FACTORS INFLUENCING THE DISTRIBUTION OF BURROWING MAYFLIES ALONG THE MISSISSIPPI RIVER [1]

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INTRODUCTION

Burrowing mayflies are abundant along much of the Mississippi River (Plate 1.). Hoardes of imagoes and subimagoes often cause nuisance problems for river residents, motorists and towboat personnel (FREMLING 1960, 1968). Yet, the three major burrowing species, *Hexagenia bilineata* (SAY), *Hexagenia limbata* (SERVILLE) and *Pentagenia vittigera* (WALSH), are not able to inhabit all sections of the river. Moreover, the distribution and relative abundance of the three species have apparently changed during the past 30 years. This report explains how various innate and environmental factors influence the distribution and relative abundance of the three species. It will also be demonstrated that mayfly distribution can be utilized to assess the well-being of a river which is so large that it cannot be monitored effectively or economically by standard methods.

DESCRIPTION OF STUDY AREA

The Mississippi River is the largest river in the United States. It winds 2319 miles from its source at Lake Itasca in Northern Minnesota to its mouth in the Gulf of Mexico, 95 miles downstream from New Orleans. The Mississippi and its tributaries drain about 41 % (about 1,244,000 square miles) of the total area of the United States. By definition, that segment upstream from the mouth of the Ohio River (at Cairo, Illinois) is called the Upper Mississippi River (U.S. ARMY CORPS OF ENGINEERS, 1958). That segment from Cairo to the Gulf of Mexico is termed the Lower Mississippi River (U.S. ARMY CORPS OF ENGINEERS, 1965). Consecutive miles of both segments of the river are numbered upstream. Thus, mile "O" on the Lower Mississippi River is the mouth of the river. Mile "O" on the Upper Mississippi River is Cairo, Illinois. The river is navigated by 9-foot draft vessels as far upstream as Minneapolis, Minnesota.

The Mississippi River exists in three distinct ecological sections — the section from its source to Minneapolis, the section from Minneapolis to St. Louis, Missouri, and the section from St. Louis to the Gulf of Mexico. The uppermost section, from the source of the river to Minneapolis, is essentially stream-like. Here it flows for 511 miles through the sand and gravel till deposited during the recent Wisconsin glacial age. The gradient of the river is fairly steep and the river contains fast water and some rapids. The river is occasionally impounded naturally as it flows through lakes. It is artificially impounded upstream from Minneapolis by dams at St. Cloud, Sartell, Little Falls, Brainerd, Aitkin and Grand Rapids. This uppermost section of the river is relatively unpolluted.

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The character of the river changes suddenly at Minneapolis. Here it enters a valley which is as much as 550 feet deep and three miles wide. From Minneapolis to Keokuk, Iowa, the river is usually flanked by steep limestone-sandstone bluffs. Prior to man's channelization projects, the river meandered, in this area, in braided channels through the broad post-glacial flood plain which forms the floor of the valley. This section of the river was navigated by shallow-draft steamboats as early as 1823. The federal government began work in 1824 to make the Mississippi River navigable as far north as Minneapolis. Early work consisted principally of removing snags and boulders and dredging shallow areas. The United States Army Corps of Engineers began, in 1878, to channelize the Upper Mississippi River and to deepen it by constructing rock closing dams on side channels (U.S. ARMY CORPS OF ENGINEERS, 1962). The most obstructive rapids were by-passed by constructing short lateral canals with navigation locks. Hundreds of rock and brush structures called wing dams were also constructed. The wing dams, often at intervals of about 1/4 mile, extend outward from the shore perpendicular to the main channel of the river. They divert the river into a narrow channel, during low flow, so that the river scours its channel clean. By 1930, the minimum depth of the main channel had been increased to 6 feet as far north as Minneapolis.

To allow navigation by deeper draft vessels, a project was begun in 1930 to provide a channel with a minimum depth of nine feet and a minimum width of 400 feet, to be achieved by the construction of a system of locks and dams, supplemented by dredging. Most of the resultant 29 locks and dams were constructed from 1930 to 1940. A notable exception is Lock and Dam 19 at Keokuk, Iowa, most of which was constructed as part of a hydroelectric facility in 1914. The dams have formed huge impoundments which often occupy the entire flood plain of the river. Consequently, the Upper Mississippi River is often much wider (but shallower) than is the Lower Mississippi River at New Orleans. Each impoundment, in turn, consists of two distinct ecological areas. The tailwater areas just downstream from the dams show the river in relatively unmodified form. The broad pools above the dams, however, are essentially lake-like and they contain heavily silted bottoms.

For many years the river has been severely polluted for about 60 miles through and downstream from metropolitan Minneapolis and St. Paul (METROPOLITAN DRAINAGE COMMISSION OF MINNEAPOLIS AND ST. PAUL, 1928). In the metropolitan area about 1,768,000,000 gallons of industrial and municipal waste water enter the river each day. About 85 % of this amount is cooling water from steam-electric generating plants (FEDERAL WATER POLLUTION CONTROL ADMINISTRATION, 1966). Although they were not constructed for that purpose, the navigation pools serve as sewage lagoons so that with each subsequent impoundment and aeration in the tailwaters, the putrescible portion of the metropolitan pollutant load is decreased. Downstream cities add more pollutants but their additions are very small compared to those of Minneapolis and St. Paul. Also, large tributary rivers such as the St. Croix, Chippewa and Wisconsin add relatively clean water to the Mississippi thus increasing its ability to assimilate its pollutant load. Biologically, the Upper Mississippi River is comparatively clean from Wabasha, Minnesota (mile 760 Upper Mississippi River), to the mouth of the Illinois River just above St. Louis.

The third ecological segment begins at the mouth of the Illinois River. Here, the Mississippi receives pollutants from Chicago, other large cities, industries and farms (MILLS, *et al.*, 1966). Prior to 1968, St. Louis added an average of 330,000,000 gallons of raw municipal sewage to the Mississippi every day. This was supplemented by additional wastes from surrounding municipalities and from many industries. Just upstream from St. Louis, the Missousiri River, adds an extremely heavy load of silt. The last dam on the Mississippi River is at St. Louis.

Downstream 185 miles from St. Louis, the Ohio River enters the Mississippi at Cairo, Illinois. Here, the Lower Mississippi begins its 954-mile path through an immense, flat alluvial delta to the Gulf of Mexico. The lower river, at one time, constantly changed its course as it meandered about its flood plain. During the past two hundred years, however, the entire lower river has been channelized with earthen dikes to prevent flooding of the fertile delta through which the river flows. Furthermore, the U.S. Army Corps of Engineers has channelized most of the lower river by armoring its banks with rock to prevent the river from changing its course. The river has also been shortened by cutting off many meanders. There are no dams on the Lower Mississippi River. The lower river is in essence a deep, narrow (200 feet deep, one-half mile wide at New Orleans), sinuous ditch which conducts most of the effluents of the United States very rapidly (average flow 611,000 cubic feet per second) to the Gulf of Mexico.

METHODS

A system was devised in 1958 whereby various river personnel were enlisted as cooperators to collect emergent mayflies. From 1958 to 1961 the project was limited to the navigable portion of the Upper Mississippi River but it was extended in 1961 to include the upper river to its source. In 1967, the sampling program was extended to include the entire Lower Mississippi River, its navigable tributaries and the Gulf Intracoastal Waterway.

Ship captains, lock masters, harbor operators, resort owners, ferry operators, and other interested river residents were asked if they would collect mayflies whenever they encountered a mass emergence. The cooperators were instructed not to collect isolated individuals but to collect only when mass emergences occurred. Self-addressed, stamped mailing tubes filled with instructions and alcohol-filled, plastic, specimen vials were mailed to about 150 cooperators each spring. Additional collecting materials were distributed to ship captains by the lockmasters at Lock and Dam 5a and Lock and Dam 19. The cooperators were asked to record on the specimen vial the name of the river, the mile number, nearest city, time and date.

Shipping strikes, floods, recruitment of new cooperators, and other uncontrollable variables made it impossible to keep collecting effort constant from year to year. It was also impossible to maintain constant collecting effort over the entire river. There are no locks on the lower river, consequently collecting was intensified on the upper river by the lockmasters there. This was particularly true at Keokuk, Iowa. Lock and Dam 19 is an extraordinarily large facility and it has more personnel on duty at any one time than any other lock (with the possible exception of Lock and dam 27 at St. Louis). Also, the Mississippi River is not used equally by ship captains throughout its length. In 1962, for example, about 35 million tons of freight were transported past Memphis, Tennessee, while less than 10 million tons were transported as far upstream as Minneapolis. Even the lower reaches of the Illinois and the Ohio Rivers account for more annual freight than does the Mississippi River above Keokuk (U.S. ARMY CORPS OF ENGINEERS, 1965).

A concerted effort was made to maintain contact with cooperators. Publications were sent to them upon request and a newsletter was distributed frequently. Each fall the returned specimens were examined and the resulting data tabulated. During the past year all of the data have been transferred to business machine cards. Programs have been written so that a computer will print distribution charts for any species, area, year or combination of years. Figures 1, 2 and 3 are modified computer print outs. In addition to plotting distributions of the various species, the print outs are very useful in predicting when an emergence of a particular species is likely to occur in a given area.

Hexagenia Bilineata

The biology of *H. bilineata* has been reviewed by Needham, *et al.* (1935) and by Fremling (1960). The species is very abundant in most of the navigation pools of the Upper Mississippi River. Most of the nuisance problems created along the river may be attributable to this species. Carlander, *et al.* (1967) report that the early July *Hexagenia* population in Pool 18 at Keokuk Iowa exceeded 3.5 billion in 1959. The species does well in silted impoundments and it is truly a "big river" mayfly. Although I once collected the species 8 1/4 miles from the river I have found that the species usually confines is swarming activities to the river's edge and its upstream oviposition flights to the river proper. During a mass emergence subimagoes may congregate on either shore if the night is virtually windless. Usually, however, they are concentrated on one shore or the other by the wind. Most nuisance problems are caused by imagoes which are attracted to the lights of boats, bridges and cities during their upstream oviposition flight (Fremling, 1968). Like the subimagoes, imagoes are usually wafted by breezes toward one shore or the other. Consequently, a city on one side of the river may be deluged with mayflies while its sister city on the opposite side of the river may be free of mayflies. In general, cities on north or east banks of the river are most prone to be consistently troubled with mayflies. I have no evidence that this species seeks out small tributary streams for oviposition.

The silted navigation pools of the Upper Mississippi River provide excellent habitat for this species. Smaller impoundments upstream from Minneapolis also provide *H. bilineata* habitat and the species has been collected at St. Cloud (mile 927 U.M.R.) Sartell (mile 935 U.M.R.) and Brainerd (mile 1001 U.M.R.).

H. bilineata is conspicuously rare in the river for 30 miles downstream from Minneapolis (Fig. 1). An extremely heavy pollutant load in that area precludes the existence of the species because the river bottom is anaerobic for much of the year. Conversations with long-time river residents have revealed that *H. bilineata* was formerly abundant in Lake Pepin (mile 766-786 U.M.R.) and that it often caused nuisance problems in Lake City (mile 773 U.M.R.). Its numbers have been severely reduced in Lake Pepin in recent years, however. Lake Pepin evidently serves as a settling basin for pollutants from the Minneapolis-St. Paul area and also for algae whose proliferation is caused by upstream fertilization. Chironomid midges have replaced burrowing mayflies throughout most of Lake Pepin. Emergence records indicate that *H. bilineata* reaches maximum concentrations in the area from Dubuque, Iowa (mile 580 U.M.R.), to Keokuk. The species is seldom reported below St. Louis (Fig. 2). It is unlikely that Vicksburg, Mississippi, is merely the southern limit of the range of *H. bilineata* in the Mississippi River because the species has been collected as far south as Florida (Berner, 1950). The scarcity of *H. bilineata* below St. Louis is due primarily to two factors. The river changes character at St. Louis (the sight of the last navigation dam) and the swift, channelized river below St. Louis provides meager habitat. The pollutant load downstream from St. Louis is extreme because of sewage from metropolitan St. Louis itself, but also from the Illinois River. The Mississippi River at St. Louis becomes an open sewer.

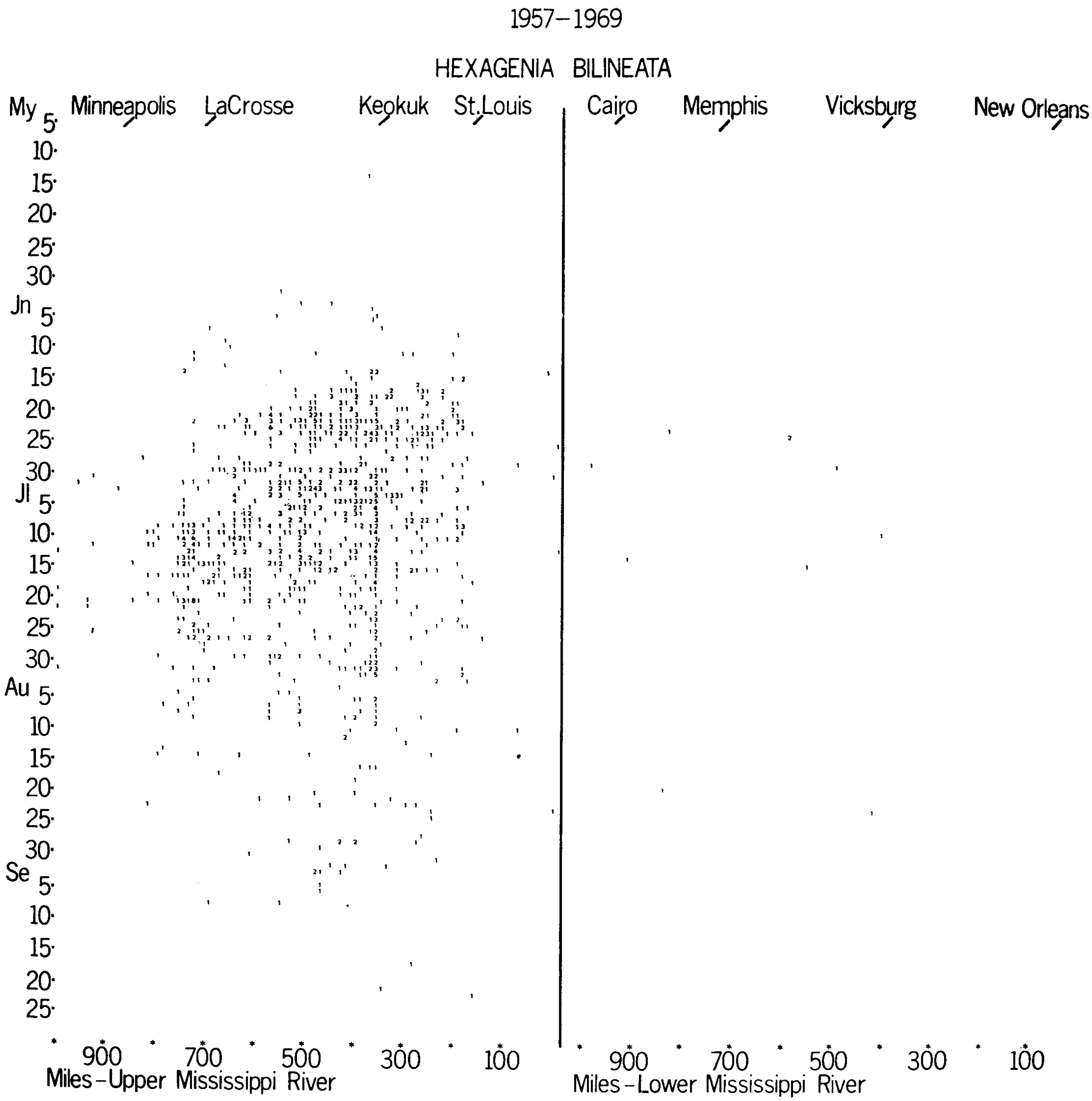

FIGURE 1. Seasonal and geographical distribution of *H. bilineata* on the Mississippi River from Brainerd, Minnesota, to the Gulf of Mexico as indicated by collections of imagoes and subimagoes during mass emergences. Each number indicates the total mass emergences thus reported at that point during the interval 1957-1969.

PLATE I

Biologist, James KRYSAN, examines *Hexagenia bilineata* mayflies attracted to automobile headlights on a Mississippi River bridge at Winona, Minnesota, 8 July 1966.

Hexagenia Limbata

The biology of *H. limbata* has been reviewed by Needham, *et al.* (1935) and by Hunt (1953). In general, the distribution of *H. limbata* follows that of *H. bilineata* on the Mississippi River (Fig. 2). *H. limbata,* however, also inhabits tributary rivers, streams and lakes in which there is sufficient respiratory oxygen the year around. *H. limbata* is a versatile mayfly and it is able to occupy a variety of silted habitats from south-central Canada to central Texas (Hamilton, 1959). On the Upper Mississippi River, *H. limbata* occurs farther north than *H. bilineata.* Adults of *H. limbata* have been collected at Little Falls (mile 965), Brainerd (mile 1000), Aitkin (mile 1055), Grand Rapids (mile 1180), Bemidji (mile 1304) and Lake Itasca (mile 1365 — the source of the river).

H. limbata, unlike *H. bilineata,* does not confine its mating and oviposition activities to the river proper. Whereas the mating swarms of *H. bilineata* are usually large and along the river's edge, *H. limbata* swarms may consist of a few individuals, often just above the tree tops and often several hundred yards from the water's edge. The oviposition flights of *H. limbata* extend far up small tributary streams and even overland. *H. limbata* is consistently found farther from the river than *H. bilineata.* Mayfly nuisance problems created in the interior areas of river cities are usually attributable to *H. limbata.*

H. limbata attains maximum concentrations in the area from Winona, Minnesota (mile 726 U.M.R.), to Prairie du Chien, Wisconsin (mile 635 U.M.R.). Here a large, early-summer population is apparently due, in part, to downstream drift of *H. limbata* nymphs from tributary rivers such as the Chippewa, Zumbro, Whitewater, Trempealeau, Black and Bad Axe as well as many smaller streams populated by *H. limbata.* Preliminary studies conducted at Winona, Minnesota, indicate that large numbers of *Hexagenia* nymphs drift down the Mississippi River. Swanson (1967) reports that mass drifting of *Hexagenia* nymphs also occurs in the Missouri River.

It is evident from Figures 1 and 2 that the Keokuk Pool, which produces many *H. limbata* in early summer, becomes marginal habitat for *H. limbata* in midsummer. Here, *H. bilineata* obviously becomes the dominant form as the summer progresses. It may also be observed that the early, upstream portion of *H. bilineata's* seasonal emergence distribution is vacant and that the early, upstream portion of *H. limbata*'s distribution fits neatly into the space. *H. limbata* emergences usually occur prior to those of *H. bilineata* because *H. limbata* is able to emerge at lower water temperatures. Under laboratory conditions, *H. limbata* has emerged and flown vigorously at temperatures as low as 14.5 °C. *H. bilineata,* on the other hand, does not emerge under laboratory conditions or from the river until water temperatures reach 18 °C (Fremling, 1964; Thomforde and Fremling, 1968). It seems likely that *H. limbata* produces a summer generation in the Mississippi River. Late summer emergences are not as abrupt as those of early-summer, however, because the latter have not been coordinated by winter.

Like *H. bilineata, H. limbata* finds the zones of degradation below Minneapolis and St. Louis unsuitable for habitation. While both *H. bilineata* and *H. limbata* are excellent indicators of good general water quality, *H. limbata* is probably the better indicator of the two on the Upper Mississippi River.

Pentagenia Vittigera

The biology of *Pentagenia vittigera* is poorly known. The nymphs, which apparently live in faster water areas than *H. bilineata* or *H. limbata* are difficult to collect. Like *H. limbata,*

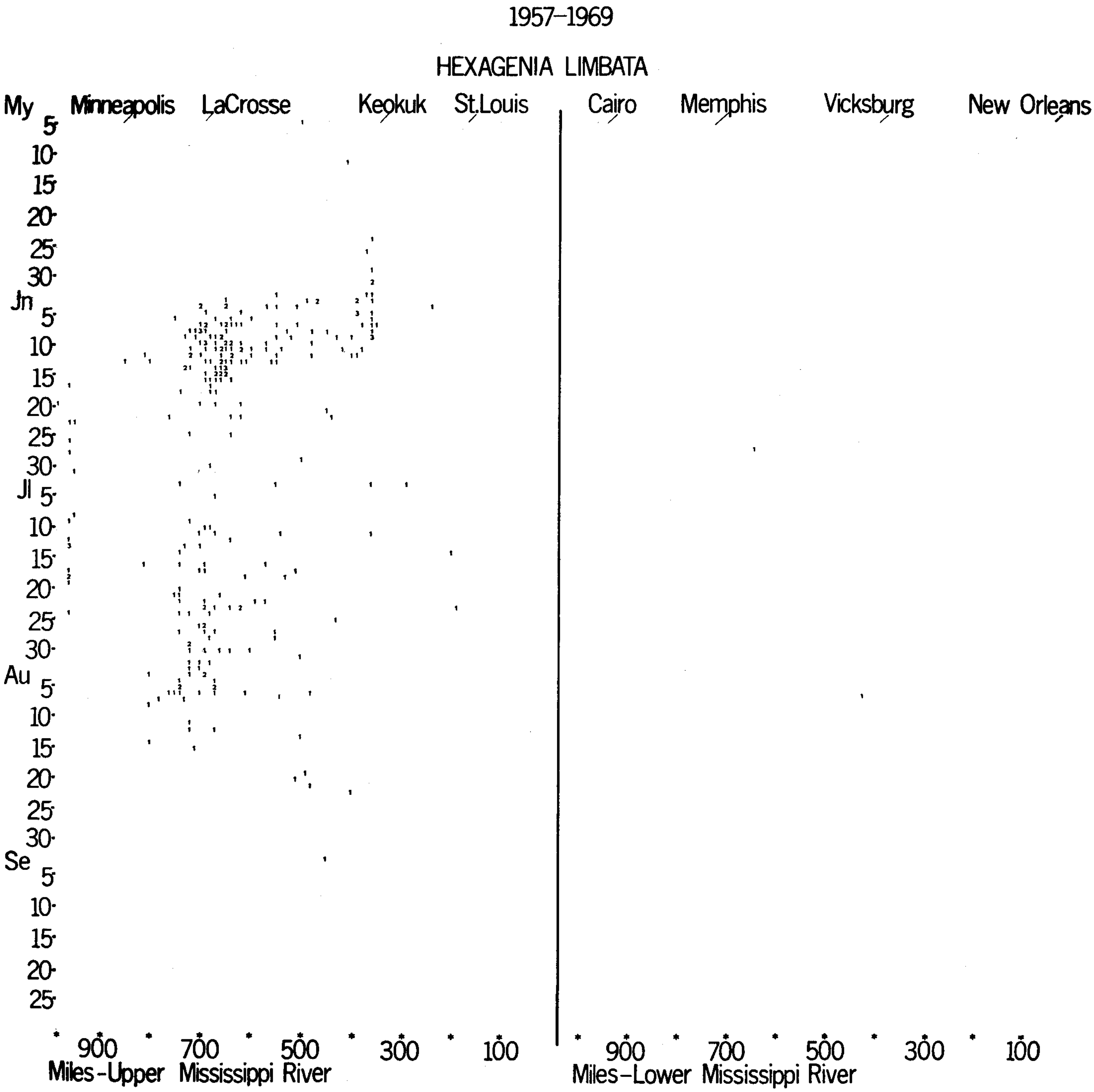

FIGURE 2. Seasonal and geographical distribution of *H. limbata* on the Mississippi River from Brainerd, Minnesota, to the Gulf of Mexico as indicated by collections of imagoes and subimagoes during mass emergences. Each number indicates the total mass emergences thus reported at that point during the interval 1957-1969.

however, the insect is versatile and it has been collected from a wide latitudinal area. IDE (1955) has collected adult *P. vittigera* along the bank of the Assiniboine River near its junction with the Red River at Winnipeg, Manitoba. *P. vittigera* has also been collected as far south as the Apalachicola River in Florida (*Berner*, 1950).

Although DAGGY reported in 1941 that the species occurred in the Mississippi River at Red Wing, Lake City and Minneapolis, Minnesota, the species is rarely collected in that area now. The seasonal distribution of *P. vittigera* is very unusual in the 400-mile segment of river below St. Louis (Fig. 3). There the insect emerges only during the very early summer and very late summer, even through it occurs all summer above St. Louis and from mile 600 L.M.R. almost to New Orleans. The pollutant load below St. Louis is apparently sufficient to render about 400 miles of the river uninhabitable during the time when river temperatures are highest. It seems likely, in that area, that organic enrichment may cause low dissolved oxygen levels during the heat of the summer even though the river is not impounded. Certainly, summer water temperatures and low dissolved oxygen levels also combine to make *Pentagenia* nymphs more vulnerable to the complex of agricultural and industrial pollutants which enter the river in the St. Louis area. Early summer and late summer emergences from the 400-mile zone below St. Louis likely are caused by nymphs which have drifted into the area when low water temperatures and elevated dissolved oxygen levels have made the zone of degradation less deadly.

DISCUSSION

Because of its impounded state, the Mississippi River provides excellent habitat for *H. bilineata* throughout much of the area from Hastings, Minnesota, to St. Louis, Missouri. The navigation dams which were constructed during the 1930's have undoubtedly increased the carrying capacity of the Upper Mississippi River for *H. bilineata* mayflies. It is likely that this very specialized species now dominates many areas which were formerly dominated by *H. limbata*.

Water pollutants are severe limiting factors to mayflies. To a degree, however, nutrients from metropolitan Minneapolis and St. Paul have increased the carrying capacity of portions of the Upper Mississippi River for *Hexagenia* mayflies. In areas where dissolved oxygen is not a limiting factor, the enrichment has caused algae to proliferate, thus causing an increased food supply for burrowing mayflies.

The compact emergence patterns of *H. bilineata* during late June and of *H. limbata* during early June are due to a "stockpiling" of large nymphs during the winter months. The nymphs are able to grow slowly during the winter but they are unable to complete last instar development until early summer temperatures are attained. Thus, early summer emergence is coordinated by cold winter temperatures. *Hexagenia* emergences which occur later in the summer are obviously less well coordinated.

In early summer, the Upper Mississippi River provides good *H. limbata* habitat as far south as Keokuk. With increasing summer temperatures, however, *H. limbata* becomes less common in the Keokuk area. Increasing summer temperatures cause the apparent displacement of *H. limbata* by *H. bilineata* in the impoundments near Keokuk.

Water pollution obviously poses a severe threat to the burrowing mayflies of the Mississippi River.. Even if sewage treatment plants effectively remove most putrescible wastes and fertilizer elements, other contaminants may eventually erradicate them. Non-biodegradable insecti-

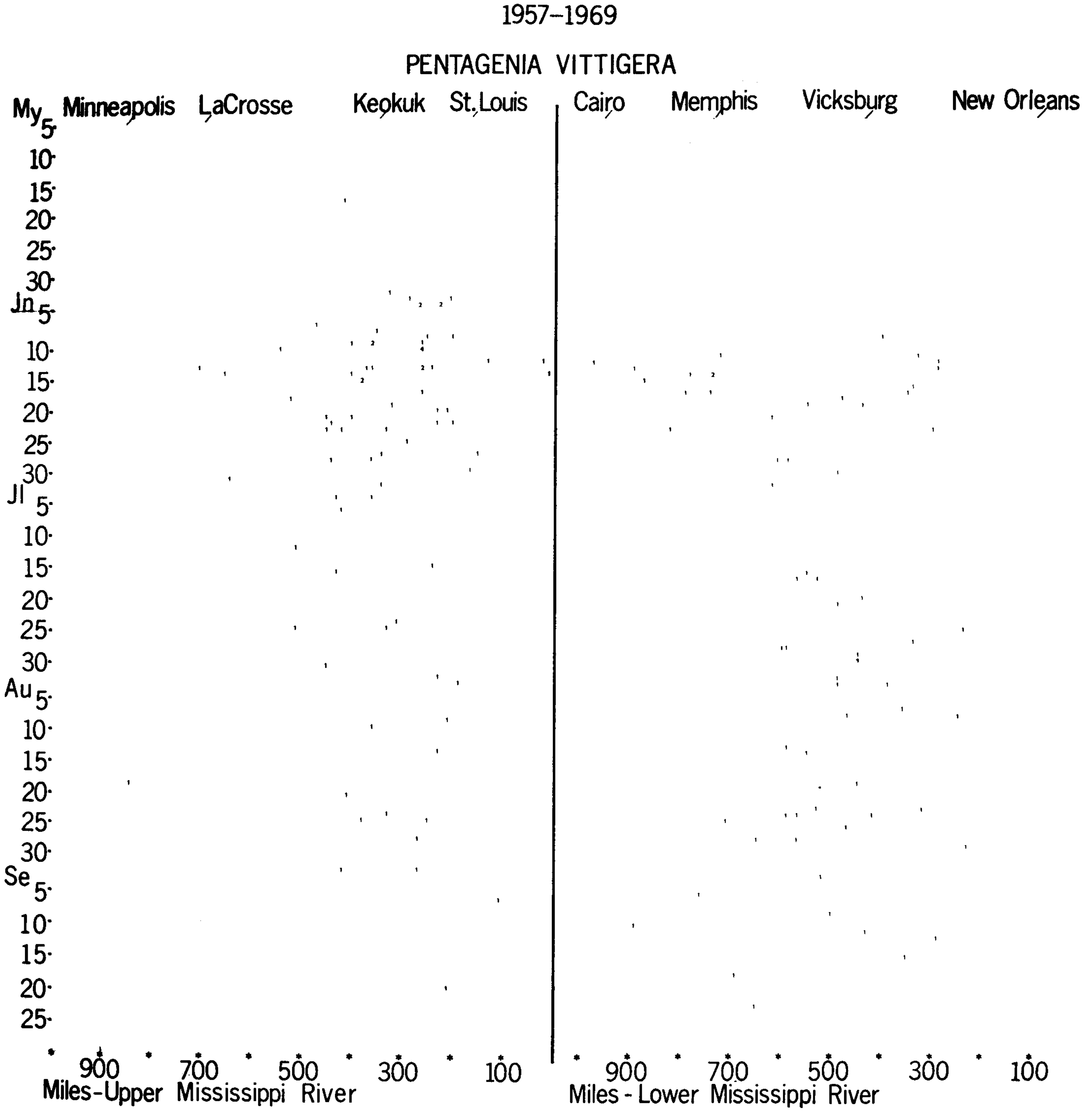

FIGURE 3. Seasonal and geographical distribution of *P. vittigera* on the Mississippi River from Brainerd, Minnesota, to the Gulf of Mexico as indicated by collections of imagoes and subimagoes during mass emergences. Each number indicates the total mass emergences thus reported at that point during the interval 1957-1969.

cides, heavy metals and other toxicants pose serious threats. Unless sewage treatment keeps pace with population growth and increased industrialization, burrowing mayflies may be eliminated from the Mississippi River as they have been in many other areas of the U.S. (FREMLING, 1968).

In many areas of the Upper Mississippi River, roads, dikes and railroads have dissected the flood plain thus cutting off the flow of water into old river channels. Such occluded channels and oxbow lakes stagnate in the summer and exhibit marked thermal stratification. The hypolimnia in such bodies of water usually become deficient in dissoved oxygen during the summer because of the high biochemical oxygen demand of bottom sediments. The same lakes often become deficient in oxygen during the winter when heavy ice and snow cover prevents sufficient light penetration to produce oxygen by photosynthesis. Such lakes usually produce no burrowing mayflies. Furthermore, they are death traps for nymphs which drift into them during spring floods.

The most insidious threat to burrowing mayfly populations on the Upper Mississippi River is sand. Ever since the Wisconsin glacial period the bed of the river from the mouth of the Chippewa River (mile 763 U.M.R.) to Keokuk has been slowly rising. Here, sand washed down from precipitous sandstone-limestone bluffs has entered the river at a rate faster than the river can remove it. The activities of man (agriculture, construction, etc.) have greatly accelerated the rate of sand deposition in recent years. The navigation dams, in turn, have provided places where the sand can accumulate. As a consequence, the pools are rapidly filling with sand. The U.S. Army Corps of Engineers dredges constantly to remove sand from the navigable channel of the river, but the dredged sand continues to accumulate outside the main channel in the navigation pools. As a consequence, silted river bottoms are rapidly being replaced by sand bars and islands. Unless corrective measures are initiated very soon, the Upper Mississippi River will be transformed into a single, narrow, unproductive channel as is the Lower Mississippi River.

Burrowing mayflies are good indicators of general water quality because their life cycles are relatively long. Although nymphs may drift for considerable distances, they are unable to swim directively for long distance to escape toxic conditions. It is obvious that even downstream drift of nymphs cannot compensate for nymphal deaths in the most severely polluted segments of the river. Unlike chemical tests which describe pollutant levels only at the time the tests were taken, mayfly distribution indicates what water conditions have been like for a prolonged period. Moreover, while chemical tests only test for specific pollutants, mayfly distribution indicates the subtle synergistic effects of combinations of many pollutants. This is especially evident below St. Louis where *P. vittigera* is only able to emerge in early and late summer. The mayfly distribution data presented in this paper should also provide valuable baseline data so that future changes in general water quality can be objectively assessed along the entire Mississippi River.

RÉSUMÉ

Facteurs influençant la distribution des éphémères fouisseuses le long du fleuve Mississippi

Le Mississippi est le plus grand fleuve des États-Unis et parcourt 2319 miles depuis sa source dans le lac Itasca, Minesota du nord, jusqu'à son embouchure dans le golfe du Mexique. La

portion du fleuve en amont de la rivière Ohio (à Cairo, Illinois) est appelée le Mississippi supérieur, tandis que la portion comprise entre Cairo et le golfe du Mexique est appelée Mississippi inférieur. Le numérotage des différentes sections se fait par nombre croissant dans la direction de l'amont. Le mile 0 du cours inférieur (abréviation L.R.O. 0) est l'embouchure du fleuve et le mile 0 du cours supérieur (U.R.O. 0) est situé à Cairo, Illinois. Le Mississippi se divise en trois sections écologiques : de sa source jusqu'à Mineapolis, Minesota; de Mineapolis à St Louis, Missouri; et de St Louis jusqu'au golfe du Mexique. La section supérieure est essentiellement de type torrentiel et la rivière coule pendant 511 miles à travers des dépôts de sable et de gravier datant de la récente période glaciaire du Wisconsin. A Mineapolis la rivière entre dans une vallée qui a 550 pieds de profondeur et 3 miles de largeur. Cette section de la rivière comporte 29 écluses et barrages, ces derniers formant de grands lacs artificiels qui souvent occupent la totalité de la plaine alluviale de la rivière. La troisième section commence à St Louis où se trouve le dernier barrage. A 185 miles en aval de St Louis le fleuve commence son parcours de 954 miles avec un immense delta plat et alluvial en direction du golfe du Mexique. Dû à sa canalisation, le cours inférieur consiste en un fossé profond, étroit et sinueux, conduisant rapidement vers le golfe du Mexique les effluents des États-Unis.

Trois espèces d'éphémères fouisseuses (*Hexagenia bilineata, H. limbata* et *Pentagenia vittigera*) sont si abondantes le long du cours du Mississippi qu'elles posent de sérieux problèmes de nuisance. La présence de ces lacs artificiels et le grossissement des eaux du cours supérieur du Mississippi ont temporairement augmenté le peuplement de la rivière par *H. bilineata* auparavant dominé par *H. limbata.* Parce que lecours du Mississippi en aval de St Louis ne comporte pas de barrages, son peuplement par *H. bilineata* et par *H. limbata* est moindre. *Pentagenia vittigera* est l'espèce dominante d'éphémère fouisseuse dans le cours inférieur du Mississippi bien qu'on la trouve aussi fréquemment dans le cours supérieur. Les polluants ont sérieusement réduit la fréquence des trois espèces sur 30 miles en aval de Mineapolis, Minesota, et sur plus de 300 miles en aval de St Louis, Missouri. *P. vittigera* dont l'émergence a lieu tout au cours de l'été en amont de St Louis, ne peut être aperçu dans la région de St Louis qu'au début et à la fin de l'été, lorsque la présence des eaux relativement froides diminue les effets toxiques dans la zone de dégradation. La productivité totale du cours supérieur est actuellement réduite par la pollution, par l'action de l'homme sur le lit de la rivière et par l'obstruction des voies navigables par le sable. La distribution des éphémères, déterminée par la récolte d'adultes pendant une période de 13 ans au cours des émergences en masse, s'est montré être un excellent indicateur de la qualité moyenne des eaux des rivières trop grandes pour être analysées effectivement ou économiquement par des méthodes standards.

ZUSAMMENFASSUNG

Faktoren welche die Verteilung der bohrenden Eintagsfliegen am Mississippi-Fluss beeinflussen

Der Mississippi ist der grösste Fluss in den Vereinigten Staaten. Er windet sich von seinem Ursprung im Itaskasee im nördlichen Minnesota 2319 Meilen bis zur Mündung im Golf von Mexiko. Der Teil der Mündung des Ohio Flusses stromaufwärts, (in Cairo, Illinois) ist der obere Mississippi, während der Teil von Cairo bis zum Golf von Mexico der untere Mississippi genannt wird. Aufeinanderfolgende Meilen der beiden Flussteile sind stromaufwärts nummeriert. Niedere Meile 0 (L.R.M. 0) ist die Mündung des Flusses, und obere Flussmeile 0 (U.R.M. 0) ist Cairo, Illinois. Der Mississippi existiert in drei verschiedenen ökologischen Sektionen: vom Ursprung bis Minneapolis, Minnesota; von Minneapolis bis St. Louis, Missouri; und von St. Louis zum Golf von Mexiko. Der oberste Teil ist im wesentlichsten stromähnlich und fliesst 511 Meilen lang durch Sand- und Kiesablagerungen, welche während der jüngsten Wisconsin Eiszeit deponiert wurden. In Minneapolis beginnt der Fluss durch ein Tal zu fliessen, das bis 550 Fuss tief und drei Meilen breit ist. Dieser Teil des Flusses hat 29 Schleussen und Dämme, und diese Dämme haben enorme Stauseen geformt, welche oft das ganze Überschwemmungsgebiet des Flusses einnehmen. Der dritte Teil beginnt in St. Louis, wo der letzte Damm ist. 185 Meilen flussabwärts von St. Louis beginnt der Fluss seinen 954 Meilen langen Weg durch ein riesiges flaches alluviales Delta zum Golf von Mexiko. Kanalisation hat den unteren Teil des Flusses im Wesentlichen zu einem tiefen, engen, windenden Graben gemacht, welcher den Abfluss von den Vereinigten Staaten schnell in den Golf von Mexiko leitet.

Drei Arten von bohrenden Eintagsfliegen (*Hexagenia bilineata*, *Hexagenia limbata* und *Pentagenia vittigera*) sind in gewissen Gegenden des Mississippi so häufig, dass sie schwere Plagenprobleme verursachen. Eindämmung und Bereicherung des oberen Mississippi haben vorübergehend die Verbreitungsfähigkeit des Flusses für *H. bilineata* vergrössert, die nun viele Flächen dominieren, welche früher von *H. limbata* beherrscht waren. Weil der Fluss unter St. Louis nicht eingedämmt ist, bietet der untere Mississippi weniger Lebensraum für beide *H. bilineata* und *H. limbata*. *Pentagenia vittigera* ist die dominierende bohrende Eintagsfliege im unteren Missisippi und erscheint auch im oberen Teil des Flusses. Verunreinigung des Flusses 30 Meilen unter Minneapolis, Minnesota, haben die Anzahl aller drei Gattungen stark reduziert; dasselbe gilt für den Teil 300 Meilen unter St. Louis, Missouri. *P. vittigera*, welche während des ganzen Sommers oberhalb von St. Louis und längs der südlichen Richtung des unteren Mississippis zum Vorschein kommt, kann nur während des Früh- und Spätsommers im Gebiet von St. Louis herauskommen, wenn die kühlen Wassertemperaturen die giftigen Effekte in der Zone der Degradierung vermindern. Die totale Produktion des oberen Mississippis ist im Moment durch Verunreinigung, Eingriffe der Menschen in die Überschwemmungsflächen und das Auffüllen der Schiffahrtbasins mit Sand reduziert. Die Verteilung der Eintagsfliegen wurde durch die Sammlung der Erwachsenen während Massenerscheinungen in einer 13-jährigen Periode bestimmt. Dies zeigte sich als eine hervorragende Anzeige der allgemeinen Wasserqualität eines Flusses, der so gross ist, dass er nicht auf effektive oder ökonomische Weise mit gewöhnlichen Methoden gemessen werden kann.

Discussion

J. Leonard : I can attest to the validity of Dr. Fremling's comments. *H. bilineata* is primarily a large river form and *H. limbata* is in small streams. In Michigan at least *H. limbata* is the principle *Hexagenia* in our trout streams and is very important in the trout stream economy. We, of course, do not get *H. bilineata* there at all and as we get further up in the cold spring runs and beaver ponds, *H. recurvata* begins to appear.

E. Myer : Does cattle grazing have a significant effect on *Hexagenia*?

C. Fremling : I used cows as an example. Really, every hiker that climbs a hill kicks sand down the hill. Natural geological forces tend to raise the floor of a river like the upper reaches of the Mississippi River. The river flows through an old glacial gorge. Man is speeding up the rate at which the valley floor rises. So every hiker, home builder, cow, deer, ... all of them contribute to the speed at which sand accumulates in the river bottom. It is not only affecting the mayflies, but it is affecting man himself and increasing the level of floods. Flooding is another factor which I could have mentioned.

L. BERNER : How much longer do you think *Hexagenia bilineata* can last in the Mississippi River?

C. FREMLING : I feel that *Hexagenia bilineata* is decreasing in numbers right now, especially downstream from Keokuk, Iowa, but it is hard for me to predict how much longer they will exist. The river is going to change; the U.S. Army Corps of Engineers has a program now to deepen the channel of the Mississippi to 12 feet. It is now 9 feet deep, and some people feel that a 12 foot navigation channel would hasten the demise of the mayflies because it would make sand deposits increase. In some ways it could improve the habitat temporarily by rejuvenating silted pools.

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