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BOTTOM ANIMAL COMMUNITIES OF THE ISLAND AREA OF WESTERN LAKE ERIE IN THE SUMMER OF 1937[1]

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The resemblance between the communities of different stream stages and those of large lakes has been mentioned frequently (Shelford, 1913) but rarely analyzed. The presence of swift-water animals on wave-beaten shores has been noted by Krecker (1924). Shelford (1913) and Clements and Shelford (1939) took account of the climaxes of large lakes and rivers. The area of study is located about the islands in western Lake Erie immediately north of Sandusky Bay. The waters studied lie within an area 11.50 x 14.35 miles (18.5 x 23.0 kilometers). The water is shallow; more than half of it is less than 30 feet (9.14 M.) and approximately one-fourth is less than 21 feet (6.4 M.) in depth. The greatest depth, located at a point north of Kelleys Island, is 52 feet (15.85 M.). The depression at this point includes three or four square miles with a depth of more than 43 feet (13.1 M.). There are three other shallower pockets northwest and southwest of South Bass Island. (Figs. 1 and 2.)

Strong currents sweep between the islands during storms. There is evidently a moderate current around the south end of Pelee Island at all times, as indicated by the bottom, which is consistently sand. In winter, ice has an important abrasive effect on local bottom conditions and is especially noticeable along the rock and boulder ridge which extends west from Kelleys Island.

The study here reported laid primary emphasis on the bottom communities of the lake proper. In shallow water down to 3.35 feet (0–1 M.) quantitative studies were made through observations made directly on the bottom or from rocks picked up by hand or with tongs. However, bottom samples taken principally with the Petersen bottom sampler formed the basis of most of the work.

The bottom sampler work was supplemented with collections made by the Ekman sampler, a triangular dredge, a Helgoland trawl, a large multiple meshed tow net, a detritus sampler, and the CoVan dredge, which was designed by Mr. CoVan, Ohio State University. It consisted of a flat triangular frame or plate with three draw rods (for attachment of a rope) rigidly fastened upright in the corners; the center of the frame or plate was an opening to which a sack was attached. When weighted at the bottom of the draw rods, this had the advantage of digging into the bottom while drawn at a sharp angle in the water. (Fig. 3.)

Dredge samples were purely qualitative. The Helgoland trawl and a large tow net with several mesh sizes were not effective in securing young fishes.

[1]Contribution from the Franz Theodore Stone Laboratory of Ohio State University, from the Zoological Laboratories of the University of Illinois and from the Department of Zoology of Miami University.

The detritus sampler used to determine the amount of detritus consisted of a lead weight in which a glass tube was inserted. This was dropped to the bottom, forced into the mud, and, in cases of very fine materials, could be brought to the surface of the water with a good sample of the detritus at the surface of the mud

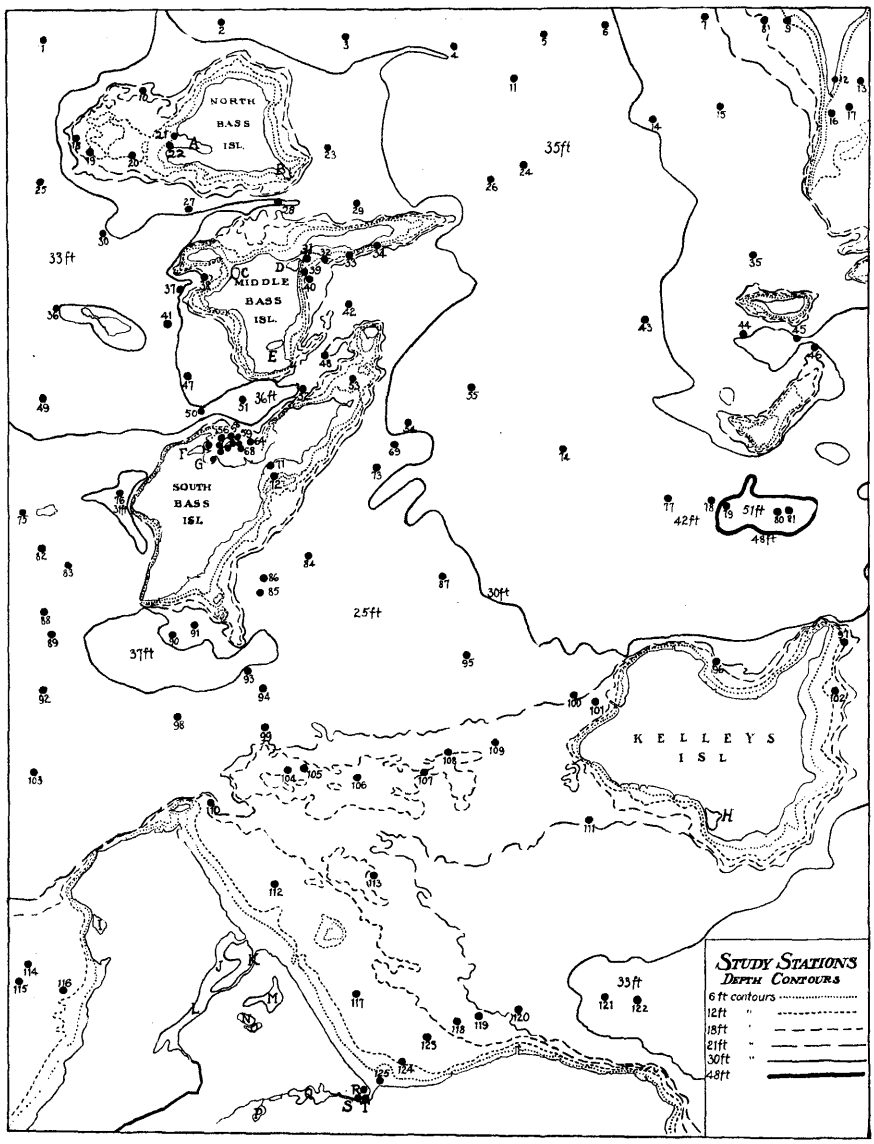

FIG. 1. Map of the area of study with depth contours and the location of stations.

as well as the mud itself. The plankton, which contributes to the detritus, has been studied by others, but no work was done in this connection by the writers.

No attempt to evaluate the stages of succession to land was made. The senior author made extensive studies of these stages at the south end of Lake

Michigan from 1906 to 1912 (Shelford, 1911b, 1911c, 1913). Western Lake Erie conditions are similar, but are characterized by a probably greater abundance of animals, a more open connection with the lake, and a confused arrangement of stages. The last condition makes a prolonged study necessary to advance the knowledge of succession greatly.

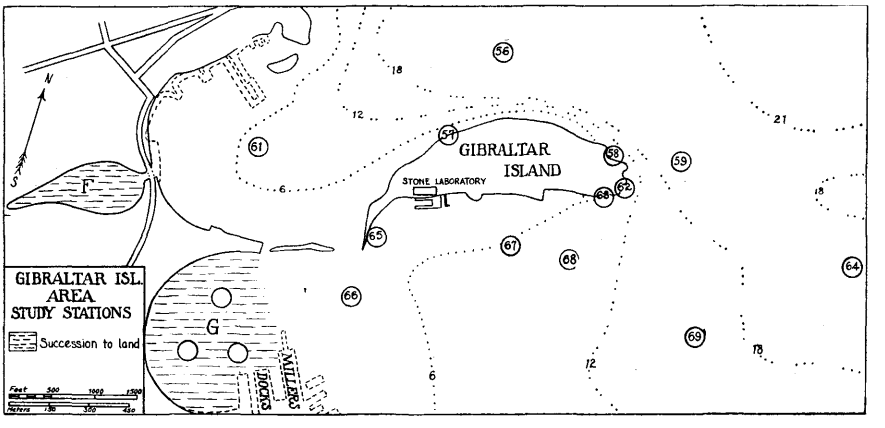

FIG. 2. The details of depth and stations about the Stone Laboratory not shown in Figure 1.

COMMUNITIES

In streams two main types of communities have been recognized, which may be provisionally identified by their habitat characteristics, viz., (a) turbulent-water, hard-bottom communities and (b) still-water, mud-bottom communities. There are also communities less distinct and usually intermediate in character (Shelford and Eddy, 1929). Climax aquatic communities are partially controlled by animals, and the habitats dominated by vegetation are usually stages of succession to land. (Fig. 4.)

In dealing with the communities in the area of study, the general subdivisions were found to apply. The still-water, mud-bottom communities will be considered last, and the turbulent-water, hard-bottom communities will be presented first.

THE GONIOBASIS-HYDROPSYCHE COMMUNITY.

According to the conclusions derived from the study of streams (Shelford in Clements and Shelford, 1939), attention is brought to the communities of turbulent waters, which stand out in contrast to those of the still water as described below.

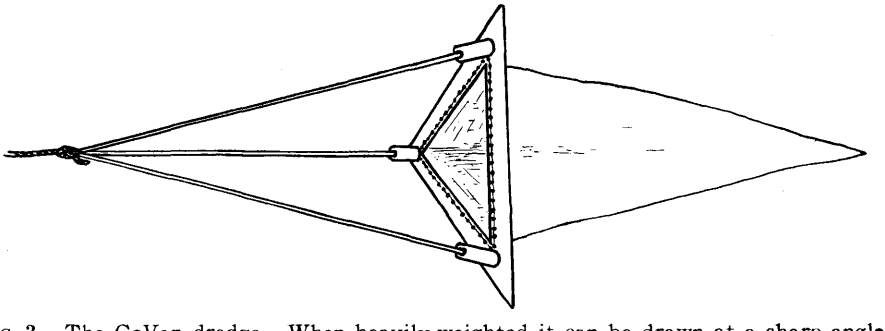

FIG. 3. The CoVan dredge. When heavily weighted it can be drawn at a sharp angle. It then only scrapes the surface and does not fill with mud quickly.

The studies of the Goniobasis-Hydropsyche community were made in an intensive manner about Gibraltar Island and at two stations where the sampler brought up efficient samples of small boulders, whose exposed surface area could be measured, as well as some good samples of gravel. List I shows the animals taken from 10 M^2. A study of occurrence of *Goniobasis* by Krecker (1924) indicated that it is most abundant in the early stages of succession to land, i. e., protected places swept clear by currents produced by oscillations in lake level. *Goniobasis* or *Hydropsyche* appeared in all of the collection stations where quantitative work could be done and the two were accordingly chosen to designate the community. In shallow water, water-penny larvae (*Psephenus lecontei*) were more often present than either of the other two. They did not appear in the deeper water, however. The area between depths of 6 and 8 meters does not have several of the species. Eight meters is approximately the depth limit of wave motion sufficient to move fine sand or coarse silt. This amount of water movement is often deeper when produced by currents and the depth to which boulders will be swept clean varies with general physiographic conditions. The lower limits of this may be expected to vary likewise.

LIST I

A collection of invertebrates from 10 M^2 of bottom in the Goniobasis-Hydropsyche community, western Lake Erie, July and August, 1937; 0–25 feet (0–8 M.) depths.

*1. *Cricotopus exilis* Joh., *et al.*, Midge larva ..... Est. 10,000
*2. *Hydropsyche sp.* Caddice-fly larva 703
3. Bryozoan colonies 317
*4. *Stenelmis crenata* Say, *et al.* Parnid beetle and larva 170
*5. *Stenonema tripunctatum* Banks and *S. pulchellum* Walsh. Flat mayfly nymphs 152
*6. *Physa sp.* Snail 128
*7. *Goniobasis livescens* Menke. Snail 121
*8. *Psephenus lecontei* (Lec.). Water-penny 72
9. Sponge colonies 27
10. *Planorbula crissilabris* Walk. Snail 21
11. Leptoceridae. Caddice-fly larva 16
12. *Glossiphonia sp., et al.* Leech 15
13. *Amnicola limosa porata.* Snail 3
14. *Helicopsyche sp.* Caddice-fly larva 2
15. *Cheumatopsyche sp.* Caddis-fly larva 2
16. *Baetis sp.* Mayfly nymph 2
17. *Pentaneura sp.* b. Midge larva 2
18. *Stenonema interpunctatum* Say. Flat mayfly 2
19. *Molanna sp.* Caddice-fly larva 1
20. *Centroptilum* sp. Mayfly nymph 1
21. *Planaria* sp 1
22. *Argia moesta* Hag. Swift-water damsel-fly nymph 1
23. *Amblema costata* Raf. Mussel 1
24. *Leptodea fragilis* Raf. Mussel 1
25. *Lampsilis siliquoidea rosacea* DeKay. Mussel 1
26. *Elliptio dilatatus sterkii* Grier. Mussel 1
27. *Chironomus sp.* p. Midge larva 1
28. *Chironomus pallidus* Joh. Midge larva 1
29. *Chironomus sp.* Midge larva 1

The collections from which List I was arranged were made at stations 21 (½ M^2, depth 2 M.), 32 (½ M^2, depth 5 M.), 57, 58, 59, 62, 63, 64 (0.6 M^2, depth 6 M.), 65 a, 65 b, 65 c, 65 d (1 M^2, depth 2 M.). The stations for which depths are not given ranged from 0–1 M. *Cricotopus exilis*, the web-forming midge, ranged from 0–1 M. The other motile species decreased in abundance with depth. Thus the results are only roughly quantitative. The observations were carried out as follows: In depths 0–1 M., ten 0.1 M^2 areas were marked off and all animals were counted as observed on and under stones and elsewhere. In depths greater than 1 M., the Petersen bottom sampler was used to pick up coarse gravel and small boulders and the exposed surfaces of these measured; all animals remaining attached to them were counted

*The asterisk before items 1, 2, 4, 5, 6, 7, and 8 indicates that the quantitative data are for stations of 0–1 M. depth. The following comments refer to the corresponding numbers in the list.

(1) *Tanytarsus exiguus* Joh. was also reared, but all specimens identified were from under stones or the deeper water. (2) *Hydropsyche*, (7) *Goniobasis livescens*, and (8) *Psephenus lecontei* were not taken below 18 feet (5½ M.). (4) *Stenelmis vittipennis* Zim. appeared in one collection. One individual is included in the 170 listed as *S. crenata*. A few others may have occurred. (5) The proportions of these two species were not determined, but the populations appear about equally divided between the two. A few *Stenonema interpunctatum* appeared in the deeper water. (6) A few *Pleurocera* were found in two stations (total, 4 specimens from 1.0 M^2).

and added to those brought up loose in the sampler. 1 M^2 was estimated to have been covered in terms of rock surface. Between 10 and 15 M^2 at a depth of 2–8 M. were picked over with the sampler or scraped with the dredges. This work covered stations 10, 20, 36, 39, 52, 53, 71,

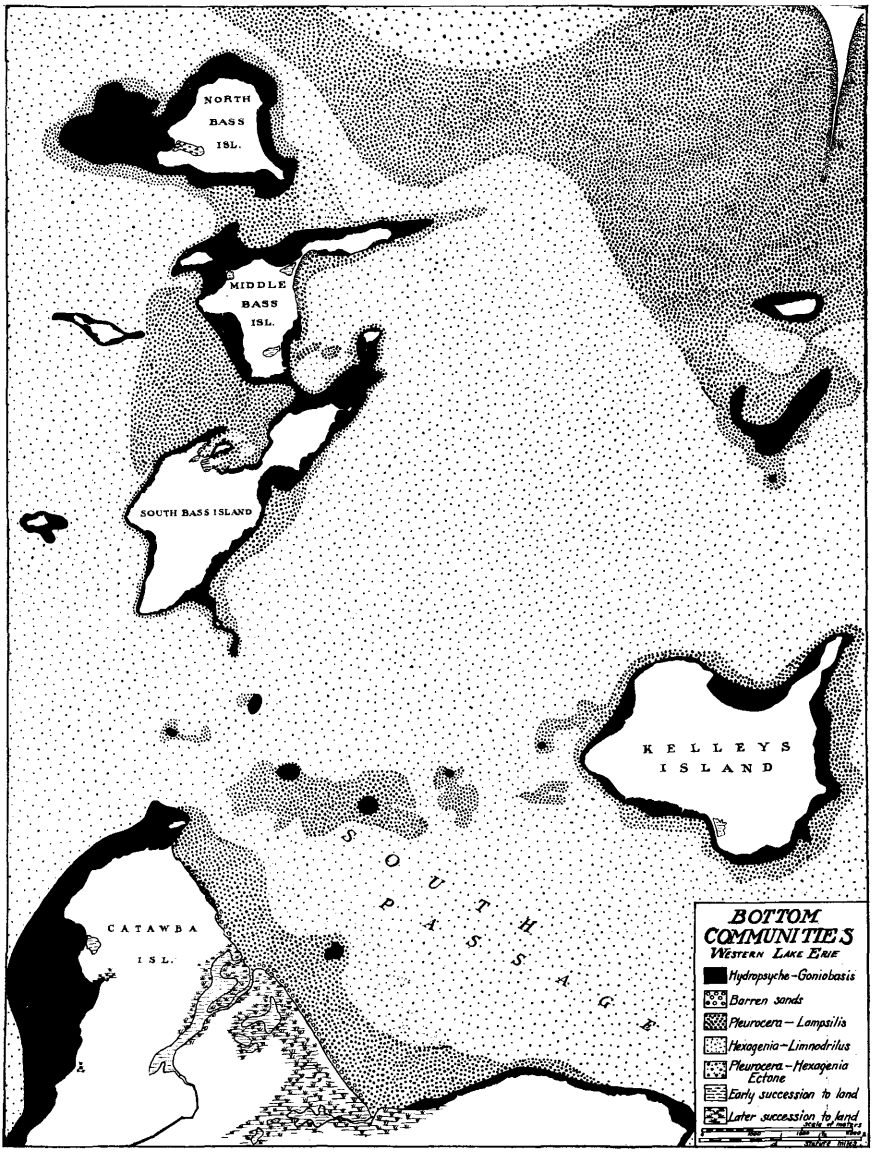

FIG. 4. Provisional map of the bottom communities. The community conditions between stations were inferred from the depth and what is known of currents and circulation.

75, 89, 94, 98, 107, 108, 114 and a few others, all on a qualitative basis. The qualitative results were of value in that they showed nearly all the species present. Heptageninae, numerous in shallow water, were not taken in the deep samples. These flat mayfly nymphs may readily wash off the stones picked up with tongs or the sampler.

The fishes listed were collected over station 65, rock and gravel bottom, depth 0–1.5 M.

1. Log-perch—*Percina caprodes* (Raf.)
2. River darter—*Cottogaster copelandi* (Jordan)
3. Yellow perch—*Perca flavescens* (Mitch.)
4. Blunt-nosed minnow—*Hyborhynchus notatus* (Raf.)
5. Steel-colored shiner—*Notropis spilopterus* (Cope)
6. Northern mimic shiner—*Notropis volucellus volucellus* (Cope)
7. Large-mouthed bass, 1 inch long—*Huro salmoides* (Lac.)

The following fishes are also noted as common in such localities by Turner (1920).

1. Yellow perch—*Perca flavescens* (Mitch.)
2. Log-perch—*Percina caprodes* (Raf.)
3. River darter—*Cottogaster copelandi* (Jordan)
4. Small-mouthed bass—*Micropterus dolomieu* Lac.
5. Spot-tailed minnow—*Notropis hudsonius* (Clinton)
6. Large-mouthed bass—*Huro salmoides* (Lac.)
7. Brook silverside—*Labidesthes sicculus* (Cope)

THE PLEUROCERA-LAMPSILIS COMMUNITY.

Intermediate between the Goniobasis-Hydropsyche and mud bottom (Hexagenia-Oecetis) communities is the Pleurocera-Lampsilis community. This is characteristic of sandy bottoms which are usually shifting. This community is not so extensive as the Hexagenia-Oecetis community or so accessible as the Goniobasis-Hydropsyche community. Bottom sampling is more difficult on account of the coarse-meshed sieves which must be used, while dredging, on the other hand, is easy. Five M^2 were sampled with the Petersen sampler and a relatively large area dredged over. This is estimated as at least 15 M^2. Twenty-nine species are listed below as representing twice the population of 5 M^2 as taken with the Petersen sampler. *Pleurocera acuta* and *Lampsilis siliquoidea rosacea* are the two most abundant and uniformly distributed species. Three other mussels are quite generally present. *Goniobasis* occurred in only 3 out of 65 Petersen samples and 1 of 15 dredge hauls. The chironomids and other insect larvae and adult corixids were scattered, usually as single individuals at a station.

LIST II

Twice the actual collection from 5 M^2 (an estimate for 10 M^2) of bottom in the Pleurocera-Lampsilis community of western Lake Erie, July and August, 1937.

1. *Pleurocera acuta* Raf. Snail.....66
2. *Lampsilis siliquoidea rosacea* DeKay. Mussel.....16
3. *Obovaria subrotunda* Raf. Mussel.....12
4. *Leptodea fragilis* (Raf.). Mussel.....10
5. *Fusconaia flava parvula* Grier. Mussel.. 8
6. *Goniobasis livescens* Menke. Snail..... 8
7. *Chironomus sp.* d..... 8
8. Leptoceridae. Caddice larva..... 6
9. *Chironomus digitatus* Malloch. Midge larva..... 6
10. *Lampsilis ventricosa* Barnes. Mussel... 4
11. *Hexagenia sp.* Mayfly nymph..... 4
12. *Ephemera sp.* Mayfly nymph..... 4
13. *Sialis sp.* Larva..... 4
14. *Procladius culiciformis* Linné. Midge larva..... 4
15. *Chironomus sp.* l. Midge larva..... 4
16. *Chironomus sp.* b. Midge larva..... 4
17. *Chironomus sp.* g. Midge larva..... 4
18. *Gammarus limnaeus* (Smith). Amphipod. 4
19. *Chironomus flavus* Joh. Midge larva.... 2
20. *Arctocorixa lineata* Forster..... 2
21. *Limnephilus sp.* Caddice larva..... 2
22. *Stenelmis bicarinatus.* Parnid larva..... 2
23. *Stenelmis crenata* Say. Parnid larva.... 2
24. *Birgella subglobosa*..... 2
25. *Micromyza fabulus*..... 2
26. *Elliptio dilatatus sterkii* Grier..... 2
27. *Chironomus sp.* k..... 2
28. Bryozoan colonies..... 2
29. *Planaria*..... 1

The status of this community is similar to that of the sandy bottoms of streams: after storms the sand is shifted, removing most of the animals and leaving areas of denuded sand, which is invaded by the species most abundant in nearby areas and a sparse population is built up, only to be washed away again. Thus areas of barren sand are common in the territory occupied by the community. Fishes frequenting these areas were not collected.

THE HEXAGENIA-OECETIS COMMUNITY.

The community of greatest significance from the standpoint of the fisheries of the area is the one occupying the still-water, mud-bottom areas and characterized by many mayfly nymphs of the genus *Hexagenia*, many chironomid larvae, and characteristic caddice-fly larvae.

LIST III

An Average Collection of Invertebrates from 10 M² of Bottom in the Hexagenia-Oecetis Community, July and August, 1937

1. *Hexagenia occulata* Walk. Burrowing mayfly nymph.....186
2. *Hexagenia rigida* McD. Burrowing mayfly nymph.....142
3. *Chironomus digitatus* Malloch. Midge larva..... 63
4. *Coelotanypus scapularis* Loew..... 42
5. *Limnodrilus*. Aquatic earthworms.... 32
6. *Procladius culiciformis* Linn. Midge larva..... 29
7. *Oecetis inconspicua* Walker. Caddice-fly larva..... 27
8. *Chironomus curtilamellatus* Malloch. Midge larva..... 22
9. *Chironomus*, several unidentified species..... 12
10. *Pentaneura monilis* Linn. Midge larva. 9
11. *Chironomus decorus* Johannsen. Midge larva..... 8
12. *Valvata tricarinata* Say. Snail..... 6
13. *Lampsilis siliquoidea rosacea* DeKay. Mussel..... 6
14. *Herpobdella punctata* (Leidy). Leech.. 6
15. *Fusconaia flava parvula* Grier. Mussel. 4
16. *Gammarus fasciatus* Say. Crustacean.. 3*
17. *Pisidium sp.* Bivalve..... 3
18. *Glossiphonia stagnalis* (L.). Leech..... 3
19. *Pleurocera acuta* Raf..... 2
20. *Cricotopus trifasciatus* Panzer. Midge larva..... 1
21. *Goniobasis livescens* (Menke.). Snail... 1
22. *Protera alata* (Say). Mussel..... 1
23. *Ligumia nasuta* (Say). Mussel..... 1
24. *Truncilla donaciformis* (Lea). Mussel. 1
25. *Cambarus argillicola*. Faxon. Crayfish. 1
26. *Amblema costata* Raf. Mussel..... 1
27. *Lunnesia undulata* (Müll.). Mite..... 1
28. *Arctocorixa lineata* (Forst). Water-boatman..... 1*
29. *Gammarus limnaeus* (Smith). Amphipod 1*

*Figures not quantitative, catch merely incidental.

The abundant fishes associated with the invertebrates enumerated and related to the bottom in their feeding and breeding relations are northern brown bullhead (*Ameiurus nebulosus nebulosus* (Le Sueur)), sheepshead (*Aplodinotus grunniens* Raf.), eastern white sucker (*Catostomus commersonnii commersonnii* (Lac.)), and the European carp (*Cyprinus carpio* Linné). To what extent these species control their habitats by destroying vegetation is not clear. Characeae are recorded as abundant from Lake St. Clair (Pieters, 1894) and very rare in Lake Michigan (Shelford, 1913, p. 74). A number of largely piscivorous fish such as the yellow pike-perch (*Stizostedion vitreum vitreum* (Mitch.)), blue pike-perch (*S. vitreum glaucum* Hubbs), eastern sauger (*S. canadense canadense* (Smith)), yellow perch (*Perca flavescens* (Mitch.)) also occur.

The life histories of the constituents enumerated above are known only for a few species. It is evident, however, that *Hexagenia* is perennially present, since in late summer young nymphs are found as well as late-emerging individuals. The caddice-fly larva *Oecetis inconspicua* Walker, appears to be a fair indicator of the community. It appears that their cases will usually be present until the larvae of the next generation become recognizable. Unfortunately, few of these were carried to the adult stage.

Out of 35 stations yielding *Hexagenia* nymphs, 17 yielded larvae of *Chirinomus digitatus* and 14 yielded larvae of *Coelotanypus scapularis*. Both midge larvae were present in only five or six stations, a fact not easily correlated with physical conditions.

The list of species present shows only 8 abundant enough so that one or two individuals may be expected in any square meter sample. Of the Mollusca *Valvata tricarinata*, *Lampsilis siliquoidea rosacea*, and *Fusconaia flava parvula* are the only ones likely to be found on two square meters. The swimming habits of the amphipods make their occurrence in collections problematical and incidental.

DETRITUS AND MICROSCOPIC FORMS OF THE BOTTOM

The surface of the bottom is covered with a layer of flocculent detritus consisting of about 90% to 95% debris from higher plants, mixed with plankton detritus. The remains of the following organisms were noted; comparison with the plankton indicates that the list is far from complete.

1. Phytoplankton detritus: (a) Diatoms: *Diatoma*, *Gomphonema*, *Melosira*, *Cyclotella*, *Stephanodiscus*, *Closterium*, *Synedra*, *Fragilaria*, *Meridion*, *Campylodiscus*, *Staurastrum;* (b) Blue-green algae: *Anabena*, *Oscillatoria;* (c) Filamentous algae: *Tribonema*, *Spirogyra*, *Zygnema*.

2. Zooplankton: copepod debris, cladoceran debris, other crustacean debris, *Triarthra* (rotifer), *Difflugia* and *Arcella* (Protozoans). 3. Living forms: *Chaetonotus brevispinosus* (Gastrotricha), *Mesostoma*, (flatworm).

The presence of so much higher plant debris obscures the brown layer resulting from plankton detritus, especially diatoms, readily seen in most bodies of still water, particularly in late summer. Mixed with the debris are small particles of silt, which have the appearance of translucent nodules when viewed under the microscope. The flocculent debris decreases and silt particles increase with depth. The top one or two millimeters are usually without an appreciable number of sand grains. The amount of sand increases with depth, but there is not much other change through the top four or five centimeters. Below this point the material is more closely consolidated but still with much plant debris to a depth of 10 or 12 cm. Separation of the particles in some 12 cm. samples shows the detritus to make up nearly half of the amount.

After severe storms the yellowish green detritus colors the water in harmony with its own color and several days are required for the water to clear.

To determine the per cent volume of the detritus, 6 samples to a depth of approximately 6 cm. and 6 samples to a depth of 3 cm. were sent to the Ohio Agricultural Experiment Station, where the work was done by courtesy of Dr. G. W. Conrey.

LIST IV

SHRINKAGE OF LAKE ERIE MUD SAMPLES ON FIRING

Station	Depth in mm.	Shrinkage Percent	Station	Depth in mm.	Shrinkage Percent
80	60	59.5	81	29	51.0
77	60	58.0	55	31	57.0
42	60	51.5	83	30	55.0
77	61	57.0	24	29	56.5
30	59	62.0	29	30	34.0
2	60	62.2	43	33	50.0

Depth refers to the distance from the bottom surface to the bottom of the sample in the tube. The shrinkage was increased to between 102 and 103 per cent of the original figures to account for an assumed 2 or 3 per cent of ash in the plant debris. The shrinkage is least where there is current flow between islands and where water is deepest.

RELATION OF DETRITUS TO THE ANIMAL ORGANISMS OF LAKE ERIE

(1) ORIGIN OF DETRITUS.

Some of the detritus material may wash in from the land, but the aquatic plants growing in the lake and lagoons, and ponds connected with it are the principal sources. The fresh-water eel-grass and tape-grass (*Vallisneria spiralis* L.) is probably the principal source. There are large areas of this, which occur about the islands in the area of study.

(2) RELATION OF THE LARGER INVERTEBRATES TO THE DETRITUS.

The stomach contents of *Hexagenia occulata* were studied. Specimens were taken from Station 42 and examined immediately. The contents of two typical specimens are enumerated.

I.
- a. Higher plant tissue (detritus).
- b. Filamentous algae.
- c. Diatom shells.
- d. Sand grains in greater proportion than in detritus, indicating some digestion.

II.
- a. Higher plant detritus.
- b. *Diatoma* shells 3
- c. *Tribonema* shells 1
- d. *Synedra* shells 1
- e. Entomostracan parts 3
- f. Copepod parts 2
- g. *Triarthra* parts 1
- h. Cladoceran parts 2

(3) Relations of the Vertebrates to the Detritus-Eating Invertebrates.

The stomachs of several of the associated fishes were examined, but in most cases they had been in the trap so long that their stomachs were empty. The bottom feeders are not likely to avoid eating detritus directly, as much of their animal food is embedded in it.

The stomach contents of a sheepshead examined very soon after its capture showed:

Hexagenia, nymphs	4	*Limnodrilus*	1
Leech	1	Chironomids	10

The chironomids were identified as *Chironomus sp.* b (not reared) taken only at stations 21, 22, 36, 72, and *Chironomus digitatus*, which was widely distributed.

The presence of these in the stomach of the fish establishes a food chain in which the principal ultimate source of nourishment is the tissues of some of the higher plants.

DISCUSSION

Two lines of thought present themselves for elaboration. (a) One is essentially a comparison of the findings in western Lake Erie with those of Petersen and his associates in the marine waters about Denmark and, (b) the other is a comparison of the three communities described and a consideration of the general system of classification of communities in fresh waters.

1. Fisheries Problems.

The outstanding work of the Danish Biological Station has attracted attention. The resemblance between the marine condition about Denmark and the west end of Lake Erie justifies a comparison with Danish findings. In the Danish waters, the principal features of the system of aquatic life are the following:

1. The bottom invertebrates make up the principal source of food of many of the commercial food fishes.
2. The invertebrates feed largely on detritus.
3. The chief source of detritus is eel-grass.
4. Eel-grass affords protection to the young of food fishes while they are small.

The conditions found in western Lake Erie appear almost parallel to those in the Danish waters as regards a large group of fishes. The extent to which plants that form the detritus also serve as shelter of small fry is evident in some cases, in general terms only.

There are large areas of fresh-water eel-grass or ribbon-grass (*Vallisneria spiralis*) and some other aquatic plants which doubtless contribute to the detritus. The beds occur in shallow water usually partially protected. The dense vegetation of the shallow bays and marshes connected with the lake contributes much. The manner in which the plant fragments are swept out of the bays and lagoons, where plants grow in profusion, is brought out by Krecker (1931) in his study of vertical oscillations in the same area studied by the writers. The inflow and outflow of water in lagoons is sufficient to leave some channels free of vegetation. The writers conclude that this indicates a current sufficient to carry plant fragments into the lake proper. Krecker refers to the importance of these open channels in that "they afford indispensable feeding and breeding grounds to thousands of fishes." To what extent the bottom feeders of the lake proper are involved has not been properly studied.

The importance of the mayflies and detritus, including that from the lagoons, to the commercial fisheries of western Lake Erie can hardly be doubted.

The Goniobasis-Hydropsyche community is evidently of considerable importance to the small and young fishes which supply food to piscivorous species. The Mollusca, no doubt, play an important role (Baker, 1916). The Pleurocera community is evidently of less importance than the Goniobasis community.

2. Comparison and Classification of Communities.

The bottom invertebrates and bottom-frequenting fish, together with the plankton and such pelagic fishes as may occur, constitute one biotic unit. The writers believe this to be the best grouping even in lakes as large as Lake Erie.

There is evidence from rivers that fishes are among the most important constituents of aquatic communities. The extensive control of substratum and vegetation by which fishes tend to maintain conditions suitable for themselves (Cahn, 1929; Ricker, 1932) can hardly occur on an important scale in waters in which rooted vegetation is unable to grow. Still the three main community types found in streams, namely, (a) swift water communities, usually on hard coarse bottoms, (b) communities on shifting bottoms—usually sand in water with moderate currents, and (c) communities in still water usually with mud bottoms, are all quite evident. Thus the three communities of which 29 constituent species are named for each in Lists I, II, and III, conform to the three types described for streams (Shelford, 1913, pp. 93–105). Shelford and Eddy (1929) did not mention the sand-bottomed habitats; Clements and Shelford (1939) followed the same plan. This results from the fact that the sand-bottom community is not usually very distinct in streams. Gersbacher (1937), however, recognized it as a definite but short-lived community.

In western Lake Erie it is a distinct community, as may be seen from a comparison of Lists I, II, and III. The three lists may also be compared with Gersbacher's Musculium-Lampsilis community. Gersbacher regarded this as a fraction of the Hexagenia community. However, according to the observations of the senior author, this does not apply to sand-bottom communities in some other streams.

SUMMARY OF CONCLUSIONS

The classification of aquatic communities has been carried out chiefly from two viewpoints.

1. The habitat, kind of bottom, *etc.*, have been used as a basis for expressing the occurrences of the animals. They are referred to as occurring on sand, on mud, *etc.* Groupings characteristic of certain conditions are recognized by Pearse (1939, Chapter 9).

2. The most abundant animals are considered as indicators of the usual presence of other less abundant ones, while all the life is regarded as constituting a community. This viewpoint has two propositions as its background, namely, (a) that there are important relations between the species concerned, and that they have important reactions on the habitat, (b) that in areas denuded of life, animals and plants appear in succession as the organisms change the character of the habitat. The occurrence of a climax stage is supported by some good evidence (Gersbacher, 1937).

Those who use interactions, succession, and climax as a basis for the classification of communities put the aggregations of organisms ahead of the physical conditions due to (1) a partial control by the organisms and (2) the fact that the physical conditions as commonly interpreted are often confusing. A given kind of bottom does not necessarily have the same community upon it under the same conditions of depth, temperature, etc., because circulation of the water medium appears to be more important than the bottom. From the point of view of this investigation, a community is regarded as being controlled by the more potent and abundant species, and the same community occurs wherever the principal organisms are the same. In some cases, a part of these organisms is the same, and a part is different. On land, at least, this is the basis for separating the large primary communities called *biomes* from the smaller subdivisions called associa-

tions. Wherever there is a complete change in all the important species, a new biome (major community) is regarded as occurring.

As to the degree of control by fishes in Lake Erie, we have no evidence. Lake St. Clair, however, is covered (Pieters, 1894) to its greatest depth (7 meters) with Characeae, wherever alluvium occurs. There appears to be no good aquaclimatic reason for their absence in Lake Erie. Cahn (1929) and Ricker (1932) and unpublished work of the Illinois Natural History Survey have indicated the potency of fishes in removing vegetation. We have unfortunately no qualitative knowledge of the fishes of Lake St. Clair. Qualitatively, the majority of the fishes known to influence bottom vegetation (dominants) are known to occur only in the tributary streams (Ms. list by C. L. Hubbs). This suggests the importance of careful study of the influence of fishes on their habitats and the associated plants in the large lakes. At least, it is evident that in the areas of study, the combination of the present hydroclimate and fish population will tend to make the communities what they are today for an indefinite period.

The Hexagenia-Oecetis[2] community type is the only one which may be regarded as permanent, stable, and probably climax in both streams and large lakes. At the same time, the other two communities described cannot be regarded as a part of a sere, or biotic succession, which are seral only in a broad physiographic sense. These communities will be succeeded by the climax Hexagenia type only after millions of years of erosion and rock disintegration, in which organisms play a part. This puts their change to the climax type in a category in no wise comparable with the development of a climax in 10 or 15 years or less, as described by Gersbacher (1937). Any attempt to discuss these two communities as seral stages only leads to confusion.

The sand-bottom community appears to the writers as comparable to moving sand on land, which is never stabilized. That on the lower beach of the Great Lakes is an example. The community on rock and boulder areas appears to be like the more stable rock and talus areas on land. These are too steep and jagged and exposed for plants to cover them and hence any approach to the climax of the area would call for millions of years of rock disintegration and erosion.

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[2]This community name is purely provisional. If further study pointed to the control by fishes, something like Cyprinus-Aplodinotus-Hexagenia would be appropriate.

BIBLIOGRAPHY

Baker, F. C. 1916. The relation of mollusks to fish in Oneida Lake. N. Y. State College of Forestry, Tech. Pub. No. 4, 16: 1–366.

Blegvad, H. 1914. Food and conditions of nourishment among the communities of invertebrate animals found on or in the sea bottom of Danish waters. Rep. Dan. Biol. Sta., 22: 41–78.

Brown, C. J. D., Clarence Clark, and Bruce Gleissner. 1938. Size of certain naiades from western Lake Erie in relation to shoal exposure. Am. Mid. Nat., 19: 682–701.

Cahn, A. R. 1929. The effect of carp on a small lake. The carp as a dominant. Ecol., 10: 271–274.

Clements, F. E., and V. E. Shelford. 1939. Bio-Ecology, New York.

Eddy, Samuel. 1934. A study of fresh water plankton communities. Ill. Biol. Mon., 12: 1–93.

Gersbacher, W. M. 1937. The development of stream communities in central Illinois. Ecol., 18: 359–390.

Krecker, F. H. 1924. Conditions under which *Goniobasis livescens* occurs in the island region of Lake Erie. Ohio Jour. Sci., 24: 299–310.

1928. Periodic oscillations in Lake Erie. Ohio St. Univ., The Franz Theodore Stone Lab., Contrib. No. 1, 1–22.

1931. Vertical oscillations or seiches in lakes as a factor in the aquatic environment. Ecol., 12: 156–163.

Krecker, F. H., and L. Y. Lancaster. 1933. Bottom shore fauna of western Lake Erie: A population study to a depth of six feet. Ecol., 14: 79–93.

Needham, J. G. 1901. Aquatic insects of the Adirondacks. N. Y. State Mus. Bull., 47.

Needham, J. G., and R. O. Christenson. 1927. Economic insects in some streams of northern Utah. Utah Agr. Exp. Sta. Bull., 201: 1–36.

Pearse, A. S. 1939. Animal ecology, New York.

Petersen, C. G. J. 1918. The sea bottom and its production of fish food. Rep. Dan. Biol. Sta., 25: 1–62.

Petersen, C. G. J., and P. B. Jensen. 1911. Valuation of the sea. I. Animal life of the sea-bottom, its food and quantity. Rep. Dan. Biol. Sta., 20: 1–76.

Pieters, A. J. 1894. The plants of Lake St. Clair. Bull. Mich. Fish. Com., 2: 1–12.

Ricker, W. E. 1932. Studies of trout lakes and ponds. Univ. of Toronto Studies Biol. Ser. Pub. Ont. Fish. Res. Lab., 36: 146–151.

Shelford, V. E. 1911a. Ecological succession. I. Stream fishes and the method of physiographic analysis. Biol. Bull., 21: 9–35.

1911b. Ecological succession. II. Pond fishes. Biol. Bull., 21: 127–151.

1911c. Ecological succession. III. A reconnaisance of its causes in ponds with particular reference to fish. Biol. Bull., 22: 1–38.

1913. Animal communities in temperate America. Chicago. Reprinted, 1937, with notes and new bibliography.

Shelford, V. E., and Samuel Eddy. 1929. Methods for the study of stream communities. Ecol., 10: 382–391.

Turner, C. L. 1920. The distribution, food and fish associates of young perch in the Bass Island region of Lake Erie. Ohio Jour. Sci., 22: 137–152.