both of the worms and of the snail showed a tendency to equal or even to exceed the numbers per square yard of bottom area found in 1922. Perhaps effects of seining, and of varying amounts of feeding by bottom-ranging fishes might be concerned in these irregularities. If they are, evidence such as we have on the variety of bottom-dwelling forms present, and their preferences, are of more importance in the definition of degrees of pollution than such numbers are likely to be.

PEORIA LAKE, 1923 COMPARED WITH 1922. AV. NOS. PER SQ. YD.

	Channel	Tubificidae total		Musculium transversum	
		1922	1923	1922	1923
Upper lake	Chillicothe	14,400	925	28,800	444
	Rome, incl. Goose Pond	48,000	15,888	49,200	312
	Spr. Bay, incl. S. B. Nar.	2,880	1,409	5,760	1,621
Middle lake	Mossville	48	8,592	768	1,296
	Maple Point	1,560*	2,208	9,600*	2,112
	Long Shore Beach		192		168
	Towhead		5,880		2,352
	Al Fresco	0	222	1,500	876

* Foot of Horshor Isl.

PEORIA LAKE, 1923 COMPARED WITH 1922. AV. NOS. PER SQ. YD.

Intermediate zone		Tubificidae total		Musculium transversum	
		1922	1923	1922	1923
Upper lake	Chillicothe	27,400	No coll.	63,300	No coll.
	Rome, incl. Goose Pond	31,320	2,664	52,400	8,773
	Spr. Bay, incl. S. B. Nar.	2,484	3,168	12,800	1,536
Middle lake	Mossville	504	3,264	2,700	5,304
	Maple Point	216*	48	1,020*	0
	Long Shore Beach		1,476		366
	Towhead		0		1,512
	Al Fresco	0	144	1,500	72

* Foot of Horshor Isl.

PEORIA LAKE, 1923 COMPARED WITH 1922. AV. NOS. PER SQ. YD.

Outer zone		Tubificidae total		Musculium transversum	
		1922	1923	1922	1923
Upper lake	Chillicothe	No coll.	No coll.	No coll.	No coll.
	Rome, incl. Goose Pond	22,800	1,664	24,100	16
	Spr. Bay, incl. S. B. Nar.	2,006	810	2,600	42
Middle lake	Mossville	408	2,152	420	856
	Maple Point	543*	502	2,080*	72
	Long Shore Beach		168		24
	Towhead		96		0
	Al Fresco	0	228	6	84

* Foot of Horshor Isl.

Numbers of midge larvae (Chironomidae) in Peoria Lake dredgings in 1923 as in 1922 were irregular and not apparently of great significance. Only two species previously associated by us definitely with pollution were taken, and it was a little mystifying to find them most abundant in collections from near the lower end of the middle lake, where snails and some of the other less tolerant groups were taken in variety. Incompleteness of the determinations has also probably included among the Chironomidae, which are in the following tables all listed as at least mildly tolerant, some species which are essentially cleaner water forms. But if that is the case, it does not probably invalidate the comparison of 1923 species lists with those of 1922 for evidence of increase in cleaner-preference species, since most of the 1923 larvae seem to have counterparts in the 1922 (or 1920) collections.

Study of the dates of collection of this group in the summer of 1923 shows that from Mossville north decidedly more Chironomidae occurred in July and August than in June collections; while in the lower half of the middle lake the largest numbers were recorded in June in one cross-section (opposite Long Shore Beach) and in July or August in two others (opposite Towhead and Al Fresco). *Chironomus plumosus* var., a supposed pollutional species, occurred in all three months, and *C. decorus*, another with a similar record, occurred both in June and August.

On the face of things to be taken as evidence of improvement in the muds since 1922 would seem to be the sizable increases shown in the twelve-month period in all three of the sections of Peoria Lake in both the total number of bottom species of all kinds taken and in the number of group II* kinds (i. e., current-loving snails, young mussels, other insects than Chironomidae, and miscellaneous associated species such as sponges, Bryozoans, Planarians, etc.). Combining all collections from all zones, and taking account of these gross figures only, without regard to possible special or localized conditions at points of exact occurrence of group II species, it is found that in the upper lake in 1923 there were 5 group II kinds taken as compared with one in 1922; in the middle lake 7 as compared with none at all; and in the lower lake, including Peoria Narrows and P. P. U. Bridge in 1922 and those two stations and the McKinley Bridge in 1923, 11 kinds as compared to 7. Correspondingly, of the total number of all kinds taken, it is found that it rose in the upper lake from 18 to 24-25 in the year; in the middle lake from 23 to 29-30; and in the lower lake from 21 to 24. Since the total number of collections in all zones combined was very nearly the same in all three lakes in 1922 and 1923 (U. L.: 1922, 23; 1923, 21; M. L.: 1922, 30; 1923, 30; L. L.: 1922, 18; 1923, 24), at least the changes in the totals would not be expected to have been due to changes in thoroughness of collecting. Further favoring improvement, particularly in the extra-channel zones of the upper and middle lakes, where the greatest increase in group II species occurred, would appear to be the fact that the increases in the number of species in those areas in both lakes took place in the face of decreases in the number of collections between 1922

* In text and tabulations that follow, the No. II group is set over against group I, made up of the more or less definitely pollutional or tolerant groups of tubificid worms, leeches, midge larvae, and sphaeriid or other snails which have "stood the racket" in Peoria Lake in the last few years.

and 1923 (U. L.: ex-channel, 1922, 20; 1923, 9; M. L.: ex-channel, 1922, 27; 1923, 20).

Points of exception that must be noted are, however, several, as will be seen from what follows:

First it is noted that the two species of snails of the family Valvatidae (*V. bicarinata* and *V. tricarinata*) which made up the sole representation of group II as above defined in the extra-channel zones of the upper lake proper in 1923 both came from very close to the west shore at Rome, and so can not be regarded as standing for any very appreciable part of the extensive upper lake wide-waters. A single occurrence of an unidentified caddis larva was also noted in the haul from the middle of the "Goose Pond", the shallow backwater to the northeast of the upper end of the upper lake which is rather better protected from sewage invasion than the open portions of the main lake. Again, in the upper lake channel in 1923 the only two group II species taken were species of Bryozoa (*Plumatella princeps,* two varieties) which attach themselves to dead shells, and do not live in the mud as do typical bottom species; and both of these have previously been found in the Illinois River to exhibit a considerable degree of tolerance to pollution if there is some current present. One of them was taken in Spring Bay Narrows only, and the other at Chillicothe*, at both of which places there is much more current than in the lake proper.

Analysis of the group II records from the middle lake shows, first of the intermediate zone (stations within first 1500 feet of the mid-channel line), that all occurrences were restricted to the lower third of the lake, and to the west† side of the channel; and that four out of the total of seven group II species were taken between Long Shore Beach and Al Fresco Park within 50 feet of the west shore. Of the three group II species taken in the outer zone of the middle lake one was taken close to the west shore opposite Mossville; one 600 feet from the west shore opposite the same station; while the third record (of *Plumatella princeps,* var. *fruticosa,* a current-loving form), from 1900 feet east of the mid-channel line opposite Al Fresco Park, is most probably based on an error—i. e., mixing of material either in the field, the field laboratory, or at Urbana. The amount found in the bottle was only a trace and could easily have been stuck in the sieve at a neighboring channel station and released at the other without having been noticed. Last, the sole representative of group II from the middle lake channel (*Valvata bicarinata* var. *normalis*) was taken in the middle of the channel in 20 feet of water in the same southwest corner of the lake that housed the great majority of the ex-channel representatives of the same group.

The principal increases in number of group II species in lower lake cross-sections over 1922 were not in the extra-channel zones, as in the

* Included as an upper lake station for better comparison with 1922 records, when Chillicothe was last station north in series.

† Stations on this side are for the most part closer to the sandy (west) bluff, and are better washed at times of flood than the formerly largely brushy lake areas to the eastward of the steamboat channel.

upper and middle lakes, but in the channel itself, where both the fastest and the average current are considerably greater than anything to be met with in either the upper or middle lake, if Spring Bay Narrows and possibly also a short stretch of channel below Al Fresco Park be excepted. Also, when the lower lake collections of 1923 are separated into hauls from the open lake, or lake proper (U. S. Slips and Main Street cross-sections), and hauls from Peoria Narrows, McKinley Bridge, and P. P. U. Bridge—included with lower lake averages, for better comparison with 1922 in some of the tables following—it is found that there were 12 species of the II group in the swifter water hauls to only one in the hauls made in the wide portion of the lake. This is quite in line with the finding of 1922 that about the only cleaner-preference forms that have survived in or re-entered these waters since the mortality of the years shortly preceding 1920, are current-loving forms—as Pleuroceridae among snails; caddis species of the family Hydropsychidae; and a few sponges and Bryozoa. The comparatively small representation both of group I and group II species in the extra-channel zones of the lower lake proper suggests, also, as did the data of 1922, that there continues here some bad effect of wind-blown local pollution.

PEORIA LAKE, 1922–1923
INCREASE OR DECREASE IN NUMBER OF COLLECTIONS

	All zones combined		Channel		Ex-channel	
	1922	1923	1922	1923	1922	1923
Upper lake Incl. Chillicothe, Goose Pond, Spr. B. Nar.	23	21	3	12	20	9
Middle lake	30	30	3	10	27	20
Lower lake Incl. Peoria Nar. McKinley Br. P. P. U. Br.	18	24	4	14	14	10

Another method of testing the extent of change since 1922 in Peoria Lake is to count the number of collections out of the total number taken in which the less tolerant Sphaeriidae (species of Musculium other than *M. transversum;* species of Pisidium; and species of Sphaerium) occurred in 1923 and the preceding year. While these little snails are known to be more tolerant than the species we have referred to Group II, they are also clearly less tolerant than the Tubificidae, than *Musculium transversum*, or than most if not all of the Chironomidae and leeches recently taken, and would be expected to spread over a greater area with any rapid improvement in the sanitary condition of the bottom muds. Tabulation shows, however, for the four commoner species in the upper lake and for six in the middle lake almost identical percentages of occurrence in both years.

	1923		1922	
	No. colls. in which taken	Total colls.	No. colls. in which taken	Total colls.
Upper lake				
All zones combined				
Musculium truncatum	6	21	7	23
Pisidium compressum	4	21	6	23
Pisidium complanatum	2	21	2	23
Pisidium pauperculum var. crystalense	3	21	2	23
Middle lake				
All zones combined				
Musculium truncatum	6	30	1	30
Pisidium compressum	18	30	16	30
Pisidium complanatum	2	30	2	30
Pisidium pauperculum crystalense	4	30	3	30
Sphaerium stamineum	6	30	5	30
Sphaerium striatinum	4	30	3	30

It is necessary finally to add to the negative side of the account in Peoria Lake the still-continuing failure to reappear, anywhere, of several of the most characteristic and, because of their large size as well as their abundance in several instances, the most conspicuous members of the old but now all but completely defunct gastropod snail fauna. Particular mention should be made of *Vivipara contectoides*, *V. subpurpurea*, *Lioplax subcarinatus*, and two or more species of Amnicolidae. Fuller lists of the species which have disappeared from Peoria Lake completely since some time before 1920 are presented in pages following. It is largely on the basis of the failure of these snails to reappear in recent years that it has been possible to distinguish the present and recent sphaeriid snail fauna of the lake and upper river as belonging to a distinctly more tolerant grouping than any except possibly one *(Campeloma subsolidum)* of the Illinois River Gastropoda.

Illinois River below Peoria, P. P. U. Bridge—Beardstown, 71.5 Miles

Some improvement is indicated as we proceed down the river from Peoria, it appears, both by the lessening variety and abundance of the tubificid worms and the more pollutional midge larvae; tables, pp 407-408. The large decreases in the total of group I—pollutional and more or less tolerant species—from 34-35 kinds in Peoria Lake to just over a dozen kinds in the two reaches of river recognized above and below Havana, do not, however, mean at all what a first glance at the figures might indicate. The far greater portion of the decrease in the number of group I species is in fact due to the dropping out below Peoria Lake of most of the less tolerant sphaeriid snails and Chironomidae; a matter without doubt due largely to the lesser suitability of the generally harder mud or sand and shell bottom of the river in these sections (if we except the first 8 miles above Hanava) than to any other cause; the species of Pisidium and Sphaerium, in particular, which have persisted through the recent pollution in Peoria Lake, never having been found either in variety or numbers in the river between Peoria and Beardstown in the past fourteen years of collecting.

So far as the group II or cleaner-preference species are concerned, again, instead of increasing down stream below Peoria as the group I kinds decrease, as we would expect if the latter indicated improvement, they also fall off rapidly in variety as we proceed south, though, it is to be noted, along with a rather marked decrease also in the number of collections; table, p. 406. The greatest variety of group II kinds in the three reaches recognized below Peoria Lake was taken in the somewhat more than 20 miles between Wesley and the Copperas Creek Dam, where 18 group II species were taken in 1923 in 27 collections, comparing with 20 in Peoria Lake from 75 collections the same season. Here there is for the most part good current, and principally harder bottom than in Peoria Lake, both of which indicate reduced sedimentation, which seems to protect a good many current-loving organisms, such as Planaria, Bryozoa of several kinds, the larvae of certain Trichoptera (caddis-flies), and others, which might otherwise succumb in the face of the new load of Peoria and Pekin pollution. Between the mouth of the Spring Lake Canal, shortly below Copperas Creek Dam, and Havana, the number of cleaner-preference species taken dropped to only twelve kinds in the total of nine collections taken; a number perhaps not unduly small, in view both of the condition of the mud and the small number of collections; though it is recalled that this was by all odds the richest section along the whole Illinois River some ten years ago, at which time it yielded nearly seventy kinds of small bottom animals, practically all of common occurrence at some stations in the range, which have since then disappeared from collections altogether: pp. 413 and 419. Here, in the first eight miles above the Spoon River bar, at Havana, sedimentation is especially active at times of flood recession, finally depositing on the bottom a goodly portion of the load of more or less putrescible suspended solids that mostly passed over the heads of the bottom animals in the reaches between Liverpool and Peoria. Below Havana, in the thirty odd miles to Beardstown, in the summer of 1923 only six group II species were found in a total of thirteen bottom hauls taken. This section of the Illinois, was, however, rather noticeably poor in bottom species at most of the stations worked in the seasons of collecting between 1913 and 1915; though even our lists from it show a total of fully two dozen kinds of small bottom animals that have failed altogether to appear in collections made since and including 1920.

DECREASE OF BOTH GROUP I AND GROUP II* SPECIES FROM PEORIA LAKE SOUTHWARD, 1923

	Group I species—with subdivision							Group I	Group II
	Tubificid worms	Leeches	Pollutional midge larvae	Other midge larvae	Very tolerant snails†	Less tolerant snails	Number colls, all zones combined	Total species	Total species
Chillicothe to ft. of Peoria L., incl. 20 mi. to P. P. U. Br.	5	4–5	2	13–14	1	9	75	34–35	20
Wesley to Copperas Cr. Dam, below 23.7 mi. P. P. U. Br. to Cop. Cr. Dam, incl.	5	2–3	2	12–13	1	1	27	23–25	18
Spring L. Canal to Havana, incl. 16.8 mi. Cop. Cr. Dam to Havana	2	4	0	5–6	1	0	19	12–13	12
Matanzas to Beardstown 31 mi. Havana to Beardstown, incl.	4	3	0	3–4	1	0	13	11–12	6

* Cleaner preference group.
† *Musculium transversum.*

TOTAL TUBIFICIDAE AND T. TUBIFEX TAKEN ABOVE PEORIA, 1923*
AVERAGE NOS. PER SQ. YD.

	Total Tubificidae			Tubifex tubifex		
	Channel	Intermediate zone	Outer zone	Channel	Intermediate zone	Outer zone
La Salle	960					
Spring Valley	312	——	576	24		
Mth. Hennepin Canal	498	——	——	24		
Hennepin	1,336					
Henry above Dam	15,120	17,088	——	——	840	
Henry below Dam	1,260	——	238,080	24	——	29,184
Lacon	961	4,684	12,478	25	——	288
3-4 mi. abv. Chillicothe	——	——	41,856	——	——	4,608
3-4 mi. in slough	——	——	1,392			
A. T. S. F. Bridge	1,926	2,280	32,640	666	12	1,152
E. channel opp. Chillicothe	——	——	1,680			
Chillicothe	925	No coll.	No coll.			
Rome (incl. Goose Pond)	15,848	2,664	1,664	128	88	48
Spring Bay (incl. Nar.)	1,409	3,168	810	42	24	12
Mossville	8,592	3,264	2,152	840	96	4
Maple Point	2,208	48	502	——	24	24
Long Shore Beach	192	1,476	168	——	24	
Towhead	5,580	——	96	144		
Al Fresco	222	144	228			
Peoria Narrows	168	2,160	804	——	——	6
U. S. Slips	1,552	No coll.	48			
Main Street	560	No coll.	96			
McKinley Bridge	3	No coll.				
P. P. U. Bridge	No coll.	No coll.	144			

* For comparison with table next following.

TOTAL TUBIFICIDAE AND T. TUBIFEX TAKEN BELOW PEORIA, 1923*
AVERAGE NOS. PER SQ. YD.

	Total Tubificidae			Tubifex tubifex		
	Channel	Intermediate zone	Outer zone	Channel	Intermediate zone	Outer zone
Wesley	192	———	940			
7 mi. Island	———	524	1,458	———	———	12
2 mi. above Pekin in dredge ditch	240	———	———	12		
Pekin	30	———	2,196	———	———	36
Old mouth Mackinaw	432					
Mackinaw	———	———	48			
Kingston Ferry	288	1,224	4,392	48		
Lancaster	96					
Cop. Cr. abv. Dam	———					
Cop. Cr. below Dam	48	———	———	12		
Spring L. Canal inside mouth	112					
Liverpool	1,008					
Quiver Beach	———	12	———			
Havana	144	———	———			
Matanzas	120	72	———			
Foot Grand Isl.	———	———	640			
Hd. Hickory Isl.	108	———	7,056	———	———	48
Mouth Sangamon	———	———	———			
Beardstown	1,688	———	———			

* To show decrease down stream from Peoria. Compare with preceding table.

When we compare with the bottom collections made in 1920—the last preceding date when we made hauls in the Illinois River below Peoria Lake—it is found that there were in all twenty group II or cleaner-preference species taken in 1923 in forty-nine collections in the seventy odd miles of river between Wesley and Beardstown, to only thirteen in thirty-six collections in a somewhat reduced distance within the same section in the summer three years preceding. Sharp increase over 1920 is noted, on the other hand, in the limited reach of around nineteen miles between the Spring Lake Canal and Havana, where in 1923 twelve cleaner-preference forms were taken in nine dredge hauls compared with only two in fourteen hauls in 1920, a finding that would seem at least on its face to indicate some improvement in the condition of the muds in the three years. The number of group II species taken below Havana was, however, only half as many in 1923 as in 1920, in a mileage considerably greater, though with the number of collections less, running to a total of only six species in thirteen collections covering thirty miles of river length in 1923, compared with twelve kinds in twenty-two collections from about 19 miles of river in the summer three years before. As already mentioned, the section of more or less shifting sand or sand and shell to hard bottom between Havana and Beardstown was known before the recent mortality for the sparseness and irregularity of distribution of its small bottom population; and because of this and the factors favorable to error that lie back of it, less importance is probably to be attached to such variations in numbers than in sections where the bottom-dwelling organisms—chiefly mud bottom forms in the Illinois River—have a more suitable and more stable substratum on which to live. A better test of the changes that have taken place in recent years in this and other sections of the Illinois River, inclusive of Peoria Lake, because it concerns both larger numbers and greater and therefore more convincing contrasts, consists in going farther back, to the period 1913-1915, comparing our recent species lists with those of that time, and noting the absentee names of the old fauna, side by side with recent survivals and new entrants.

CHANGES IN NUMBER OF GROUP II (CLEANER PREFERENCE) SPECIES BETWEEN 1920 AND 1923

ALL ZONES COMBINED

	1923		1920	
		Number colls.		Number colls.
Chillicothe—P. P. U. Bridge, incl.	20	75	7*	35
Wesley—Beardstown, incl.	20	49	13	36
Wesley—Copperas Creek Dam, below, incl.	18	27	——	None
Spring Lake Canal—Havana, incl.	12	9	2†	14
Matanzas—Beardstown, incl.	6	13	12‡	22

* All from lower lake.
† Liverpool to Havana.
‡ Matanzas to head of Hickory Lake.

The Missing Small Bottom Animals of the 1913-1915 Species Lists, apparently Exterminated some Time between 1915 and 1920. Head of Peoria Lake to Beardstown

To any one familiar with the biology of the Illinois River between 1910 and 1923 a more striking change in the period than even the intrusion of pollutional forms and their increase has been the complete disappearance in the nearly ninety miles between the head of Peoria Lake and Beardstown of a long list of the more sensitive snails and associated bottom animals in the less than ten year period between 1910 and 1920. In making comparisons of the more recent species lists with those of 1913-1915, allowance needs to be made for some inequalities in number and distribution of collections, as well as in completeness of determination of material, in the two periods. The total number of dredge hauls made between Chillicothe and Beardstown in the seasons 1913-1915 was 210, distributed quite evenly, as will be seen in table, p. 413, between the four short reaches distinguished in this distance. In the three years of collecting between 1920 and 1923 there were taken in all 266 collections in substantially the same areas and linear distance, but with much greater emphasis on the area embraced under the head of Peoria Lake, which, inclusive of Chillicothe and the P. P. U. Bridge, amounts to an even twenty miles; and where 181 of the total number of 266 hauls were made. In the three short reaches recognized below Peoria collections ran only 27, 23, and 35, compared with 50, 55, and 59 in the same sections in the period 1913-1915. In both periods there was an essentially similar distribution of collections as between channel and shore, or shallower water zones; with the difference, itself apparently attributable to the same influence that destroyed the bottom organisms, that more vegetation was encountered at the shallower stations in the earlier than in the more recent collecting. In making the comparisons many of the more distinctly weed-forms have been thrown out entirely, though some species of both periods that live a part of the time in the bottom and a part on vegetation are necessarily included. To equalize matters further, some of the 1913-1915 material that had been earlier rather incompletely determined for a mass-valuation calculation, was gone over again in 1923 for additional species, at the expense of several weeks' time.

The results of the comparisons are shown in the table on page 413, following. Briefly, the figures show around a dozen kinds of formerly common cleaner-preference species of small bottom animals that have disappeared from Peoria Lake in ten years; a similar number for the twenty odd miles between Peoria and the Copperas Creek Dam; nearly seventy kinds that have recently failed to appear in the first ten to nineteen miles above Havana; and twenty-four or more kinds that are missing in the more than thirty miles between Havana and Beardstown. These numbers include no fresh-water mussels except a very few scattering occurrences of very young or dwarf individuals, taken with the mud dipper, small Blake dredge, or Petersen dredge; and would be very much larger, particularly in Peoria Lake, had it been possible recently to cover the area thoroughly with a commercial mussel bar, for comparison with Danglade's 1911-1912* lists of mussels from the Illinois River.

Despite the inequalities and deficiencies mentioned, the results of the comparisons seem for the most part understandable, as they are consistent with each other and with otherwise ascertained facts of the biology and hydrography. First, with regard to the relatively enormous losses of cleaner-preference species in the formerly exceedingly rich reach of river just above Havana: Here is where the bottom fauna formerly had both its greatest variety and its greatest abundance; favored both by the slacker current above the Havana or Spoon River bar and the rich soft mud bottom resulting therefrom. Here also because of the same factor of more abundant sedimentation was where the more sensitive bottom organisms might be expected to be put in the greatest jeopardy as the stability of the suspended matters carried this far down the river became lessened.

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* Report, U. S. Bureau of Fisheries, 1913.

The notably small size of the list of missing species of the old 1913-1915 fauna of Peoria Lake, on the other hand, particularly when it is considered that the number of collections taken in the earlier period, 46 in all, was more than four-fifths as many as supplied the abundantly varied species lists from the reach Liverpool-Havana, seems at first practically unexplainable unless we assume that Peoria Lake had already been injured by the sewage of Chicago and up-river towns still earlier than that time. Conspicuous among the missing forms in Peoria Lake collections in 1913-1915 were various aquatic insects, particularly those belonging to groups other than the Diptera: as Odonata, Hemiptera, Neuroptera, and Coleoptera. Though the shallower areas at that time were abundantly supplied with aquatic plants it was noticed that results even of "weed tank" collecting were extremely poor, also, as compared with results obtained in the same way in the shallow lakes at Havana. But though aquatic insects other than Chironomidae were rare, the relatively sensitive Viviparidae and Amnicolidae, that have since disappeared as far south as Beardstown, were still holding on, though not in nearly as great numbers as near Havana. And as late as 1912-1914 Danglade in work for the U. S. Fisheries Bureau found more than forty kinds of mussels between Chillicothe and Peoria Lake, of which twenty kinds were counted in the piles picked over at Chillicothe. Evidently, if there was any injury previously to 1913-1915 it must have been principally in the wide waters—the mussels are for the most part of the channel or near it—and would point to certain groups of aquatic insects as even more sensitive than the recently exterminated Gastropoda.

Of the "missing" lists from the reaches distinguished below Peoria Lake it may be noted that the first one, that between Wesley and the Copperas Creek Dam, was very probably quite as early as 1913-1915 influenced somewhat unfavorably by the heavy load of Peoria and Pekin wastes; as well as by the limiting influences on the variety of small bottom animals of the swifter current and harder bottom. In the latter respect the section of river between Havana and Beardstown was similar, to a large though not to quite so great an extent, perhaps, if the slack water pool above the mouth of the Sangamon be taken into account. That, and the greater distance from the Peoria and Pekin drains, favored a somewhat greater variety of cleaner-preference forms ten years ago than we could have expected between Peoria and the Copperas Creek Dam; though far from that which seemed to develop so easily in the lake-like section of ten or so miles just above Havana.

NUMBER OF SPECIES* OF SMALL BOTTOM ANIMALS IN 1923 COLLECTIONS COMPARED WITH NUMBER MISSING IN SAME COLLECTIONS ON BASIS OF 1913–1915 RECORDS . ALL ZONES COMBINED

	1923			1913–1915	
	Group I spp.†	Group II spp.‡	Total colls.	Group III spp.¶	Total colls.
Chillicothe to P. P. U. Br., incl.	34–35	20	75	12	46
Wesley to Cop. Creek Dam (below), incl.	23–25	18	27	13	50
Spring Lake Canal to Havana, incl.	12–13	12	9	68–69	55
Matanzas to Beardstown, incl.	11–12	6	13	24–25	59

* Includes no mussels except a very few young individuals or dwarf species such as are occasionally taken with small apparatus.

† Pollutional or tolerant. ‡ Cleaner preference spp. ¶ Now missing.

TOTAL NUMBERS OF GROUP II, OR CLEANER-PREFERENCE SPECIES, COMPARED WITH TOTAL NUMBER OF COLLECTIONS, 1920–1923

	Species of			Species of
	1920	1922	1923	1920–1923, incl.* No duplication
Chillicothe to P. P. U. Br. incl.	7† 35	8 71	20 75	23 181
Wesley to Copperas Cr. Dam (below) incl.	——‡	——	18 27	18 27
Spring L. Canal to Havana, incl.	2 14	——	12 9	13 23
Matanzas to Beardstown, incl.	12 22	——	6 13	13 35

* Purpose of this table to show that adding in the 1920 and 1921 collections adds very little—except in the Matanzas-Beardstown section—to the total number of Group II species taken in 1923.

† The upper line of figures against an entry gives the number of species; the lower one, the number of collections.

‡ A dash indicates no collection.

Small Bottom Invertebrates* of Illinois River and Peoria Lake, La Salle to Beardstown, 1923

GROUP I

POLLUTIONAL OR MORE OR LESS TOLERANT SPECIES†

1. Small Annelid Worms. (Tubificidae)
   - *Limnodrilus* species like *L. hoffmeisteri* Claparède
   - *Limnodrilus* species like *L. claparedeianus* Ratzel
   - *Limnodrilus* species
   - *Tubifex tubifex* Müller, or var.
   - *Tubifex* species, apparently undescribed.
   - *Dero* species, one occurrence, outer zone, Peoria Narrows.
   - Other Oligochaeta, unidentified, in bad state of preservation, or immature, several thousand specimens.

* No mussels included except very young individuals or dwarf species, taken with 1/12 sq. yd. Petersen sampler.

† See definitions of terms in introduction.

2. Leeches (Hirudinea).

At least four or five species, including apparently, *Erpobdella punctata* (Leidy), and two species of Helobdella; taken in all zones of the river and lake, from Lacon southward, 1923. The species of Erpobdella mentioned was definitely associated with pollution in Weston and Turner's studies of the Coweeset River in 1914.

3. Midge Larvae of pollutional habit. (Chironomidae)
   - *Chironomus plumosus* Linnaeus, var.
   - *Chironomus decorus* Johannsen
   - *Chironomus lobiferus* Say
   - Several undetermined Chironominae and Tanypinae, like the three species of Chironomus preceding, with range from Chillicothe or head of upper Peoria Lake, south.

4. Other Chironomidae, with distribution for most part from middle or lower Peoria Lake southward.
   - *Chironomus digitatus* Malloch
   - *Cricotopus* species
   - *Orthocladius*
   - *Palpomyia* spp., probably two.
   - *Forcipomyia* species
   - *Procladius* species
   - *Tanypus* species
   - Unidentified Chironominae and Tanypinae, several species.

It is quite possible that some of these imperfectly determined forms are in reality species with distinct preference for clean bottom; but occurrence in Peoria Lake, even in the outer zones, in its recent condition, may be taken to indicate rather more than the degree of tolerance shown by the more sensitive species of that description.

5. Sphaeriid Snail of especially tolerant habit.

Musculium transversum Say. This species was found associated with sludge worms of the genera Limnodrilus and Tubifex, where there was almost complete oxygen exhaustion one foot from bottom, both in 1920 and 1922.

6. Sphaeriid Snails of less tolerant* habit.
   - *Musculium truncatum* Linsley
   - *Pisidium compressum* Prime
   - *Pisidium complanatum* Sterki
   - *Pisidium pauperculum* var. *crystalense* Sterki
   - *Pisidium* species
   - *Sphaerium stamineum* Conrad
   - *Sphaerium striatinum* Lamarck
   - *Sphaerium striatinum* var. *lilycashense* Baker
   - *Sphaerium* species

* The distribution of this subdivision of group I, and reasons for their distinction in degree of tolerance from other Illinois River snails, is discussed in detail in the 1922 paper on Peoria Lake.

7. Viviparid Snail of unusual tolerance.

Campeloma subsolidum Anthony. This species was taken in upper Peoria Lake in 1922; and in the river as far north as Starved Rock in 1912, which was at that time slightly above the lower limit of the Sphaerotilus zone.

GROUP II

CLEANER PREFERENCE SPECIES; BUT SEE QUALIFICATIONS BELOW

Though these species are clearly to be grouped as cleaner-preference forms by comparison with those included in Group I preceding, as compared with the assemblage of species wholly exterminated in Peoria Lake and the Illinois River to a point below Havana shortly before 1920 even they may be judged to possess a measurable, if rather slight, degree of tolerance. They are for the most part, both in Peoria Lake and elsewhere, however, confined either to locations very near shore; to the swifter water sections, as the narrows of the lake, or shortly below dams; or to the southwest corner of middle Peoria Lake, just above Peoria Narrows (see p. 17, and foot-note thereto).

1. Mussels (Unionidae)
   - *Lampsilis parvus* Barnes. S. W. portion of middle lake and Peoria Narrows.
   - *Lampsilis gracilis* Barnes, young. Wesley, shore-zone in good current.
   - *Lampsilis* species, young. Wesley and Seven Mile Island, in current.
   - *Plagiola donaciformis* Lea. Quiver Beach, more probably from the lake than the river hauls. Label does not distinguish.

2. Snails. (Valvatidae and Pleuroceridae)
   - *Valvata bicarinata* Lea. W. beach, Rome.
   - *Valvata tricarinata* (Say). W. beach, Rome; also taken in same location summer 1922.
   - *Valvata bicarinata* var. *normalis* Walker. Shore zone, Mossville; channe, Al Fresco Parkl
   - *Goniobasis livescens* Menke. Channel, Peoria Narrows and McKinley Bridge, in strong current.
   - *Pleurocera elevatum* var. *lewisii*. Channel, Peoria Narrows, McKinley Bridge, and Pekin, in strong current.

3. Sponges (Porifera)
   - One or more species taken. Channel at Peoria Nerrows and Pekin, in strong current.

4. Fresh-water Hydroids. (Hydrozoa)
   - *Cordylophora lacustris* Allman. Kingston Ferry near shore.

5. Planarian Worms. (Turbellaria)

Several unidentified species. Common in the channel from Spring Bay south; and in outer zones from P. P. U. Bridge south.

6. Crustaceans. (Amphipoda and Isopoda)

Hyalella knickerbockeri Bate. Channel from Peoria Narrows south; outer zone, as far north, once, as below dam at Henry.

Asellus intermedius Forbes. Channel, Kingston Ferry.

7. *Moss Animals. (Bryozoa)

Plumatella princeps Kraepelin, var. *fruticosa*. From Chillicothe south, in the channel; was noted to be especially tolerant, also, in the upper river in 1911-1912, at that time occurring as far north as Starved Rock, but incorrectly named. A recorded occurrence in 1923 in the outer zone opposite Al Fresco Park is probably an error, as the organism requires good current unless conditions are otherwise excellent.

Plumatella princeps Kraepelin, var. *mucosa-spongiosa*. Channel, Peoria Narrows south.

Plumatella polymorpha Kraepelin, var. *repens*. Channel, Wesley south, in current.

Paludicella ehrenbergii van Benden. Channel, McKinley Bridge south, in good current; outer zone, Seven Mile Island and Kingston and south.

Urnatella gracilis Leidy. Channel at McKinley Bridge and Pekin, in strong current.

8. Caddis-fly Larvae. (Trichoptera)

Hydropsyche species. Channel, Peoria Narrows south, in current; outer zone at foot of Grand Island.

Polycentropus species. Channel, Copperas Creek below dam and south, in current.

Molanna species. Near shore, Quiver Beach. Probably a lake collection, as this is a sand beach form.

Unidentified species. Unknown current-loving form at McKinley Bridge in channel, and south; one or two stagnant-water species, with basket-shaped cases, in outer zones from Rome south.

9. May-fly Nymphs (Ephemerida)

Hexagenia bilineata Say. Channel at Havana and at head of Hickory Island; near shore, once at Pekin and once each at foot of Grand Island and head of Hickory Island.

* I think a better common name would be soft-walled or fresh-water coral; as the group was originally included with the marine corals by Ehrenberg about a hundred years ago.

10. Dragon-fly Nymphs (Odonata)

    Ischnura species. Channel, McKinley Bridge, in strong current.
    Gomphus plagiatus Selys. Channel at Liverpool.
    Gomphus species. Near shore at Kingston Ferry.

11. Orl-fly Larvae (Neuroptera)

    Sialis infumata Newman. Near shore, S. W. end lower Peoria Lake.

Pre-1920 Bottom Species* Recently Missing from Illinois River and Peoria Lake Dredge Hauls

From Species Lists of 1913–1915, referred to as Group III in preceding Tables

1. *Illinois River and Peoria Lake, Chillicothe to P. P. U. Bridge, inclusive. Twelve species; 46 collections; all zones combined.*

    Mollusca
    - Viviparidae
        - *Vivipara contectoides* W. G. Binney
        - *Vivipara subpurpurea* Say
        - *Lioplax subcarinatus* (Say)
    - Amnicolidae
        - *Amnicola emarginata* Küster
        - *Amnicola limosa* (Say)
        - *Somatogyrus subglobosus* (Say)
    - Ancylidae
        - *Ancylus* species

    Insects
    - Ephemerida
        - *Hexagenia bilineata* Say
        - *Callibaetis* species
        - *Caenis* species
    - Diptera
        - *Chironomus tentans* Fabricius
        - *Chironomus nigricans* Johannsen

2. *Illinois River, Pekin to Copperas Creek Dam, inclusive. Thirteen species; 50 collections; all zones combined.*

    Mollusca
    - Unionidae
        - *Anodonta imbecillis* Say

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* No mussels included except very young individuals or dwarf species; i. e., those taken with mud dipper or small iron dredge.

Viviparidae
Vivipara contectoides W. G. Binney
Vivipara subpurpurea Say
Lioplax subcarinatus (Say)
Campeloma subsolidum Anthony
Pleuroceridae
Goniobasis livescens Menke
Ancylidae
Ancylus species
Amnicolidae
Amnicola emarginata Küster
Amnicola lustrica Pilsbry
Valvatidae
Valvata tricarinata (Say)
Planorbidae
Planorbis parvus Say
Porifera
Unidentified fresh-water sponges, at least one species.
Crustacea
Isopoda
Asellus intermedius Forbes

3. *Illinois River, Liverpool to Havana inclusive. Sixty-nine species; 55 collections; all zones combined.*

Mollusca
Unionidae
Anodonta corpulenta Cooper. Young
Anodonta imbecillis Say
Lampsilis luteolus (Lamarck). Young
Lampsilis fallaciosus Simpson, Young
Lampsilis parvus Barnes
Plagiola donaciformis Lea
Sphaeriidae
Sphaerium stamineum Conrad
Sphaerium striatinum Lamarck
Sphaerium simile Say
Viviparidae
Vivipara contectoides W. G. Binney
Vivipara subpurpurea Say
Campeloma decisum Say
Lioplax subcarinatus (Say)
Pleuroceridae
Goniobasis livescens Menke
Pleurocera elevatum, var. *lewisii* Lea
Amnicolidae
Somatogyrus subglobosus (Say)

Amnicola cincinnatiensis (Anthony)
Amnicola limosa (Say)
Amnicola lustrica Pilsbry
Valvatidae
Valvata tricarinata Lea
Valvata bicarinata (Say)
Physidae
Apparently at least two species
Planorbidae
Planorbis parvus Say
Planorbis trivolvis Say
Planorbis exacutus Say
Lymnaeidae
Lymnaea humilis Say
Lymnaea palustris (Müller)
Ancylidae
Ancylus species
Porifera
Unidentified fresh-water sponges, at least 3 kinds
Hirudinea
Apparently at least 3 species of leeches not recently taken.
Crustacea
Palaemonidae
Palaemonetes exilipes Stimpson
Insects
Ephemerida
Callibaetis species
Caenis species
Hexagenia bilineata Say
Heptagenia species
Odonata
Calopteryx species
Unidentified Agrionidae, at least two species.
Mesothemis simplicicollis Say
Epicordulia princeps Hagen
Hemiptera
Corixa burmeisteri Fieber
Corixa species
Notonecta species
Zaitha fluminea (Say)
Neuroptera
Sialis infumata Newman
Corydalis species
Trichoptera
Rhyacophila species

Polycentropus species
Coleoptera
Berosus species
Tropisternus species
Peltodytes species
Stenelmis species
Unidentified parnid, etc., at least two species.
Diptera
Chironomus tentans Fabricius
Chironomus viridicollis v. d. Wulp
Chironomus ferrugineovittatus Zetterstedt
Chironomus modestus Say
Cricotopus trifasciatus Panzer
Corethra punctipennis Say
Sepedon species
Odontomyia species
Unidentified tabanid
Psychoda species

4. *Illinois River, Matanzas to Beardstown, inclusive. Twenty-five species; 59 collections; all zones combined*

Mollusca
Unionidae
Strophitus edentulus (Say). Young
Plagiola elegans Lea. Young
Anodonta imbecillis Say
Viviparidae
Vivipara contectoides W. G. Binney
Vivipara subpurpurea Say
Lioplax subcarinatus Say
Pleuroceridae
Pleurocera elevatum, var. *lewisii* Lea
Goniobasis livescens Menke
Amnicolidae
Amnicola emarginata Küster
Somatogyrus subglobosus (Say)
Physidae
Apparently at least two species.
Ancylidae
Ancylus species
Hirudinea
At least two species of leeches not recently taken.
Insects
Ephemerida
Hexagenia bilineata Say

Heptagenia species
Coleoptera
Stenelmis species
Diptera
Tanypus monilis Linnaeus
Palpomyia longipennis Loew
Chironomus dux Johannsen
Chironomus ferrugineovittatus Zetterstedt
Chironomus tentans Fabricius
Cricotopus trifaciatus Panzer
Procladius concinnus Coquillett

STATE OF ILLINOIS
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NATURAL HISTORY SURVEY
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Vol. XV. BULLETIN Article VII.

Some Observations on the Oxygen Requirements of Fishes in the Illinois River

BY

DAVID H. THOMPSON

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A. M. Shelton, *Director*

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Article VII.—*Some Observations on the Oxygen Requirements of Fishes in the Illinois River.* By David H. Thompson.

Introduction

The amount of oxygen dissolved in the water is one of the most important factors limiting the fish life of the Illinois River. Every year low dissolved oxygen concentrations over a large portion of the river profoundly affect the food, distribution, and even the existence of the fishes. In the conservation of the Illinois River fishery it becomes necessary to evaluate the oxygen requirements of the more common fishes. The Illinois Natural History Survey and the State Water Survey have for many years conducted a biological and chemical survey of the Illinois River. As a result, the general oxygen conditions are rather completely known for the various parts of the river during the different seasons of the year, and the distribution of fishes is well enough understood to show the general relation to the range of oxygen concentrations. The present paper is the result of an attempt to determine more precisely the minimal oxygen requirements of the common fishes and some of the effects of low dissolved oxygen concentrations, especially in winter.

Dr. R. E. Greenfield and Mr. A. L. Sotier, of the State Water Survey, made a series of dissolved oxygen determinations on the river during the latter part of January, 1925. They reported that the fishes were crowding into the "spring holes" in Peoria Lake, evidently on account of unsuitable conditions in parts of the lake which were frozen over. The writer, accompanied part of the time by Mr. Sotier, spent the latter part of January and all of February gathering data on the fish life of the river and making dissolved oxygen determinations in places where fishes were being taken, where fishes were dying, and where fishes usually had been taken but were absent at the time on account of special conditions of the water. Much credit is due a number of fishermen for collateral information and for their co-operation in the field work.

Some valuable determinations of dissolved oxygen in the channel were made by the State Water Survey on January 23 and 24 and on February 6 and 7, 1925, which are published here for the first time.

The General Relation of Ice and Dissolved Oxygen

It is a common observation that fish often die in the winter under the ice. This has been noticed most often where the ice has completely covered the water for a considerable period. It is also commonly said by fishermen, in certain places, that when a hole is cut in the ice the fish will come to the place "to get air" and are very easily taken. It seems quite clear that the reason fish die under ice or come to holes in the ice is because there is a deficiency of dissolved oxygen in the water.

A layer of ice over a body of water very effectually prevents the interchange of gases between the water and the air. The ice itself does not decrease the amount of oxygen, but it stops the aeration of the water. The decrease in amount of dissolved oxygen is brought about by the oxidation of organic matter in the water. This organic matter does not oxidize directly, but it forms the food of the bacteria and of larger plankton—the immense numbers of minute plants and animals which utilize the oxygen in their life processes. As a result, the amount of dissolved oxygen that is removed from the water depends on the amount of organic matter present and on the rate at which this is consumed by aquatic organisms.

The life processes of these plants and animals which consume the oxygen go on very slowly in water that is cold enough to be covered with ice. It would seem that for this reason those lakes and very sluggish streams which are frozen over early and thaw out late would suffer most from the lack of oxygen. However, due to their sluggishness the solid organic matter settles to the bottom and can not quickly reduce the dissolved oxygen content of the whole body of water. In the deeper lakes fish do not die under the ice, probably because of the relative scantiness of organic matter and the greater amount of dissolved oxygen in the deeper water. In most streams large amounts of organic matter are constantly being added by drainage from the land and by wastes from cities. The stirring action of the current is usually sufficient to keep much of the solid organic matter in suspension and thus it exposes all parts of the stream to loss of oxygen. Some streams are so swift that they do not freeze over completely, and enough open water is left to keep the dissolved oxygen content of the water high enough for the life of fishes.

Recent Observations on the Relation of Ice and Dissolved Oxygen in the Illinois River

The Illinois River is not often covered with ice long enough for the oxygen dissolved in the water to be reduced to a point where the fish show signs of distress. The river froze over in December, 1924, and did not thaw out until the first week in February, 1925. It was completely covered with ice except for small patches of open water where the current was swiftest, notably in Peoria Narrows and below all bridges. Fishermen say that this is the first time the river has been frozen over for any considerable time since the winter of 1917-1918. Kofoid* states that during the winter of 1894-95 the river froze over the latter part of December and the ice did not go out until the last of February. This

* Bul. Ill. State Lab. Nat. Hist., 6:176, 1901.

ice was present during a prolonged period of low water, and it was accompanied by the almost complete disappearance of the plankton organisms and by the death of large numbers of fish. Although this occurred before the Chicago Drainage Canal was opened, it must be remembered that the Illinois River was even then a heavily polluted stream. At that time the volume of water carried was much smaller than at present and the rate of flow was slower. It seems probable that the river because of its slower current was more likely to freeze over then than now, but that this tendency was partially counteracted by greater changes in level which tended to break up the ice and keep the channel open.

During January and February, 1925, dissolved oxygen determinations were made in the Illinois River and related waters between La Salle and Meredosia. Table I shows the results of these determinations together with notes on ice conditions and temperature of the water. Since the river froze over before Christmas, it seems probable that when the field work was begun, January 23, dissolved oxygen concentration had reached its lowest point. Samples taken on January 23 and 24 showed about 1.7 parts per million of dissolved oxygen at Peoria Narrows, Pekin, and Havana, but those from Henry and La Salle showed about 6 parts per million. This is probably not because of better aeration up-stream but because the initial charge of oxygen dissolved in the water that diluted the sewage had, on account of the low temperature, not yet been consumed. It is quite probable that at this time the very low oxygen prevailed from Peoria Narrows to the mouth of the river at Grafton. On February 2, oxygen concentrations as low as 0.4 part per million were found in Mud Lake, which is partly fed by river water. Records of bullheads dying in the traps and seines in Treadway Lake and Coleman Lake indicate that low dissolved oxygen concentrations prevailed also in those backwaters that are fed by the river. A sample taken in the middle of Quiver Lake showed 2.3 parts per million of dissolved oxygen. This comparatively high figure is due to the highly oxygenated water coming out of Quiver Creek. On February 4 samples taken in Treadway Lake and Coleman Lake showed over 5 parts per million of dissolved oxygen. This high figure is brought about by the dilution of these lakes with Sangamon River water. By February 5, when the river channel was partly open, samples at Beardstown showed 3.3 and 3.7 parts per million of dissolved oxygen in mid-channel with 4.6 and 4.1 near the east bank, due to the better water coming out of Sangamon River. On February 6 and 7 there was much open water, but the water temperature was still between 0° and 4° C. Samples taken at Henry and Chillicothe showed about 5 parts per million of dissolved oxygen, which is somewhat lower than the up-stream samples taken two weeks previously; but the samples taken at Peoria Narrows and Pekin gave about 3 parts per million, almost twice the amount found on the earlier trip. The thawing continued until the channel was free of ice by February 8. On February 10 at Browning the channel showed 5.8 parts per million of dissolved oxygen. The next day at Beardstown it was 6.6.

Table I. The Relation of Ice and Dissolved Oxygen in the Illinois River and Related Waters, 1925

Location	Miles above Grafton	Date 1925	Ice conditions	Water temp. C.	Sample taken from	Dissolved oxygen parts per million
Peoria Narrows, mid-channel	166	Jan. 23	Heavy ice everywhere except a little open water in the Narrows and below the bridge	0.5–1.5	Bottom	1.7
				"	Top	1.6
Henry, mid-channel	196	Jan. 23	A little open water below the bridge. Heavy ice elsewhere	"	Bottom	5.7
				"	Top	5.8
Henry, E. of channel	196	Jan. 23		"	Bottom	6.3
				"	Top	6.4
Pekin, mid-channel	153	Jan. 23	Completely frozen over except in the draw of the bridge	"	Bottom	1.7
				"	Top	1.7
Pekin, W. of channel	153	Jan. 23		"	Bottom	1.8
La Salle, mid-channel below wagon bridge	224	Jan. 24	Channel has been open 3-4 days. Some shore ice	"	Bottom	6.1
				"	Top	5.9
				"	Bottom	6.2
Havana, mid-channel	120	Jan. 24	All heavy ice except a little open water below bridge	"	Bottom	1.4
				"	Top	2.0
Clear Lake, Haven's Landing	132	Feb. 2	Completely covered with heavy ice	3.0	Bottom	1.7
Mud Lake, in the middle	132	Feb. 2	"	4.0	Bottom	0.4
				2.5	Top	1.2
Mud Lake, E. shore	132	Feb. 2	"	2.5	Middle	1.0
Quiver Creek	125	Feb. 3	All open water except a little shore ice	2.0	Bottom	11.4
				1.5	Top	11.1
Quiver Lake near mouth of Quiver Creek	125	Feb. 3	Open water about the mouth of Quiver Creek	1.0	Bottom	5.7
Quiver Lake, in the middle	124	Feb. 3	Covered with heavy ice	1.0	Bottom	2.3
Coleman Lake, in the middle	93	Feb. 4	"	2.0	Bottom	5.0
				1.0	Top	5.4
Treadway Lake, E. shore	93	Feb. 4	"	—	Bottom	5.0

TABLE I. *(Continued)*

Location	Miles above Grafton	Date 1925	Ice conditions	Water temp. C.	Sample taken from	Dissolved oxygen parts per million
Treadway Lake, in the middle	93	Feb. 4	Covered with heavy ice	—	Bottom	5.4
Phelps Ditch	92	Feb. 4	"	—	Bottom	1.5
Beardstown, E. of channel	88	Feb. 5	Channel partly open	4.0	Bottom	4.6
				4.0	Top	4.1
Beardstown, mid-channel	88	Feb. 5	"	4.0	Bottom	3.3
				3.9	Top	3.7
Beardstown, W. of channel	88	Feb. 5	"	2.0	Middle	3.3
Phelps Ditch	92	Feb. 5	Covered with heavy ice. Much snow water coming in	—	Bottom	2.0
				—	Top	7.1
					Snow water on top of ice.	10.2
Treadway Lake	93	Feb. 6	Some open water in the channel	—	Bottom	5.2
				—	Bottom	5.1
Coleman Lake	93	Feb. 6	A little open water	—	Bottom	5.1
Pekin, mid-channel	153	Feb. 6	Channel open. Shore ice	2.0	Bottom	3.3
				2.0	Top	3.4
Peoria Narrows, mid-channel	166	Feb. 6	Channel open except in the wide waters of Peoria Lake	1.5	Bottom	2.8
				1.5	Top	3.0
				2.0	Bottom	2.9
				2.0	Top	3.1
Henry, mid-channel	196	Feb. 7	Channel half open	2.0	Bottom	4.7
				2.4	Top	4.7
Chillicothe, mid-channel	180	Feb. 7	Channel open	2.0	Bottom	5.5
				2.0	Top	5.6
Brockschmidt's Swale	92	Feb. 9	Much open water	1.0	Bottom	8.0
Treadway Lake near boat-landing	92	Feb. 9	"	—	Bottom	7.9
				—	Bottom	8.2

TABLE I. (*Concluded*)

Location	Miles above Grafton	Date 1925	Ice conditions	Water temp. C.	Sample taken from	Dissolved oxygen parts per million
Browning, mid-channel	97	Feb. 10	No ice	1.5	Bottom	5.8
				1.5	Top	5.7
Browning, W. shore	97	Feb. 10	"	3.0	Middle	5.8
Coleman Lake, E. shore	93	Feb. 11	Some new ice	—	Middle	6.4
Beardstown, mid-channel	88	Feb. 11	No ice	—	Top	6.6
Spring Bay near grain elevator	174	Feb. 17	Some new ice	—	Bottom	8.7
Peoria Narrows, mid-channel	166	Feb. 17	No ice	—	Top	7.6
Dickinson's Slough	175	Feb. 17	Some shore ice	—	Bottom	6.8
				—	Bottom	5.9
Lower Peoria Lake, E. shore	164	Feb. 18	West half of lake open	—	Bottom	4.1
				—	Bottom	3.9
Peoria Narrows, mid-channel	166	Feb. 18	Lakes half open	—	Top	7.2
Lower Peoria Lake, E. shore	164	Feb. 19	Lakes open. Some shore ice	—	Bottom	7.4
				—	Bottom	6.9
				—	Bottom	5.7
Water-works Point, mid-channel	164	Feb. 19	"	—	Bottom	8.9
Beardstown, mid-channel	88	Feb. 21	No ice	3.5	Middle	7.9
				2.4	Top	7.6
Brockschmidt's Swale	92	Feb. 24	"	4.0	Bottom	8.9
				5.5	Bottom	9.3
Meredosia Bay at the head	78	Feb. 26	"	—	Middle	9.1
				—	Middle	10.7
Meredosia, mid-channel	71	Feb. 26	"	—	Top	9.0
				—	Top	10.3
Vette Swale	93	Feb. 27	"	—	Bottom	8.9
				—	Bottom	9.0

A sample taken February 17 at Peoria Narrows with some new shore ice present showed 7.6 parts per million of dissolved oxygen, and a sample on February 18 showed 7.2 at the same place, with no change in temperature. On February 19 at Water-works Point, where there was still some shore ice, samples showed 8.9 parts per million of dissolved oxygen. For the remainder of February the dissolved oxygen figures ranged from 8 to 10 parts per million in the vicinity of Beardstown and Meredosia, with no ice and with the water temperature about 4° C.

From late autumn until late spring the water of the Illinois River is cold enough to slow down the oxygen consumption of the organisms that utilize the sewage and other organic matter in the river to a point where the rate of aeration balances or exceeds the rate of oxygen consumption. Under these conditions the amount of oxygen present is sufficient for the ordinary river animals. If, however, aeration is stopped by the freezing over of the river the dissolved oxygen is gradually exhausted until it becomes so low in Upper Peoria Lake that fish show signs of distress. When this condition is established, it does not change until the ice goes out or until it is diluted with a large amount of water highly charged with oxygen. When the ice goes out of a small fraction of the channel there is a marked increase in the amount of oxygen dissolved in the water, and in about a week the normal cold water concentration of dissolved oxygen is established.

The Effect of Low Dissolved Oxygen Concentrations on the Fishes of the Illinois River

Fishes, like all other living things, require a more or less constant supply of oxygen to maintain the activities of life, but the minimal amount may vary greatly for the different forms of life. A striking example of this is the problem in hand. The minute organisms which feed on sewage and other organic matter can live and consume oxygen in concentration too small to support the life of fishes. Some of them, indeed, can live in a total absence of dissolved oxygen, since they are able to derive oxygen from complex organic compounds.

A fact of fundamental importance to the existence of fishes is their ability to avoid oxygen concentrations that would be fatal to them. When low dissolved oxygen concentration obtains in a body of water, such as the Illinois River, the fishes retreat into backwater lakes, spring holes, mouths of tributaries, and other places where stagnation has not developed.

A case of this kind recently occurred near the town of Spring Bay on the east shore of upper Peoria Lake, where there is a lagoon fed by springs. At rather low stages of the river this lagoon, which has an area of about two acres, is filled with clear, well-aerated water, warm enough to prevent freezing. Some time after the river was completely frozen over in January, 1925, the fishes began to crowd into this spring hole, and several carloads of carp and buffalo were taken here during the last two weeks of January. A rise in the stage of the river largely diluted this better water with the oxygen-deficient river water, and large numbers of minnows, large-mouth black bass fingerlings, crappies, sunfishes, etcetera, died; and the carp became much distressed and swam at the surface with their heads out of the water. Part of the ice then went out of the channel, the dissolved oxygen in the river water increased, and the fishes no longer were attracted to this place. The unusually large numbers of gulls that frequented the river at that time may indicate an unusually large number of dead fishes; but, with the above exception, no dead fishes were seen by the writer except where they had been confined in live-boxes, traps, and nets, and could not escape from the oxygen-deficient water.

Those animals which are more sedentary in their habits and can not so readily avoid oxygen-deficient water suffer more severely than the fishes. After the recent prolonged period of ice, large numbers of dead snails were washed up on the east shore of lower Peoria Lake. Fishermen in the vicinity of Meredosia and Beardstown have in recent years remarked the growing scarcity of air-breathing animals that hibernate on the bottom of the river, such as bull-frogs, snapping turtles, and soft-shelled turtles. Some of the turtles, however, such as the painted turtle, the ridge-back turtle, and the terrapin, do not bury themselves in the mud and hibernate, but remain active, as shown by the fact that they are caught in hoop-nets and traps throughout the winter. These latter species of turtles are much more plentiful in the lower Illinois River than the hibernating species. In cold water, frogs and turtles utilize the oxygen in the water and can dispense with the use of their lungs. If they remain active they select the better water the same as the fish; but if they bury themselves in the mud and become dormant, it may be that they die there from deficiency of oxygen during times of stagnation.

In the attempt to determine what dissolved oxygen concentrations the different fishes avoid and what concentrations are fatal to them, dissolved oxygen determinations were made where fish were being taken, where they customarily had been taken but were absent at the time, and where fish were dying. The procedure followed was to accompany a fisherman who was raising hoop-nets and take dissolved oxygen samples at the nets. This was done at nets which had been fishing one, two, or at most three days, and, when convenient, both when the nets were set and when they were raised. The samples were usually taken near the bottom because that is where the fish spend most of their time. One advantage of hoop-nets is that they can be used in all kinds of situations where the hauling of seines is often impossible. For the purpose of ascertaining the relations of fish life to dissolved oxygen, hoop-nets have the further advantage, that they fish a very restricted area. The amount of fish taken by them depends on conditions which cause the fish to move about, such as high winds, changes in the stage of water, changes in the quality of the water, and changes in temperature. What may be considered a disadvantage of hoop-nets is their selectiveness. Sluggish fish are not caught as often as active fish. Carp avoid small-mesh nets and traps, but they are readily taken in large-mesh nets. Channel cat and bullheads seem to go most readily into small-mesh nets and basket traps, probably because, being largely nocturnal and hiding during the day, they go into the nets for concealment.

Table II gives the winter data showing the relation of fishes to different conditions of ice and dissolved oxygen. It seems quite certain that dissolved oxygen concentrations between zero and two parts per million will kill all kinds of fishes. Carp and buffalo have been found living in water showing as low as 2.5 parts per million. As a rule, a variety of fishes were found only when they were four or more parts per million, and the greatest variety of fishes was taken when there were nine parts per million. This catch was made on February 26-27 in Vette Swale when at least twenty-two and perhaps as many as twenty-six species of the larger fishes were taken in nine 2½-inch mesh four-foot hoop-nets.

It was noticed a number of times that carp and buffalo taken from oxygen-deficient water were very light in color and sluggish in their movements, while the same kinds of fishes taken from well-aerated water were quite darkly pigmented and very active when disturbed.

Mention was made by fishermen, from time to time, at several points on the Illinois River, of the inferior value of certain fish because they were "gassy"—their expression for a taste and smell of the flesh of the fish, like the smell of coal gas. Others have described it as like the taste of kerosene or of tar; but to the writer it seems more than anything else like the smell of the putrifying mud on the bottom of the river, which is very like that of coal gas. This taste is often so pronounced as to make the fish very disagreeable as food. "Gassy" fish are definitely associated with periods of prolonged ice on the river, mortality in nets and traps, and other indications of a scanty supply of dissolved oxygen. The species which most commonly have this taste are carp, buffalo, channel cat, and bullheads, and these are the species which are most often found living in water with a low oxygen concentration. If these fishes are kept in well-aerated water for a few days, they lose this "gassy" taste.

During the winter, except when the river is frozen over, fishes do not suffer directly from lack of dissolved oxygen. From November to May, in open water, the rate of aeration exceeds the rate of oxygen consumption, so that there is usually a sufficiency of dissolved oxygen.

In midsummer, down as far as Peoria and sometimes below, except during high water, lack of dissolved oxygen excludes fishes from large feeding grounds and destroys large amounts of fish food. For example, Mr. Richardson observed a heavy mortality of snails in Peoria Lake in August, 1917. As increase in temperature accelerates the life processes of fishes, lack of dissolved oxygen can not be endured in warm water as long as in cold.

TABLE II. THE RELATION OF ICE, DISSOLVED OXYGEN, AND FISH LIFE IN THE ILLINOIS RIVER AND RELATED WATERS, 1925

Location	Date 1925	Ice conditions	Dissolved oxygen parts per million	Notes on fish life, etc.
Clear Lake, at Haven's Landing	Feb. 2	Completely covered with heavy ice	1.7 Bottom	No fish here now. Fish caught in hoop-nets die. Carp, buffalo, yellow bass, bullheads and channel cat as well as some sunfish and crappies are ordinarily taken here.
Mud Lake, in the middle	Feb. 2	"	0.4 Bottom 1.2 Top	No fish here now. Carp, buffalo, yellow bass, bullheads, channel cat, crappies and sunfish ordinarily taken here.
Mud Lake, E. shore	Feb. 2	"	1.0 Middle	Ten days ago a river seine was hauled here under the ice and 300 lbs. of buffalo were caught. A few gizzard shad and gars were also taken.
Quiver Creek	Feb. 3	All open water except a little shore ice	11.4 Bottom 11.1 Top	See column A. Fishes taken in ten 2-inch mesh, 4-foot hoop-nets in one day.
Quiver Lake near the mouth of Quiver Creek	Feb. 3	Open water about the mouth of Quiver Creek	5.7 Bottom	Hoop-nets in this open water are catching many carp, buffalo, and "fine fish."
Quiver Lake, in the middle	Feb. 3	Covered with heavy ice	2.3 Bottom	A seine haul last week caught 800 lbs. of carp and buffalo that were very pale and sluggish. Strings of bullheads are being taken with the hands at the edge of the ice along the shore.
Coleman Lake, in the middle	Feb. 4	Covered with heavy ice	5.0 Bottom 5.4 Top	Samples taken at some hoop-nets set on Feb. 2.
Treadway Lake, E. shore	Feb. 4	"	5.0 Bottom	"
Treadway Lake, in the middle	Feb. 4	"	5.4 Bottom	"
Phelps Ditch	Feb. 4	"	1.5 Bottom	Fish caught in hoop-nets in this ditch smother quickly. Gar, crappies, sunfish, black bass, yellow bass, bullheads, channel cat, carp, buffalo, and dogfish commonly taken here.

TABLE II. *(Continued)*

Location	Date 1925	Ice conditions	Dissolved oxygen parts per million	Notes on fish life, etc.
Phelps Ditch	Feb. 5	Completely covered with ice. Much snow water coming in	2.0 Bottom 7.1 Top	
Treadway Lake	Feb. 6	Some open water in the channel	5.2 Bottom 5.1 Bottom	See column B. Fishes taken in twenty-nine 2½-inch mesh, 4-foot hoop-nets in four days.
Brockschmidt's Swale	Feb. 6	Some open water		See column C. Fishes taken in three 2½-inch mesh, 4-foot hoop-nets in one day.
Coleman Lake	Feb. 6	A little open water	5.1 Bottom	See Column D. Fishes taken in twenty-five 2½-inch mesh, 4-foot hoop-nets in three days.
Brockschmidt's Swale	Feb. 9	Much open water	8.0 Bottom	Heavy rain yesterday; river rose a foot. See column E. Fishes taken in three 2½-inch mesh, 4-foot hoop-nets in three days.
Treadway Lake near boat landing	Feb. 9	"	7.9 Bottom 8.2 Bottom	Heavy rain yesterday; river rose a foot. See column F. Fishes taken in seven 2½-inch mesh, 4-foot hoop-nets in two days.
Dickinson's Slough	Feb. 17	Some shore ice	6.8 Bottom	See column G. Fishes taken in one 1½-inch mesh, 2-foot hoop-net in two days.
Dickinson's Slough	Feb. 17	"	5.9 Bottom	See column H. Fishes taken in one 2-inch mesh, 4-foot hoop-net in two days.
Lower Peoria Lake, E. shore	Feb. 18	West half of lake open	4.1 Bottom 3.9 Bottom	See column I. Fishes taken in five 1½-inch mesh, 3-foot hoop-nets in two days.
Lower Peoria Lake, E. shore	Feb. 19	Lakes open. Some shore ice	7.4 Bottom 6.9 Bottom 5.7 Bottom	See column J. Fishes taken in nine 1½-inch mesh, 3-foot hoop-nets in one to three days.
Brockschmidt's Swale	Feb. 24	No ice	8.9 Bottom 9.3 Bottom	See column K. Fishes taken in eight 2½-inch mesh, 4-foot hoop-nets in one day.
Coleman Lake	Feb. 24	"		See column L. Fishes taken in two 2½-inch mesh, 4-foot hoop-nets in one day.
Vette Swale	Feb. 27	"	8.9 Bottom 9.0 Bottom	See column M. Fishes taken in nine 2½-inch mesh, 4-foot hoop-nets in two days. The river is rather high and these nets were set among brush. A high wind blew all day yesterday.

TABLE II. (*Concluded*)

Kinds and Numbers of Fishes Taken

Name	A	B	C	D	E	F	G	H	I	J	K	L	M	Total
Carp	137	173	3	68	12	42		9	39	81	14	4	64	646
Big-mouth buffalo	27	20	2	11		1			7	22		1	11	102
Mongrel buffalo		1		5		1			5	3			4	19
Small-mouth buffalo		19	1	21	14	1			3	3	11	2	17	92
River carp	55	10		5		2			5	14	2		15	108
Hogsucker		1											1	2
Common sucker						2			1	1			1	5
Spotted sucker						1							1	2
Chub-sucker				1						1				2
Red-horse		1		3							2		2	8
Short-nosed gar	2		1	2			1		11	15			3	35
Long-nosed gar				1										1
Dogfish				2									2	4
Bullheads	4	13		26			11		8	34			15	111
Channel cat	32	11		1					1	1	2		1	49
Sheepshead	2										2		5	9
Yellow bass	44												4	48
Large-mouth black bass	1			3									12	16
White crappie		2		21									14	37
Black crappie				11					1				6	18
Blue-gill		1		15			2						9	27
Warmouth bass							1						2	3
Green sunfish							1		3	3			3	10
Eel													1	1
Total	304	252	7	196	26	50	16	9	84	178	33	7	193	1355

Summary of Table II

Column	No. of nets	Width of mouth	Mesh inches	Fishes per net per day
A	10	4	2	30.4
M	9	4	2½	10.7
I	5	3	1½	8.4
G	1	2	1½	8.0
J	9	3	1½	6.6
H	1	4	2	4.5
K	8	4	2½	4.1
F	7	4	2½	3.6
L	3	4	2½	3.5
E	3	4	2½	2.9
D	25	4	2½	2.6
C	2	4	2½	2.5
B	29	4	2½	2.2

Observations made at Peoria Narrows in the summer of 1923 showed that fishes died over night in water having less than two parts of oxygen per million. Dogfish seemed to be most sensitive to low oxygen concentrations, for individuals of that species were often found dead when all other species remained alive in the same hoop-net. Carp seemed to be the most resistant, being often caught farther out in the channel than other species, in nets where the water was deficient in oxygen. Gars were more abundant than any other species in water with little or no oxygen, probably because of their habit of breathing at the surface.

The Effect of Dissolved Oxygen Concentration on the Fish Yield of the Illinois River

Table III gives the fish yields for the different sections of the Illinois River in representative years covering almost two decades. The peak of fish production was reached in 1908, when the Illinois River produced over 19 million pounds, according to the Illinois Fish Commission report, and almost 24 million pounds, according to the U. S.

Bureau of Fisheries. The factors entering into the increase of the fish yield were principally:

(1) The introduction of the German carp.

(2) The increase in fishing operations.

(3) The increase in the area of the river due to the addition of water from Lake Michigan.

(4) The increase in the food supply resulting from the sewage.

TABLE III. COMPARISON OF THE FISH YIELDS OF THE DIFFERENT SECTIONS OF THE ILLINOIS RIVER

Year	Authority	La Salle-Chillicothe	Peoria-Browning	Beardstown-Grafton	Total
		Pounds	Pounds	Pounds	Pounds
1896	Ill. Fishermen's Ass'n	735,500	3,854,281	2,643,281	7,232,811
1897	"	1,904,095	5,579,963	2,412,650	9,896,708
1899	"	2,040,045	6,025,671	3,541,800	11,607,516
1900	"	1,803,600	5,178,140	4,542,440	11,524,180
1907	Ill. Fish Commission	1,455,000	9,900,000	3,384,000	14,739,000
1908	"	1,722,000	13,600,000	3,948,000	19,270,000
1921	Bureau of Fisheries	542,985	1,989,249	1,474,233	4,006,467
1922	"	1,055,184	5,856,778	3,694,710	10,606,672

Since 1908 there has been a marked decrease. A census taken by the U. S. Bureau of Fisheries in 1921, a poor fishing year, showed 4 million pounds; and in 1922, a favorable year for fishing, the census showed 10½ million pounds. The factors entering into this decrease are:

(1) The reclamation of the bottomlands and lakes along the middle and lower sections of the river.

(2) The exclusion of fishes from large areas of the upper and middle river during a large part of the year, due to conditions produced by an excess of sewage.

(3) Occasional periods of extraordinary pollution which wipe out whole populations of organisms that serve as fish food and which destroy large numbers of the fishes themselves in places where they can not retreat into better water.

Messrs. Alvord and Burdick, in their report on "The Illinois River and its Bottomlands" (1915), have shown that the fish yield is closely correlated with the water area. In the Beardstown-Grafton section of the river there has been no very marked change in the amount of fish taken. Here the factors making for increased yield have been offset largely by reclamation of the bottomlands. The greatest change took place in the Peoria-Browning section, where there was a marked increase in fish yield up to 1908 and an equally marked decrease after 1908. Here the reclamation of bottomlands, notably the Thompson's Lake district, took place several years later than in the lower section of the river. In the upper section (La Salle-Chillicothe), although considerably less land has been reclaimed, and the higher stage of the river has increased the area of water, the fish yield shown by the 1921 and 1922 figures is scarcely half its former value. This decrease has been brought about entirely by the conditions produced by an excess of sewage. The most important effect of an excess of sewage is the reduction of dissolved oxygen to a point where fish life is excluded from immense areas of water.

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE
NATURAL HISTORY SURVEY
STEPHEN A. FORBES, Chief

Vol. XV. BULLETIN Article VIII.

An Entomological Survey of the Salt Fork of the Vermilion River in 1921, with a Bibliography of Aquatic Insects

BY

CHARLES P. ALEXANDER

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
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INTRODUCTION

Publication of the following paper, prepared in 1921, setting forth the effects on aquatic insects of the heavy pollution of a small stream by sewage from the twin towns of Champaign and Urbana, has been delayed by deficiency of funds for the printing of articles in the Bulletin of the State Natural History Survey, preference having been given there to papers of a more immediate importance.

The recent installation of an adequate plant for the purification of the sewage of these towns before it enters the stream has removed, it is hoped forever, the pollutional conditions here described, and the biological effects of this renovation can presently be made manifest by a comparison of the restored insect life of the stream with that here discussed. As an indispensable and irreplaceable basis for such a comparison this paper has acquired a very special value, and fortunately its publication need be no longer delayed.

A wide-spread campaign, vigorously promoted by the Izaak Walton League, for the suppression of stream pollution is stimulating a study of the subject throughout the country, and a carefully prepared bibliography appended to this report will doubtless be found useful as a guide to published information, widely scattered as this is in very many journals, American and European.

Stephen A. Forbes.

Article VIII.—*An Entomological Survey of the Salt Fork of the Vermilion River in 1921, with a Bibliography of Aquatic Insects.* By Charles P. Alexander.

The Salt Fork is the most westerly of the three Illinois branches of the Vermilion River, and one of the chief affluents of the Wabash from the west. It takes rise in a group of small streams in the west-central part of Champaign county, Illinois, flowing south to Urbana, thence east to near St. Joseph. Near this village the stream takes a large bend and flows southward to near the village of Sidney, after which it flows in a general easterly direction, uniting with the Vermilion River just west of Danville. The Middle Fork unites with the Salt Fork between the villages of Oakwood and Hillery.

Originally a clean-water, permanent stream, the Salt Fork was later utilized to receive the sewage and manufacturing wastes of the cities of Urbana and Champaign, with the inevitable consequence that for several miles beyond the Twin Cities the stream became badly polluted and contaminated to the elimination of a great majority of the less tolerant members of the original fauna and flora. Thus we have on a small scale almost a duplication of the conditions obtaining in the upper reaches of the Illinois River which receives the sewage of Chicago and cities along its banks. The biological changes that have taken place in the Illinois River as a result of the diversion of the Chicago sewage to this stream twenty-five years ago, have been critically studied and recorded in a series of papers by Forbes and Richardson cited in the general bibliography in the second part of this paper. The Salt Fork stream, flowing close to the University of Illinois, has more recently attracted the attention of local naturalists, and one paper has already been published which is concerned with the effects of pollution on its fauna. This paper by Baker (1922) on the molluscan fauna of the Vermilion River and the Salt Fork is of especial value in its particular field in this connection. At the suggestion of Dr. Stephen A. Forbes, Chief of the State Natural History Survey, the writer in 1921 attempted to supplement Mr. Baker's studies from a purely entomological view-point. The stream was examined at short intervals, from above the source of pollution near Crystal Lake, Urbana, to just beyond the union of the Salt and Middle forks near Hillery in Vermilion county, Illinois. A total of thirty-three stations were established, corresponding rather closely with the collecting points chosen by Mr. Baker and with the bacteriological stations of the Illinois Water Survey. The collections of insects taken at the various stations are recorded later in this paper. An effort has been made to decide which of the species may be taken as indicators of the various degrees of pollution commonly recognized, but the results have scarcely justified any sharp lines of subdivision except that between foul-water and clean-water species. The rather numerous tolerant species that can dwell in a varying degree of contamination occupy an intermediate classification that is discussed in some detail in its proper place.

When a stream becomes polluted by sewage or chemicals, the most sensitive and least tolerant species of plants and animals are soon eliminated, being gradually replaced by more tolerant forms as the amount and degree of pollution increases. The destruction of the clean-water insect fauna is often compensated for by a marked increase in the number of species and individuals of certain unusually tolerant or foul-water forms, notably species of small annelid worms (Tubificidae) and larvae of midges (Chironomidae) which, in places, form an important source of food for the few species of tolerant fish that exist in such waters. Thus in certain areas of both the Illinois River and the Salt Fork, almost the only water-breathing insect life consists of larvae of a few species of various genera of midges which are often extremely abundant.

Sewage Entomology

Considerable literature has been written upon the fauna and flora of polluted water-courses and sewage-disposal plants. The entomology of polluted streams exhibits certain general features which may be briefly outlined as follows.

The septic or grossly polluted portions of a stream are those in which the decomposition of organic matters is progressing actively, producing an abundance of carbon dioxide and the earlier and more complex nitrogenous decomposition products to the more or less complete exclusion of dissolved oxygen. The organisms of this zone are those which have been termed by Kolkwitz and Marsson (1909) polysaprobic and by Forbes and Richardson (1913) *septic* or *saprobic*. The lower forms of plant life, especially Schizomycetes, are abundant. Insects are very rare and include no water-breathing forms. The most conspicuous insects of this zone, both in America and Europe, are the so-called "rat-tailed maggots"—larvae of certain syrphid flies (*Eristalis* and *Helophilus*). *Eristalis tenax* (Linn.) was the only insect recorded by Kolkwitz and Marsson (1909), Johnson (1914), and Suter and Moore (1922) from this zone. It should be understood that this larva is air-breathing, obtaining its oxygen supply through the spiracles at the tip of a long, extensile breathing tube, the spiracular disk being held at the surface while the animal feeds at will beneath. The range of oxygen content usually selected by this species of *Eristalis* is stated by Suter and Moore (1922) to be from 0 to 40 per cent saturation. Other characteristic organisms of this region are the sludge-worms belonging to the family Tubificidae. The mud bottoms of the saprobic zone invariably have an offensive odor and are blackened by deposits of iron sulphide which churn up in dark clouds when the bottom is disturbed.

The polluted or mesosaprobic zone represents the next step toward purification of the waters. A variety of higher water-plants may exist in this zone and there may be considerable amounts of dissolved oxygen present. The natural physical re-aeration of the water and the oxygen given off by the higher plants or the more tolerant phytoplanktonts permit the existence of a much larger and more diversified fauna than was found in the saprobic zone. To this zone Kolkwitz and Marsson gave the name *mesosaprobic*, and further divided it into the sub-zones alpha, more strongly polluted, and beta, less strongly polluted. The two subdivisions of this region correspond in a general way to the *pollutional* and *contaminate* zones of Forbes and Richardson (1913). The fermentations that consume oxygen have become less here and the decomposition of the nitrogenous products has progressed to the stage where free amomnia usually predominates, though amounts of both ammonia nitrogen and dissolved oxygen are subject to change in a wide range. Kolkwitz and Marsson (1909) record eight insects from their alpha zone, and nine from their beta zone. Of the alpha forms, all but three are air-breathers, these being *Stratiomyia chamaeleon* L., *Psychoda phalaenaides* L., *P. sexpunctata* Curt. (=*alternata* Say), *Ptychoptera contaminata* L., and *Velia currens* Fabr. An orl-fly, *Sialis lutaria* L., and the two midges *Chironomus plumosus* L. and *Tanypus monilis* L. are water-breathers. From the beta sub-zone all but one of the species are water-breathers. The air-breathing species is *Culex annulata* F.; the water-breathing forms are caddis-worms (Trichoptera, 4) and Diptera (4). From this same zone Johnson (1914) records three species of Diptera only, these being *Chironomus plumosus* L., *Psychoda phalaenoides* L., and *P. sexpunctata* Curt. (=*alternata* Say), all air-breathing species. Suter and Moore describe the sewage-fly (*Psychoda alternata* Say) and the sewage crane-fly (*Erioptera* sp.) from conditions which belong to this zone. The large, brick-red larvae of the phantom crane-fly, *Bittacomorpha clavipes* (Fabr.), were found by Weston and Turner (1917) to be important factors in the reduction of sewage in the Coweeset stream near Brockton, Massachusetts, and to belong to the mesosaprobic zone. In the Salt Fork, the writer found a considerable number of insects which would seem to find their place chiefly in the beta mesosaprobic or weakly pollutional zone. This list includes a variety of water-scavenger beetles (Hydrophilidae), belonging to the genera *Tropisternus* (2), *Helophorus* (1), *Enochrus* (1), *Paracymus* (1), *Berosus* (2), almost all adult air-breathing beetles but including also many larvae. The occurrence of the immature stages of these beetles and others listed in the first section of this paper, together with water-breathing nymphs of a May-fly, *Callibaetis* sp., in company with large numbers of sludge-worms (Tubificidae), suggests that the insects are more than ordinarily tolerant of pollution.

The part of a stream lying between the mesosaprobic lower limit and that of the cleanest zone normal to rivers has been called by Kolkwitz and Marsson *oligosaprobic*, and by Forbes and Richardson the zone of clean water. The water here is regularly of the normal purity characteristic of streams unpolluted by man, and the waste organic nitrogen has been more or less completely mineralized. The rate of consumption of dissolved oxygen is slow, and is often more than balanced by mechanical and biological re-aeration. The water has a slightly alkaline reaction and is at low stages highly transparent, unless colored by algae. A great variety of both plant and animal life occurs, but characteristic saprobic forms are, at least in large numbers, lacking. Members of the Characeae, very sensitive to pollutional conditions, begin to reappear where physical conditions are suitable and in their proper geographical range. The gradual increase in the amount and variety of light green algal forms, replacing the blue-greens, further indicates a clearing up of the water. From this region Kolkwitz and Marsson record a rather extended list of insects belonging to the following groups: Plecoptera (4), Ephemerida (6), Anistoptera (2), Zygoptera (2), Trichoptera (7), Hemiptera (8), Diptera *(Sayomyia* (1), Coleoptera (6), Dytiscidae (4), Gyrinidae (1), Hydrophilidae (1). The Plecoptera and Ephemerida have in the past experience of the writer and of other American authors been usually associated with the best aerated and most nearly pure water in this zone. There is often some invasion of the freer-ranging cleaner water species into the mososaprobic, beta, or contaminate zone, especially after heavy rains, these species often including higher forms of aquatic life, such as fish.

The above remarks apply chiefly to sewage in streams. A rather similar condition obtains in the disposal of organic matter in sewage-disposal plants. Here the principal insect involved is the sewage-fly, *Psychoda alternata* Say, which sometimes occurs in vast numbers. The gelatinous or amorphous film (milk of aluminum) which is used in the filters supports a myriad of lower organisms and it is upon these forms that the sewage-fly lives. It apparently does no harm in the filter-plant, but when it becomes numerous, as happens in some of the larger eastern cities, as Baltimore, the adult flies become a serious nuisance to housewives in the vicinity. This subject has been discussed in detail by Headlee and Beckwith (1918) and Headlee (1919).—see p. 460.

Description of the Stations made in the 1921 Survey of the Salt Fork of the Vermilion River

As mentioned above, a total of thirty-three stations were established during the progress of the survey. The location of these stations, with lists of the insects occurring at each, is given below.

The Salt Fork above the entrance of the Urbana and Champaign sewers is a small, clean-water stream. Beyond the mouths of these sewers for a distance of several miles, the stream has been artificially straightened and deepened into what is termed the Drainage Ditch, a distanec of approximately thirteen miles. This ditch continues to just west of the village of St. Joseph. The condition of the water in the drainage ditch is very bad, with no water-breathing insects present. About a mile west of St. Joseph, or a short distance above (west of) the entrance of Spoon River, the conditions are considerably ameliorated and numerous tolerant insects and other forms of life are found. This pollutional or upper mesosaprobic condition obtains to near mid-distance between St. Joseph and Sidney where the water becomes still cleaner, and may be considered mesosaprobic, beta, or contaminate, in the classifications already cited. At or near the village of Sidney, the exact place varying with the season and amount of rains, the condition of the stream has become such that it supports a fauna that may be considered as oligosaprobic, or that normal to clean water, and this continues to the union of the stream with the Vermilion River.

The conditions by stations may be briefly summarized as follows:

Station 1.—Salt Fork stream above the sewer outlets; clean-water or oligosaprobic fauna. (Check Station)

Stations 2, 3.—Pollutional or mesosaprobic, alpha.

Stations 4-9, 31.—Septic or polysaprobic.

Stations 10, 12, 13, 29, 30.—Pollutional or mesosaprobic, alpha.

Station 11.—Spoon River; clean-water fauna or oligosaprobic. (Check Station.)

Stations 14, 15, 26-28, 32.—Contaminate or mesosoprobic, beta.

Stations 16-25, 33.—Clean-water, or oligosaprobic.

Station 1.—Taken on the Salt Fork at the bridge over Market Street, Urbana, in Crystal Lake Park, July 20. Water clear, the fauna strictly a clean-water one.

Ephemerida.	Ephemeridae: *Heptagenia* sp.: naiades.
	Caenis sp., possibly *diminuta* Walk.
Hemiptera.	Veliidae: *Rhagovelia obesa* Uhl.
	Gerridae: *Trepobates pictus* (H. S.)
Trichoptera.	Hydropsychidae: *Hydropsyche* sp.
Decapoda.	*Cambarus* sp., abundant.

Station 2.—The Boneyard stream, near the Big Four Shops, Urbana, immediately before it unites with the Salt Fork, July 20 The stream here is about eight feet wide, heavily polluted on the south side, the north three feet much clearer. Depth approximately one foot. Bottom gravel, without much sludge.

Hemiptera.	Corixidae.
Coleoptera.	Dytiscidae: *Laccophilus proximus* Say, adults.
Diptera.	Chironomidae: *Tanypus* sp., two larvae.
Sludge-worms, Tubificidae, abundant.	

Station 3.—Salt Fork, 100 feet below the entrance of the Boneyard stream, July 20. Collections made in the riffles where the water was fairly well aërated in spite of the pollution.

Coleoptera.	Haliplidae: *Peltodytes 12-punctatus* (Say), adults.
	Dytiscidae: *Laccophilus proximus* Say, adults.
	L maculosus (Germ.), adults.

Diptera. Chironomidae: *Chironomus* sp., larvae.
Sludge-worms, *Tubificidae,* very abundant.
Adults of the damsel-fly, *Hetaerina americana* (Fabr.) were very abundant along the stream but no naiades could be found.

Station 4.—Salt Fork, one-fourth mile below the outlet of the Champaign sewer, July 20. Stream wide and fast-flowing, but the bottom black and with a foul odor.

Hemiptera. Gerridae: *Gerris marginatus* Say, one adult.

Beneath the surface, the only life found was a sparse number of sludge-worms. The damsel-fly *Ischnura verticalis* (Say) was common but no naiades were to be found.

Station 5.—Salt Fork at the first iron bridge (between the Champaign sewer outlet and the Augurville bridge), July 20. The water runs rapidly and the upper surfaces of the rocks appear rather clean, though blackened. On lifting the rubble, however, a mass of inky black sludge is loosened that would preclude any except the most septic organisms. No insects occurred and no other life except a few specimens of sludge-worms.

Station 6.—The Augurville or Brownfield Bridge, July 20. The stream here is broken into riffles but this does not suffice to support a fauna any more varied than at the last station. No insects occur and only a few sludge-worms. Adults of the following Odonata were noted: *Plathemis lydia* (Dru.) and *Argia violacea* (Hagen). These presumably come from ponds or backwaters with clean water, as no naiades were taken at this station.

Station 7.—Third bridge over the Salt Fork, July 20. Conditions quite as at Station 6. No insects were to be found and only a few sludge-worms.

Station 8.—Cottonwood Bridge, July 20. The stream here was very low (July 20) and extremely black and polluted. Odor bad. No life of any sort

Station 9.—Mayview Bridge, July 20. Conditions here about as at Station 8. The only insects in the water were large swarms of whirligig beetles, *Dineutes americanus* Say. A careful search was made for their larvae but these do not occur and the swarms must migrate from purer water. Adults of Odonata, *Plathemis lydia* (Dru.) and *Ischnura verticalis* (Say) were noted, but not ovipositing.

Station 10.—The Salt Fork, 100 yards above (west of) the mouth of Spoon River, near St. Joseph, July 23. Water low (6 to 9 inches) but the sandy bottom very clear, not polluted heavily as in Stations up to nine. There is no apparent bad odor, but the people living here state that later in the season at times the odor is very bad. Frogs and turtles live in this water but no fish were found, although they probably come in from Spoon River at high water. Insect life was surprisingly abundant and included many water-breathing species.

Hemiptera.	Belostomatidae: *Belostoma flumineum* Say, nymphs of all sizes, adults.
	Gerridae: *Gerris marginatus* Say, adults.
	Mesoveliidae: *Mesovelia mulsanti* White, adults common, some winged.
Coleoptera.	Dytiscidae: *Laccophilus maculosus* (Germ.), adults and larvae.
	Bidessus lacustris (Say), adults.
	Gyrinidae: *Dineutes americanus* Say, adults.
	Hydrophilidae: *Tropisternus glaber* (Hbst.), adults and larvae.
	T. lateralis (Fabr.), adults.
	Helophorus lineatus Say, adults.
	Berosus peregrinus (Hbst.), adults.
	Enochrus ochraceus (Melsh.), adults.
	Paracymus subcupreus (Say), adults.
	Helmidae: *Stenelmis* sp., one adult.
Diptera.	Chironomidae: *Chironomus viridicollis* v. d. W., extremely abundant, larvae.
	Tabanidae: *Tabanus* sp., one larva.

The great abundance of water scavenger-beetles, Hydrophilidae, and *Chironomus viridicollis* indicate a polluted but scarcely septic condition of the water.

Station 11.—Spoon River, 100 yards above the union with Salt Fork, July 23. Studied as a check on the main stream. The stream here is very muddy but the bottom is hard, composed of gravel, small crushed stones, and broken shells. The stream is almost choked with great beds of water-willow, *Dianthera americana.*

Ephemerida.	Ephemeridae: *Hexagenia bilineata* Say, large naiades.
Odonata.	Aeschnidae: *Anax junius* (Dru.), young naiades.
	Libellulidae: *Plathemis lydia* (Dru.), adults.
	Coenagrionidae: *Ischnura verticalis* (Say), adults.
	Enallagma exsulans (Hag.), adults and naiades abundant.
	E. antennatum (Say), naiades.
Hemiptera.	Corixidae: unidentified.
	Gerridae: *Trepobates pictus* (H. S.), adults and nymphs.
Neuroptera.	Sialidae: *Sialis infumata* Newm., larvae of various sizes.
Coleoptera.	Dytiscidae: *Laccophilus maculosus* (Germ.), adults.

	Haliplidae: *Peltodytes 12-punctatus* (Say), adults.
	P. edentulus (Lec.), adults rare.
	Hydrophiliade: *Berosus striatus* (Say), adults.
Diptera.	Chironomidae: *Procladius* sp., larvae.
	Chironomus sp., larvae, few.

The occurrence of *Hexagenia* and *Sialis* usually indicates a clean-water fauna, though *Sialis infumata* has been found to prefer trashy and sometimes slightly foul places.

Station 12.—Station made in the Salt Fork, one mile west of the junction with Spoon River, July 23. The Fork here is deep but foul-smelling. Masses of sludge lie about the bottom, giving it a mottled appearance.

Odonata.	Libellulidae: *Libellula pulchella* Dru. and *Plathemis lydia* (Dru.). Adult females were observed ovipositing in the stream but no naiades were found.
Hemiptera.	Corixidae: common, all adults.
	Gerridae: *Gerris marginatus* Say, adults.
Coleoptera.	Dytiscidae: *Laccophilus proximus* Say, adults.
	Haliplidae: *Peltodytes 12-punctatus* (Say), adults.
	Hydrophilidae: *Berosus striatus* Say, adults.
Diptera.	Chironomidae: *Chironomus* sp., larvae abundant.
	Palpomyia sp., larvae common.
Sludge-worms.	A very large species of *Tubifex* occurs.

Station 13.—Railroad Bridge west of St. Joseph, July 23. The river here is of bad odor and the bottom blotched with small masses of sludge. Small patches of duckweed (*Lemna*) float on the stream-surface.

Ephemerida.	Ephemeridae: *Callibaetis* sp., possibly *ferruginea* Walk., a few naiades. This is the most tolerant May-fly known to the writer.
Odonata.	Aeschnidae: *Anax junius* (Dru.), naiades.
	Libellulidae: *Libellula pulchella* Dru., naiades.
Hemiptera.	Mesoveliidae: *Mesovelia mulsanti* White, adults.
Coleoptera.	Dytiscidae: *Laccophilus proximus* Say, adults.
	Haliplidae: *Peltodytes 12-punctatus* (Say), adults.
	P. edentulus (Lec.), adults, few.
	Hydrophilidae: *Tropisternus* sp., large larvae.
	Enochrus ochraceus (Melsh.), adults.
	Berosus striatus (Say), adults.
Diptera.	Chironomidae: *Palpomyia* sp., larvae common.
	Procladius sp., larvae, few.
	Chironomus sp., larvae, abundant.

Sludge-worms, *Tubifex* sp., and blood-worms, *Chironomus* sp., are abundant in the shallow waters.

Station 14.—Benchmark 666, south of St. Joseph, August 9. The stream here is comparatively clear. There are some small masses of sludge but the whole stream is virtually choked with great masses of the water-net, *Hydrodictyon.* In the water, small areas of *Sagittaria* are growing, indicating a clearing up of polluted conditions.

Hemiptera. Corixidae: extremely abundant, mostly adults but including many large nymphs.
Diptera. Chironomidae: *Procladius* sp., larvae.
Chironomus sp., larvae, a few only.

No Ephemeridae, Odonata, or Coleoptera were taken here on this date (compare with Station 28 later). A few sludge-worms were found.

Station 15.—The Shakerack Bridge, one and one-half miles west of Tipton, August 9. The bridge is at the west end of a small woodland. The stream here is comparatively deep but dirty. No algal or other plant life occurs.

Ephemerida. Ephemeridae: *Callibaetis* sp., possibly *ferruginea* Walk., fully grown naiades.
Odonata. Aeschnidae: *Gomphus* sp., small naiades of a burrowing species.
Hemiptera. Corixidae: common, mostly young nymphs, although a few adults were found.
Diptera. Chironomidae: *Chironomus* sp., few larvae.
Sludge-worms still common.

Station 16.—The Stone bridge, one-half mile east of Sidney, August 9. The stream here appears practically normal. Great beds of water-willow, *Dianthera,* almost choke the stream. A large and varied aquatic insect fauna occurs here, including abundant Odonata and ephemerid naiades.

Ephemerida. Ephemeridae: *Hexagenia bilineata* Say, naiades.
Heptagenia sp., fully grown naiades.
Caenis sp., possibly *diminuta* Wk., naiades.
Callibaetis sp., naiades.
Odonata. Libellulidae: *Libellula pulchella* Dru., naiades.
Coenagrionidae: *Ischnura verticalis* (Say), naiades.
Enallagma sp., naiades.
Hemiptera. Corixidae: common.
Notonectidae: *Notonecta variabilis* Fieb., several, adults and nymphs.
Buenoa platycnemis Fieb., adults and nymphs.
B. margaritacea Bueno, adults.
Gerridae: *Metrobates hesperius* Uhl., adults and nymphs.

	Mesoveliidae: *Mesovelia mulsanti* White, adults and nymphs.
	Hydrometridae: *Hydrometra martini* Kirk, adults.
	Belostomatidae: *Belostoma fluminеum* Say, common, the males with egg-masses.
Neuroptera.	Sialidae: *Sialis infumata* Newm., larvae.
Coleoptera.	Haliplidae: *Peltodytes 12-punctatus* (Say), adults.
	Hydrophilidae: *Tropisternus glaber* (Hbst.), larvae and adults.
	Berosus striatus (Say), larvae and adults.
Diptera.	Chironomidae: *Chironomus* sp., a few larvae.

No sludge-worms are present. *Cambarus* sp. and *Hyalella knickerbockeri* are common. The occurrence especially of *Hexagenia* and *Sialis* point to clean-water conditions. These genera were last taken at Station 11, the Spoon River. Tadpoles, and young catfish and sunfish are common.

Station 17.—Five miles east of Sidney, about three miles west of Homer Park, August 17. At the place where collections were made the stream has a bottom that is almost pure clay. Small fish of fingerling length are abundant and many set-lines of the natives indicate good fishing. Insect life in this clay bottom is not large or varied.

Odonata.	Aeschnidae: *Gomphus* sp., a few naiades.
Hemiptera.	Corixidae: common.
	Gerridae: *Metrobates hesperius* Uhl., nymphs of the second and third instars common.
Neuroptera.	Sialidae: *Sialis infumata* Newm., larva.
Coleoptera.	Gyrinidae: *Dineutes americanus* Say, adults.

Station 18.—Below the dam at Homer Park, August 17. Riffles over the broken stone and small pebbles. An entirely clean-water fauna present.

Plecoptera.	Perlidae: *Perla* sp., naiades.
Ephemerida.	Ephemeridae: *Polymitarcys albus* (Say), naiades.
	Ephemerella sp.
	Caenis sp., possibly *diminuta* Wk.
	Heptagenia sp.
	Baetis sp.
	Chirotenetes albomanicatus Ndm.
Odonata.	Aeschnidae: *Ophiogomphus* sp., naiades.
	Agrionidae: *Hetaerina americana* (Fabr.), adults were common, ovipositing in the clean water.
	Coenagrionidae: *Argia moesta putrida* Hag., adults were common, ovipositing in the clean water.
Hemiptera.	Corixidae: common.
	Hydrometridae: *Hydrometra martini* Kirk., few adults.

	Gerridae: *Metrobates hesperius* Uhl., adults and nymphs abundant.
	Veliidae: *Rhagovelia obesa Uhl.,* adults and nymphs abundant.
Neuroptera.	Sialidae: *Corydalis cornuta* (Linn.), small larvae common.
	Sialis infumata Newm., larvae.
Trichoptera.	Hydropsychidae: *Hydropsyche* sp., extremely common with their nets.
Coleoptera.	Hydrophilidae: *Tropisternus glaber* (Hbst.), adults.
	Berosus striatus (Say), adults.
	Enochrus ochraceus (Melsh.), adults.
	Helmidae: *Stenelmis* sp., adults and larvae common.
Diptera.	Chironomidae: *Chironomus* sp., small larvae.

Station 19.—One and one-half miles east of Homer Park, August 22. Great beds of water-willow, *Dianthera,* in the stream. Collections were made principally in these dense beds.

Ephemerida.	Ephemeridae: *Hexagenia bilineata* Say, naiades.
Odonata.	Aeschnidae: *Gomphus* sp., naiades.
	Coënagrionidae: *Enallagma* sp., naiades.
Hemiptera.	Belostomatidae: *Belostoma fluminеum* Say, adults and nymphs.
	Gerridae: *Gerris marginatus* Say, adults.
	Trepobates pictus (H. S.), adults and nymphs.
	Mesoveliidae: *Mesovelia mulsanti* White, adults and nymphs.
	Hydrometridae: *Hydrometra martini* Kirk., adults and nymphs.
Coleoptera.	Helmidae: *Helmis vittata* Melsh., adults.
	Stenelmis sp., adults and larvae abundant.
	Dascyllidae: *Cyphon* sp., or *Scirtes* sp., larvae very common.
Diptera.	Chironomidae: *Chironomus* sp., larvae.

Cambarus sp., very abundant. Small catfish and sunfish are very numerous.

Station 20.—Two miles southwest of Fithian, August 22. Here the stream is nearly choked with water-willow, *Dianthera,* with some beds of *Elodea.*

Plecoptera.	Perlidae: *Perla* sp., naiades.
Ephemerida.	Ephemeridae: *Hexagenia bilineata* Say, naiades.
	Polymitarcys albus (Say), naiades.
	Caenis sp., possibly *diminuta* Wk., naiades.
	Baetis sp., naiades.
	Heptagenia sp., naiades.

Odonata.	Libellulidae: *Macromia* sp., possibly *illinoiensis* Walsh, numerous small naiades.
	Coenagrionidae: *Enallagma antennatum* (Say), small naiades.
	Enallagma sp., naiades abundant.
	Agrionidae: *Hetaerina americana* (Fabr.), adults common, ovipositing in the stream.
Hemiptera.	Nepidae: *Ranatra americana* (Mont.), adults.
	Hydrometridae: *Hydrometra martini* Kirk., adults abundant.
	Mesoveliidae: *Mesovelia mulsanti* White, adults abundant.
	Gerridae: *Trepobates pictus* (H. S.), few nymphs and adults.
Neuroptera.	Sialidae: *Sialis infumata* Newm., fully grown larvae.
Coleoptera.	Gyrinidae: *Gyrinus aeneolus* Lec., adults.
	Helmidae: *Helmis vittata* Melsh., adults.
	Stenelmis sp., adults and larvae.
Diptera.	Culicidae: *Anopheles punctipennis* Say, larvae.

Station 21.—Salt Fork, one-fourth mile below its union with Stony Creek, August 25. The bottom is covered with coarse rubble, forming riffles. The banks and margins of the stream are dense with *Dianthera* which in places quite chokes the stream.

Plecoptera.	Perlidae: *Perla* sp., naiades.
Ephemerida.	Ephemeridae: *Hexagenia bilineata* Say, naiades.
	Ephemera sp., naiades.
	Baetis sp., naiades abundant.
	Heptagenia sp., several species, naiades.
	Chirotenetes albomanicatus Ndm., naiades.
Odonata.	Agrionidae: *Hetaerina americana* (Fabr.), adults common, ovipositing in the stream.
	Coenagrionidae: *Argia moesta putrida* Hag. and *Ischnura verticalis* (Say), adults common, ovipositing in the stream.
Hemiptera.	Gerridae: *Metrobates hesperius* Uhl., adults abundant.
	Veliidae: *Rhagovelia obesa* Uhl., adults abundant.
	Mesoveliidae: *Mesovelia mulsanti* White, adults abundant.
Neuroptera.	Sialidae: *Corydalis cornuta* (Linn.) larvae very abundant, all sizes from newly emerged to almost fully grown.
Trichoptera.	Hydropsychidae: *Hydropsyche* sp., larvae and their nets.

Coleoptera. Gyrinidae: *Dineutes americanus* Say, adults scarce.
Helmidae: *Stenelmis* sp., larvae.
Diptera. Chironomidae: *Tanytarsus* sp., larvae and cases.
Cambarus and species of darters were common in the stream.

Station 22.—Stony Creek, one-half mile above its union with the Salt Fork; a check station, August 25. The stream here is small but flowing in riffles. The fauna is strictly that of normally clean water, though slightly different from that of the adjoining parts of the Salt Fork.

Hemiptera. Corixidae: unidentified.
Gerridae, *Trepobates pictus* (H. S.), adults abundant.
Hydrometridae: *Hydrometra martini* Kirk., adults.
Coleoptera. Haliplidae: *Peltodytes 12-punctatus* (Say), adults.
Dryopidae: *Helichus lithophilus* (Germ.), adults abundant.
Helmidae: *Stenelmis* sp., adults abundant.
Diptera. Tabanidae: *Chrysops* sp., larvae.

Station 23. Bridge south of Oakwood, Aug. 29. The collections made here show a large and varied fresh-water fauna.

Plecoptera. Perlidae: *Perla* sp., half-grown naiades.
Ephemerida. Ephemeridae: *Hexagenia bilineata* Say, naiades abundant.
Polymitarcys albus (Say), naiades.
Caenis sp., possibly *diminuta* Wk., naiades.
Heptagenia sp., two species, naiades.
Chirotenetes albomanicatus Ndm.
Baetis sp., naiades.
Odonata. Aeschnidae: *Epiaeschna heros* (Fabr.), naiades.
Gomphus sp., burrowing species, naiades.
Libellulidae: *Macromia* sp., possibly *illinoiensis* Walsh, naiades of various sizes.
Agrionidae: *Hetaerina americana* (Fabr.), adults very abundant, ovipositing in water.
Coenagrionidae: *Enallagma* sp., naiades common.
E. exsulans Hag., adults common.
Hemiptera. Nepidae: *Ranatra americana* (Mont.), adults.
Gerridae: *Trepobates pictus* (H. S.), adults and nymphs.
Metrobates hesperius Uhl., adults and nymphs.
Veliidae: *Rhagovelia obesa* Uhl., adults and nymphs.
Mesoveliidae: *Mesovelia mulsanti* White, adults and nymphs.

	Corixidae: adults.
	Gelastocoridae: *Gelastocoris oculatus* (Fabr.) adults and nymphs along wet margins of stream
Neuroptera.	Sialidae: *Sialis infumata* Newm., larvae.
	Corydalis cornuta (Linn.), larvae.
Trichoptera.	Hydropsychidae: *Hydropsyche* sp., larvae and nets.
Coleoptera.	Gyrinidae: *Dineutes americanus* Say, adults.
	Haliplidae: *Peltodytes 12-punctatus* (Say), adults.
	Hydrophilidae: *Tropisternus glaber* (Hbst.), adults.
	Dryopidae: *Helichus lithophilus* (Germ.), adults.
Diptera.	Tipulidae: *Eriocera* sp., possibly *gibbosa* Doane, larvae beneath stones in rapid water.
	Chironomidae: *Chironomus* sp., larvae abundant.
	Tabanidae: *Tabanus* sp., larva.

Station 24.—Collections made beyond the mouth of the Middle Fork, one and one-half miles south of Hillery. The conditions here were very much as in the Salt Fork farther west. Most collections were made in the rapids and among the roots of the *Dianthera* beds. The water at this date (August 31) was very low and had a strong odor like that of decaying fish.

Plecoptera.	Perlidae: *Pteronarcys dorsata* Say, naiades.
	Perla sp., naiades of various sizes.
Ephemerida.	Ephemeridae: *Caenis* sp., possibly *diminuta* Wk., naiades.
	Heptagenia sp., naiades.
	Chirotenetes albomanicatus Ndm., naiades.
	Callibaetis sp., possibly *ferruginea* Wk., naiades.
Odonata. .	Aeschnidae: *Gomphus* sp., naiades.
	Libellulidae: *Macromia* sp., possibly *illinoiensis* Walsh, naiades common.
	Agrionidae: *Hetaerina americana* (Fabr.), naiades abundant.
	Coenagrionidae: *Argia moesta putrida* Hag., naiades abundant.
Hemiptera.	Corixidae: adults and nymphs.
	Gerridae: *Metrobates hesperius* Uhl., adults.
	Mesoveliidae: *Mesovelia mulsanti* White, adults.
	Veliidae: *Rhagovelia obesa* Uhl., adults and nymphs abundant.
Neuroptera.	Sialidae: *Corydalis cornuta* (Linn.), larvae, all sizes, extremely abundant.
Trichoptera.	Hydropsychidae. *Hydropsyche* sp., larvae abundant.

Coleoptera. Gyrinidae: *Dineutes americanus* Say, adults.
Dryopidae: *Helichus lithophilus* (Germ.), adults.
Helmidae: *Stenelmis* sp., larvae and adults.
Diptera. Tipulidae: *Eriocera* sp., possibly *gibbosa* Doane, larva.

Station 25.—The bridge at Sidney, re-check on September 9 (equals Station 16). Conditions are about as on the previous examination (August 9) except that the water is higher due to heavy rains. A farmer states that until three years ago the stream was pure and supported many fish. The past two years, however, the stream became polluted, although the water looked clear, and all life died out. In 1921 the stream was muddy and vertebrate life re-appeared, this including certain fish, frogs, and turtles. It is of interest to note that the following summer (1922) the stream was again badly polluted and vertebrate life, including virtually all of the fish, was destroyed to a distance of two or three miles beyond Sidney. The exact nature of the pollution has not been ascertained, although it seems probable that it was a waste product of some one of the factories of Champaign and Urbana. Officers from the State Fish Commission who were sent to examine this condition in 1922 at the instance of the local Fish and Game Clubs, reported that it might be some years before the stream re-established its former condition.

Odonata. Coenagrionidae: *Enallagma* sp., naiades.
Hemiptera. Corixidae: adults and nymphs.
Nepidae: *Ranatra americana* (Mont.), adults.
Hydrometridae: *Hydrometra martini* Kirk., adults.
Notonectidae: *Buenoa platycnemis* Fieb., adults and nymphs.
Coleoptera. Dytiscidae: *Laccophilus proximus* Say, adults.
L. maculosus (Germ.), adults.
Hydroporus sp.

Station 26.—The Shakerack Bridge, re-check on September 9 (equals Station 15). The second collection revealed some species that were not noted on the former visit. Stream muddy, with no bottom vegetation.

Ephemerida. Ephemeridae: *Callibaetis* sp., possibly *ferruginea* Walk., naiades abundant.
Odonata. Libellulidae: *Sympetrum* sp., naiades.
Hemiptera. Corixidae: adults and nymphs abundant.
Coleoptera. Dytsicidae: *Laccophilus proximus* Say, adults and larvae abundant.
Diptera. Chironomidae: *Procladius* sp., larvae.
Chironomus sp., larvae abundant.

Station 27.—Benchmark 66, re-check on September 9 (equals Station 14). A very abundant fauna at this time.

Ephemerida. Ephemeridae: *Callibaetis* sp., possibly *ferruginea* Walk., naiades.

Odonata.	Libellulidae: *Plathemis lydia* (Dru.), naiades.
Hemiptera.	Corixidae: adults and nymphs.
Coleoptera.	Dytiscidae: *Laccophilus maculosus* (Germ.), adults.
	Comptotomus interrogatus (Fabr.), adults.
	Dytiscid larvae abundant.
	Haliplidae: *Peltodytes 12-punctatus* (Say), adults.
	P. edentulus Lec., adults.
	Hydrophilidae: *Berosus* sp., larvae abundant.
Diptera.	Chironomidae: *Palpomyia* sp., larvae.
	Procladius sp., larvae.
	Chironomus sp., larvae abundant.

Sludge worms abundant.

Station 28.—Salt Fork, 100 yards south of the railroad bridge near St. Joseph, September 16 (nearly equals Station 13). The water is high and several land areas present on the first examination (July 23) are now submerged. The fauna here is almost identical with that of Station 27.

Ephemerida.	Ephemeridae: *Callibaetis* sp., possibly *ferruginea* Walk., naiades.
Hemiptera.	Corixidae: adults and nymphs abundant.
	Belostomatidae: *Belostoma flumineum* Say, adults and nymphs.
	Gerridae: *Gerris marginatus* Say, adults.
	Mesoveliidae: *Mesovelia mulsanti* White, nymphs.
Coleoptera.	Dytiscidae: *Laccophilus maculosus* (Germ.), adults.
	Haliplidae: *Peltodytes 12-punctatus* (Say), adults abundant.
	Hydrophilidae: *Tropisternus glaber* (Hbst.), adults.
	Berosus striatus Say, adults.
Diptera.	Chironomidae: *Procladius* sp., larvae and pupae.
	Chironomus sp., larvae abundant.

Station 29.—Salt Fork one mile west of the junction with Spoon River, re-check September 16 (equals Station 12). Water very high at this date.

Hemiptera.	Corixidae: adults.
	Belostomatidae: *Belostoma flumineum* Say, adults and nymphs of all sizes.
Coleoptera.	Haliplidae: *Peltodytes 12-punctatus* (Say), adults.
	Hydrophilidae: *Tropisternus glaber* (Hbst.), adults and larvae abundant.
Diptera.	Chironomidae: *Chironomus viridicollis* v. d. W., larvae very abundant.

No Odonata or Ephemerida found.

Station 30.—Salt Fork 100 feet below (east of) Spoon River, September 16. The water is high and very muddy but when the bottom is disturbed it churns up black. The pure water of Spoon River undoubtedly helps very considerably in purifying the waters of the Fork but these are still polluted, at least at this season.

Hemiptera. Corixidae: adults and nymphs.
Coleoptera. Dytiscidae: *Laccophilus proximus* Say, adults.
L. maculosus (Germ.), adults.
Hydrophilidae: *Tropisternus glaber* (Hbst.), adults.
T. lateralis (Fabr.), adults.
Enochrus ochraceus (Melsh.), adults.
Diptera. Chironomidae: *Chironomus* sp., larvae abundant.

No sludge-worms were noted today.

Station 31.—Collections made in the Salt Fork 100 feet below (east of) the entrance of the Boneyard stream, September 23. Water very foul, all stones being draped with the foul-water fungus, *Sphaerotilus natans* Kützing.

Diptera. Chironomidae: *Chironomus* sp., a few larvae.

No sludge-worms noted.

Station 32.—Collection made 100 feet above (west of) the Boneyard stream, September 23. The water looks clear but along the margins the net stirs up black clouds as in a polluted stream.

Odonata. Coenagrionidae: *Ischnura verticalis* (Say), naiades.
Coleoptera. Haliplidae: *Peltodytes 12-punctatus* (Say), adults.
Hydrophilidae: *Tropisternus glaber* (Hbst.), adults.

Asellus is very common here.

Station 33.—Collection made in the Salt Fork 250 feet above (west of) the entrance to the Boneyard stream, September 23. The water here is comparatively pure, the stones being draped with green algae, with beds of *Elodea* growing along the margin.

Hemiptera. Veliidae: *Rhagovelia obesa* Uhl., adults.
Trichoptera. Hydropsychidae: *Hydropsyche* sp., larvae and nets.
Coleoptera. Haliplidae: *Peltodytes 12-punctatus* (Say), adults.

Cambarus sp., young and adults, and *Asellus* are very common at this point.

Notes on the Species of Insects Collected

Plecoptera

As stated elsewhere in this paper, stone-fly naiades are notable inhabitants of rapids and well-aërated streams. In the present collection none were found except in clean water. The majority of specimens discovered in 1921 were species of the genus *Perla*. *Pteronarcys* was found only in the stream beyond the union of the Middle and Salt forks.

Ephemerida

Most species of May-flies are markedly intolerant of pollution. In the present survey, one species *(Callibaetis)* was constantly found in contaminated waters, or even, in one case, in waters that might be considered as polluted. All other members of the family Ephemeridae found, were distinctly clean-water species, these belonging to the genera *Hexagenia, Ephemera, Polymitarcys, Heptagenia, Baetis, Chirotenetes, Caenis, Callibaetis,* and *Ephemerella.*

Odonata

Naiades of *Anax junius* and *Libellula pulchella* were taken at Station 13 under conditions indicating pollution. The latter species has been taken in the Boneyard stream by students in the Department of Zoology at the University of Illinois and must be considered as being the most tolerant species encountered on this survey. Species of the genera *Gomphus* and *Sympetrum* were found in the stream at the Shakerack bridge (Stations 15 and 26) under conditions indicating contamination. All of the above are water-breathing forms. No naiades of the suborder Zygoptera were to be found in the stream except in clean water but there they occurred in great abundance. The Odonate fauna of the unpolluted portions of the Salt Fork belong to the genera *Gomphus, Ophiogomphus, Epiaeschna, Macromia, Hetaerina, Enallagma,* and *Ischnura.* In addition to these naiades, adult dragon-flies were observed ovipositing in the stream. These included *Libellula pulchella* and *Plathemis lydia* at Station 12, where the stream was strongly polluted, but it can not be stated that the naiades mature in polluted or septic streams. The fact that these insects oviposit in places where there is no chance of the continuance of the species is well known, as in temporary puddles over concrete pavement. In clean parts of the Salt Fork other adult dragon-flies seen ovipositing in the stream included such species as *Hetaerina americana, Argia moesta putrida,* and *Ischnura verticalis.*

Hemiptera

A water-strider, *Gerris marginatus,* was observed at Station 4 where conditions were unquestionably septic. As the insect is an air-breather its occurrance here has no significance. At Station 10, where the water was considered to be polluted, the following groups of water-bugs were found: Corixidae, Belostomidae (*Belostoma flumineum,* including nymphs of various sizes as well as adults), Gerridae (*Gerris marginatus* adults), and Mesoveliidae (*Mesovelia mulsanti*, adults; some of them winged—a rather rare occurrence in aquatic Heteroptera and one most frequently observed under conditions such as the present ones). The abundance of these insects under pollutional conditions is scarcely significant since they are all air-breathing forms that can come to the water-surface to obtain their supply of oxygen. The smaller water-striders (Gerridae, *Trepobates pictus* and *Metrobates hesperius;* Velilidae, *Rhagovelia obesa*); the back-swimmers (Notonectidae, *Notonecta variabilis, Buenoa platycnemis, B. margaritacea*); the Nepidae *(Ranatra americana)*, and the Hydrometridae *(Hydrometra martini)* were all closely associated with clean water in the present survey. A number of genera and species of Corixidae were taken but the names are not vailable for consideration in this report.

Neuroptera

The larva of the orl-fly *Sialis infumata* is to be considered as an indicator of fairly clean water conditions, though it has been observed by Needham to prefer trashy places, and one of the European species, *S. lutaria*, was recorded by Kolkwitz and Marsson as living under strongly pollutional conditions. Similarly the larvae of the other Nearctic members of the family Sialidae, *Chauliodes* spp. and *Corydalis cornutus* L., are apparently confined to unpolluted waters. The larvae of the latter, the familiar Dobson or hellgrammite of bass fishermen, was very numerous in the lower portions of the Salt Fork and after the union with the Middle Fork.

Trichoptera

Species of the genus *Hydropsyche*, together with their nets and cases, were very common in the clean waters of the stream. None was observed anywhere in the stream under conditions that could be considered as being pollutional or even contaminate.

Coleoptera

At Station 8 in the most septic part of the Salt Fork, large swarms of whirligig beetles, *Dineutes americanus*, were noted. These, being air-breathers, are quite independent of the poisonous conditions beneath them and a careful search failed to reveal any sign of their larvae. There can be no doubt that they breed in clean waters and later move to the places where found. Whirligigs were common at intervals along the stream and in most instances proved to belong to this same species. Water scavenger-beetles (Hydrophilidae) were common at Stations 10, 13, 28, and 29, in polluted and contaminated portions of the stream. These included a rather considerable number of genera and species *(Tropisternus, Helophorus, Berosus, Enochrus,* and *Paracymus)*. In clearer waters members of this family was less abundant. The polluted waters included not only the adult beetles but also a great abundance of larvae of the same.

Almost the same statements apply to the Haliplidae, two species of *Peltodytes* being very numerous in the stream between St. Joseph and Sidney under conditions that were strongly contaminate. Dytiscidae, the predaceous water-beetles, were about equally common in contaminated portions of the stream and at the critical station (25 and 16) near the bridge at Sidney where clean water conditions obtain for the first time. The Parnid beetles (Dryopoidea) included adults of a species of *Stenelmis* under pollutional conditions at Station 10. The majority of the members of this group appeared only in the cleaner water situations, however, as shown by the large numbers of specimens of *Helichus lithophilus*, *Helmis vittata*, and species of *Stenelmis* taken, the last-named being found both in the larval and adult stages. Although careful search was made for them, no specimens of the water-penny, *Psephenus herricki* (DeKay), were noted.* It may be that the range of the species is more northerly than the latitude of the Salt Fork. Members of the family Dascyllidae were noted commonly along the stream margins and among the beds of *Dianthera* in clean water conditions. The larval stage was the only one noted, and these may belong either to the genus *Cyphon* or to *Scirtes*.

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* The writer can see no just reason for ignoring DeKay's name, *Fluvicola herricki*, applied to the larva of this species, under the misconception of its being an isopod crustacean, six years before the adult beetle was named *Psephenus lecontei* by Leconte. The generic name *Fluvicola* is preoccupied in Aves (Swainson 1827) and so can be dropped from consideration. However, there seems to be no reason for ignoring DeKay's specific name based on the immature stages. Similarly DeKay's *Fluvicola tuberculata* is very probably the larva of *Helichus lithophilus*. An entirely comparable case is found in the May-fly *Prosopistoma foliaceum* Fourc, in Europe, and in this instance the use of this name has never been questioned. The insect was described in 1764 by Geoffrey as a crustaceous form and re-named by Fourcroy in 1785 as a species of Crustacea. It was fully a century after its original discovery that the true relationship of this remarkable insect was made known.

Diptera

Together with the tubificid worms, members of the dipterous families Psychodidae, Chironomidae, and Syrphidae are considered as among the best indicators of septic or pollutional conditions. The larvae of the Psychodidae and Syrphidae are air-breathers, obtaining their supply of oxygen directly from the atmosphere through breathing-tubes, very short in the former case, extremely long and extensile in the case of the rat-tailed maggots (*Eristalis* and *Helophilus*). No members of these septic groups were encountered in the 1921 survey. The great family of midges, Chironomidae, includes a range of species from forms which can stand pollution (such as *Tanypus monilis*, L., *Chironomus plumosus* L., *C. maturus* Joh., and *C. frequens* Joh.); and less tolerant forms (such as *Chironomus crassicaudatus* Mall., *C. decorus* Joh., *C. globiferus* Say, *C. viridicollis* v. d. W., *Tanypus dyari* Coq.) to others which appear to be strictly clean-water species and unable at all to stand pollutional conditions (such as *Chironomus nigricans* Joh., C. *ferrugineovittatus* Zett., and *Procladius concinnus* Coq.). For a detailed consideration of these species the reader is referred to the paper by Richardson (1921a, page 72 and table).

In Europe, Rhode (1912) records *Chironomus interruptus* (Kieff.) and *C. rhyparobius* (Kieff.) as being polysaprobic; *Chironomus dichromocerus* (Kieff.), *Prodiamesa ichthyobrota* (Kieff.) and *Pelobia enhydra rhypophila* Kieff. as being between polysaprobic and alpha mesosaprobic. From the alpha mesosaprobic sub-zone he records *Chironomus pentatomus* (Kieff.), *C. thummi* (Kieff.), *Isocladius albipes* Kieff., *Cricotopus petiolatus* Kieff., *Psectrotanypus brevicalcar* Kieff., *Trichotanypus bifurcatus* Kieff., var., *Dactylocladius setosipennis* Kieff., and *D. hamifer* Kieff. From the beta mesosaprobic zone he records three species of *Chironomus.* The long, snake-like larvae of *Palpomyia* were common in polluted waters at Stations 12, 13, and 27.

The only Tipulidae noted on this survey were a few larvae of a carnivorous species (*Eriocera*) in strictly clean waters. The sewage cranefly (*Erioptera* sp., possibly *vespertina* O. S., discussed by Suter and Moore (1922), is a species that can stand rather unusual conditions of pollution for members of this genus. The two common genera of Ptychopteridae, *Bittacomorpha* and *Ptychoptera*, are well-known inhabitants of contaminated water situations in streams. In Europe, *Ptychoptera contaminata* lives in filthy waters and was found by Kolkwitz and Marsson in their mesosaprobic or polluted zone. Similarly *Bittacomorpha clavipes* was found by Weston and Turner (1917) in the polluted Coweeset stream in Massachusetts. The larvae of members of this family are generally similar to the rat-tailed maggots in form, having the spiracles situated at the ends of an enormously elongated and extensile breathing tube that is projected above the water-level while the larva feeds at will beneath the surface.

A Bibliography of Aquatic Insects

In the following pages is given a list of the papers relating to aquatic insects. An especial effort has been made to complete the bibliography for the past decade. No attempt has been made to include scattered references to distribution, anatomy, histology, and similar subjects, but it has been endeavored to make the bibliography as complete as possible for the immature stages, biology, ecology, and physiology. It should be noted that the references include only those to the stage found in the water—the naiades of Odonata, Plecoptera, and Ephemerida; the nymphs and adults of Hemiptera; the larvae and pupae of Neuroptera, Trichoptera, Lepidoptera, Diptera, and certain Coleoptera; and the larvae and adults of Coleoptera and Hymenoptera. The numerous references to the aerial stages of these insects are altogether omitted. It is the intended purpose of this bibliography to aid the students of hydrobiology and limnology to determine the forms of insect life that they find in the water, and the inclusion of other stages would serve no especial function.

The literature of aquatic insects is widely scattered and there are no exhaustive lists of references except in a few special groups. The relevant articles in these groups are incorporated in the present paper, and those which are provided with a bibliography are indicated in the following list by an asterisk preceding the title.

Sewage Entomology

Headlee, Thomas J.

1919. Practical application of the methods recently discovered for the control of the sprinkling sewage filter fly (*Psychoda alternata*). Journ. Econ. Ent. 12: 35-41, 4 figs., 2 pls.

Headlee, Thos. J., and Beckwith, Charles S.

1918. Sprinkling sewage filter fly, *Psychoda alternata* Say. *Idem,* 11: 395-401.

Johnson, J. W. Haigh

1914. * A contribution to the biology of sewage disposal. Journ. Econ. Biol. 9: 108-124, 127-184, 33 figs.

Kolkwitz, R., and Marsson, M.

1909. Ökologie der tierischen Saprobien. Beiträge zur Lehre von der biologischen gewässerbeurteilung. Internat. Revue Hydrobiol. und Hydrogr. 2: 126-152.

Marsson, M.

1904. Die Abwasser-Flora und -Fauna einiger Kläranlagen bei Berlin und ihre Bedeutung für die Reinigung Stadtischer Abwasser. Mitt. aus d. Konig. Prufungsanstalt fur Wasserversorgung und Abwasserbeseitigung, 4:

Rhode, Carl

1912. Tendipediden des anorganisch verschmutzten Wassers. Deutsch. Ent. Zeitsch., 1912: 289-291.

1912a. Tendipediden des organisch verschmutzten Wassers. *Idem,* 291-298.

Suter, Russell, and Moore, Emmeline

1922. Stream Pollution Studies. New York State Conserv. Comm. 1922: 3-27, 7 pls.

Weston, Robert Spurr, and Turner, C. E.

1917. Studies on the digestion of a sewage-filter effluent by a small and otherwise unpolluted stream. Mass. Inst. Tech. 10: 1-98.

For additional references see Hydrobiology list, Richardson, 1921a; Baker, 1922.

Hydrobiology

Annandale, N.

1921. The aquatic fauna of Seistan. A summary. Rec. Indian Museum, 18: 235-253.

BAKER, FRANK COLLINS

1920. Animal life and sewage in the Genesee River, New York. Amer. Nat., 54: 152-161.

1922. The molluscan fauna of the Big Vermilion River, Illinois, with special reference to its modifications as the result of pollution by sewage and manufacturing wastes. Illinois Biol. Mon.: 1-126, 15 pls.

BROCHER, FRANK

1910. Les Phénomènes capillaires. Leur importance dans la biologie aquatique. Ann. biol. lacustre, 4: 89-138.

DAKIN, WM. J.

1912. Aquatic animals and their environment. The constitution of the external medium, and its effect upon the blood. Internat. Revue Hydrobiol. und Hydrogr. 5: 53-80.

FORBES, STEPHEN A.

1888. Studies on the food of fresh-water fishes. Bul. Illinois State Lab. Nat. Hist., 2: 433-473.

1888a. On the food relations of fresh-water fishes; a summary and discussion. *Idem*, 2: 475-538.

FORBES, STEPHEN A., AND RICHARDSON, R. E.

1913. Studies on the biology of the upper Illinois River. *Idem*, 9: 481-574, pls. 65-85.

1919. Some recent changes in Illinois River biology. *Idem*, [cont. as Bul. Ill. State Nat. Hist. Surv.] 13: 139-156.

GARMAN, H.

1890. A preliminary report on the animals of the Mississippi bottoms near Quincy, Illinois, in August, 1888. Part I. Bul. Ill. State Lab. Nat. Hist., 3: 125-184.

KOLKWITZ, R., AND MARSSON, M.

1908. Ökologie der pflanzlichen Saprobien. Bericht. Deutsch. Bot. Gesellsch., 26 A:

KRAATZ, WALTER C.

1921. * A preliminary general survey of the macrofauna of Mirror Lake on the Ohio State University Campus. Ohio Journ. Sci., 21: 137-182, 2 pls.

LAMPERT, KURT

1910. * Das Leben der Binnengewässer, pp. 1-856, 279 figs., 17 pls.

LUTZ, FRANK E.

1913. Factors in aquatic environments. Journ. N. Y. Ent. Soc., 21: 1-4.

MOORE, EMMELINE
1913. * The Potamogetons in relation to pond culture. Bul. U. S. Bur. Fish., 33 : 255-291, pls. 22-39.

MUTTKOWSKI, RICHARD ANTHONY
1918. * The fauna of Lake Mendota : a qualitative and quantitative survey with special reference to the insects. Trans. Wisconsin Acad. Sci. Arts and Letters, 19 : 374-482, map.

NEEDHAM, JAMES G.
1921. A biological examination of Lake George, N. Y. Scient. Monthly, 1921 : 433-437.

NEEDHAM, JAMES G., JUDAY, CHAUNCY, MOORE, EMMELINE, SIBLEY, CHARLES K., AND TITCOMB, JOHN W.
1922. A biological survey of Lake George, N. Y. N. Y. State Conserv. Comm., 1922 : 1-78, 27 figs.

PALMER, E. LAURENCE
1920. Life-history chart of some common small water creatures. Cornell Rural School Leaflet, 14 : 123-158, 4 pls.

PEARSE, A. S.
1915. * On the food of the small shore fishes in the waters near Madison, Wisconsin. Bul. Wisconsin Nat. Hist. Soc., (n. s.) 13 : 7-22, fig.

PICADO, C.
1913. * Les broméliacées épiphytes. Bul. Sci. France et Belgique, 47 : 215-360, pls. 6-24.

PLATT, EMILIE LOUISE
1915. The population of the "blanket-algae" of freshwater pools. Amer. Nat., 49 : 752-762, 1 map.

RICHARDSON, ROBERT E.
1921. The small bottom and shore fauna of the middle and lower Illinois River and its connecting lakes, Chillicothe to Grafton : its valuation ; its sources of food supply ; and its relation to the fishery. Bul. Illinois State Nat. Hist. Surv., 13 : 363-522, fig., maps.
1921a. Changes in the bottom and shore fauna of the middle Illinois River and its connecting lakes since 1913-1915 as a result of the increase, southward, of sewage pollution. *Idem*, 14 : 33-75.

SCOTT, WILL
1911. The fauna of a solution pool. Proc. Indiana Acad. Sci., 1911 : 395-440.

SHELFORD, V. E.
1913. * Animal communities in temperate America. Bul. Geog. Soc. Chicago, 5: 1-362, diags. 9, figs. 306.

STEINMANN, PAUL
1907. * Die Tierwelt der Gebirgsbäche, eine faunistisch-biologische Studie. Ann. biol. lacustre, 2: 30-163, 11 figs., pl.

WARD, HENRY B., AND WHIPPLE, GEORGE C.
1918. Fresh-water Biology, pp. 1-1111, 1547 figs.

WESENBERG-LUND, CHARLES
1911. Über die Respirationsverhältnisse bei unter dem Eise überwinternden, luftatmenden Wasserinsekten, besonders der Wasserkäfer und Wasserwanzen. Internat. Revue Hydrobiol. und Hydrogr., 3: 467-486.
1915. Insektlivet i ferske vande, pp. 1-524, 378 figs.

GENERAL ENTOMOLOGY

BORNHAUSER, KONRAD
1912. Die Tierwelt der Quellen in der Umgebung Basels. Internat. Revue Hydrobiol. und Hydrogr., Biol. Suppl., 5: 1-90, 2 charts.

BROCHER, FRANK
1911. Observations biologiques sur quelques insectes aquatiques Ann. biol. lacustre, 4: 367-379.
1914a. Recherches sur la respiration des insectes aquatiques (imagos). Nèpe, Hydrophile, Notonecte, Dytiscidés, Haemonia, Elmidés. Internat. Revue Hydrobiol. und Hydrogr., 6: 250-256.

CLAASSEN, P. W.
1921. * Typha insects: their ecological relationships. Cornell Univ. Agr. Exper. Sta. Mem. 47: 459-531, pls. 39-49.

COMSTOCK, J. H.
1918. Nymphs, naiades and larvae. Ann. Ent. Soc. America, 11: 222-224.

HART, C. A.
1895. On the entomology of the Illinois River and adjacent waters. First paper. Bul. Illinois State Lab. Nat. Hist., 4: 149-273, pls. 1-16.

HEYMONS, R.
1896. Grundzuge der Entwickelung und der Korperbaues von Odonaten und Ephemeriden. Abhand. Akad. wissenschaft. Berlin, Anhang, 1896, pp. 66, pls. 2.

MIALL, LOUIS COMPTON
1895. The natural history of aquatic insects, pp. 1-395, 116 figs.

MUTTKOWSKI, RICHARD A.
1920. The respiration of aquatic insects. Bul. Brooklyn Ent. Soc., 15: 89-96, 131-141.

NEEDHAM, JAMES G.
1908. Aquatic insects of Walnut Lake. Report of the State Geologist to the Board of Geol. Survey of Michigan, 1917: 252-271, 1 pl.
1908a. Report of the entomologic field station conducted at Old Forge, N. Y., in the summer of 1905. Bul. N. Y. State Mus. 124: 156-263, 32 pls.
1918. Aquatic Insects, *in* Ward and Whipple's Fresh-water Biology, pp. 876-946, figs. 1354-1392.

NEEDHAM, JAMES G., AND BETTEN, CORNELIUS
1901. Aquatic insects in the Adirondacks. Bul. N. Y. State Mus. 47: 383-612, 36 pls. 42 figs., 2 maps.

NEEDHAM, JAMES G., AND LLOYD, J. T.
1916. * The Life of the inland waters, pp. 438, 244 figs.

NEEDHAM, JAMES G., MACGILLIVRAY, ALEX D., JOHANNSEN, O. A., AND DAVIS, K. C.
1903. Aquatic insects in New York State. Bul. N. Y. State Mus. 68: 199-517, 52 pls.

NEEDHAM, JAMES G., MORTON, KENNETH J., AND JOHANNSEN, O. A.
1905. May-flies and midges. Bul. N. Y. State Mus. 86: 1-352, 37 pls.

NEERACHER, F.
1912. Die Insektenfauna des Rheins und seiner Zuflüsse bei Basel. Archiv für Hydrobiol. und Planktonkunde, 7: 140-160.

NOWROJEE, D.
1912. Life-histories of Indian insects—II. Some aquatic Rhynchota and Coleoptera. Mem. Dept. Agr. in India, Ent. Ser., 2: 165-191, col. pls. 20-26.

ROTH, WILHELM
1909. * Studien uber konvergente Formbildung an der Extremitaten schwimmender Insekten. I. Teil. Hemiptera. Internat. Revue Hydrobiol. und Hydrogr., 2: 187-230, 12 figs., pl. 13.
1909a. * II. Teil. Coleoptera. *Idem,* 2: 668-714, 7 figs., pl. 14.

ROUSSEAU, E. (with collaborators)
1921. * Les larves et nymphes des insectes d'Europe. (Morphologie, biologie, systematique) Vol. 1: xx + 1-967, 341 figs.

THIENEMANN, AUGUST
1912. * Der Bergbach des Sauerlandes. Faunistisch-biologische Untersuchungen. Teil I. Die Organismen des mitteldeutschen Bergbaches. Internat. Revue Hydrobiol. und Hydrogr., Biol. Suppl., 4: 1-125, 5 charts.

COLLEMBOLA

HEYMONS, R. AND H.
Collembola. Sűsswasserfauna Deutschlands, 7: 1-16, 24 figs.

PLECOPTERA

KATHARINER, L.
1901. Zur Biologie von *Perla maxima* Scop. (Orthopt.) Allgemein. Zeitsch. Ent., 6: 258-260, 1 fig.

KLAPÁLEK, FR.
1900. Plekopterologische-Studie. Bul. de l'Acad. sci. Bohemê, 9: 1-34, pls. 2.
1909. Plecoptera, Steinfliegen. Süsswasserfauna Deutschlands, 8: 33-95, figs. 123.

KOPONEN, J. S. W.
1917. Plecopterologische Studien. II. Bisher unbekannte larven und nymphen einiger Plecopteren-Arten. Acta Soc. Fauna Flora Fenn., 44, pt. 4: 1-28, 12 figs.

LAUTERBORN, ROBERT
1903. Trakeenkiemen an den Bienen einer Perliden-Larve (*Taeniopteryx nebulosa* L.). Zool. Anzeig., 26: 637-642, 2 figs.

LESTAGE, J.-A.
1918. Études sur la biologie des Plécoptères. I. La Larve de "*Leuctra geniculata* Stephens". Ann. biol. lacustre, 9: 257-268.
1920. II. La larve de "*Nephelopteryx nebulosa* L." *Idem*, 10: 231-260.
1921. * Plecoptera, *in* Rousseau, Les Larves et nymphes aquatiques des insectes d'Europe, pp. 274-320, figs. 73-88.

NEEDHAM, JAMES G., AND SMITH, LUCY W.
1916. The stoneflies of the genus *Peltoperla*. Can. Ent., 48: 80-88, pl. 5.

NUNNEY, W. H.
1892. The British Perlidae or stoneflies. Science Gossip, 1892: 35-39, 49-51.

Pictet, François Jules

1832. Mémoires sur les larves des Némoures. Ann. sci. nat., 26: 369-391, 2 col. pls.

1833. Mémoires sur les métamorphoses des Perles. *Idem*, 28: 44-65, 2 col. pls.

1841–42. Histoire naturelle générale et particulière des insectes Neuroptères. Premier monographie. Famille des Perlides, pp. 423, 53 col. pls.

Reuter, Enzio

1900. Tidigt uppträdande af Perliden *Taeniopteryx nebulosa* L. Medd. Soc. Fauna Flora Fenn., 30: 99-100.

Schoenemund, Eduard

1912. * Zur Biologie und Morphologie einiger *Perle*-Arten. Zool. Jahrb., Anat., 34: 1-56, pls. 1-2.

Schwermer, Wilhelm

1914. * Beiträge zur Biologie und Anatomie von *Perla marginata* Scopoli. Zool. Jahrb., Anat., 37: 267-312, 18 figs.

Smith, Lucy Wright

1913. The biology of *Perla immarginata* Say. Ann. Ent. Soc. America, 6: 203-211, 2 figs., pl. 23.

1917. Studies of North American Plecoptera (Pteronarcinae and Perlodini). Trans. Amer. Ent. Soc., 43: 433-489, 5 figs., pls. 29-34.

Ephemerida

Alm, Gunnar

1918. Till kännedomen om *Prosopistoma foliaceum* Fourc. Ent. Tidskr., 39: 54-59, fig.

Bengtsson, Simon

1909. Beiträge zur Kenntnis der Paläarktischen Ephemeriden. Lund Univ. Årsskr., 5: 1-19.

1913. * Undersökningar öfver äggen hos Ephemeriderna. Ent. Tidskr., 34: 272-318, 14 figs., 3 pls.

1917. Weitere Beiträge zur Kenntnis der nordischen Eintagsfliegen. *Idem*, 38: 174-194.

Bernard, Carl

1907. Über die vivipare Ephemeride *Chloëon dipterum*. Biol. Centralbl., 27: 467-479, 6 figs.

Berry, Edward W.

1903. New or hitherto unknown Ephemerid nymphs of the Eastern United States. Amer. Nat.; 37: 25-31, 4 figs.

CLEMENS, WILBERT AMIE

1913. New species and life histories of Ephemeridae or may flies. Can. Ent., 45: 246-262, 329-341, pls. 5-7.

1915. Rearing experiments and ecology of Georgian Bay Ephemeridae. *In* Contributions to Canadian Biology, being studies from the Biological Stations of Canada, 1911-1914. Fasc. II. Freshwater Fish and Lake Biology. Ann. Rep. Dept. Marine and Fisheries, 47, Suppl.

1915a. Life-histories of Georgian Bay Ephemeridae: observations on *Heptagenia* and breeding experiments. *Idem.*

1915b. Mayflies of the *Siphloneurus* group. Can. Ent., 47: 245-260, pls. 9-11.

1917. * An ecological study of the mayfly *Chirotenetes*. Univ. Toronto Studies, Biol. ser., 17: 1-43, pls. 1-5.

1922. A parthenogenetic mayfly (*Ameletus ludens* Needham). Can. Ent., 54: 77-78.

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DRENKELFORT, HEINRICH

1910. * Neue Beiträge zur Kenntnis der Biologie und Anatomie von *Siphlurus lacustris* Eaton. Zool. Jahrb., Anat., 29: 527-617, pls. 40-42.

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GRENACHER, H.

1868. Beiträge zur Kenntniss des Eies der Ephemeriden. Zeitsch. wissensch. Zool., 18: 95-98, pl. 5.

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1887. Note on the oviposition and the duration of the egg-stage of *Ephemerella ignita*. Ent. Mo. Mag., (1) 23: 235.

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1911. * Zur Biologie und Anatomie von *Cloëon dipterum* L., *Baetis binoculatus* L. und *Habrophlebia fusca* Curt. Jenaische Zeitsch. für Naturwiss., 53: 289-310, 43 figs.

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1905. *Polymitarcys albus* Say. Bul. N. Y. State Mus. 86: 60-62, pl. 12.

KLAPÁLEK, FR.

1909. Ephemerida, Eintagsfliegen. Süsswassersfauna Deutschlands, 8: 1-32, 53 figs.

LESTAGE, J.-A.

1917. * Contribution à l'étude des larves des Ephémerès paléarctiques. Ann. biol. lacustre, 8: 213-458, 54 figs.

1918. The same, ser. 2. *Idem*, 9: 79-182, 13 figs.

1921. * Ephemeroptera, *in* Rousseau, Les larves et nymphes aquatiques des insectes d'Europe, pp. 162-273, figs. 40-72.

MORGAN, ANN HAVEN

1911. May-flies of Fall Creek. Ann. Ent. Soc. Amer., 4: 93-126, pls. 6-12.

1913. * A contribution to the biology of may-flies. *Idem,* 6: 371-426, pls. 42-54.

MORRISON, EMILY REED

1919. The may-fly ovipositor, with notes on *Leptophlebia* and *Hagenulus*. Can. Ent., 51: 139-146, pls. 10-11.

MURPHY, HELEN E.

1922. Notes on the biology of some of our North American species of May-flies. Bul. Lloyd Library, Ent. ser., 2: 1-46, 7 pls.

NEEDHAM, JAMES G.

1901. Ephemerida. Bul. N. Y. State Mus. 47: 418-429.

1905. Ephemeridae. *In* Mayflies and Midges, *Idem*, 86: 17-62, 14 figs., pls. 4-12.

1920. * Burrowing mayflies of our larger lakes and streams. Bul. Bur. of Fisheries, 36: 265-292, pls. 71-82.

PETERSEN, P. ESBEN-

1914. *Rhithrogena ussingi* E. Peters. and its larva. Ent. Meddelel., 10: 168-171, 2 figs.

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POPOVICI-BAZNOSANU, A.

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Walsh, Benj. D.
1864. On the pupa of the Ephemerinous genus *Baetisca* Walsh. Proc. Ent. Soc. Philadelphia, 3: 200-206, fig.

Wodsedalek, J. E.
1911. Phototactic reactions and their reversal in the may-fly nymphs *Heptagenia interpunctata* (Say). Biol. Bul., 21: 265-272.
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1904. New dragonfly nymphs in the United States National Museum. Proc. U. S. Nat. Mus., 27: 685-720, pls. 38-44.

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BY

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ARTICLE IX.—*The Lake as a Microcosm**. BY STEPHEN A. FORBES.

A lake is to the naturalist a chapter out of the history of a primeval time, for the conditions of life there are primitive, the forms of life are, as a whole, relatively low and ancient, and the system of organic interactions by which they influence and control each other has remained substantially unchanged from a remote geological period.

The animals of such a body of water are, as a whole, remarkably isolated—closely related among themselves in all their interests, but so far independent of the land about them that if every terrestrial animal were suddenly annihilated it would doubtless be long before the general multitude of the inhabitants of the lake would feel the effects of this event in any important way. It is an islet of older, lower life in the midst of the higher, more recent life of the surounding region. It forms a little world within itself—a microcosm within which all the elemental forces are at work and the play of life goes on in full, but on so small a scale as to bring it easily within the mental grasp.

Nowhere can one see more clearly illustrated what may be called the *sensibility* of such an organic complex, expressed by the fact that whatever affects any species belonging to it, must have its influence of some sort upon the whole assemblage. He will thus be made to see the impossibility of studying completely any form out of relation to the other forms; the necessity for taking a comprehensive survey of the whole as a condition to a satisfactory understanding of any part. If one wishes to become acquainted with the black bass, for example, he will learn but little if he limits himself to that species. He must evidently study also the species upon which it depends for its existence, and the various conditions upon which *these* depend. He must likewise study the species with which it comes in competition, and the entire system of conditions affecting their prosperity; and by the time he has studied all these sufficiently he will find that he has run through the whole complicated mechanism of the aquatic life of the locality, both animal and vegetable, of which his species forms but a single element.

It is under the influence of these general ideas that I propose to examine briefly to-night the lacustrine life of Illinois, drawing my data

*This paper, originally read February 25, 1887, to the Peoria Scientific Association (now extinct), and published in their Bulletin, was reprinted many years ago by the Illinois State Laboratory of Natural History in an edition which has long been out of print. A single copy remaining in the library of the Natural History Survey is used every year by classes in the University of Illinois, and a professor of zoology in a Canadian university borrows a copy regularly from a Peoria library for use in his own classes. In view of this long-continued demand and in the hope that the paper may still be found useful elsewhere, it is again reprinted, with trivial emendations, and with no attempt to supply its deficiencies or to bring it down to date.

from collections and observations made during recent years by myself and my assistants of the State Laboratory of Natural History.

The lakes of Illinois are of two kinds, fluviatile and water-shed. The fluviatile lakes, which are much the more numerous and important, are appendages of the river systems of the state, being situated in the river bottoms and connected with the adjacent streams by periodical overflows. Their fauna is therefore substantially that of the rivers themselves, and the two should, of course, be studied together.

They are probably in all cases either parts of former river channels, which have been cut off and abandoned by the current as the river changed its course, or else are tracts of the high-water beds of streams over which, for one reason or another, the periodical deposit of sediment has gone on less rapidly than over the surrounding area, and which have thus come to form depressions in the surface which retain the waters of overflow longer than the higher lands adjacent. Most of the numerous "horseshoe lakes" belong to the first of these varieties, and the "bluff-lakes," situated along the borders of the bottoms, are many of them examples of the second.

These fluviatile lakes are most important breeding grounds and reservoirs of life, especially as they are protected from the filth and poison of towns and manufactories by which the running waters of the state are yearly more deeply defiled.

The amount and variety of animal life contained in them as well as in the streams related to them is extremely variable, depending chiefly on the frequency, extent, and duration of the spring and summer overflows. This is, in fact, the characteristic and peculiar feature of life in these waters. There is perhaps no better illustration of the methods by which the flexible system of organic life adapts itself, without injury, to widely and rapidly fluctuating conditions. Whenever the waters of the river remain for a long time far beyond their banks, the breeding grounds of fishes and other animals are immensely extended, and their food supplies increased to a corresponding degree. The slow or stagnant backwaters of such an overflow afford the best situations possible for the development of myriads of Entomostraca, which furnish, in turn, abundant food for young fishes of all descriptions. There thus results an outpouring of life—an extraordinary multiplication of nearly every species, most prompt and rapid, generally speaking, in such as have the highest reproductive rate, that is to say, in those which produce the largest average number of eggs and young for each adult.

The first to feel this tremendous impulse are the protophytes and Protozoa, upon which most of the Entomostraca and certain minute insect larvæ depend for food. This sudden development of their food resources causes, of course, a corresponding increase in the numbers of the latter classes, and, through them, of all sorts of fishes. The first fishes to feel the force of this tidal wave of life are the rapidly-breeding, non-predaceous kinds; and the last, the game fishes, which derive from the others their principal food supplies. Evidently each of these classes must act as a check upon the one preceding it. The development of animalcules is arrested and soon sent back below its highest point by the consequent development of Entomostraca; the latter, again, are met, checked, and reduced in number by the innumerable shoals of fishes with which the water speedily swarms. In this way a general adjustment of numbers to the new conditions would finally be reached spontaneously; but long before any such settled balance can be established, often of course before the full effect of this upward influence has been exhibited, a new cause of disturbance intervenes in the *disappearance of the overflow*. As the waters retire, the lakes are again defined; the teeming life which they contain is restricted within daily narrower bounds, and a fearful slaughter follows; the lower and more defenceless animals are penned up more and more closely with their predaceous enemies, and these thrive for a time to an extraordinary degree. To trace the further consequences of this oscillation would take me too far. Enough has been said to illustrate the general idea that the life of waters subject to periodical expansions of considerable duration, is peculiarly unstable and fluctuating; that each species swings, pendulum-like but irregularly, between a highest and a lowest point, and that this fluctuation affects the different classes successively, in the order of their dependence upon each other for food.

Where a water-shed is a nearly level plateau with slight irregularities of the surface many of these will probably be imperfectly drained, and the accumulating waters will form either marshes or lakes according to the depth of the depressions. Highland marshes of this character are seen in Ford, Livingston, and adjacent counties,* between the head-waters of the Illinois and Wabash systems; and an area of water-shed lakes occurs in Lake and McHenry counties, in northern Illinois.

The latter region is everywhere broken by low, irregular ridges of glacial drift, with no rock but boulders anywhere in sight. The intervening hollows are of every variety, from mere sink-holes, either dry or occupied by ponds, to expanses of several square miles, forming marshes or lakes.

This is, in fact, the southern end of a broad lake belt which borders Lakes Michigan and Superior on the west and south, extending through eastern and northern Wisconsin and northwestern Minnesota, and occupying the plateau which separates the headwaters of the St. Lawrence from those of the Mississippi. These lakes are of glacial origin, some filling beds excavated in the solid rock, and others collecting the surface waters in hollows of the drift. The latter class, to which all the Illinois lakes belong, may lie either parallel to the line of glacial action, occupying valleys between adjacent lateral moraines, or transverse to that line and bounded by terminal moraines. Those of our own state

*All now drained and brought under cultivation.

all drain at present into the Illinois through the Des Plaines and Fox; but as the terraces around their borders indicate a former water-level considerably higher than the present one it is likely that some of them once emptied eastward into Lake Michigan. Several of these lakes are clear and beautiful sheets of water, with sandy or gravelly beaches, and shores bold and broken enough to relieve them from monotony. Sportsmen long ago discovered their advantages and club-houses and places of summer resort are numerous on the borders of the most attractive and easily accessible. They offer also an unusually rich field to the naturalist, and their zoology and botany should be better known.

The conditions of aquatic life are here in marked contrast to those afforded by the fluviatile lakes already mentioned. Connected with each other or with adjacent streams only by slender rivulets, varying but little in level with the change of the season and scarcely at all from year to year, they are characterized by an isolation, independence, and uniformity which can be found nowhere else within our limits.

Among these Illinois lakes I did considerable work during October of two successive years, using the sounding line, deep-sea thermometer, towing net, dredge, and trawl in six lakes of northern Illinois, and in Geneva Lake, Wisconsin, just across the line. Upon one of these Illinois lakes I spent a week in October, and an assistant, Prof. H. Garman, now of the University, spent two more, making as thorough a physical and zoölogical survey of this lake as was possible at that season of the year.

I now propose to give you in this paper a brief general account of the physical characters and the fauna of these lakes, and of the relations of the one to the other; to compare, in a general way, the animal assemblages which they contain with those of Lake Michigan —where also I did some weeks of active aquatic work in 1881—and with those of the fluviatile lakes of central Illinois; to make some similar comparisons with the lakes of Europe; and, finally, to reach the subject which has given the title to this paper—to study the system of natural interactions by which this mere collocation of plants and animals has been organized as a stable and prosperous community.

First let us endeavor to form the mental picture. To make this more graphic and true to the facts, I will describe to you some typical lakes among those in which we worked; and will then do what I can to furnish you the materials for a picture of the life that swims and creeps and crawls and burrows and climbs through the water, in and on the bottom, and among the feathery water-plants with which large areas of these lakes are filled.

Fox Lake, in the western border of Lake county, lies in the form of a broad irregular crescent, truncate at the ends, and with the concavity of the crescent to the northwest. The northern end is broadest and communicates with Petite Lake. Two points projecting inward from the southern shore form three broad bays. The western end opens into Nippisink Lake, Crab Island separating the two. Fox River enters the lake from the north, just eastward of this island, and flows directly through the Nippisink. The length of a curved line extending through the central part of this lake, from end to end, is very nearly three miles, and the width of the widest part is about a mile and a quarter. The shores are bold, broken, and wooded, except to the north, where they are marshy and flat. All the northern and eastern part of the lake was visibly shallow—covered with weeds and feeding water-fowl, and I made no soundings there. The water there was probably nowhere more than two fathoms in depth, and over most of that area was doubtless under one and a half. In the western part, five lines of soundings were run, four of them radiating from Lippincott's Point, and the fifth crossing three of these nearly at right angles. The deepest water was found in the middle of the mouth of the western bay, where a small area of five fathoms occurs. On the line running northeast from the Point, not more than one and three fourths fathoms is found. The bottom at a short distance from the shores was everywhere a soft, deep mud. Four hauls of the dredge were made in the western bay, and the surface net was dragged about a mile.

Long Lake differs from this especially in its isolation, and in its smaller size. It is about a mile and a half in length by a mile in breadth. Its banks are all bold except at the western end, where a marshy valley traversed by a small creek connects it with Fox Lake, at a distance of about two miles. The deepest sounding made was six and a half fathoms, while the average depth of the deepest part of the bed was about five fathoms.

Cedar Lake, upon which we spent a fortnight, is a pretty sheet of water, the head of a chain of six lakes which open finally into the Fox. It is about a mile in greatest diameter in each direction, with a small but charming island bank near the center, covered with bushes and vines—a favorite home of birds and wild flowers. The shores vary from rolling to bluffy except for a narrow strip of marsh through which the outlet passes, and the bottoms and margins are gravel, sand, and mud in different parts of its area. Much of the lake is shallow and full of water plants; but the southern part reaches a depth of fifty feet a short distance from the eastern bluff.

Deep Lake, the second of this chain, is of similar character, with a greatest depth of fifty-seven feet—the deepest sounding we made in these smaller lakes of Illinois. In these two lakes several temperatures were taken with a differential thermometer. In Deep Lake, for example, at fifty-seven feet I found the bottom temperature 53½°—about that of ordinary well-water—when the air was 63°; and in Cedar Lake, at forty-eight feet, the bottom was 58° when the air was 61°.

Geneva Lake, Wisconsin, is a clear and beautiful body of water about eight miles long by one and a quarter in greatest width. The banks are all high, rolling, and wooded, except at the eastern end, where its outlet rises. Its deepest water is found in its western third, where it reaches a depth of twenty-three fathoms. I made here, early in November, twelve hauls of the dredge and three of the trawl, aggregating about three miles in length, so distributed in distance and depth as to give a good idea of the invertebrate life of the lake at that season.

And now if you will kindly let this suffice for the background or setting of the picture of lacustrine life which I have undertaken to give you, I will next endeavor—not to paint in the picture; for that I have not the artistic skill. I will confine myself to the humble and safer task of supplying you the pigments, leaving it to your own constructive imaginations to put them on the canvas.

When one sees acres of the shallower water black with water-fowl, and so clogged with weeds that a boat can scarcely be pushed through the mass; when, lifting a handful of the latter, he finds them covered with shells and alive with small crustaceans; and then, dragging a towing net for a few minutes, finds it lined with myriads of diatoms and other microscopic algæ, and with multitudes of Entomostraca, he is likely to infer that these waters are everywhere swarming with life, from top to bottom and from shore to shore. If, however, he will haul a dredge for an hour or so in the deepest water he can find, he will invariably discover an area singularly barren of both plant and animal life, yielding scarcely anything but a small bivalve mollusk, a few low worms, and red larvæ of gnats. These inhabit a black, deep, and almost impalpable mud or ooze, too soft and unstable to afford foothold to plants even if the lake is shallow enough to admit a sufficient quantity of light to its bottom to support vegetation. It is doubtless to this character of the bottom that the barrenness of the interior parts of these lakes is due; and this again is caused by the selective influence of gravity upon the mud and detritus washed down by rains. The heaviest and coarsest of this material necessarily settles nearest the margin, and only the finest silt reaches the remotest parts of the lakes, which, filling most slowly, remain, of course, the deepest. This ooze consists very largely, also, of a fine organic *debris*. The superficial part of it contains scarcely any sand, but has a greasy feel and rubs away, almost to nothing, between the fingers. The largest lakes are not therefore, as a rule, by any means the most prolific of life, but this shades inward rapidly from the shore, and becomes at no great distance almost as simple and scanty as that of a desert.

Among the weeds and lily-pads upon the shallows and around the margin—the Potamogeton, Myriophyllum, Ceratophyllum, Anacharis, and Chara, and the common Nelumbium,—among these the fishes chiefly swim or lurk, by far the commonest being the barbaric bream[1] or "pumpkin-seed" of northern Illinois, splendid with its green and scarlet and purple and orange. Little less abundant is the common perch (*Perca lutea*) in the larger lakes—in the largest out-numbering the bream itself. The whole sunfish family, to which the latter belongs, is in fact the dominant group in these lakes. Of the one hundred and thirty-two fishes of Illinois only thirty-seven are found in these waters—about twenty-

[1]Lepomis gibbosus.

eight per cent.—while eight out of our seventeen sunfishes (*Centrarchinae*) have been taken there. Next, perhaps, one searching the pebbly beaches or scanning the weedy tracts will be struck by the small number of minnows or cyprinoids which catch the eye or come out in the net. Of our thirty-three Illinois cyprinoids, only six occur there—about eighteen per cent.—and only three of these are common. These are in part replaced by shoals of the beautiful little silversides (*Labidesthes sicculus*), a spiny-finned fish, bright, slender, active, and voracious—as well suppliel with teeth as a perch, and far better equipped for self-defense than the soft-bodied and toothless cyprinoids. Next we note that of our twelve catfishes (*Siluridae*) only two have been taken in these lakes—one the common bullhead (*Ictalurus nebulosus*), which occurs everywhere, and the other an insignificant stone cat, not as long as one's thumb. The suckers, also, are much less abundant in this region than farther south, the buffalo fishes[1] not appearing at all in our collections. Their family is represented by worthless carp[2] by two redhorse[3], by the chub sucker[4] and the common sucker (*Catostomus teres*), and by one other species. Even the hickory shad[5]—an ichthyological weed in the Illinois—we have not found in these lakes at all. The sheepshead[6], so common here, is also conspicuous there by its absence. The yellow bass[7], not rare in this river, we should not expect in these lakes because it is, rather, a southern species; but why the white bass[8], abundant here, in Lake Michigan, and in the Wisconsin lakes, should be wholly absent from the lakes of the Illinois plateau, I am unable to imagine. If it occurs there at all, it must be rare, as I could neither find nor hear of it.

A characteristic, abundant, and attractive little fish is the log perch (*Percina caprodes*)—the largest of the darters, slender, active, barred like a zebra, spending much of its time in chase of Entomostraca among the water plants, or prying curiously about among the stones for minute insect larvæ. Six darters in all (*Etheostomatinae*), out of the eighteen from the state, are on our list from these lakes. The two black bass[9] are the most popular game fishes—the large-mouthed species being much the most abundant. The pickerels[10], gar[11], and dogfish[12] are there about as here; but the shovel-fish[13] does not occur.

Of the peculiar fish fauna of Lake Michigan—the burbot[14], white fish,[15] trout,[16] lake herring or cisco,[17] etc., not one species occurs in these smaller lakes, and all attempts to transfer any of them have failed completely. The cisco is a notable fish of Geneva Lake, Wisconsin, but does not reach Illinois except in Lake Michigan. It is useless to attempt to introduce it, because the deeper areas of the interior lakes are too limited to give it sufficient range of cool water in midsummer.

In short, the fishes of these lakes are substantially those of their

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[1]Ictiobus bubalus. [2]Ictiobus cyprinus. [3]Moxostoma aureolum and M. macrolepidotum. [4]Erimyzon sucetta. [5]Dorosoma cepedianum. [6]Haploidonotus. [7]Roccus interruptus. [8]Roccus chrysops. [9]Micropterus. [10]Esox. [11]Lepidosteus. [12]Amia. [13]Polyodon. [14]Lota. [15]Coregonus clupeiformis. [16]Salvelinus namaycush. [17]Coregonus artedi.

region—excluding the Lake Michigan series (for which the lakes are too small and warm) and those peculiar to creeks and rivers. Possibly the relative scarcity of catfishes (*Siluridae*) is due to the comparative clearness and cleanness of these waters. I see no good reason why minnows should be so few, unless it be the abundance of pike and Chicago sportsmen.

Concerning the molluscan fauna, I will only say that it is poor in bivalves—as far as our observations go—and rich in univalves. Our collections have been but partly determined, but they give us three species of Valvata, seven of Planorbis, four Amnicolas, a Melantho, two Physas, six Limnæas, and an Ancylus among the Gastropoda, and two Unios, an Anodonta, a Sphærium, and a Pisidium among the Lamellibranchiates. *Pisiduim variabile* is by far the most abundant mollusk in the oozy bottom in the deeper parts of the lakes; and crawling over the weeds are multitudes of small Amnicolas and Valvatas.

The entomology of these lakes I can merely touch upon, mentioning only the most important and abundant insect larvæ. Hiding under stones and driftwood, well aware, no doubt, what enticing morsels they are to a great variety of fishes, we find a number of species of ephemerid larvæ whose specific determination we have not yet attempted. Among the weeds are the usual larvæ of dragon-flies—Agrionina and Libellulina, familiar to every one; swimming in open water the predaceous larvæ of Corethra; wriggling through the water or buried in the mud the larvæ of Chironomus—the shallow water species white, and those from the deeper ooze of the central parts of the lakes blood-red and larger. Among Chara on the sandy bottom are a great number and variety of interesting case-worms—larvæ of Phryganeidæ—most of them inhabiting tubes of a slender conical form made of a viscid secretion exuded from the mouth and strengthened and thickened by grains of sand, fine or coarse. One of these cases, nearly naked, but usually thinly covered with diatoms, is especially worthy of note, as it has been reported nowhere in this country except in our collections, and was indeed recently described from Brazil as new. Its generic name is Lagenopsyche, but its species undetermined. These larvæ are also eaten by fishes.

Among the worms we have of course a number of species of leeches and of planarians,—in the mud minute Anguillulidæ, like vinegar eels, and a slender Lumbriculus which makes a tubular mud burrow for itself in the deepest water, and also the curious *Nais probiscidea*, notable for its capacity of multiplication by transverse division.

The crustacean fauna of these lakes is more varied than any other group. About forty species were noted in all. Crawfishes were not especially abundant, and most belonged to a single species, *Cambarus virilis*. Two amphipods occurred frequently in our collections; one, less common here but very abundant farther south—*Crangonyx gracilis*—and one, *Allorchestes dentata*, probably the commonest animal in these waters, crawling and swimming everywhere in myriads among the submerged water-plants. An occasional *Gammarus fasciatus* was also taken in the dredge. A few isopod Crustacea occur, belonging to *Mancasellus tenax*—a species not previously found in the state.

I have reserved for the last the Entomostraca—minute crustaceans of a surprising number and variety, and of a beauty often truly exquisite. They belong wholly, in our waters, to the three orders, Copedoda, Ostracoda, and Cladocera—the first two predaceous upon still smaller organisms and upon each other, and the last chiefly vegetarian. Twenty-one species of Cladocera have been recognized in our collections, representing sixteen genera. It is an interesting fact that twelve of these species are found also in the fresh waters of Europe. Five cyprids have been detected, two of them common to Europe, and also an abundant Diaptomus, a variety of a European species. Several Cyclops species were collected which have not yet been determined.

These Entomostraca swarm in microscopic myriads among the weeds along the shore, some swimming freely, and others creeping in the mud or climbing over the leaves of plants. Some prefer the open water, in which they throng locally like shoals of fishes, coming to the surface preferably by night, or on dark days, and sinking to the bottom usually by day to avoid the sunshine. These pelagic forms, as they are called, are often exquisitely transparent, and hence almost invisible in their native element—a charming device of Nature to protect them against their enemies in the open lake, where there is no chance of shelter or escape. Then with an ingenuity in which one may almost detect the flavor of sarcastic humor, Nature has turned upon these favored children and endowed their most deadly enemies with a like transparency, so that wherever the towing net brings to light a host of these crystalline Cladocera, there it discovers also swimming, invisible, among them, a lovely pair of robbers and beasts of prey—the delicate Leptodora and the Corethra larva.

These slight, transparent, pelagic forms are much more numerous in Lake Michigan than in any of the smaller lakes, and peculiar forms occur there commonly which are rare in the larger lakes of Illinois and entirely wanting in the smallest. The transparent species are also much more abundant in the isolated smaller lakes than in those more directly connected with the rivers.

The vertical range of the animals of Geneva Lake showed clearly that the barrenness of the interiors of these small bodies of water was not due to the greater depth alone. While there were a few species of crustaceans and case-worms which occurred there abundantly near shore but rarely or not at all at depths greater than four fathoms, and may hence be called littoral species, there was, on the whole, little diminution either in quantity or variety of animal life until about fifteen fathoms had been reached. Dredging at four or five fathoms were nearly or quite as fruitful as any made. On the other hand, the barrenness of the bottom at twenty to twenty-three fathoms was very remarkable. The total product of four hauls of the dredge and one of the trawl at that depth, aggregating fully a mile and a half of continuous dragging, would easily go into a two-dram vial, and represents only nine animal species—not counting dead shells, and fragments which had probably floated in from shallower waters. The greater part of this little collection was composed of specimens of Lumbriculus and larvæ of Chironomus. There were a few Corethra larvæ, a single Gammarus, three small leeches, and some sixteen mollusks, all but four of which belonged to Pisidium. The others were two Sphæriums, a *Valvata carinata,* and a *V. sincera.* None of the species taken here are peculiar, but all were of the kinds found in the smaller lakes, and all occurred also in shallower water. It is evident that these interior regions of the lakes must be as destitute of fishes as they are of plants and lower animals.

While none of the deep-water animals of the Great Lakes were found in Geneva Lake, other evidences of zoölogical affinity were detected. The towing net yielded almost precisely the assemblage of species of Entomostraca found in Lake Michigan, including many specimens of *Limnocalanus macrurus* Sars; and peculiar long, smooth leeches, common in Lake Michigan but not occurring in the small Illinois lakes, were also found in Geneva. Many *Valvata tri-carinata* lacked the middle carina, as in Long Lake and other *isolated* lakes of this region.

Comparing the Daphnias of Lake Michigan with those of Geneva Lake, Wis. (nine miles long and twenty-three fathoms in depth), those of Long Lake, Ill. (one and a half miles long and six fathoms deep), and those of other, still smaller, lakes of that region, and the swamps and smaller ponds as well, we shall be struck by the inferior development of the Entomostraca of the larger bodies of water in numbers, in size and robustness, and in reproductive power. Their smaller numbers and size are doubtless due to the relative scarcity of food. The system of aquatic animal life rests essentially upon the vegetable world, although perhaps less strictly than does the terrestrial system, and in a large and deep lake vegetation is much less abundant than in a narrower and shallower one, not only relatively to the amount of water but also to the area of the bottom. From this deficiency of plant life results a deficiency of food for Entomostraca, whether of algæ, of Protozoa, or of higher forms, and hence, of course, a smaller number of the Entomostraca themselves, and these with more slender bodies, suitable for more rapid locomotion and wider range.

The difference of reproductive energy, as shown by the much smaller egg-masses borne by the species of the larger lakes, depends upon the vastly greater destruction to which the paludal Crustacea are subjected. Many of the latter occupy waters liable to be exhausted by drought, with a consequent enormous waste of entomostracan life. The opportunity for reproduction is here greatly limited—in some situations to early spring alone—and the chances for destruction of the summer eggs in the dry and often dusty soil are so numerous that only the most prolific species can maintain themselves.

Further, the marshes and shallower lakes are the favorite breeding grounds of fishes, which migrate to them in spawning time if possible, and it is from the Entomostraca found here that most young fishes get their earliest food supplies—a danger from which the deep-water species are measurably free. Not only is a high reproductive rate rendered unnecessary among the latter by their freedom from many dangers to which the shallow-water species are exposed, but in view of the relatively small amount of food available for them, a high rate of multiplication would be a positive injury, and could result only in wholesale starvation.

All these lakes of Illinois and Wisconsin, together with the much larger Lake Mendota at Madison (in which also I have done much work with dredge, trawl, and seine), differ in one notable particular both from Lake Michigan and from the larger lakes of Europe. In the latter the bottoms in the deeper parts yield a peculiar assemblage of animal forms which range but rarely into the littoral region, while in our inland lakes no such deep water fauna occurs, with the exception of the cisco and the large red Chironomus larva. At Grand Traverse Bay, in Lake Michigan, I found at a depth of one hundred fathoms a very odd fish of the sculpin family (*Triglopsis thompsoni* Gir.) which, until I collected it, had been known only from the stomachs of fishes; and there also was an abundant crustacean, Mysis—the "opossum shrimp", as it is sometimes called—the principal food of these deep lake sculpins. Two remarkable amphipod crustaceans also belong in a peculiar way to this deep water. In the European lakes the same Mysis occurs in the deepest part, with several other forms not represented in our collections, two of these being blind crustaceans related to those which in this country occur in caves and wells.

Comparing the other features of our lake fauna with that of Europe, we find a surprising number of Entomostraca identical; but this is a general phenomenon, as many of the more abundant Cladocera and Copepoda of our small wayside pools are either European species, or differ from them so slightly that it is doubtful if they ought to be called distinct.

It would be quite impossible, within reasonable limits, to go into details respecting the organic relations of the animals of these waters, and I will content myself with two or three illustrations. As one example of the varied and far-reaching relations into which the animals of a lake are brought in the general struggle for life, I take the common black bass. In the dietary of this fish I find, at different ages of the individual, fishes of great variety, representing all the important orders of that class; insects in considerable number, especially the various water-bugs and larvæ of day-flies; fresh-water shrimps; and a great multitude of Entomostraca of many species and genera. The fish is therefore directly dependent upon all these classes for its existence. Next, looking to the food of the species which the bass has eaten, and upon which it is therefore indirectly dependent, I find that one kind of the fishes taken feeds upon mud, algæ, and Entomostraca, and another upon nearly every animal substance in the water, including mollusks and decomposing organic matter. The insects taken by the bass, themselves take other insects and small Crustacea. The crawfishes are nearly omnivorous, and of the other crustaceans some eat Entomostraca and some algæ and Protoza. At only the second step, therefore, we find our bass brought into dependence upon nearly every class of animals in the water.

And now, if we search for its competitors we shall find these also extremely numerous. In the first place, I have found that all our young fishes except the Catostomidæ feed at first almost wholly on Entomostraca, so that the little bass finds himself at the very beginning of his life engaged in a scramble for food with all the other little fishes in the lake. In fact, not only young fishes but a multitude of other animals as well, especially insects and the larger Crustacea, feed upon these Entomostraca, so that the competitors of the bass are not confined to members of its own class. Even mollusks, while they do not directly compete with it do so indirectly, for they appropriate myriads of the microscopic forms upon which the Entomostraca largely depend for food. But the enemies of the bass do not all attack it by appropriating its food supplies, for many devour the little fish itself. A great variety of predaceous fishes, turtles, water-snakes, wading and diving birds, and even bugs of gigantic dimensions destroy it on the slightest opportunity. It is in fact hardly too much to say that fishes which reach maturity are relatively as rare as centenarians among human kind.

As an illustration of the remote and unsuspected rivalries which reveal themselves on a careful study of such a situation, we may take the relations of fishes to the bladderwort[1]—a flowering plant which fills many acres of the water in the shallow lakes of northern Illinois. Upon the leaves of this species are found little bladders—several hundred to each plant—which when closely examined are seen to be tiny traps for the capture of Entomostraca and other minute animals. The plant usually has no roots, but lives entirely upon the animal food obtained through these little bladders. Ten of these sacs which I took at random from a mature plant contained no less than ninety-three animals (more than nine to a bladder), belonging to twenty-eight different species. Seventy-six of these were Entomostraca, and eight others were minute insect larvæ. When we estimate the myriads of small insects and Crustacea which these plants must appropriate during a year to their own support, and consider the fact that these are of the kinds most useful as food for young fishes of nearly all descriptions, we must conclude that the bladderworts compete with fishes for food, and tend to keep down their number by diminishing the food resources of the young. The plants even have a certain advantage in this competition, since they are not strictly dependent on Entomostraca, as the fishes are, but sometimes take root, developing then but very few leaves and bladders. This probably happens under conditions unfavorable to their support by the other

[1]Utricularia.

method. These simple instances will suffice to illustrate the intimate way in which the living forms of a lake are united.

Perhaps no phenomenon of life in such a situation is more remarkable than the steady balance of organic nature, which holds each species within the limits of a uniform average number, year after year, although each one is always doing its best to break across boundaries on every side. The reproductive rate is usually enormous and the struggle for existence is correspondingly severe. Every animal within these bounds has its enemies, and Nature seems to have taxed her skill and ingenuity to the utmost to furnish these enemies with contrivances for the destruction of their prey in myriads. For every defensive device with which she has armed an animal, she has invented a still more effective apparatus of destruction and bestowed it upon some foe, thus striving with unending pertinacity to outwit herself; and yet life does not perish in the lake, nor even oscillate to any considerable degree, but on the contrary the little community secluded here is as prosperous as if its state were one of profound and perpetual peace. Although every species has to fight its way inch by inch from the egg to maturity, yet no species is exterminated, but each is maintained at a regular average number which we shall find good reason to believe is the greatest for which there is, year after year, a sufficient supply of food.

I will bring this paper to a close, already too long postponed, by endeavoring to show how this beneficent order is maintained in the midst of a conflict seemingly so lawless.

It is a self-evident proposition that a species can not maintain itself continuously, year after year, unless its birth-rate at least equals its death-rate. If it is preyed upon by another species, it must produce regularly an excess of individuals for destruction, or else it must certainly dwindle and disappear. On the other hand, the dependent species evidently must not appropriate, on an average, any more than the surplus and excess of individuals upon which it preys, for if it does so it will continuously diminish its own food supply, and thus indirectly but surely exterminate itself. The interests of both parties will therefore be best served by an adjustment of their respective rates of multiplication such that the species devoured shall furnish an excess of numbers to supply the wants of the devourer, and that the latter shall confine its appropriations to the excess thus furnished. We thus see that there is really a close *community of interest* between these two seemingly deadly foes.

And next we note that this common interest is promoted by the process of natural selection; for it is the great office of this process to eliminate the unfit. If two species standing to each other in the relation of hunter and prey are or become badly adjusted in respect to their rates of increase, so that the one preyed upon is kept very far below the normal number which might find food, even if they do not presently obliterate each other the pair are placed at a disadvantage in the battle for life, and must suffer accordingly. Just as certainly as the thrifty business man who lives within his income will finally dispossess his shiftless competitor who can never pay his debts, the well-adjusted aquatic animal will in time crowd out its poorly-adjusted competitors for food and for the various goods of life. Consequently we may believe that in the long run and as a general rule those species which have survived, are those which have reached a fairly close adjustment in this particular.[1]

Two ideas are thus seen to be sufficient to explain the order evolved from this seeming chaos; the first that of a general community of interests among all the classes of organic beings here assembled, and the second that of the beneficent power of natural selection which compels such adjustments of the rates of destruction and of multiplication of the various species as shall best promote this common interest.

Have these facts and ideas, derived from a study of our aquatic microcosm, any general application on a higher plane? We have here an example of the triumphant beneficence of the laws of life applied to conditions seemingly the most unfavorable possible for any mutually helpful adjustment. In this lake, where competitions are fierce and continuous beyond any parallel in the worst periods of human history; where they take hold, not on goods of life merely, but always upon life itself; where mercy and charity and sympathy and magnanimity and all the virtues are utterly unknown; where robbery and murder and the deadly tyranny of strength over weakness are the unvarying rule; where what we call wrong-doing is always triumphant, and what we call goodness would be immediately fatal to its possessor,—even here, out of these hard conditions, an order has been evolved which is the best conceivable without a total change in the conditions themselves; an equilibrium has been reached and is steadily maintained that actually accomplishes for all the parties involved the greatest good which the circumstances will at all permit. In a system where life is the universal good, but the destruction of life the well-nigh universal occupation, an order has spontaneously arisen which constantly tends to maintain life at the highest limit—a limit far higher, in fact, with respect to both quality and quantity, than would be possible in the absence of this destructive conflict. Is there not, in this reflection, solid ground for a belief in the final beneficence of the laws of organic nature? If the system of life is such that a harmonious balance of conflicting interests has been reached where every element is either hostile or indifferent to every other, may we not trust much to the outcome where, as in human affairs, the spontaneous adjustments of nature are aided by intelligent effort, by sympathy, and by self-sacrifice?

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[1]For a fuller statement of this argument, see Bul. Ill. State Lab. Nat. Hist. Vol. I. No. 3. pages 5 to 10.

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