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Distribution and Status of Ohio River Fishes

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DISTRIBUTION AND STATUS OF OHIO RIVER FISHES

Report Prepared by

William D. Pearson and Louis A. Krumholz

Water Resources Laboratory
University of Louisville
Louisville, Kentucky 40292

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ABSTRACT

The Ohio River has been modified extensively by the activities of the nearly 40 million people living within its basin. The effects of siltation following clearing of the forests in the 19th century and the construction of a system of dams for maintaining navigation between 1900 and 1929 affected the entire river, while pollution (industrial and domestic) was most severe in the upper third of the river in the 1940's. In this report we have tried to assess the current status and distributions of fish in the Ohio River and relate them to river habitats and conditions. We found records of 154 species of fishes reported from the Ohio River between 1817 and 1983. Fourteen of these species were introduced by man. Only 13 species which were represented before 1970 were not found in the river between 1970 and 1983. Of these 13 species which have disappeared, only one, the lake sturgeon, was ever an abundant fish in the Ohio River. However, several other important or unique fishes have declined alarmingly in abundance or distribution since 1900. These include the shovelnose sturgeon, paddlefish, muskellunge, and blue sucker.

The ten most-abundant fishes in the Ohio River lock chamber rotenone collections of 1957-80 were: emerald shiner, gizzard shad, freshwater drum, mimic shiner, channel catfish, common carp, bullheads, skipjack herring, white crappie, and threadfin shad.

Between 1957 and 1980 fish densities increased dramatically in the upper 100 miles of the river where water quality improvements were greatest. Fish populations remained relatively stable in the lower two-thirds of the river between 1957 and 1980. Many of the long-term changes in relative

abundances can be explained by considering the effects of siltation and canalization of the river on spawning habitats. Fishes which produce pelagic or semi-pelagic eggs and/or larvae have come to dominate the fish community (i.e., emerald shiner, gizzard shad, and freshwater drum), while fish which require clean gravel substrates for spawning have declined (i.e., sturgeons, paddlefish, blue sucker, and redhorses).

The goals of P.L. 92-500 to eliminate pollutants have been approached with corresponding improvements in fish densities and distributions, particularly in the upper portions of the river. We recommend that these goals be vigorously pursued and that the regulatory and management agencies responsible for the fishery resources of the Ohio River establish an overall fishery resource plan which would coordinate all fishery investigations on the river to achieve a specific and prioritized set of objectives.

EXECUTIVE SUMMARY

The Ohio River Valley constitutes one of the great coal-producing regions of the world and is inhabited by nearly 40 million people. The Ohio mainstem has on its shores nearly 40 major power plants which use the river for cooling purposes, along with major industrial concentrations at Pittsburgh, Cincinnati, and Louisville. The mainstem is also impounded by 20 locks and dams which maintain a 9-foot channel for the movement of nearly 150 million tons of waterborne cargo per year.

All of these human activities have, naturally, had tremendous impacts on the Ohio River and its biota. By the 1930's and 40's, pollution of the upper half of the Ohio River was so severe, with regular outbreaks of waterborne diseases, that eight states along the river formed the Ohio River Valley Water Sanitation Commission (ORSANCO) in 1948 to begin cleaning up the river. Thereafter, significant decreases in some pollutants were recorded as nearly all municipalities along the river installed primary and secondary treatment facilities by the late 1960's.

The National Environmental Policy Act of 1969 (NEPA) and The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) have had two important effects which led to this report: 1) Both NEPA and P.L. 92-500 have required the preparation of many environmental impact statements, environmental reports, and compliance reports on the effects of new projects and the operations of existing facilities on the Ohio River and its biota; and 2) P.L. 92-500 has established a national goal of eliminating the discharge of pollutants into all navigable waters by 1985.

Our objectives in preparing this report were: 1) to describe the distribution and relative abundances of fishes in the Ohio River

between 1970 and 1983 and compare these with those reported before 1970; 2) to gather, and analyze, the scattered data on larval fish distribution in the Ohio River produced since 1970 and determine their significance; 3) to identify riverine habitats critical for reproduction of fish, and 4) to draw conclusions regarding the current status and well-being of the Ohio River fish community.

Historical Overview

The Ohio River and its predecessor, the Teays River, have channeled waters of the region to the Mississippi system for over 200 million years. The present channel of the Ohio lies roughly at the edge of the southernmost extension of the last glacial invasion of North America (10,000 years ago). When the first French and English explorers reached the river in the 1600's they described it as a beautiful, clean stream flowing through extensive hardwood forests, with marshy areas along the floodplain and at nearly every creek mouth. Floods were common and provided easier navigation over several rocky rapids and the many snags and drift piles.

When the Northwest Territory was opened to settlement by the Americans after the Revolutionary War, the Ohio River became the primary route to the "West". The movement of cargo along the river increased rapidly after the first steamboat was launched on the river in 1811, and the Louisville and Portland Canal was completed in 1830 to provide a means of passing the major low-water obstacle on the river, The Falls of the Ohio at Louisville. In 1909 a decision to maintain a year-around 9' channel for navigation was reached, and by 1929 there were 50 dams on the river providing lifts of 5.6 to 12 feet each (the dam at Louisville was an exception with a lift of 37 feet). This system of 50 dams and locks was replaced with

a newer system of high-lift (10-35 feet) dams between 1955 and 1980. Today (1983) there are 20 dams on the Ohio River.

Water Quality

Actual records of water quality in the Ohio River are rarely found for the years before 1920. However, the few records and observations recorded in the 19th century indicate that the quality of water declined as the population of European settlers increased in the Ohio River Basin after 1810. There were increases in mean turbidity, total dissolved solids, chlorides, nitrates, and sulfates up to the 1940's. During the same period dissolved oxygen values declined, particularly after 1900, and downstream from the major metropolitan areas. Acid mine drainage in the upper Ohio River Basin resulted in pH values of less than 4.0 in the upper 100 miles of the river before 1950. Mean monthly total coliform bacteria counts in the river often exceeded 20,000/100 ml in the 1940's.

Primary sewage treatment facilities were installed for over 90% of the basin's residents by 1960, while secondary facilities were in place by the middle 70's. As a result of all pollution control measures combined there were significant decreases in coliform bacteria counts after the 1950's. However, between 1960 and 1983, coliform bacteria counts declined most in the upper 100 miles of the river. In the lower two-thirds of the river, coliform bacteria counts remained relatively stable between 1960 and 1983.

There were slight, but significant, decreases in turbidity and sulfate concentrations in the river between 1953 and 1983. The concentration of nitrates, phosphates, and total dissolved solids remained stable in the same period.

The occurrence of low pH events, which had been a serious problem in the upper third of the river before 1950, were virtually eliminated by 1960, following effective controls placed on acid-mine drainage and industrial effluents.

In summary, water pollution was most serious in the upper 100-200 miles of the river, and during the 1940's. Significant improvements in water quality were made throughout the river between 1950 and 1983. Since 1960 the most dramatic improvements have been made in the upper 100 miles of the river while water quality in the lower two-thirds of the river has either remained stable or improved only slightly. Nevertheless, in view of the increased population of the basin during these two decades, such a stabilization is encouraging.

Fishery Investigations of the Ohio River

Early accounts of fishes collected from the Ohio River before 1920 cannot be relied upon for determination of relative abundances. However, they can, when compared to recent data, indicate the disappearances of some species and severe reductions in species which were once common enough to have been fished commercially.

The earliest general account of fishes in the Ohio River was provided by the eccentric naturalist Constantine S. Rafinesque, who traveled down the river in the summer of 1818. Rafinesque described 52 species of fish from the Ohio River and made some very general comments on their relative abundances. The very few recorded observations on fishes of the Ohio River between 1820 and 1920 is astonishing. Even these few reports are clumped about the areas of Cincinnati, Louisville, and Cairo in the middle and lower river sections.

Between 1920 and 1969 several investigators provided baseline data on Ohio River fish populations, and interpreted their findings in light of human disturbances in the river basin. Trautman (1957 and 1981) in his long and thoughtful considerations of Ohio fishes and the changes in their distributions,discussed all of the Ohio River fishes in the Ohio portion of the river. The ORSANCO (1962) study of 1957-60 provided the first comprehensive view of fish populations in the Ohio River from mouth to source. This monumental work was based upon 123 lock chamber rotenone samples supplemented by 125 collections made with seines, electric shocker, otter trawls, hoop nets, gill nets, and trammel nets. Other studies of Ohio River fishes during this interval include those of Gerking (1945), Lachner (1956), Carter (1961, 1962), Tebo (1965), Preston (1969), and Clay (1975).

Between 1970 and 1983 the number of fishery investigations on the Ohio River increased dramatically, primarily as a result of the requirements of the National Environmental Policy Act of 1969 and P. L. 92-500 of 1972. These acts, and their subsequent amendments, have forced the preparation of environmental impact statements and/or other environmental reports for virtually every project of size proposed along the Ohio River. We examined 95 of these reports containing original data on Ohio River fishes published between 1970 and 1983. In addition, regional biologists seemed to have become more numerous and more active in this decade, and we examined many works of ichthyologists and agency biologists published during this period.

Abundance and Diversity of Ohio River Fishes Through Time

Although estimates of the relative abundances of Ohio River fishes before 1900 are based upon the impressions of early workers rather than quantitative measurements, it appears that the following fishes were

greatly reduced in abundance by 1950: lake sturgeon, shovelnose sturgeon, muskellunge, bigeye chub, and blue sucker. Fishes which had increased in relative abundance by 1950 included the introduced common carp and the gizzard shad. Important fishes which seemed to have changed little in abundance were the freshwater drum, channel catfish, and emerald shiner.

Between 1950 and 1983 the amount of quantitative data available on fishes of the Ohio River permits a more detailed description of changes in relative abundances. It was during this 33-year period that three additional introduced species (goldfish, white catfish, and banded killifish) established themselves in the river. It also seems possible that the grass carp will become established in the lower river in the next few years.

Densities of all fish species combined in the 243 lock chamber rotenone samples taken between 1957 and 1980 were divided into four time periods: 1957-60, 1967-70, 1974-77, and 1978-80. There were significant increases in densities of all fishes combined after the 1957-60 period in the upper 100 miles of the river, between ORM 400-600 and 800-900. There were no significant decreases in densities after 1957-60 at any location. Biomasses of all fish species combined doubled between 1957-60 (205 ±218 kg/ha) and the three subsequent periods (i.e., 1978-80, 458 ±82 kg/ha) in the lock chamber collections.

Abundance and Diversity of Fishes Along the Ohio River

Many species of fish were more widely distributed throughout the length of the Ohio River in the early 1800's than those same species are today, according to the writings of Rafinesque, Lesueur and others. For example, Lesueur described the blue sucker from the river at Pittsburgh and Rafinesque also found it there a few years later in 1818.

However, the blue sucker has been reported above ORM 300 only once since 1950. Similarly, many other species of fish which were reported from the upper 175 miles of the river by early workers (before 1900), have not been seen in that region since 1920 (i.e., least brook lamprey, paddlefish, shovelnose sturgeon, shortnose gar, mooneye, speckled chub, eastern sand darter, and blackside darter). Many of those species which are still found in the lower two-thirds of the river are most abundant in the last 200 miles of the river (i.e., paddlefish, shortnose and spotted gars, and shovelnose sturgeon).

A total of 154 species of fishes (including introduced species) have been reported from the Ohio River. Before 1920 reports listed 111 species. Between 1920 and 1969 reports listed 121 species. Between 1970 and 1983 reports listed 130 species. When the data from these three periods are combined, 120, 122, and 115 species had been reported from the upper, middle, and lower thirds of the river, respectively — a remarkably even distribution of species along the river. Eighty-six of the 154 species were found in all three sections of the river. Only 11, 8, and 15 species were found only in the upper, middle, and lower thirds, respectively. Species diversity indices ($\overline{H}$) increased significantly in the upper 100 miles of the river between 1957 and 1980.

When the 243 lock chamber rotenone samples taken between 1957 and 1980 were divided into 100-mile sections of the river and analyzed, it became clear that the highest densities of all fishes combined were found in the upper third of the river (14,764/ha). Densities in the middle and lower thirds of the river (6210 and 5393/ha) were about half that of the upper third. The high densities in the upper third of the river were due primarily to large numbers of emerald and mimic shiners.

Nearly all species of fishes increased in density between 1957 and 1980 in the upper 100 miles of the river, with the most dramatic increases seen after 1974. Below ORM 100, the densities of emerald shiner, mimic shiner, silver chub, and several other minnows decreased while densities of common carp, white crappie, sauger, white bass, and freshwater drum increased after 1957. Gizzard shad densities increased in the lock chamber samples above ORM 600, but decreased slightly below ORM 600. The densities of paddlefish, longnose gar, and skipjack herring increased slightly between 1957 and 1980 in the lower third of the river.

Densities of bullheads (all species combined) and blue catfish declined in most sections of the river between 1957 and 1980, and there was an apparent shift from black to brown bullheads in the upper third of the river.

Biomasses of all fishes combined, however, were greatest (485 kg/ha) in the lower third of the river according to the lock chamber rotenone samples. Biomasses in the upper and middle thirds of the river (251 and 258 kg/ha) were slightly more than half those in the lower third. Large catches of gizzard shad, common carp and bigmouth buffalo were primarily responsible for the high biomasses in the lower third of the river.

Emerald shiners, gizzard shad, and freshwater drum were the three most abundant fishes in the lock chamber samples of 1957-80. Emerald shiner densities were much greater in the upper third of the river than in the lower two-thirds. Gizzard shad densities were much more uniform throughout the length of the river, while freshwater drum densities were greatest in the middle and lower thirds. Mimic shiners were fourth in abundance, but, even more than the emerald shiner, were concentrated in the upper third of the river. Channel catfish were fifth in abundance,

and were distributed uniformly along the river. The remaining five species on the 10-most-abundant list were: common carp, bullhead (all species combined), skipjack herring, white crappie, and threadfin shad.

The fishes presenting the greatest biomasses in the lock chamber samples were gizzard shad and common carp. These two species were distributed throughout the river, but stocks were greatest in the lower 200 miles. The biomasses of freshwater drum and channel catfish ranked 3rd and 4th and were rather uniformly distributed along the river. The bigmouth buffalo ranked 5th in biomass, primarily due to a few unusually heavy catches made in the lower half of the river after 1979. The four species ranked 6th to 10th in biomass were: smallmouth buffalo, emerald shiner, paddlefish, flathead catfish, and bullheads (all species combined).

Reproduction and Spawning Habitats

We have found that an understanding of the spawning habits of Ohio River fishes, combined with knowledge of how man has altered the spawning habitats available to fishes in the Ohio River, will lead to some very convincing explanations of the observed changes in the fish community during historical times.

Most Ohio River fishes are spawned in the mainstem, not in tributary streams or the recently-created embayments. Originally the river provided extensive reaches of clean gravel substrate in the near-shore zone. Consequently, the majority of fish species found in the river were (and are) lithophils (fishes which spawn over clean gravel-rock). When the Ohio basin was cleared for agriculture and then canalized for navigation, those gravel substrates in shallow areas were altered by siltation and inundation. Therefore, many gravel-rock spawners (i.e., shovelnose sturgeon, redhorses, blue sucker, paddlefish) declined in abundance,

while those fishes which produce pelagic eggs and/or larvae (i.e., freshwater drum, emerald shiner, and gizzard shad) which float above the bottom increased in relative, if not absolute, abundance. Fishes (i.e., buffalofishes, carpsuckers) which spawn over vegetative matter (usually terrestrial vegetation and debris) maintained their relative abundances without noticeable change, perhaps because the vegetative substrate is renewed each year and, being lighter, will rest above the silt layer.

The nest-guarding sunfishes and basses (i.e., bluegill, largemouth, smallmouth, and spotted basses) are only abundant where protected embayments are available for spawning. We theorize that the constant disturbances due to wakes of passing towboats prevent spawning of the sunfishes and basses (but not crappies) in most portions of the mainstem.

Relative Abundances and Distribution of Larval Fishes

A tremendous amount of effort has been expended in determining larval fish densities in the Ohio River as a result of the National Environmental Policy Act of 1969 and P.L. 92-500 of 1972. We assembled the available information from these reports and reduced it to comparable units of measure.

Fish eggs and larvae first appeared in the river in April and reached peak densities in May and June of each year and declined dramatically thereafter. We could detect no significant differences in larvel fish densities between the years 1973-80.

We found a significant increase in the density of all larval fish taxa combined with increasing distance downstream. In the upper third of the river mean densities during the spawning peak were approximately 9.6/100 m^3, in the middle reaches of the river they were 56.5/100 m^3, while in the lower third of the river they increased to nearly 600/100 m^3.

Cyprinid and percid larvae were the most abundant taxa in the upper third of the river, while clupeids, cyprinids, and catostomids were most abundant in the lower two-thirds.

Distributional Check-list of Ohio River Fishes

We extracted distribution data from 197 separate publications appearing between 1817 and 1983, and supplemented this data with unpublished data, museum records, and personal accounts. Distribution maps were completed for the 132 species which were represented by two or more record-locations. The 154 species reported from the Ohio River were distributed in 61 genera and 24 families. We also list 51 additional species which have been reported in tributary streams near the Ohio River, and which could occur as strays in the Ohio River.

Major Conclusions

1. The Ohio River has been converted from a free-flowing river to one of relatively constant width with a minimum channel depth of 9' by the current system of 20 navigation dams. This system, coupled with land-use and flood control practices in the basin, has resulted in the siltation and inundation of extensive areas of gravel substrate, particularly in the lower half of the river.

2. Water quality, which was severely degraded in the upper third of the river by 1940, has improved dramatically in the upper river since 1960, and especially since 1973.

3. Nearly 80 major embayments were created in creek mouths adjacent to the mainstem by the installation of the the new high-lift navigation dams. These embayments are located along the upper half of the river, and offer important habitat for basses and other sunfishes.

4. The diversity of fish species is remarkably constant along the length of the river.

5. Of the 154 species of fish which have been recorded from the Ohio River, 14 have been introduced by man. Only the common carp, goldfish, white catfish, and banded killifish have established substantial, reproducing populations.

6. Only thirteen species reported before 1970 have not been reported between 1970 and 1983. Included in these presumably absent species are the lake sturgeon, which was abundant before 1900; the alabama shad, which has not been seen since the 1890's; and the burbot, which was always rare and may have been introduced. The crystal and gilt darters were very scarce forms which disappeared after the large riffles were inundated by the navigation dams between 1900 and 1920. The remaining eight species are all typically small stream inhabitants which probably strayed into the Ohio mainstem or only found the river habitable before impoundment.

7. Fishes which were still present in 1970-1983 but were judged to be severely reduced in numbers from their pre-1900 densities included: most lampreys, shovelnose sturgeon, paddlefish, alligator gar, muskellunge, and blue sucker. Several minnows and darters could probably be included with this group, but the early investigators often left us no idea of their relative abundances before 1900.

8. Fishes which increased in abundance between 1900 and 1980 were: common carp, gizzard shad, threadfin shad, and perhaps river carpsucker.

9. The ten most abundant fishes in the Ohio River between 1957 and 1980, according to the lock chamber rotenone samples, were (in order of abundance): emerald shiner, gizzard shad, freshwater drum, mimic shiner, channel catfish, common carp, bullheads, skipjack herring, white crappie, and threadfin shad.

10. Many of the typical riverine species of fishes were forced downstream between 1900 and 1940 as water quality deteriorated in the upper 200-300 miles of the river. Since 1970 many of these fish populations have begun to move back upstream. The most dramatic recoveries are seen in the upper 100 miles of the river where sauger, white crappie, goldeye, white bass, and freshwater drum densities increased between 1970 and 1980.

11. The three most abundant fishes in the Ohio River (emerald shiner, gizzard shad, and freshwater drum) are all either pelagophils or litho-pelagophils. The eggs and/or larvae of these fishes float in the water column — a reproductive strategy which must have been tremendously advantageous after the river was impounded and silted. Most fish species in the river are lithophils which must spawn over clean gravel. We believe that many of these fishes declined in relative abundance after 1900 (i.e., lake sturgeon, redhorses, blue sucker).

12. The density of all larval fish species combined, at the peak of the spawning season in April-June, increased from about 6/100 m^3 to nearly 600/100 m^3 as you go downstream from the upper to the lower third of the river.

13. The goals of P.L. 92-500 to eliminate pollutants have been approached with corresponding increases in fish populations. Although the most dramatic improvements have been seen in the upper 100 miles of the river where pollution was most severe, the modest improvements in the lower river in the face of an ever-increasing human influence, indicate the real value of pressing forward to a full realization of the goals stated in P.L. 92-500.

Recommendations

1. There is a great need for coordinating the many fishery investigations being conducted on the Ohio River. During the past decade many lists of fishes have been drawn up based upon collections near the site of each proposed project on the river. Fishes near some power plants have been sampled repeatedly and diligently for 8-10 successive years. However, many of these studies have no clear objective other than the need on the part of the part of the project proposer, to meet a legislated requirement.

To achieve the maximum return for our efforts, we recommend that regulatory and management agencies develop a set of realistic objectives covering Ohio River fishery resources centered on the three resource groups: 1) commercial species, 2) sport fishes, and 3) native fishes not fitting into the previous two categories.

Once an overall set of objectives has been agreed upon and prioritized, the regulatory and management agencies would be able to identify data gaps, draft a river-wide study plan, coordinate the efforts of all investigators working on the river and recommend individual studies which would maximize the usefulness of all information gathered, while reducing duplication and meaningless compilations.

2. The lock chamber rotenone samples provide the most economical and reproducible means of monitoring Ohio River fish populations and should be continued. However, it would be advisable to conduct the sampling program in a more uniform manner and enlist the aid of specialists for identifying smaller or unusual fishes. It would also be advantageous to conduct a study to validate the lock chamber results by comparing them with open-river populations near the locks.

3. Regulatory agencies should develop a set of documentation regulations which would ensure that all data developed under their requirements be collected and expressed in a uniform manner, and that copies of all documents submitted be deposited in both regional and national depositories where they will be preserved and available to the public.

5. Since the lower 62 miles of the Ohio River represent the last relatively free-flowing section of the river and provides important habitat for the shovelnose sturgeon, paddlefish, blue sucker, blue catfish, alligator gar, and other depressed big-river fishes, we recommend that any project planned in this area be examined with special care and fully compensatory programs be required to offset any deleterious effects expected as a result of approved projects. One such mitigative action might be a program of re-introducing the lake sturgeon to the Ohio River through a long-term stocking program.

INTRODUCTION

The fishes of the Ohio River have always been important to people living along the river, first as a source of food, and later as a means of making a living, the basis for recreational angling, as curiosities of nature, and as indicators of the overall quality of water in the river. When the European settlers began to arrive the fishes were reportedly large, abundant, and easily captured at the traditional fishing sites of the Indians (e.g., the Falls of the Ohio at Louisville, Kentucky). As the human population in the Ohio River Basin expanded, the character of the river was altered by human activities in the watershed. Initially, the clearing of the vast hardwood forests and the introduction of agriculture were the dominant influences.

But the Ohio River Valley lies in one of the great coal-producing regions of the world, and the realized and potential impacts of energy extraction from these coal fields on the river are enormous. The Ohio River Valley supports a large human population (nearly 40 million) including, on the banks of the river, the metropolitan areas of Pittsburgh, Cincinnati, and Louisville with many large industries including steel and other heavy manufacturing, chemical plants, and refineries, distilleries, meat-packing plants, and electric generating facilities. Plans are also being made to develop many synthetic fuel plants in the next decade. The U. S. Army Corps of Engineers maintains a nine-foot channel in the river for the passage of about 150 million tons of waterborne cargo each year through the operation of a system of offstream reservoir releases, dredging operations, and 20 lock and dam installations.

The resultant impacts of human activities on water quality, aquatic habitats, and aquatic life in the Ohio River have not gone without notice and concerned action. By the 1930's and 1940's drinking water supplies for communities along the river were in jeopardy, waterborne diseases were widespread, and the esthetic characteristics of the river below the metropolitan areas were disgraceful. Although most of the states along the Ohio River had formed water commissions in the 1920's or before, their individual influences had been small. The formation of the Ohio River Valley Water Sanitation Commission (ORSANCO) in 1948, with the primary objective of cleaning up the Ohio River resulted from a compact between eight states that either bordered on the Ohio River or its major tributaries (the Allegheny, Monongahela, Cumberland, Wabash, and Tennessee rivers, Figure 1).

In 1948 only about 1% of the industries in the Ohio River basin were equipped with treatment facilities, while by 1962 the figure had increased to 80%, and in 1975 it was nearly 100% (Dames & Moore 1975b). The percent of the human population of the basin served by sewage treatment facilities has also increased from 38% in 1948 to 90% in 1962, and 97% in 1975.

These impressive statistics on the progress of pollution control in the Ohio River Valley have been made possible by the enactment of the National Environmental Policy Act of 1969 (NEPA) and the Federal Water Pollution Control Act and its amendments, including the 1972 amendments (also known as Public Law 92-500), which requires all dischargers to obtain permits and meet specific requirements, and has provided extensive funding to municipalities for water pollution control. The National Environmental Policy Act has required the preparation of environmental impact assessments for new construction projects along the river by private industry,

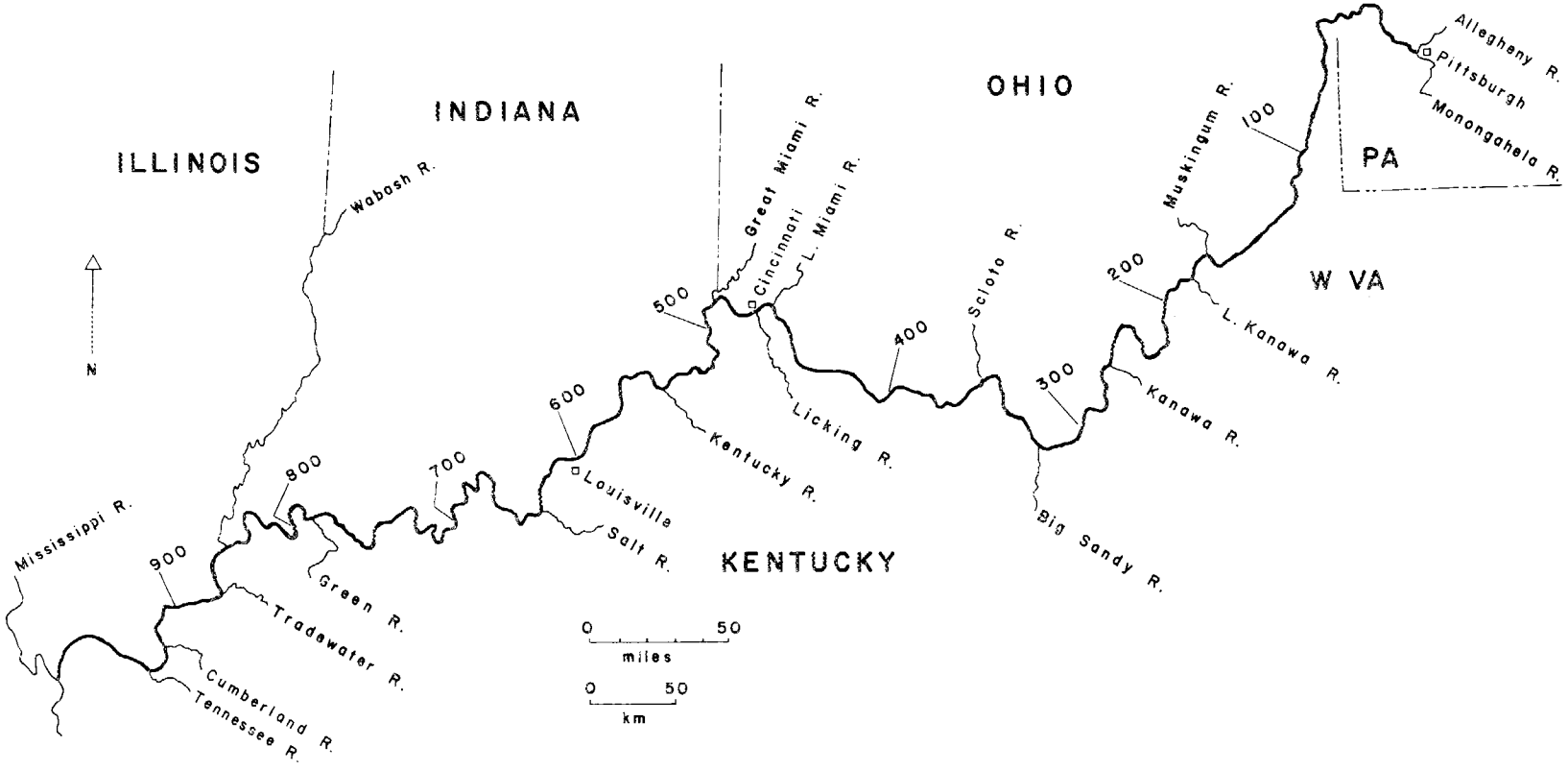

Figure 1. The Ohio River and its major tributaries; the numbers indicate Ohio River Miles (ORM), or the miles below the source at Pittsburgh as shown on U. S. Army Corps of Engineers navigation charts.

especially the electric power industry, the U. S. Army Corps of Engineers, and by private and governmental agencies involved in the development of riverports and similar projects.

The passage of Public Law 92-500 in 1972 established a national goal of eliminating the discharge of pollutants into all navigable waters by 1985. Significant steps have been taken toward meeting that objective in the past eleven years. To meet the requirements of NEPA and P.L. 92-500 (particularly the requirements of Sections 316a and 316b of the Act) there have been many studies of the effects of cooling water withdrawals and discharges of heated effluents by electric power plants on fishes in the Ohio River between 1970 and 1983. Most of these studies were restricted to the immediate vicinity of the facility under consideration.

These reports and environmental assessments have been interpreted largely on a project-by-project basis. Now is clearly the time to assemble all of the information gathered during these individual projects and produce an overview of the current status of the fish populations of the Ohio River. To this end our specific objectives are:

(1) To describe the distribution and relative abundance of fishes in the Ohio River between 1970 and 1980, and to compare them with those reported prior to 1970.

(2) To assemble the scattered data on spatial and temporal distributions of eggs and larvae of Ohio River fishes as generated by Section 316b of P.L. 92-500 and other reports, published and unpublished, and to determine their significance.

(3) to identify critical habitats in the river that may be essential to the reproduction and survival of fishes.

(4) To use the information gathered by meeting objectives 1-3 above to draw conclusions regarding the current status and well-being of the fish community of the Ohio River so that we may identify problems and outline necessary projects or monitoring strategies to solve those problems.

HISTORICAL CHARACTERIZATION OF THE OHIO RIVER

The Ohio River and its many predecessors have channeled waters to the mighty Mississippi River basin for over 200 million years. The first named precursor of the Ohio was the ancient Teays River, which headed in the Piedmont region of North Carolina and flowed north to Huntington, West Virginia. From Huntington the Teays flowed northwest across Ohio and then turned westerly across Indiana and Illinois to join the Mississippi 200 miles north of their present union (Janssen 1952). The Pliestocene glacial invasion, which began 1 million years ago and ended just 10,000 years ago with the retreat of the Wisconsin glacier, resulted in enormous changes on the drainage pattern of the Ohio River basin (Fowke 1933). As each successive glacier advanced from Canada into the eastern United States all north-flowing streams were blocked and their waters, combined with meltwater from the glaciers, were turned along the ice margins forming temporary impoundments which backed up the river valleys and eventually spilled over divides into existing south-flowing streams. The channels thus formed at the southernmost extensions of the glacier were subsequently the major waterways of the area, since as the glaciers retreated they buried all former channels beneath them (including much of the ancient Teays) with many feet of glacial till (Flint 1947). The present course of the Ohio River is, therefore, due to the reversal of flow of the Allegheny, Monongahela, and several smaller river systems due to glacial blockage, and the current river valley lies just 10-80 miles south of the southernmost extent of the ice sheets in most places. The conditions prevailing in the Ohio River as the glaciers crept to their southernmost extent were of great importance in

determining the present-day fauna. The river, and indeed the climate itself, would have been colder, and the coldwater fishes (trouts, ciscos, whitefishes, etc.) would have been at an advantage. As Trautman (1957, 1981) has explained, geologists and geographers differ on whether the Ohio would have been extremely cold and frozen over for most of the year, or whether the climate may have been much warmer, with occasional summer air temperatures of 70°F even at the maximum intrusion of the glaciers. It can definitely be deduced, however, that portions of the Ohio River were inundated by temporary lakes, that the volume of flow fluctuated widely with changes in the volume of meltwater added to the basin, and that the amounts of gravel, sand, and glacial rock washed into the valley were enormous.

The first human settlers along the Ohio River arrived 13,000-6,000 years ago. These were the people of the Indian Knoll Culture who were probably not many generations beyond the first humans to enter North America via the frozen Bering Strait. The stories of these peoples and their successors, the mound-building Adena and Hopewell cultures, have been told by Banta (1949) and others and need not be retold. It is sufficient to note that the early Indian settlers in the Ohio River Valley arrived after the retreat of the last glaciers, and occupied the same second-bottom fields near the mouths of major tributaries that European settlers would later claim. The Indians depended heavily upon shellfish and fishes from the river judging from the immense heaps of shells and fishing artifacts found in their middens. While a few descendants of these mound-builders persisted in the southern portion of the Ohio Valley into the 1700's most of them had been replaced by the semi-nomadic tribes known to the early European settlers — the Shawnee, Miami, Mingo, Cherokee and Delaware.

The first European to record his visit to the Ohio River was LaSalle in 1669, although the visit is questioned by some historians. The French had heard, from captives brought north by the Iroquois, of a beautiful river to the south by means of which the Indians could reach the ocean and trade with the Spaniards. LaSalle meant to find that river and its outlet to (hopefully) the Pacific. By 1700 the river which the French called "La Belle Riviere", the beautiful river, was well-known to the Europeans. The English name "Ohio" has been derived from either the Indian word "oyo", meaning beautiful or "ohiopeekhanne", meaning the white foaming river, according to Hulbert (1903).

The English first officially expressed an interest in the "Ohio" country in 1744 when delegates from the New England colonies purchased from the Iroquois League a loosely defined tract of land to the west of the colonies. This sale formed the basis for subsequent British and American claims to the upper Ohio basin. In 1749 the British chartered the Ohio Company of Virginia and granted it 500,000 acres on both sides of the Ohio River. This charter prodded the French into immediate action, and resulted in that same year, in the expedition of Ciloran de Bienville. Ciloran and a party of 200 traveled in canoes down the Allegheny and the Ohio to the mouth of the Great Miami River. During the next six years the French made every effort to establish a presence on the Ohio to validate the claims of Ciloran, establishing several small forts including, in 1754, Ft. Duquesne at the joining of the Allegheny and Monongahela rivers. When the French were defeated in the French and Indian Wars the Ohio River Valley passed into the uncontested hands of the British and their American colonists.

Ft. Duquesne was captured by the British and renamed Ft. Pitt, later Pittsburgh. The American colonists then began to drift slowly

into the Ohio River Valley. When the colonists declared independence from Britain they faced renewed warfare with the Indians and their British allies across the Ohio. Louisville was founded in 1778. Although a provisional peace was signed with the British in 1783, the settlers along the Ohio were never free of the danger of raids from the Indian side of the river. Still, they trickled in, founding Marietta, Ohio in 1787 and Cincinnati the following year. Finally, the Indian raids became intolerable and several forces were organized to march across the Ohio. After the great victory of Anthony Wayne at the Battle of Fallen Timbers and the signing of the Treaty of Greenville in 1795, the Americans obtained ownership of southern and eastern Ohio. and exclusive purchase rights, and rights of free movement, in the remainder of the Northwest. This ended the most serious threats of Indian attack on settlers in the Ohio Valley, and the trickle of immigration began to swell. Most of the subsequent warfare of the War of 1812 in the region occurred in the Great Lakes region, and 1813 saw virtually the end of Indian hostilities along the Ohio.

Most of the settlers in the Ohio River Valley at the time traveled overland to Pittsburgh and then moved down the Ohio River on flatboats. It has been estimated that 3,000 such flatboats descended the Ohio each year between 1810 and 1820.

Many of these earliest visitors to the Ohio River (between 1669 and 1820) left diaries and journals of their experiences. Their reports are sometimes obviously exaggerated because the authors often had land to sell, reputations to build, or other motivations for trying to impress the seaboard reader back in New England and Virginia. As might be expected, the fishes of the river were often mentioned, but we must recognize that these early writers were adventurers, soldiers, land

speculators, traders, and immigrants, not trained naturalists. It is also well to keep in mind Hulbert's (1903) observation that "Travelers, as is always the case, are interested in what is unusual, not in what is typical and commonplace." Therefore, it is not surprising that many of the early travelers remark upon the odd appearance of the gar, the huge catfishes and muskellunges of the river, while failing to mention anything about the minnows, sunfishes, and other smaller fishes with which they were, perhaps, already familiar. Still, the impressions of these early travelers are important in providing an understanding of what the river habitat available to fishes was like in its pristine state, and in assessing the original fish community of the river. These early observations have been summarized to a certain extent by Hulbert (1903), Banta (1949), Lachner (1956), Trautman (1957, 1977, 1981), Jackson (1962), and Gammon (1977).

River Conditions Before 1820

When the European settlers arrived on the Ohio they found it flowing through an immense hardwood forest from source to mouth. Above the Muskingum River the forest was typically Appalachian oak forest. Between the Muskingum and the Scioto River existed a mixed mesophytic forest. From the Scioto to below the Salt River was a combination of the oak-hickory and beech-maple forests, while below the Salt River the stream coursed through a modified southern floodplain forest with oak-hickory stands away from the river itself.

In reading accounts of the early travelers, soldiers, and settlers throughout Kentucky, Indiana, and Ohio, one repeatedly hears of the troublesome marshes, mires, and soft boggy areas through which the travelers moved. Newcomers to the area also commented frequently on

the yellowish appearance of the first settlers, on the prevalence of fevers and "vapors" to be contracted in the low-lying areas near the river, and of the dense clouds of mosquitos which made their lives miserable. Early accounts of nearly all settlements along the river comment on the large areas of swampy ground which impeded travel, building projects, and agriculture. The natural vegetation covering and protecting the land, together with the filtering action of the extensive swampy areas must have resulted in very clear waters in the Ohio River and indeed, almost without exception the early reports describe the Ohio waters as clear, except during floods or "freshes".

Rafinesque (1820b) traveled the entire length of the Ohio in 1818 and described the waters of the Ohio as "...slightly turbid, and become much more so in the rises. At a low stage they are almost clear, and at all times very salubrious."

Rafinesque also described how smallmouth buffalo could be "...commonly taken with the dart at night when asleep...." indicating that the fish must have been resting in relatively still water of great clarity to have been seen by lantern or torch light.

Floods have been a regular, annual feature of the Ohio River, one need only consider the topography of its valley and early accounts to be assured of that. Seven floods, with crests sometimes exceeding 60 feet, were reported in 1762, 1763, and in three years between 1774 and 1792. The power of such a volume of water is not to be denied, and there must have been a great deal of erosion of the river banks despite the natural cover of vegetation. We can assume that Cramer's (1814) warning to early boatmen on the Mississippi to beware of tying up beneath a vertical bank of sandy soil lest the bank cave in on the

boat, could have been applied to the Ohio as well. The ornithologist, Alexander Wilson, traveled down the Ohio by canoe in 1810 and mentioned (1812) the bank swallows, which "...commonly scratch out holes for their nests...on (in) the high sandy banks of a river...in several places along the Ohio, they congregate in immense multitudes." Indeed, even today the bank swallows excavate their nest holes in the vertical banks of the river where it erodes into the floodplain, much to the distress of landowners along the river. Rafinesque, again writing of his experiences in 1818, described the banks of the Ohio as "...all alluvial and of a deep and rich soil, seldom quite sandy or muddy. There are in many bottoms a second and a third bank, all very steep and from ten to forty feet high. The first bank is almost every where overflowed at high waters, the second never....Many banks sink or are washed away in inundations, when the channel sets against them."

The floods occurred mainly in the spring and fall, although minor "freshes" could be expected after any major rainfall, and were eagerly awaited in the summer by travelers wishing to ride their flatboats over the bars and "rapids". In the summer river levels sometimes fell so low that the river could be forded in many places between Cincinnati and Pittsburgh, at the Falls, and near Shawneetown and Cairo. In some places the river did not exceed 1-3 feet in depth during drought periods. Nuttall (1821) claimed that no boat drawing more than 9-10" of water could pass over many of the rapids between ORM 0 and 25 in October, 1818.

Trautman (1957) quotes a number of early boatmen who indicated that the substratum of the Ohio was composed mostly of clean gravels, sands, and rock. Cramer (1818) mentions many sand and gravel bars, rock outcroppings, and sandy banks but only one mud bank along the Ohio. On

the other hand, Schultz (1810) stated that "The country above Cincinnati is healthy, and free from all kinds of bilous complaints, although the shores of the river are generally one continuous and impassable bed of mud and slime. On the contrary, the shores below (Cincinnati) are dry and gravelly...." It seems safe to conclude that before 1818 the bed of the Ohio River did consist of more clean gravel and sand deposits than at present, but there probably were silt and mud deposits in the deeper pools and along the shore shortly after receding floods.

The early boatmen on the Ohio were, naturally, concerned with, and mentioned frequently, the various hazards to navigation other than low waters. These included a great many downed trees or snags including the vertical "planters" and the inclined "sawyers". It seems likely that the number of snags would have been increased by the early logging activities in the basin. Rafinesque (1820b) listed the main hazards to navigation as the numerous gravel and sand bars, "sinking banks", sunken rocks, rocky ledges, drifted logs, snags or sunken logs, rises and falls, shallow water, ripples and rapids. He states that many ripples become rapids at low water, but that all rapids disappeared at high water, "...even those called the falls, which lie below Louisville." He named Letart's rapids and Hurricane rapids as the most dangerous after the Falls, "...yet they are merely large rock ripples." Cramer tells us in The Navigator (1818) that during flood time vessels of "almost any tonnage...." could descend the river, and that it never got so low that canoes and other small boats could not be used. Cramer also offered the opinion that most of the impediments to navigation could, at low water, be easily removed with teams or blasting powder.

Rafinesque (1820b) claimed there were about 130 islands in the Ohio

River when he journeyed down it in 1818, and since he was under contract to a Pittsburgh book publisher to produce a map of the river, we can assume that he made an actual count. Cramer (1818) also lists the number of islands to be over 100 and mentions that although beautiful, the islands usually had associated with them many shoals, sandbars, and troublesome currents which added to the hazard of navigation.

There are no recorded temperature readings for the Ohio before 1818, but we can surmise that the greater shading of the river and its tributaries by trees, and the more abundant spring flows present in those days would have resulted in slightly lower summertime water temperatures than are now found in the river.

Navigation On The Ohio River

The Ohio River became the primary western route during the settling of the Northwest Territory (Ohio, Indiana, Illinois, Michigan, and Wisconsin) and the middle Mississippi River Valley between 1800 and 1850. The great rush of immigrants increased the population of Kentucky, Ohio, Indiana, and Illinois from less than 700,000 in 1810 to over 2 million in 1830. Many more passed through on their way to points farther west and south.

The first steamboat to operate on the Western Waters, as the Ohio and Mississippi river system was known, was the New Orleans which was actually launched on the Monongahela River at Pittsburgh in 1811. The advantages of steam propulsion on the Ohio over the earlier flatboats and keelboats became so obvious that construction of such vessels began in earnest at Pittsburgh, Cincinnati, and Louisville. By 1835, at least 684 steamboats had been built on the western rivers, principally at the three cities mentioned.

This burgeoning volume of boat traffic provided its own lobby for improved navigation on the Ohio (U.S. Army Corps of Engineers 1979a). In 1819 an interstate commission surveyed 102 bars and shoal areas which were hazardous to navigation. The first "Rivers and Harbors Act" of 1824 authorized funds for removing snags fixed to the bed of the river between Pittsburgh and the Mississippi River. One year later the Louisville and Portland Canal Company was formed to build a canal around the principal impediment to navigation on the Ohio River — the 37-foot-fall of the river over a run of nearly 2 miles at the "Falls of the Ohio" at Louisville. This canal was completed in 1830 and was soon passing 1500 steamboats and 500 keel- and flatboats through its three locks (50' × 185') each year. Thousands of other boats ran over the "Falls" during high water, since there was originally no dam associated with the canal.

Between 1837 and 1866 the Federal Government continued the snag-removal program and constructed 47 back-channel dams and 111 training dikes on the Ohio River. The purpose of these structures was to confine water to the channel of the river, thereby deepening the river at times of low flow. Some dredging of the channel and rock-removal operations were also begun during this period. Between 1834 and 1875 a series of successful projects employing dams passable by gated locks were installed on the smaller Green, Monongahela, and Muskingum rivers, and Ohio rivermen began to urge the construction of a similar system on the Ohio River. A new survey was made in 1875 which supported the usefulness and efficiency of such a system on the Ohio.

As a result, the first cross-channel dam on the Ohio River was constructed at Davis Island, 5 miles below Pittsburgh in 1885. The Davis

Island Dam was of the "moveable wicket" type, that is, it had a navigable pass section consisting of a series of hinged wickets which were only raised during low-flow conditions. Under high-flow conditions the wickets were collapsed flat on the river bed and tows (and fish as well) could pass up or downstream over the dam, rather than through the locks.

Between 1909 and 1910 a decision to maintain a 9-foot channel throughout the length of the river was made and an additional 12 dams were constructed between Louisville and Pittsburgh. In 1927 a new movable dam (#41) was completed at Louisville. This structure was of special importance because it was the first of the permanent "high-lift" dams. All previous dams on the river were provided with a navigable section over which both tows and fish could pass during high flow periods. The new dam provided a 37' lift at Lock 41 and made it impossible for fish to pass upstream at Louisville by any means other than locking through with the tows, or by either negotiating the small gated sections or topping the dam at flood stages. By 1929 there were 50 dams on the river, each with a 110' × 600' lock (except Emsworth and Dashields which also had 56' × 360' auxillary chambers). At the 38 structures above Louisville the lift of each dam ranged from 5.6-11 feet, while at the 11 dams below Louisville the lift varied from 7-12 feet. All of the dams except #41 at Louisville, and Emsworth and Dashields above Mile 14, were provided with a navigable pass at high-water periods. Although the original slackwater navigation system specified 54 low dams on the river, the construction of somewhat larger dams at Louisville and on the upper river resulted in just 46 dams in 1937 following the completion of the Gallipolis Dam.

Between 1937 and 1950 barge traffic on the river continued to increase, and the average size of both tows and towboats also increased. Therefore, the U. S. Army Corps of Engineers began a replacement and modernization program in 1955 which has gradually replaced the older, low, movable wicket dams with fewer high, non-navigable, gated, high-lift dams. The replacement of most of the older 110' × 600' lock chambers with 110' × 1200' locks has also been accomplished. At present (1982) there are 20 lock and dam structures on the Ohio River (Table 1), with the last of the small wicket-type dams (#52 and #53) in the lower river scheduled for possible replacement by a new high-lift dam between Mound City and Olmsted, Illinois. All of these dams are equipped with the new and larger 110' × 1200' locks except Gallipolis and Lock and Dam #53.

The new, non-navigable dams have lifts of 10 to 35' above Louisville and 16-25' below Louisville, or nearly twice that of the older structures. The new structures above mile 720 are of the non-navigable, gated dam with fixed wier type, while those below mile 720 are of the gated, navigable wier type. The primary difference being that the lower dams have a fixed wier section over which tows can pass when the locks are closed during high water. The gated structures above Mile 720 have tainter, roller, or vertical lift gates which release water near the bottom rather than over the top. Bottom release has the advantage of flushing oxygen-deficient water and silt from the pools above the dams, but also makes upstream movement of fishes difficult if not impossible at low flow. Even at flood stages when the non-movable sections of the dams are topped and the movable sections are fully open it seems likely that upstream movements of many fish would still be restricted.

Table 1. Characteristics of dams on or proposed for the Ohio River in 1983 (U.S. Army Corps of Engineers 1980a).

Completion Date	Name	O.R. Mile	Lift	Type	Lock Sizes (ft)
1921	Emsworth	6.2	18'	non-navigable, gated dam	56 x 360, 110 x 600
1929	Dashields	13.3	10'	non-navigable, fixed crest dam	56 x 360, 110 x 600
1936	Montgomery Island	31.7	17.5'	non-navigable, gated dam	56 x 360, 110 x 600
1961	New Cumberland	54.4	20.5'	non-navigable, gated dam	600 x 110, 110 x 1200
1965	Pike Island	84.2	21.0'	non-navigable, gated dam	600 x 110, 110 x 1200
1975	Hannibal	126.4	21.0'	non-navigable, gated dam	600 x 110, 110 x 1200
1976	Willow Island	161.7	20.0'	non-navigable, gated dam	600 x 110, 110 x 1200
1969	Belleville	203.9	22.0'	non-navigable, gated dam	600 x 110, 110 x 1200
1970	Racine	237.5	22.0'	non-navigable, gated dam	600 x 110, 110 x 1200
1937	Gallipolis	279.2	23.0	non-navigable, roller gated	110 x 360, 110 x 600
1964	Greenup	341.0	30.0'	non-navigable, gated dam	110 x 600, 110 x 1200
1964	Meldahl	436.2	30.0'	non-navigable, gated dam	110 x 600, 110 x 1200
1964	Markland	531.5	35.0'	non-navigable, gated dam	110 x 600, 110 x 1200
1964	McAlpine	604.0	37.0'	non-navigable, gated dam	56 x 360, 110 x 600, 110 x 1200

Table 1. (cont.)

Completion Date	Name	O.R. Mile	Lift	Type	Lock Sizes (ft)
1974	Cannelton	720.7	25.0'	non-navigable, gated dam	110 x 600, 110 x 1200
1975	Newburgh	776.1	16'	gated dam plus navigable fixed weir	110 x 600, 110 x 1200
1975	Uniontown	846.0	18'	gated dam plus navigable fixed weir	110 x 600, 110 x 1200
1979	Smithland	918.5	22'	tainter-gated dam plus navigable fixed weir	two 110 x 1200, 110 x 600
1929	Lock and Dam 52	938.9	12.0'	movable wicket-navigable pass	110 x 1200 (temp.)
1929	Lock and Dam 53	962.6	13.0'	movable wicket-navigable pass	110 x 600 (temp. 110 x 1200' under construction)
Proposed	Mound City	975.2	31.0'	gated dam and navigable fixed weir	two (2) 110 x 1200

The amount of freight traffic on the Ohio River has increased steadily from about 7.3 million tons in 1915, to 15 million tons in 1929, 85 million tons in 1962, and 151 million tons in 1977. The distribution of traffic density on the river has also undergone changes. In 1935 traffic on the river in the Pittsburgh area was approximately twice that of the Huntington area and 4 times that in the area below Cincinnati. In the ensuing years there has been a shift in traffic distribution to the middle and lower river reaches. By 1955 traffic densities were approximately equal in the three areas, while by 1975 traffic density in the Pittsburgh area was less than half that near Paducah and two-thirds that of the Huntington area (ORSANCO 1978b).

In the 1970's there were about 80 bars which occasionally required dredging by the U. S. Army Corps of Engineers or their contractors. About 20 of these required dredging each year and an average of 3.2 million yd^3 of material was removed annually (U. S. Army Corps of Engineers 1979a).

River Conditions Between 1820 And 1983

The quality of water in the Ohio River probably declined between 1820 and 1940 in proportion to the number of people living in the basin and their combined technological capabilities. As Wolman (1971) has pointed out, we do not have good, long-term records of water quality for the major rivers of North America. Most of the continuous water quality and hydrologic records extend over just the last 60-70 years. Determining mean values for water quality parameters before 1920 is also made difficult because samples were taken at irregular intervals (making it impossible to calculate mean values for later comparisons), and analytical techniques and sampling locations have changed (Wolman 1971).

However, the broken records which began in the late 1800's indicate that Ohio River waters increased significantly in turbidity, total dissolved solids, chlorides, nitrates, and sulfates (Wolman 1971) up to the 1940's. The nadir in water quality probably occurred during the droughts of 1930-31, and 1934, when dilution effects were minimal (Cleary 1967) and domestic sewage treatment facilities were rare in the Ohio River Basin (U. S. Ohio River Committee 1944).

We have already described, in the introduction, the beginning attempts at improving water quality in the 1940's, primarily by the construction of municipal and industrial effluent treatment facilities (Cleary 1967). In a recent assessment of water quality in the Ohio River (ORSANCO 1977) changes in water quality between 1953 and 1975 were described. It was within this interval that most of the treatment facilities for point-source pollutants were constructed in the Ohio River Basin, We have relied heavily on this report by the Ohio River Valley Water Sanitation Commission because it presents trend analyses for those water quality parameters which have been measured regularly over the past three decades. Our distillation of the ORSANCO (1977) findings have been supplemented by additional information on water quality conditions contained in the following reports: U. S. Ohio River Committee 1944; ORSANCO 1962, 1974, 1975a, 1976, 1977, 1978a, and the series of annual reports of 1949-82; U. S. Army Corps of Engineers 1969, 1975a; Wolman 1971; Butz et al. 1974; U. S. Environmental Protection Agency 1974; Kentucky Department of Natural Resources 1975; and Dames and Moore 1975a and b.

In selecting the water quality parameters to be discussed we have included those traditionally thought to be important as determinants of

fish distribution and reproductive success (i.e., turbidity, dissolved oxygen, temperature, dissolved solids, and pH; Brayshaw 1967 and Balon 1975); heavy metals and other compounds considered contaminants of fish flesh (i.e., arsenic, mercury, lead, PCB's, etc.); and bacteria considered to be indicators of domestic sewage (i.e., coliform bacteria).

Turbidity

We have described, in the introduction, how reporters in the early 1800's described the Ohio River waters as "clear and salubrious". With the clearing of the forests, the beginnings of intensive agriculture, and the draining of swampy areas, the waters of the Ohio became more turbid, and the substrate accumulated more silt.

In February of 1848 Walt Whitman traveled down the Ohio River on his way to New Orleans and later wrote in the New Orleans Daily Crescent of March 6, 1848: "..., these rivers are talked of as though they were clearly streams; but it is astonishing what a difference is made by the simple fact that they are always and altogether excessively muddy — mud indeed, being the prevailing character both afloat and ashore."

The general influences of the siltation of streams in Ohio, Indiana, and Illinois between 1820 and 1900 have already been described by Trautman (1957, 1981), Gammon (1977), and Smith (1979). The effects of siltation were undoubtedly greatest on fish communities of the smaller streams and brooks. Fishes of the Ohio River were accustomed to, and adapted for, occasional exposure to the high turbidities which had always accompanied the spring "freshes", while the fishes which preferred the small, clear forest brooks were not so adapted. The emphasis placed on the adverse effects of turbidity and siltation on fishes of the regions by Trautman, Gammon, Smith, and Pflieger (1971) applies more to the small-stream species

than to the Ohio River fishes. Exceptions to this generalization would include those fishes which depended upon clear, silt-free riffles in the small streams for spawning (i.e., the lake sturgeon and some lampreys) and those which require silt-free expanses of coarse sand and/or gravel in the Ohio River channel (i.e., gravel chub, crystal darter, channel darter, and river darter). Pflieger (1971), in a discussion of the three major arms of the Mississippi River system, stated that the Missouri River has long been a very turbid stream, even before the arrival of the European settlers. By comparison, the upper Mississippi River was relatively clear, while the Ohio River has always been the clearest of the three (a conclusion also reached by Mark Twain in "Life on the Mississippi" in 1883).

Between 1952 and 1955 ORSANCO (annual report of 1957) reported mean monthly turbidity values of 2-576 units at 43 monitoring stations along the entire length of the Ohio River. In 1962-63 the reported range was 2-1301 units. In 1977 ORSANCO reported a significant, although slight, decrease in turbidity at all monitoring stations between 1953 and 1975. The probable cause of these reductions was the construction of numerous flood-control reservoirs on most of the major tributaries of the Ohio River in the last 40 years. These impoundments trap sediments and release clear waters to the Ohio River. It seems likely that the range of turbidity to which fish in the Ohio River have been exposed in historical times have not been significantly greater than in prehistoric times. However, since 1820 the mean turbidities to which fish have been exposed have been higher than in prehistoric times. We suspect that these higher mean turbidities would have influenced the fish community of the river through indirect effects (i.e., on primary

production, reductions of favored food supplies, reduced visibility of foods, and reduction of suitable spawning areas) rather than by direct effects (i.e., clogging gills, smothering of eggs or larvae, etc.).

Dissolved oxygen

Measurements of dissolved oxygen (D.O.) were not made frequently enough to permit annual comparisons until the 1930's. Mean monthly values for D.O. reported in 1939-1941 were usually above 6.5 ppm in all seasons and in all reaches of the river except for the first 10-30 miles below Pittsburgh, where mean monthly values were as low as 4.0 ppm during low flow months (late summer and fall), and individual readings at Emsworth Dam (ORM 6) were as low as 2.8 ppm (U. S. Ohio River Committee 1944). After 1930 oxygen levels in the Ohio River were lowest immediately below the three major population centers of Pittsburgh, Cincinnati, and Louisville, but the concentrations usually returned to acceptable levels within 20-40 miles downstream. The exceptions may have been below Pittsburgh where industrial facilities line the river for many miles downstream and oxygen levels were occasionally depressed significantly for 40-90 miles below the source.

During periods of low flow, particularly in summer and fall months, oxygen concentrations of less than 4.0 ppm have occasionally been reported at nearly all monitoring stations on the Ohio River during the months of June-September (i.e., U. S. Ohio River Committee 1944, ORSANCO 1962, Woods 1965, Dames and Moore 1975b, ORSANCO 1978a). However, in the late 1970's with the completion of secondary sewage treatment facilities at most major cities on the river, the number of low-flow oxygen records below 5.0 ppm was reduced considerably, and such events are usually seen where treatment facilities are temporarily shut down for repairs or

maintenance, or in emergencies such as the contamination of the Louisville plant with hexachlorocylopentadiene in 1977 (ORSANCO 1978a, 1979, 1980).

Although improvements in dissolved oxygen concentrations have been made, fish are still subjected to chronically low levels below the metropolitan areas. In 1977, for example, the daily mean D.O. concentration in the month of June was less than 5.0 ppm 12% of the time at ORM 102.4, 91% of the time at ORM 531.5, and 50% of the time at ORM 625.9 (ORSANCO, 1978a). In June 1982 mean daily dissolved oxygen levels were less than 5.0 ppm for 13-20% of the time at ORM 531, 601, and 791. In the months of August and September 1982 very low flow conditions resulted in mean daily dissolved oxygen concentrations of less than 5.0 ppm for 20-76% of the time at ORM 490, 531, 601, and 626 (ORSANCO Quality Monitor Data). These low values in the Cincinnati-Louisville area result from inadequate secondary treatment of sewage in both cities. The month of June is important to fishes because the larval stages of most species are still small and vulnerable. While large-scale oxygen depletions which result in dramatic fish kills have not been seen in the Ohio River in the last decade, the combination of low-oxygen stress and other stresses may be depressing larval fish survival rates.

Temperature

Since no long-term continuous records are available before 1820, we can only assume the following: with the increase in turbidity associated with intensive agriculture the mean annual temperature of the Ohio River may have increased slightly between 1820 and 1900 when good temperature records began. The cause of this slight increase may have been absorbtion of sunlight by suspended particles, clearing of shade trees along tributaries as well as the mainstem Ohio, and faster runoff of rainwater

leading to reduced groundwater contributions during low-flow periods.

According to Wolman (1971), Butz et al. (1974), and ORSANCO (1977) there have been no significant changes in the temperature of the Ohio River during the past 20 years. The river temperature is highly correlated with air temperature and generally increases steadily from source to mouth. Mean daily temperatures are usually lowest in February and ranged from 44.5°F at ORM 15.8 to 47.8°F at ORM 791.5 during the winters of 1964-74 (ORSANCO 1975b). The highest mean daily temperatures usually occur in July-September and ranged from 86.6°F at ORM 158 to 87.9°F at ORM 791.5 in 1964-74 (ORSANCO 1975b). Surface water temperatures of 32°F are often reached in winter, although the river seldom freezes solidly from shore to shore below Louisville. Maximum summer water temperatures of 91.4°F (ORSANCO 1977) have occurred in the lower half of the river, although higher records can be found below heated effluents and in shallow backwaters. Despite its impoundment, the river does not stratify thermally, and is usually well-mixed from top to bottom. The large volume of the river relative to its smaller tributaries, results in a considerable lag in warming during the spring and cooling during the fall months.

The Ohio River has between 30 and 40 power-generating facilities located on its banks with a combined power generation capacity of over 30,000 MW. Most of these facilities have flow-through cooling systems which are capable of raising the river temperature a maximum of 7.25°F at low-flow seasons (ORSANCO 1975b). In the most severe, low-flow situations the maximum rise in river temperature due to the combined actions of the plants is thought to be less than 1°F (Butz et al. 1974) and to present little danger to aquatic life in the river (ORSANCO 1975b).

The established thermal standards for the river (usually a maximum rise of 5°F over ambient, and an upper maximum dependent upon season) are, however, rather liberal, and the potential exists for serious direct or indirect effects of heated effluents on fishes in localized areas.

Dissolved solids

The records for total dissolved solids (TDS) begin in the late 19th century (Wolman 1971) and indicate that significant increases in chloride, sulfate, nitrate, and total dissolved solids have occurred since that time. We can only speculate that the increases began much earlier in the 19th century with the first clearing of the forests for agriculture. The concentration of TDS usually increases downstream and is inversely correlated with flow.

Wolman (1971) cited ORSANCO data which indicated that chloride concentrations at various points on the Ohio River increased 50-114% between 1910 and 1966. The maximum chloride levels were apparently reached in the 1950's at most locations and have declined slightly thereafter (Wolman 1971; ORSANCO 1965, 1974, 1975a, 1977, 1979, 1980). Annual mean values for chloride at Cairo and Joppa (ORM 981 and 952) increased from 10-15 mg/l between 1910 and 1919 to 23.6 mg/l in 1966, then declined to 16 mg/l in 1977.

ORSANCO (1977) has also reported significant, though slight, reductions in sulfate between 1953 and 1974, while concentrations of nitrates and phosphates appear to have remained about the same.

The historic change in total dissolved solids probably parallels that of chlorides. In the 1970's mean annual TDS values for all monitoring stations on the Ohio River were typically 185-210 mg/L (ORSANCO 1973, 1974, 1975a, 1976, 1977, 1979, 1980). The maintenance or even

lowering of TDS levels at most stations in the past decade, despite increasing population in the basin, had been attributed to reduction of point-source pollution and reduction of mine drainages in the upper portion of the basin (ORSANCO 1977).

Hydrogen-ion concentration (pH)

The pH of the Ohio River was probably near neutrality (7.0) with values ranging upwards to perhaps 8.5 in prehistoric times. Natural leaching of sulfuric acid and acid salts from the coal deposits of the upper Ohio Basin caught the attention of several early travelers between 1698 and 1806, and invited comparisons with the red and yellow streams of the coal-mining regions of Wales (Cleary 1967). When coal-mining activities became common in the Allegheny and Monongahela basins in the last half of the 19th century, acid mine wastes began depressing pH in the upper Ohio River. When the U. S. Ohio River Committee (1944) surveyed the Ohio River in 1939-1940, pH values as low as 4.7 were found above ORM 172. These low values were due to acid mine runoff in the Allegheny and Monongahela basins where pH's of less than 4.0 were common during the same period (U. S. Ohio River Committee 1944).

Between 1940 and 1965 pH records of less than 5.0 (often less than 4.0) were commonly recorded in the upper 100 miles of the Ohio River (ORSANCO 1962, 1963, 1964, 1965). Below ORM 100 pH values usually increased gradually to mean values of 7.2 to 7.8 between Cincinnati (ORM 463) and Cairo (ORM 981). During this same period unusually high recordings of between 9.0 and 10.0 were occasionally seen in all reaches of the river, usually during periods of low flow when algal growth rates were very high.

The damaging effects of acid mine drainage on both the Monongahela

and Allegheny rivers was recognized over 60 years ago, and the first efforts to reduce these effects were begun in the 1930's when the Federal government began sealing abandoned coal mines (U. S. Ohio River Committee 1944, Cleary 1967). During the 1960's and 70's much more progress was made in reducing both acid mine pollution and acid industrial pollution in the upper Ohio Basin. The success of these efforts can be seen in the annual reports of ORSANCO for the period 1974-1980. In most of these years 100% compliance with the established standards for pH (6.0 minimum and 9.0 maximum) has been achieved at all monitoring stations on the Ohio River. In 1976, 1978, and 1979 compliance percentage with the standards were 98 to 99%. The non-compliance events occurred in the upper 110 miles of the river. In 1974, the hourly mean values for pH over the entire river was 7.2, while the range was 6.4-8.5 (ORSANCO 1974).

In conclusion, it is evident that pH conditions have improved dramatically in the last two decades in the upper third of the Ohio River. This improvement has resulted from control of acid mine drainage, and nearly 100% treatment of industrial wastes. Low pH events in this region should result only from major spills or blowouts in the future.

Heavy metals and organic contaminants

As ORSANCO reported in 1962, fishes from the upper third of the Ohio River have long possessed objectionable taste (usually reported as oily, muddy, or gasoline flavors) and/or odors. Clay (1962a, 1968) concluded that the taste of fishes in the Ohio River was so poor in the upper third of the Ohio River that commerical fishing was impossible. In the middle third of the river Clay found some zones where the fish

were acceptable, but it was only in the lower third that commercial fishing was possible in all areas of the river.

In a later study (Thomas 1973) found that commerical fish of acceptable quality for eating were regularly found only between Newburgh, Indiana (ORM 778) and Cairo, Illinois (ORM 981). Nevertheless, the quality of fishes varied tremendously, and some fish of acceptable quality could be found throughout the river. It appears that most of the improvement in fish quality has taken place in the upper third of the river, and is the result of reduced industrial and municipal discharges and the creation of embayments where popular panfishes (centrarchids) are sought by sport fishermen.

In the last 20 years fisheries managers charged with managing Ohio River fishes have become concerned about the accumulation of several heavy metals, pesticides, and other organic and inorganic compounds in fish flesh. The primary concern has been for the health of humans consuming the fish, but direct effects of these materials on the fishes may also be significant. The levels of many of these elements and compounds cannot be followed through time because analyses for most have only been made in the last 2-10 years. The following is an annotated list of such contaminants:

Mercury — Mercury concentrations of 0.09 to 0.5 ppm were found in channel catfish taken in the lock chamber poisonings at ORM 172, 493, and 944 in 1970 (Dames and Moore 1975b). In 1957 and 1976 one catfish fillet (ORM 607) exceeded the FDA limits of 0.5 ppm mercury (ORSANCO 1977). In 1978-80 some of the fish tissues examined contained mercury levels above 0.5 ppm (ORSANCO 1978b, 1979, 1980). Mercury concentrations in Ohio River water samples have fluctuated from year to

year since 1975, but are usually less than 0.5 μg/l and seem to be fairly uniform throughout the length of the river, excepting unusual introductions. In 1978 and 1979 the standard maximum criterion of 0.2 μg/l was exceeded in 19% of the mean monthly values, most of the violations occurred in the upper 265 miles of the river.

Polychlorinated biphenyls (PCB's) — The FDA recommendation limit for PCB concentrations in fish flesh (5 ppm) has been exceeded in channel catfish fillets from Ohio River fishes since 1975. Only a limited number of determinations have been made (between 28 and 44 each year except 1977 when 244 specimens were examined: ORSANCO 1977, 1978a, 1979, 1980, 1983) which makes it difficult to assess trends over this short period of time. However, both the number of specimens found to contain PCB's in excess of 5.0 ppm and the maximum concentrations found have declined throughout the period 1975-1981. In 1975, 35% of the specimens examined averaged 0.5 ppm PCB's, and the maximum concentration (20.8 ppm) was observed in a channel catfish from McAlpine Lock and Dam (ORM 607). In subsequent years the percentages of specimens in which the concentrations exceed 5.0 ppm have declined to 3-11%. Although PCB's have been found in fish throughout the length of the river, most of the samples containing over 5.0 ppm have been from the upper 200 miles of the river.

Pesticides — Chlordane, dieldrin, DDT, DDD, and BHC have all been found in significant amounts in fishes from the Ohio River. Determinations of these compounds began to be reported in 1963 and indicate that while pesticides do occur occasionally at levels above the FDA limits, the exact extent of the problems remain unknown (U. S. Environmental Protection Agency 1974; Dames & Moore 1975b; ORSANCO 1977, 1978a, and 1980).

Phenolics — Phenolic compounds originate as by-products of the coke

and chemical industries of the upper Ohio River Basin. They present special taste and odor problems in drinking water, but may also taint fish flesh. Most of the violations of ORSANCO standards in the 1970's occurred in the upper half of the river. According to ORSANCO (1980) numbers of violations reported have declined since 1977.

Coliform bacteria

Although the direct effects of coliform bacteria on fishes are thought to be negligible, their concentrations in the river serve as good indicators of the extent of domestic sewage pollution. Municipal sewage inputs to the river are important to fishes through effects on nutrient levels, BOD, D.O., suspended solids, and a host of more or less esoteric organic compounds.

Originally only total coliform bacteria concentrations were measured in the Ohio River, but beginning in the early 1970's ORSANCO began to report concentrations of just fecal coliform organisms (which typically make up about 20% of the total) as being more indicative of human sewage pollution.

Domestic sewage pollution has always been a more serious problem in the upper quarter of the Ohio River where the population along the river is greatest. Between Pittsburgh (ORM 0) and Wheeling (ORM 86) there are more than 40 municipal discharges categorized as major point sources of coliform bacteria (ORSANCO 1977). No other comparable distance on the river has more than 14 municipal discharges per 100 miles, while the lower section of the river may have as few as seven discharges per 100 miles.

When the U. S. Ohio River Committee (1944) reported upon the condition of the Ohio River in the period 1939-1943 it listed monthly mean

total coliform counts of over 20,000/100 ml for between 31 and 61% of the time at stations throughout the river. When the ORSANCO compact was signed in 1948 only 1% of the population living along the river treated domestic sewage before dumping it into the river. In 1952, ORSANCO (1954) reported annual mean coliform concentrations of 15,100 to 52,100/100 ml in the upper 87 miles of the river (Table 2), while concentrations downstream decreased to 3800-4000/100 ml. Also, no mean monthly concentrations exceeded 20,000/100 ml whereas in 1939-43 between 31 and 61% of the monthly mean values reported by the U. S. Ohio River Committee (1944) had exceeded this value.

The established ORSANCO standards at this time were <5000 coliform organisms/100 ml for drinking water and <2000/100 ml for recreation uses. During the two years 1953-54 there was only one month in which the mean coliform concentration was less than the standard of 5000/100 ml at ORM 87 (Wheeling), and only 3 months at ORM 62 (Wierton). In the lower two-thirds of the river the standard was met in 6-22 months of the period at all stations. There were usually noticeable increases in coliforms just below Cincinnati and Louisville.

By 1963-64, 97% of the population along the Ohio was served by sewage treatment facilities, and ORSANCO (1964, 1965) found that concentrations of coliform organisms in the upper 100 miles of the river had fallen dramatically (i.e., from a mean amount at Wheeling of 52,100/100 ml in 1952 to just 950/100 ml). Concentrations in the middle and lower reaches of the river, however, remained much as they had been in 1952-53, or had declined slightly (Table 2).

With the installation of improved sewage treatment facilities in the 1960's and 70's it was expected that coliform levels in the river would

Table 2. Mean annual total coliform organism concentrations in the Ohio River 1952-53 and 1963-64.

Ohio River Mile and City	organisms/100 ml	
	1952-53	1963-64
62 (Weirton)	15,100	10,000
87 (Wheeling)	52,100	950
304 (Huntington)	4,000	4,000
463 (Cincinnati)	4,000	1,900
601 (Louisville)	3,800	3,800
792 (Evansville)	—	6,100

decline markedly again (Dames & Moore 1975b), but in reality this has not occurred. In the middle 1970's ORSANCO began reporting only fecal coliform organism concentrations as a better indication of human sewage, which complicates comparison somewhat. In 1976 ORSANCO (1977) reported that the new drinking water standard of 2000 fecal coliform organisms/ 100 ml was exceeded in just 2 of the mean monthly values at ORM 62. The maximum mean monthly value at this station was 2510/100 ml, which, if we accept that fecal coliforms are usually 20% of total, would translate to a total coliform value of 12,550/100 ml.

ORSANCO (1978a) reported that in 1977 the recommended fecal standards were exceeded in 8 months at ORM 62 and 5 months at ORM 87. At the four monitors between ORM 304 and 792 the standards were met in each month of the year. By 1978 and 1979 ORSANCO (1979, 1980) reported nearly 100% compliance in the lower two-thirds of the river and compliance about three-fourths of the time in the upper 100 miles of the river. Again, it is necessary for comparison with earlier data to remember that compliance meant a total coliform count of less than about 10,000 organisms/100 ml.

In summary, it appears that the largest decrease in coliform organisms occurred before the 1960's when primary sewage treatment facilities were constructed and mean monthly counts in excess of 20,000/100 ml were eliminated at most stations. The most dramatic decrease occurred in the upper 100 miles of the river. Between 1960 and 1980 it appears that counts in the upper 100 miles of the river have continued to decrease noticeably, although most violations of the standards in recent years still occur in this section of the river. In the lower two thirds of the river the coliform counts appear to have declined only slightly, if at all, since 1960 (ORSANCO 1977) despite large-scale improvements in

treatment facilities. These small declines have variously been attributed to the input of storm and combined sewer overflow, inadequate disinfection at treatment plants (particularly at Louisville and Charlestown in the late 1970's), and nonpoint sources (ORSANCO 1977, 1979, 1980).

Flow and flood control

Variations in river flow are extremely important to fishes through effects on both water quality and availability of suitable habitat. Flow is very strongly correlated with almost all water quality parameters, season of the year, and energy inputs to the river, as well as rainfall.

At its origin the Ohio River has a long-term mean flow of approximately 32,300 cfs (Figure 2). For the first 150 miles, the river increases in size very little, but the addition of waters from the Muskingum, Little Kanawa, Kanawha, and others more than double the mean flow to 77,620 cfs at Huntington (ORM 308.3). The increase in flow below Huntington is rather gradual, reaching 133,900 cfs at Evansville (ORM 792.5). Below Evansville the Wabash, Tennessee, and Cumberland rivers are largely responsible for the rapid increase in mean flow to 258,500 cfs at Metropolis (ORM 944.0).

The highest flows during most years occur in March, while the low-flow months are typically September and October (Figure 3). Peak flows in recent years have typically been 8-11 times the low flows recorded. The maximum flow rates recorded during severe floods range from 412,000 cfs in the upper 100 miles to 1,780,000 cfs near the mouth during the 1937 flood (U. S. Army Corps of Engineers 1969).

Floods were regular winter and late spring occurrences along the Ohio, even before clearing of the watershed. In the introduction we mentioned records of 60' rises in stage before 1800. The greatest

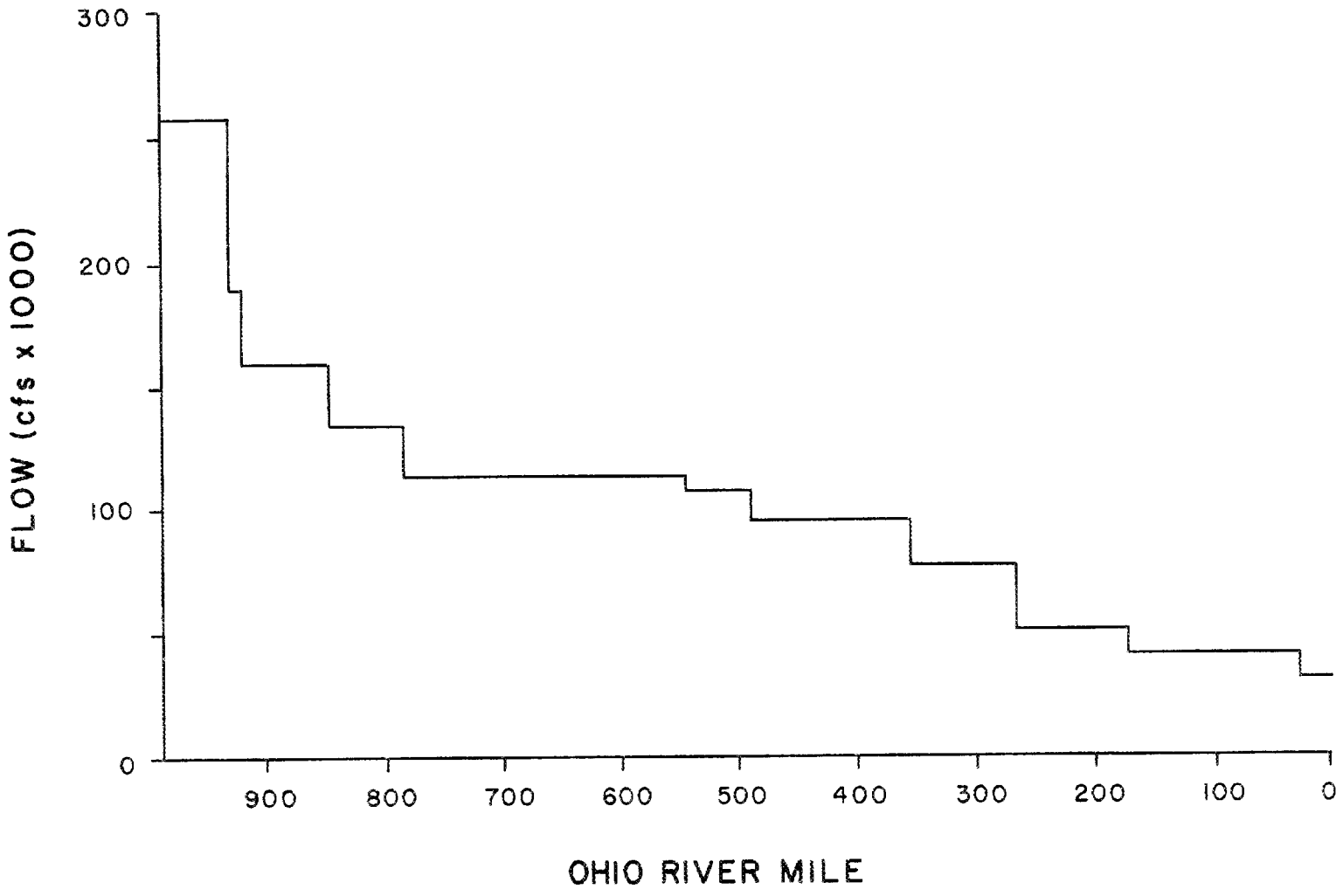

Figure 2. Long-term flows for the Ohio River from ORM 0 to 981 (adapted from ORSANCO 1978a).

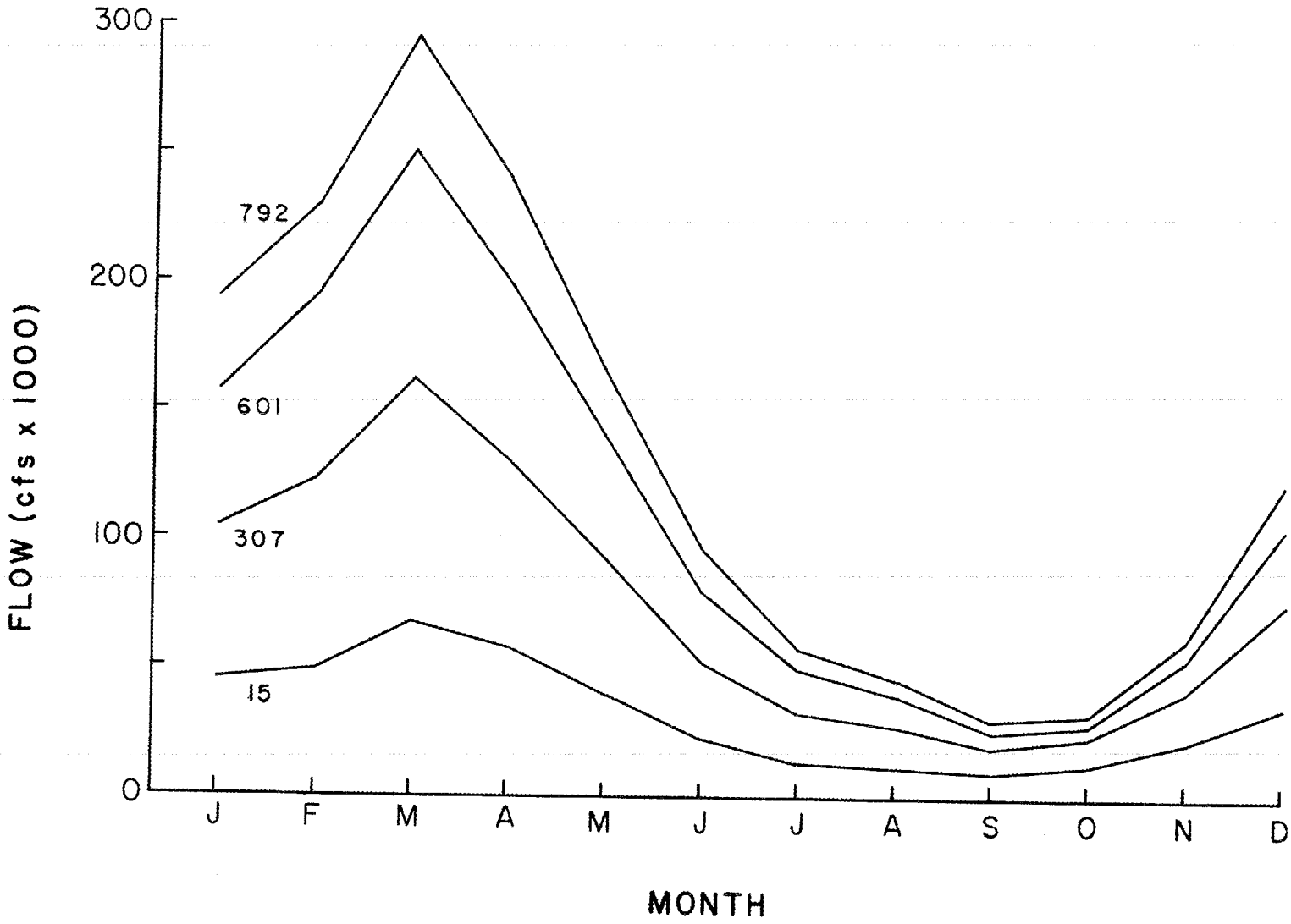

Figure 3. Long-term mean monthly flows for the Ohio River at ORM 15, 307, 601, and 792 (adapted from ORSANCO 1978a).

flood on record was the 1937 flood when the river reached a stage of 80 feet at Cincinnati, nearly 28 feet above flood stage.

To reduce flood damages the U. S. Army Corps of Engineers has constructed a system of reservoirs which control about one-third of the entire Ohio River drainage basin (U. S. Army Corps of Engineers 1978a). In addition, runoff on large additional areas of the drainage are controlled by flood control dams operated by the Tennessee Valley Authority, the Soil Conservation Service, independent water conservation districts, and state and local governments. This vast system of reservoirs on tributaries of the Ohio have three major effects on the mainstem: 1) flood waters are stored and released slowly, reducing the maximum seasonal flow rates and lengthening the duration of bank-full stages, 2) low flow rates during times of drought are nearly twice pre-impoundment levels, and 3) the water released into the mainstem from the reservoirs is often less turbid than pre-impoundment waters. Wolman (1971) expressed the opinion that these effects of flow regulation might eventually be shown to have greater significance than pollution in altering the character of the nation's large rivers.

CHANGES IN THE OHIO RIVER FISH COMMUNITY

Fishes Reported Before 1818

The early visitors to the Ohio River were not trained naturalists, and their reports on the fishes must be viewed with skepticism. Most of the Ohio River fishes seen by Europeans before 1818 were probably captured by hook and line, although many were also taken with the spear, or large-meshed seines. It is not, therefore, surprising that the 19 recognizable "types" of fishes mentioned by the early reporters on the Ohio River (Table 3) are made up almost entirely of the largest varieties (i.e., sturgeon, paddlefish, gar, catfishes, muskellunge) and those most likely to be caught on hook and line. Every one of the common names in Table 3 could have been represented by a species which is susceptible to hook and line fishing. For example, the "shads" and "herrings" are mentioned by many authors. This is not surprising, because the Atlantic coast rivers have large runs of American shad (*Alosa sapidissima*) and other clupeids with which these early travelers along the Ohio would have been familiar. However, they may actually have been catching skipjack herring (*Alosa chrysochloris*), goldeye (*Hiodon alosoides*), or mooneye (*H. tergisus*), all three of which bite on minnow-like bait. If one were to send a few dozen adventurers with no training in ichthyology down the Ohio River today and ask them to describe the fishes they might encounter along the way, we would expect them to see all of the 19 types which were described before 1818, except for the lake sturgeon (*Acipenser fulvescens*) and muskellunge (*Esox masquinongy*), and perhaps the blue sucker (*Cycleptus elongatus*). All of the others are either still common in cursory surveys

Table 3. Probable species list of fishes reported by travelers on the Ohio River before 1818. Largely after Jackson's (1962) review.*

Common Name	Possible Species	Source
Lake sturgeon	*Acipenser fulvescens*	Trautman 1957
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	Trautman 1957
Paddlefish	*Polyodon spathula*	Hulbert & Schwarze 1910
Gar	*Lepisosteus* spp.	Hulbert & Schwarze 1910
American eel	*Anguilla rostrata*	Filson 1784
Shad	*Dorosoma, Alosa ?*	Cramer 1814
Herring	*Alosa, Dorosoma, Hiodon ?*	Cramer 1814
Muskellunge	*Esox masquinongy*	Trautman 1957
Chub	*Notropis, Hybopsis, Semotilus, Micropterus ?*	Schultz 1810
Suckers	*Catostomus, Moxostoma, Carpiodes, Hypentelium ?*	Filson 1784
Buffalo	*Ictiobus* spp.	Filson 1784
Blue sucker	*Cycleptus elongatus*	Hulbert & Schwarze 1910
Blue catfish	*Ictalurus furcatus*	Hulbert & Schwarze 1910
Channel catfish	*I. punctatus*	Hulbert & Schwarze 1910
Bullhead	*I. nebulosus, I. melas, I. natalis ?*	Hulbert & Schwarze 1910
Flathead catfish	*Pylodictis olivaris*	Hulbert & Schwarze 1910
Sunfish	*Lepomis* spp.	Filson 1784
Walleye or Sauger	*Stizostedion canadense* or *S. vitreum*	Filson 1784
Freshwater drum	*Aplodinotus grunniens*	Hulbert & Schwarze 1910

*Here, and throughout the text we employ the common and scientific names recommended by Robins et al. (1980).

conducted on the river today, or they are large enough and strange enough in appearance that a single encounter would make a lasting impression.

Constantine S. Rafinesque

Serious consideration of Ohio River fishes must begin with this man. Constantine Samuel Rafinesque was born near Constantinople in 1783. Rafinesque's life has been described both by himself (Rafinesque 1836) and several biographers (Call 1895, Fitzpatrick 1911, and Pennell 1940). We will, here, bring out only those aspects of his life which might bear upon his description of the Ohio River fishes.

Originally there were plans to send young Constantine to a university in Switzerland, but reverses in the family's business prevented this and Rafinesque never received formal training in the natural sciences, which came, nevertheless, to absorb nearly all of his time and interest. Rafinesque entered the trading business with his brother and uncle, and in 1802 the brother and Rafinesque sailed for Philadelphia. Rafinesque remained in the United States for just three years on this first visit, but traveled a great deal collecting plants in New York, Pennsylvania, Delaware, New Jersey, and Maryland. The next ten years of Rafinesque's life were spent on the island of Sicily where he continued his naturalist studies. William Swainson, the English naturalist, was stationed in Sicily for three years and described in some detail how he and Rafinesque carried out their botanical and ichthyological studies on the island.

> "M. Cuvier often asserts that all M. Rafinesque's species were described from preserved specimens; but this is an error—they were all taken from the life. We both used to frequent the fish-markets, and we procured all our specimens there,

> or from fishermen who were in our employ. I was frequently urgent with my friend to preserve, at least, such as were the most remarkable of his new genera, anticipating the incredulity that has since been attached to them; but this advice, unfortunately, he never adopted. The greater part of those which I examined, after being drawn and described, were thrown away or eaten...."

These observations are worth noting because they may indicate how Rafin esque conducted similar investigations years later on the Ohio.

In 1815 Rafinesque returned to the United States. In May, 1818, Rafinesque, at the request of his friend, John Clifford of Lexington, Kentucky, set out for the West — which at that time meant Kentucky, Ohio, Indiana, and Illinois. He walked over the Alleghenys to Pittsburgh, arriving on the 25th of May (Pennell 1940) for his first view of the Ohio River. While in Pittsburgh Rafinesque contracted with the booksellers Cramer and Spear to produce a map of the Ohio River. He also wrote a letter to his friend Zaccheus Collins in which he states "I have begun to study the fishes of the Ohio; they are all new species, unless described already by Mr. Lesueur..." Rafinesque himself (1836) describes how he joined a Mr. Molin and other French gentlemen going to Illinois in the purchase of an "ark":

> "...we bought an ark or flat covered boat, and floated slowly down the river, stopping every night. I was then at leasure to survey and explore, we had a smaller boat to land where we pleased, botanize, and buy provisions. We had a guide as far as Gallipolis, a gentleman of that town, who was returning there with his family in another ark, which

was lashed to ours. Thus we avoided many accidents, and I began to study the fishes which we caught or bought, make drawings, etc...We went by Steubenville, Wheeling, Marietta, etc. without stopping long; but we tarried two days at Gallipolis and two in Vevay."

The party arrived in Louisville on the 4th of July. Rafinesque was delighted with the shells and fishes at the Falls of the Ohio and, apparently, with the fishes found in the markets at Louisville. He spent at least 16 days in the Louisville area. In a second letter to Collins (Pennell 1940), dated 20th July at the Falls, Rafinesque says: "I have been rewarded by the discovery of about 22 new species of fishes out of 32 existing." In his biography Rafinesque (1836) tells us he spent his time at the Falls "...studying the fishes and shells of the river, of which I made a large collection, drawing them on the spot at the same time. I was surprized to find them nearly all new: this rendered my researches still more important and interesting."

Rafinesque then took passage down river on a keelboat which, he tells us, "...was to go by day only, in order to continue my survey of the valley and river Ohio." Apparently Rafinesque felt this boat was too slow and abandoned it at Henderson, Kentucky, to visit with John J. Audubon, the ornithologist who had been on the Ohio for 8 years. He remained 3 weeks with Audubon, writing to his friend Collins on August 12th: "I have since the date of my last letter increased to about 60 species the ichthyology of the Ohio, all new and undescribed except 5 or 6 and of which several appear to be new genera." Audubon (1899) tells us that "M. de T. (Rafinesque) remained with us for three weeks and collected multitudes of plants, shells, bats and fishes...." Audubon was

at best an ungracious host who published, while Rafinesque was still living, an account of this visit which portrays Rafinesque as a most eccentric, almost foolish, individual. Audubon also played upon his guest's consuming desire to describe new species by supplying him with drawings and oral accounts of eleven fantastic and fictitious fishes which Audubon shamefully claimed to have seen in the Ohio River. To Rafinesque's credit he very carefully assigned the credit for these chimeras to Audubon, in the Ichthyologia Ohiensis, and expressed honest doubt about the authenticity of at least one of them.

Rafinesque then obtained a horse and made an overland journey to New Harmony, Indiana, on the Wabash River, down to Shawneetown, Illinois and on to a spot either at or near the mouth of the Ohio River. On September 12, 1818, he continued his previous letter to Collins: "Since writing the above, I have visited the Wabash and Green Rivers, the praries of Indiana and Illinois, the Barrens of Kentucky, etc.; but want of time and bad roads have prevented me from reaching the Mississippi and Missouri. I hope to have nearly completed the Ichthyology and Conchology of the Ohio, having detected, figured, described (and often preserved) 64 species of fishes, and 48 species of shells! All new, except very few."

This is the only mention of preserved specimens of fishes (assuming that was his meaning) Rafinesque made, and none of his specimens are known, or have been known to ichthyologists.

After shipping his collections to Philadelphia via Pittsburgh, Rafinesque traveled to Lexington, Kentucky, where his friend John Clifford had secured a post as professor of Natural History and Botany at Transylvania University for Rafinesque, and the winter of 1818-1819

was spent writing and preparing for the move. Rafinesque spent nearly seven years at Lexington, and during the first two years (1818-1820) he did obtain a few fishes from local streams and ponds (i.e., fathead minnow, *Pimephales promelas*; mottled sculpin, *Cottus bairdi*; creek chub, *Semotilus atromaculatus*) which are described in the supplement to the Ichthyologia Ohiensis. After the year 1820, Rafinesque's writings dealt with botany and the many other subjects which interested him and, with but a single exception, he never described another fish.

Before listing the species which Rafinesque found in the Ohio River we might review his trip and speculate on several aspects which would have influenced his results. First, Rafinesque was probably on or near the river only between 25 May and, perhaps, September 1 — roughly 3 months. We can deduce that he must have spent 2-3 weeks (perhaps as many as 4) in Pittsburgh, 2 weeks in Louisville, and 3 weeks in Henderson, Ky. While he or members of his party may have fished with hook and line between these three points, it seems safe to conclude that most of Rafinesque's fishes were taken near these three locations. He mentions the use of seines by the fishermen throughout the Ichthyologia. We have been unable to find any reference to the length and mesh sizes of the seines in use at this time, but it seems likely that they would have been several hundred feet long, perhaps 6-14' deep and of a mesh size large enough (1-3") to permit easy hauling while still retaining larger fish of the edible species that could be sold in the markets. It is not surprising, therefore, that of the 52 species of fish which Rafinesque reported from the Ohio River in all of his publications between 1818 and 1820 (Table 4), and which are recognized as species in Robins et al. (1980), all but nine are fish which attain an adult size large enough to be caught

Table 4. A list of the 52 species of fishes which Rafinesque reported as having been taken from the Ohio River in 1818 (Rafinesque 1818a, b, c, d and 1820a, b). The list presents current names from Robbins et al. (1980) and relies on the interpretations of Rafinesque's work by Jordan (1877), Evermann (1918), and Fowler (1945) as well as our own.

Common Name	Scientific Name
American brook lamprey	*Lampetra appendix* (DeKay)
Lake sturgeon	*Acipenser fulvescens* Rafinesque
Shovelnose sturgeon	*Scaphirhynchus platorynchus* (Rafinesque)
Paddlefish	*Polyodon spathula* (Walbaum)
Longnose gar	*Lepisosteus osseus* (L.)
Shortnose gar	*Lepisosteus platostomus* Rafinesque
Alligator gar	*Lepisosteus spatula* Lacepede
American eel	*Anguilla rostrata* (Lesueur)
Skipjack herring	*Alosa chrysochloris* (Rafinesque)
Gizzard shad	*Dorosoma cepedianum* (Lesueur)
Goldeye	*Hiodon alosoides* (Rafinesque)
Mooneye	*Hiodon tergisus* Lesueur
Grass pickerel	*Exox americanus vermiculatus* Lesueur
Northern pike	*Esox lucius* L.
Muskellunge	*Esox masquinongy* Mitchill
Central stoneroller	*Campostoma anomalum* (Rafinesque)
Bigeye chub	*Hybopsis amblops* (Rafinesque)
Hornyhead chub	*Nocomis biguttatus* (Kirtland)
Golden shiner	*Notemigonus crysoleucas* (Mitchill)
Emerald shiner	*Notropis atherinoides* Rafinesque
Common shiner	*Notropis cornutus* (Mitchill) [perhaps *N. chrysocephalus*]

Table 4. (cont.)

Common Name	Scientific Name
Bluntnose minnow	*Pimephales notatus* (Rafinesque)
River carpsucker	*Carpiodes carpio* (Rafinesque)
Highfin carpsucker	*Carpiodes velifer* (Rafinesque)
White sucker	*Catostomus commersoni* (Lacepede)
Blue sucker	*Cycleptus elongatus* (Lesueur)
Creek chubsucker	*Erimyzon oblongus* (Mitchill)
Northern hog sucker	*Hypentelium nigricans* (Lesueur)
Smallmouth buffalo	*Ictiobus bubalus* (Rafinesque)
Black buffalo	*Ictiobus niger* (Rafinesque)
Spotted sucker	*Minytrema melanops* (Rafinesque)
Silver redhorse	*Moxostoma anisurum* (Rafinesque)
Black redhorse	*Moxostoma duquesnei* (Lesueur)
Golden redhorse	*Moxostoma erythrurum* (Rafinesque)
Blue catfish	*Ictalurus furcatus* (Lesueur)
Black bullhead	*Ictalurus melas* (Rafinesque)
Yellow bullhead	*Ictalurus natalis* (Lesueur)
Channel catfish	*Ictalurus punctatus* (Rafinesque)
Stonecat	*Noturus flavus* Rafinesque
Flathead catfish	*Pylodictis olivaris* (Rafinesque)
White bass	*Morone chrysops* (Rafinesque)
Green sunfish	*Lepomis cyanellus* Rafinesque
Bluegill	*Lepomis macrochirus* Rafinesque
Smallmouth bass	*Micropterus dolomieui* Lacepede
Spotted bass	*Micropterus punctulatus* (Rafinesque)
Largemouth bass	*Micropterus salmoides* (Lacepede)

Table 4. (cont.)

Common Name	Scientific Name
White crappie	*Pomoxis annularis* Rafinesque
Greenside darter	*Etheostoma blennioides* Rafinesque
Fantail darter	*Etheostoma flabellare* Rafinesque
Logperch	*Percina caprodes* (Rafinesque)
Walleye	*Stizostedion vitreum vitreum* (Mitchill)
Freshwater drum	*Aplodinotus grunniens* Rafinesque

on hook and line, or in a 2" mesh seine. Many of these fish were indeed new, as Rafinesque had claimed, and the Ohio River is the type locality for 28 of them plus one additional fish added since [least brook lamprey, *Lampetra aepyptera* (Abbott 1860) Table 5]. Rafinesque's colleague, Lesueur, had visited Pittsburgh a few years before Rafinesque's visit and described (Lesueur 1817, 1818) three species from the source of the Ohio (mooneye, *Hiodon tergisus*; blue sucker, *Cycleptus elongatus*; and black redhorse, *Moxostoma duquesnei*).

Fishery Investigations Between 1818 and 1920

After Lesueur and Rafinesque, little attention was paid to the Ohio River fishes for 18 years. Dr. Jared P. Kirtland began a series of papers (Kirtland 1838, 1941a, 1841b, 1841c, 1844a, 1844b, 1844c, 1847a, 1847b, 1847c) in 1838 which described 72 fishes of the Ohio River, Lake Erie, and their tributaries within the State of Ohio. Although the collecting methods and locations are omitted from most of Kirtland's work, he mentioned, in a letter to the Boston Society of Natural History dated Sept. 20, 1839, that: "The arrangement of my business is such, that I am required to spend the winters at Cincinnati, and the summers in Cleveland." A careful examination of Kirtland's papers shows that most of his collecting efforts were probably expended in the Cleveland area during warm weather. His winter efforts at collecting Ohio River fishes in the Cincinnati area were probably centered on the fish markets of this city, and he relied heavily on earlier works of Rafinesque (Krumholz 1981).

Between Kirtland's work and the 1870's there are only two scattered references to Ohio River fishes: the description of the least brook lamprey by Abbott in 1860, and a mention of lake sturgeon at Cincinnati by Dumeril (1870).

Table 5. Fishes (29) for which the Ohio River is the type locality.

Common Name	Scientific Name
Least brook lamprey	*Lampetra aepyptera* (Abbott)
Shovelnose sturgeon	*Scaphirhynchus platorynchus* (Rafinesque)
Shortnose gar	*Lepisosteus platostomus* Rafinesque
Skipjack herring	*Alosa chrysochloris* (Rafinesque)
Goldeye	*Hiodon alosoides* (Rafinesque)
Mooneye	*Hiodon tergisus* Lesueur
Bigeye chub	*Hybopsis amblops* (Rafinesque)
Bluntnose minnow	*Pimephales notatus* (Rafinesque)
River carpsucker	*Carpiodes carpio* (Rafinesque)
Highfin carpsucker	*Carpiodes velifer* (Rafinesque)
Blue sucker	*Cycleptus elongatus* (Lesueur)
Smallmouth buffalo	*Ictiobus bubalus* (Rafinesque)
Black buffalo	*Ictiobus niger* (Rafinesque)
Spotted sucker	*Minytrema melanops* (Rafinesque)
Silver redhorse	*Moxostoma anisurum* (Rafinesque)
Black redhorse	*Moxostoma duquesnei* (Lesueur)
Golden redhorse	*Moxostoma erythrurum* (Rafinesque)
Black bullhead	*Ictalurus melas* (Rafinesque)
Channel catfish	*Ictalurus punctatus* (Rafinesque)
Stonecat	*Noturus flavus* Rafinesque
Flathead catfish	*Pylodictis olivaris* (Rafinesque)
White bass	*Morone chrysops* (Rafinesque)
Green sunfish	*Lepomis cyanellus* Rafinesque
Bluegill	*Lepomis macrochirus* Rafinesque
Spotted bass	*Micropterus punctulatus* (Rafinesque)
White crappie	*Pomoxis annularis* Rafinesque
Greenside darter	*Etheostoma blenninoides* Rafinesque
Logperch	*Percina caprodes* (Rafinesque)
Freshwater drum	*Aplodinotus grunniens* Rafinesque

In 1875 David Starr Jordan began his teaching career at Indianapolis High School, moving a year later to Butler University. Soon he and Herbert Copeland decided that the study of fishes would prove more fruitful than studies of flowers and birds. Jordan (1922) wrote: "...we decided that fishes offered the most fruitful field for original work....fishes were everywhere about us." One of their first projects was an attempt to confirm the identifications of fishes described at the Falls of the Ohio by Rafinesque. Although Jordan (1877) described his review of Rafinesque's work as being the result of "...nearly three years of "fieldwork" in the region fished in by Rafinesque.", he also states that the original manuscript was first prepared in the spring of 1876, just one year after he arrived in Indianapolis. A careful reading of both Jordan's (1876 and 1877) reviews of Rafinesque's work and other works of Jordan (1890, 1891, 1922) lead us to conclude that Jordan probably never collected fish from the Ohio River, and his reference to collecting in the same region fished by Rafinesque probably meant that he had collected minnows in some of the same streams around Lexington which Rafinesque had examined. Jordan did examine some fishes from the Ohio River and its tributaries near the Falls, but they were probably preserved specimens from the collections of Dr. John Sloan, a physician and amateur naturalist of New Albany, Indiana (Jordan 1891). Jordan wrote summary reports on the fishes of both Ohio (1882) and Indiana (1878, 1891; Jordan and Evermann 1877), which contain many references to fishes of the Ohio River, but one gets the impression that he is speaking of specimens reported by others, not personal collections (Krumholz 1981). Jordan left Indiana in 1891 to become the first president of Stanford University. One of his students, Barton W. Evermann, did visit the Falls of the Ohio

in May, 1898, and reported (Evermann 1902, 1918) upon the fishes found there.

In 1876 Stephen A. Forbes began collecting fishes in Illinois. His results were published 32 years later (Forbes and Richardson 1908, later reprinted in 1920) and made many references to fishes of the Ohio River bordering Illinois. Forbes, like nearly all of the ichthyologists of this period, relied primarily on small seines which could be operated by two men, and were most effective in smaller streams. As he pointed out (Forbes and Richardson 1920), for the larger and more abundant fishes "...we have depended largely upon an inspection of fish markets, and an examination of the catches of commercial fishermen...." Similar sources of specimens have been mentioned by Rafinesque, Kirtland, Jordan, Hay, and Call, and are evidence of the greater economic importance, and perhaps abundance, of riverine fishes during the late 1800's.

There seemed to be a blossoming (albeit minor) of interest in the fishes of the region in the 1880's and 90's. Henshall published two papers (1888, 1889) on the fishes of Ohio, which included personal observations on Ohio River fishes; Hay (1894) published a review of the fishes of Indiana which included the results of his prowling the fish markets of Madison and Louisville; and Osburn (1901) reviewed the fishes of Ohio, including many first-hand observations of Ohio River fishes. R. Ellsworth Call published an account of the fishes to be found at the Falls of the Ohio in 1896. He listed only those "...forms which have actually passed under observation, either in the markets or as fresh specimens just taken. Large numbers of *Notropis* are taken in nets and sold by boys to fishermen...." Call (1896) also made an interesting comparison of the fish populations existing during his time and at the

time of Rafinesque's visit: "...He (Rafinesque) embraced the opportunity to acquire information concerning the fishes, then far more numerous than now, since sewerage and similar decimating influences were at their minimum."

In the twenty-year span 1890-1910, a number of catalogs of the fishes of various states bordering the Ohio River were published. Although the authors of these reports make numerous references to the fishes of the Ohio River, these references appear to be based on the works of others (especially Rafinesque), not actual collections by the authors. In this category we place the following works: Cope (1881, Pennsylvania); Bean (1892, Pennsylvania); Eigenmann and Beeson (1893, Indiana); Goldsborough and Clark (1908, West Virginia); Meek (1908, Indiana); and Fowler (1919 and 1940, Pennsylvania).

The following points concerning ichthyological investigations along the Ohio between 1820 and 1920 are important in assessing changes in the fish communities of the river: 1) the early workers were limited by the small two-man seines which they employed, 2) therefore, they relied heavily on examining the catches of commercial fishermen and on the reports of earlier workers, 3) most of these men were taxonomists and made no attempt to assess populations, and 4) specific locations at which fish were taken on the river were often either omitted in the reports or were unknown to the authors. Hence, the works available to us for this period are useful in assessing the species present, and perhaps, in a very coarse fashion, their abundance relative to each other, but they are of little value in assessing the populations of fish present.

Fishery Investigations Between 1920 And 1969

It wasn't until after the first World War that fishery investigations

on the Ohio River began again. In 1922 Milton B. Trautman began his long, careful study of the fishes of Ohio which included a great deal of collecting in the Ohio River, and special attention to the reports of commercial fishermen working on the river. It is to be regretted that other states bordering the river did not have, in this period, individuals with the means to produce works equal to Trautman's (1957, 1981) magnificent "Fishes of Ohio". One of the especially valuable aspects of Trautman's work is that it provides a view of the Ohio River fishes during the time when man's influences on the river through the construction of the navigation system and pollution were increasing to their maxima. Trautman was painfully aware of the effects of man's activities on fishes, and paid particular attention to the effects of siltation (Trautman 1933) and impoundment on fishes in the Ohio River.

Two regional works on fish distribution were published in the 1930's, but both contained only a few reports of Ohio River fish (Blatchley 1938, Raney 1938). Gerking (1945) reported a few Ohio River collections from the Indiana shore made in 1942 as a part of the survey of Indiana fishes (see also Gerking 1955, 1957, and Gammon and Gerking 1966). Additional distribution summaries have been published which contain many original records from this period (Clay 1962b, 1975 - collections begun in 1938 in Kentucky; Smith 1979 - collections begun in 1950 in Illinois). Bailey and Cross (1954) list a number of literature citations and museum specimens of shovelnose sturgeon from the Ohio River before 1952.

Lachner (1956) published an overview of changes in the fish populations of the Ohio River Basin which is interesting because it was written at a time when degradation of streams in the basin through human influences was near its maximum. Lachner listed 18 species of fish which

were reported before 1900 "...in the upper portions of the Ohio River Basin in Pennsylvania and northward in some of the tributaries of the Monongahela or Allegheny rivers, some of which were common or abundant, but have not been reported in recent years." Of these 18 we can now conclude that Lachner's interpretation was correct for the following seven species which still have not returned to the Ohio River of Pennsylvania: paddlefish, lake and shovelnose sturgeons, shortnose gar, bowfin (*Amia calva*), highfin carpsucker, and blue sucker. We could add to this group the mooneye, which was described from Pittsburgh in 1817 but has never been reported from the Ohio River of Pennsylvania since. Four of these 18 species listed by Lachner (goldeye, smallmouth buffalo, blue catfish, and river carpsucker) have not been reported from the Ohio River of Pennsylvania since before 1900, but have been taken within 15 miles of the Pennsylvania border since 1970.

The American eel, sauger (*Stizostedion canadense*), and drum were all taken within 50 river miles of the Pennsylvania border in the ORSANCO (1962) survey, and all have been recorded within the Pennsylvania portion of the river since 1970. They represent three species which have made a significant recovery in distribution.

The gizzard shad and the river shiner (*Notropis blennius*) were found in the Ohio River of Pennsylvania in fair abundance during the ORSANCO survey of 1957-59, an indication that Lachner may have been in error in stating that they had disappeared from that portion of the river. Both species seem also to have increased in abundance during the 1960's and 70's.

Two additional species which Lachner could have included in his list of fishes not seen in the Ohio River of Pennsylvania since before 1900 would have been the black redhorse and the muskellunge which have returned

to this section of the river in the 1970's (the muskellunge through stockings).

Two of the species Lachner considered absent from the basin in 1956 (longnose dace, *Rhinichthys cataractae* and Mississippi silvery minnow, *Hybognathus nuchalis*) had only been reported from tributary streams in the basin before 1900, never from the Ohio mainstem.

Of the additional six species which Lachner regarded as rare in the Ohio Basin of Pennsylvania, two (Ohio lamprey, *Ichthyomyzon bdellium* and slenderhead darter, *Percina phoxocephala*) have never been reported from the mainstem Ohio River of the state. Another two of these six (shorthead redhorse, *Moxostoma macrolepidotum* and flathead catfish) seem to have held their own in the region, and have occasionally been reported from the Ohio mainstem of Pennsylvania since 1970. The spotted sucker seems to have been rare in Pennsylvania rivers before 1900. The only known record for this fish in the Ohio River of Pennsylvania is from ORSANCO (1962) taken in 1957. Finally, the warmouth (*Lepomis gulosus*) seems to have increased slightly in abundance since 1970. It has been taken occasionally in the area both before and after 1970.

It was in the 1950's and 60's that the State and some Federal agencies began a few investigations of fishery resources in the Ohio River. Initially they concentrated on the commercial fishery, because the sport fishery was perceived as being of low quality, and the river was (and is) difficult to manage compared to lakes, ponds, impoundments, and small streams.

Also, since the sole ownership of the river below ORM 317 rested with Kentucky, the states of Illinois, Indiana, and to some extent Ohio, were not responsible for managing fishery resources in the river. During this

period, as Lachner (1956) has pointed out, the fishery resources of the Pennsylvania portion of the river were terribly reduced by severe pollution, giving Pennsylvania little to manage. Reports from the agencies during this time interval include reports from West Virginia (Robinson 1959); Kentucky (Carter 1961, 1962, and Renaker and Carter 1966); Indiana (Lockard 1966, Zook 1970); the U. S. Public Health Service (Tebo 1965); and the U. S. Environmental Protection Agency (Preston 1969, 1979).

The most extensive and complete inventory of fishes of the Ohio River undertaken to date was begun in 1957 by investigators at the University of Louisville under the sponsorship of the Ohio River Valley Sanitation Commission. This study resulted in the "Aquatic-Life Resources of the Ohio River", a 218-page report (ORSANCO 1962), which represented three years of intensive collecting efforts expended throughout the length of the river. Using a variety of gear types, the investigators collected nearly 3/4 million fish weighing over 16 tons. Probably the most significant collections (124) were made by poisoning lock chambers on the river with rotenone. The aquatic-life study resulted, either directly or indirectly, in many other publications on Ohio River fishes by scientists at the University of Louisville (i.e., Krumholz 1958; Cavanah 1959; Minckley and Krumholz 1960; Williams, Hannegan, and Clay 1961; Minckley 1962; Williams 1963; Bryan 1964; and Krumholz and Minckley 1964).

Fishery Investigations Between 1970 and 1983

The requirements of the National Environmental Policy Act of 1969 and P.L. 92-500 of 1972 with their subsequent amendments, have forced the preparation of environmental impact statements and/or other reports for every project of size proposed along the entire river. Both private and public projects which require dredging; bank or channel modifications;

operation and maintenance of the navigation system; modification and construction of dams, power plants, river ports and marinas; and especially withdrawals and discharges of cooling waters, have all been required to undertake environmental studies between 1970 and 1983. In typical cases these studies have been conducted by private consulting firms, university personnel, or biologists employed by state and Federal agencies. In a typical project the original report is submitted by the consultant to the firm sponsoring the project, which often rewrites the report and submits it to the appropriate governmental agency where it may, again, be modified before final acceptance. In the case of long-running projects there may also be numerous quarterly, annual, etc. interim reports submitted between levels. Often, the actual amount of data presented is reduced as the report is distilled at various levels. Therefore, if one reviews the final report there is no guarantee that all information gathered during the production is at hand. Another common practice has been to collect no original data but merely use data collected and reported upon previously at nearby sites to draft an environmental impact statement or report. The result has been a most confusing, multi-layered, and difficult to obtain proliferation of what has been termed gray literature. Rosenberg et al. (1981) have recently reviewed this problem and offered some suggestions for overcoming it.

To prepare the distribution maps we examined 95 of these reports that contained original data of fish collections between 1970 and 1983. We also examined a like number of interim and final reports which contained no original fish data, but which were, nevertheless, added to the literature cited section. Many of these documents are listed in Hannon (1978).

During the period of 1970-1981 a number of works were published by regional and national ichthyologists. Especially useful were those by Clay (1975), Pflieger (1975), Smith (1979), Burr and Mayden (1979), Burr (1980), Lee et al. (1980), and Trautman (1981). Additional distribution records for the Ohio River in this decade were found in White (1974), Clark and Pearson (1978, 1979), Clark (1979), Pearson et al. (1979), and Buckner (1980). We also incorporated some unpublished data on fishes collected from the Ohio River and provided by Stout (1980), Water Resources Laboratory at the University of Louisville (1980), and Cavender (1981).

State and Federal agency personnel also collected fishes from the Ohio River between 1970 and 1983. We have examined the reports of Preston and White (1978), Charles et al. (1979), Axon et al. (1980), Jernejcic (1980), and Pierce et al. 1983), as well as stocking reports contained in the annual water quality condition assessments of ORSANCO (ORSANCO 1975a, 1976, 1977, 1978a, 1979). We have supplemented the findings with personal communication with many agency biologists. Unpublished records were made available by L. B. Starnes (1980) of the Tennessee Valley Authority and H. R. Preston (1979) of the U. S. Environmental Protection Agency.

Determinations Of Diversity And Abundance Of Ohio River Fishes Through Time

There were no quantitative studies of the Ohio River fishes before 1957, and it is, therefore, impossible to calculate diversity indices before that year. Our descriptions and conclusions regarding diversity, relative abundances, and densities before 1957 are based upon rather liberal interpretations of the early works, especially those of Rafinesque, Kirtland, Forbes, Evermann, Henshall, Hay, Osburn, Call, and Trautman.

Species composition

The 19 species of fish tentatively identified as having been mentioned by early travelers on the Ohio River before 1818 (Table 3) were all mentioned by Rafinesque (1820b) as well (Table 4). Of the 52 species assigned to Rafinesque in Table 4, only two have not been reported in the Ohio River since 1970: lake sturgeon and the hornyhead chub. However, if we assume that Rafinesque's hurried and limited means of collecting would have yielded only those species which were fairly common, then the following species, which were rarely reported in the Ohio River between 1970 and 1980, have declined significantly in abundance since Rafinesque's days: American brook lamprey, shovelnose sturgeon, alligator gar, grass pickerel, muskellunge, bigeye chub, and blue sucker. However, Rafinesque himself (1820b) regarded American brook lamprey, alligator gar, and grass pickerel rare, while he considered only shovelnose sturgeon as "common". We know from the writings of Forbes, Evermann, Hay, Osburn, Call, and Trautman that shovelnose sturgeon and blue sucker were still common in the Ohio between 1890 and 1900, while the remaining six fishes on the preceding list were less abundant. The muskellunge has been reported occasionally in the upper river since 1970, but probably as a result of stocking programs.

To clarify the changes in species composition over time we first examined all records broken down into three time periods: before 1920, 1920-1969, and 1970-83. We also divided the records into the upper, middle, and lower thirds of the river (Tables 6 and 7). The number of species recorded through time increased slightly from 111 species before 1920, to 121 during 1920-1969, and 130 species between 1970 and 1983.

Species introduced to the river or its basin by man were common carp (*Cyprinus carpio*) and American shad before 1920; northern pike,

Table 6. Number of fish species reported from the upper, middle, and lower thirds of the Ohio River during the three periods: before 1920, 1920-1969, 1970-1983.

Before 1920			1920-1969			1970-1983		
ORM 0-327	ORM 328-654	ORM 655-981	ORM 0-327	ORM 328-654	ORM 655-981	ORM 0-327	ORM 328-654	ORM 655-981
37	89	42	95	96	90	100	94	91
Total number for each subperiod =		111			121			130

Table 7. Number of fish species reported from the upper, middle, and lower thirds of the Ohio River up to 1983 (all subperiods combined).

ORM 0-327 only	ORM 0-654 only	ORM 328-654 only	ORM 328-981 only	ORM 655-981 only	ORM 0-327 and 655-981 only	ORM 0-981 (Each Third)
11	20	8	10	15	4	86
Total number for each third of the river (all subperiods combined) =		Upper - 120, Middle - 122, Lower - 115				
Overall Total (all subperiods and Sections) =		154				

goldfish (*Carassius auratus*), white catfish (*Ictalurus catus*), banded killifish (*Fundulus diaphanus*), and mummichog (*Fundulus heteroclitus*) between 1920 and 1969; and alewife (*Alosa pseudoharengus*), coho salmon (*Oncorhyncush kisutch*), rainbow trout (*Salmo gairdneri*) brown trout (*Salmo trutta*), grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), and striped bass (*Morone saxatilis*) since 1970. Of these introduced species only common carp, goldfish, white catfish, and banded killifish exist in well-established, reproducing populations.

Only nine of the species reported before 1920 have not been reported since that year. American shad were planted in the river in the late 1800's but did not become established. Least brook lamprey, Alabama shad (*Alosa alabamae*), Ozark minnow (*Notropis nubilus*), mud darter (*Etheostoma asprigene*), gilt darter (*Percina evides*), and longhead darter (*Percina macrocephala*) were mentioned in just one report, while hornyhead chub and crystal darter (*Ammocrypta asprella*) were mentioned in just two reports. Only Alamama shad and perhaps crystal and longhead darters could be considered large river species.

Five species of fish were reported from the Ohio River before 1920 and during 1920-69, but have not been reported since 1970: lake sturgeon and burbot (*Lota lota*) are large river species which have disappeared from the river in the last decade. Southern redbelly dace (*Phoxinus erythrogaster*), dusky darter (*Percina sciera*) and banded sculpin (*Cottus carolinae*) are small- to medium-sized stream species which are common in tributaries to the Ohio River.

Seven species of fish were first reported from the Ohio River between 1920 and 1969 but have not been reported since 1970. The report for greater redhorse (*Moxostoma valenciennesi*, Tebo 1965) could be a

misidentification. The cypress minnow (*Hybognathus hayi*) and stripe-tail darter (*Etheostoma kennicotti*) are not large-river species and probably strayed into the Ohio mainstem. The gravel chub (*Hybopsis x-punctata*) is relatively rare in the northern half of the Ohio River basin, while the range of the blacktail shiner (*Notropis venustus*) barely reaches into the lower end of the basin.

Twenty-one species of fish which were first reported from the Ohio River between 1920 and 1967, have also been reported since 1970. Included in this group are three introduced species: goldfish, white catfish, and banded killifish. Many of these 21 species were undoubtedly present in fair numbers in the Ohio River before 1920 but were probably not distinguished from similar, closely-related species by early workers, i. e., spotted gar (*Lepisosteus oculatus*), threadfin shad (*Dorosoma petenense*), ghost shiner (*Notropis buchanani*), striped shiner (*N. chrysocephalus*), red shiner (*N. lutrensis*), silver shiner (*N. photogenis*), silverband shiner (*N. shumardi*), spotfin shiner (*N. spilopterus*), sand shiner (*N. stramineus*), mimic shiner (*N. volucellus*), steelcolor shiner (*N. whipplei*), bullhead minnow (*Pimephales vigilax*), mountain madtom (*Noturus eleutherus*), northern madtom (*Noturus stigmosus*), and redear sunfish (*Lepomis microlophus*). Three of these 21 species were probably strays from small streams (silverjaw minnow, *Ericymba buccata*; bigeye shiner, *Notropis boops*; and pirate perch, *Aphredoderus sayanus*).

Thirteen species of fish have first been reported from the Ohio River after 1970. Seven of these were introduced by man (alewife, coho salmon, rainbow trout, brown trout, grass carp, silver carp, and striped bass). Six of the 13 are not large-river species, and probably strayed into the Ohio mainstem (redside dace, *Clinostomus elongatus*; ribbon shiner, *Notropis*

fumeus; blacknose shiner, *N. heterolepis*; redfin shiner, *N. umbratilis*; orangethroat darter, *Etheostoma spectabile*; and banded darter *E. zonale*). The channel darter (*Percina copelandi*) was probably present in the upper Ohio before 1900, may have retreated into tributaries during the years of severe pollution, and has apparently returned to the upper Ohio River since 1970.

Finally, one species of fish, the American brook lamprey, was first reported from the river before 1920, was not reported between 1920 and 1969, and then reappeared in the records after 1970.

Diversity

Shannon-Wiener diversity indices (H) were calculated for the 243 lock chamber rotenone collections made between 1957 and 1980. The samples were divided into four time periods: 1957-60, 1967-70, 1974-77, and 1978-80; and into ten 100-mile sections of the river (Figure 4). Overall H values were also determined for each period.

Although the variations between 100-mile sections of the river were great, the overall H values increased slightly from 1.54 in 1957-60 to 2.00 in 1967-1970, and then declined to 1.41 in 1974-77. The overall H value for 1978-80 increased to 1.81. This increase in diversity after 1977 was largely due to increases between ORM 100-300, 400-700, and 900-981 (Figure 4). These four H values were all significantly different from one another at the 0.01 level according to t tests.

Density

No estimates of the density of fishes in the Ohio River were made until 1957. We can only speculate on densities before this date. The previously cited statement of Call (1896) to the effect that fishes were

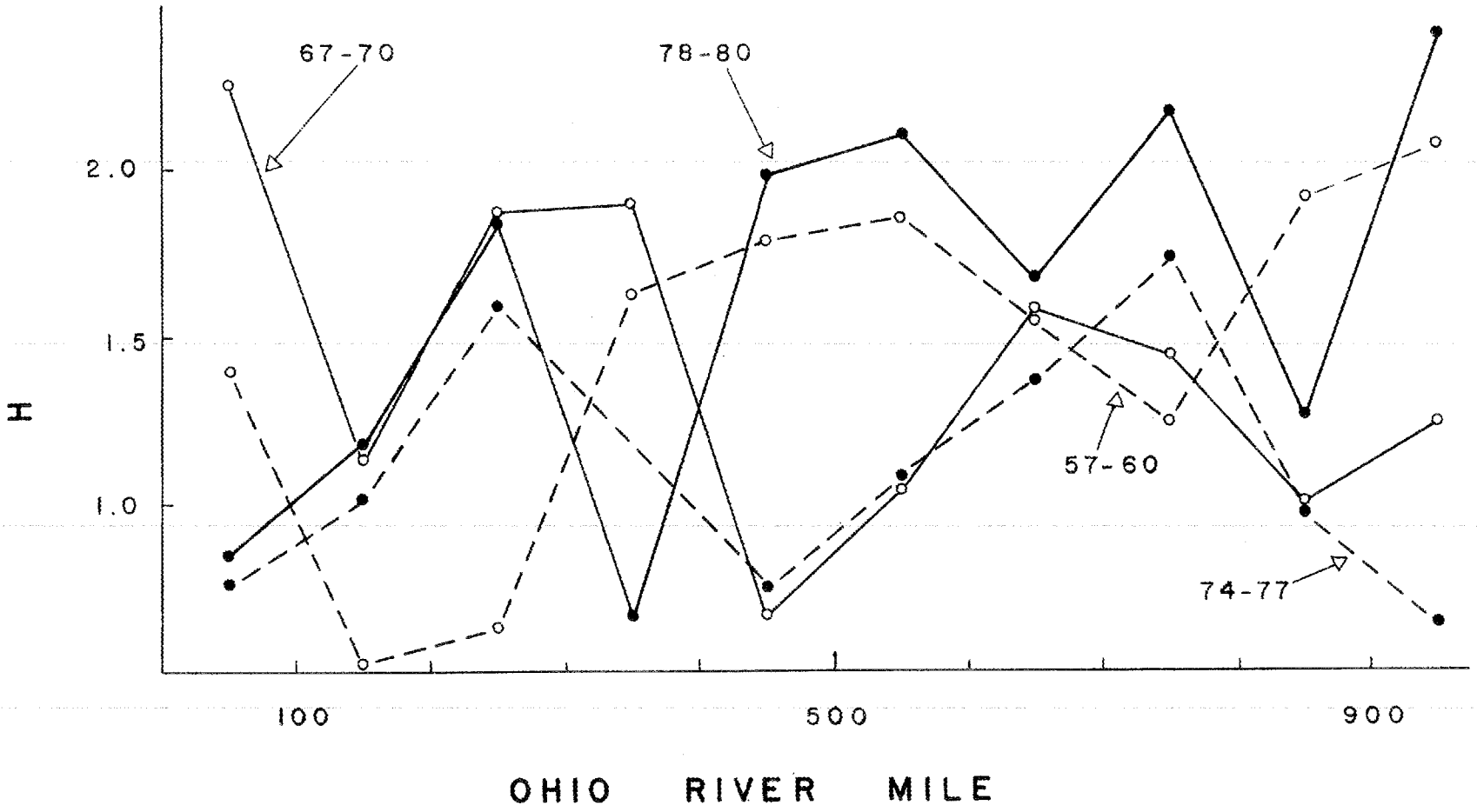

Figure 4. Shannon-Weiner diversity indices (H) for lock chamber rotenone samples from the Ohio River during the time periods: 1957-60 (open circles-dashed line), 1967-70 (open circles-solid line), 1974-77 (solid circles-dashed line), and 1978-80 (solid circles-solid line). The abcissa represents miles below the source at Pittsburgh.

much more abundant in Rafinesque's time than in his own, is typical of the general conclusions reached by Trautman (1957), Gammon (1977), Pflieger (1975), Smith (1979), and others who have described a general reduction in the numbers of fishes in waters of the Ohio River basin.

We cannot determine what the actual densities of fishes in the Ohio River were before 1957 when quantitative studies began. Densities in the upper 200 miles of the river probably were reduced by the severe pollution after 1900. In the rest of the river we have only the verbal accounts of commercial fishermen and the meager records of ichthyologists who were not concerned with quantitative studies. Commercial fishing is not as important on the Ohio River today as it apparently was before 1900, but this decline could be ascribed to changes in consumer demand, and the lowering of fish palatability due to pollution (Carter 1961, 1962; Clay 1962, 1968). In assessing the density of fishes before 1900 one should also keep in mind that before impoundment the river dwindled down to a much smaller volume each summer and would have concentrated the fishes in a manner which would have made them much more vulnerable to the commercial fishermen's seines.

To assess changes in relative density of the entire fish community of the river since 1957, we again divided the 243 lock chamber rotenone samples into four time periods and plotted the density (No./ha) of all species of fish combined (± one standard error = SE) for each 100-mile section of the river (Figure 5). In 1957-60 the mean density of all fishes on the entire river, as represented by the lock chamber samples, was (± SE) 8812 ±1942/ha. The density declined slightly to 7615 ±1053/ha during 1967-70, then increased to 14171 ±5831/ha in 1974-77 before falling to 7533 ±1451/ha in 1978-80. However, none of these values

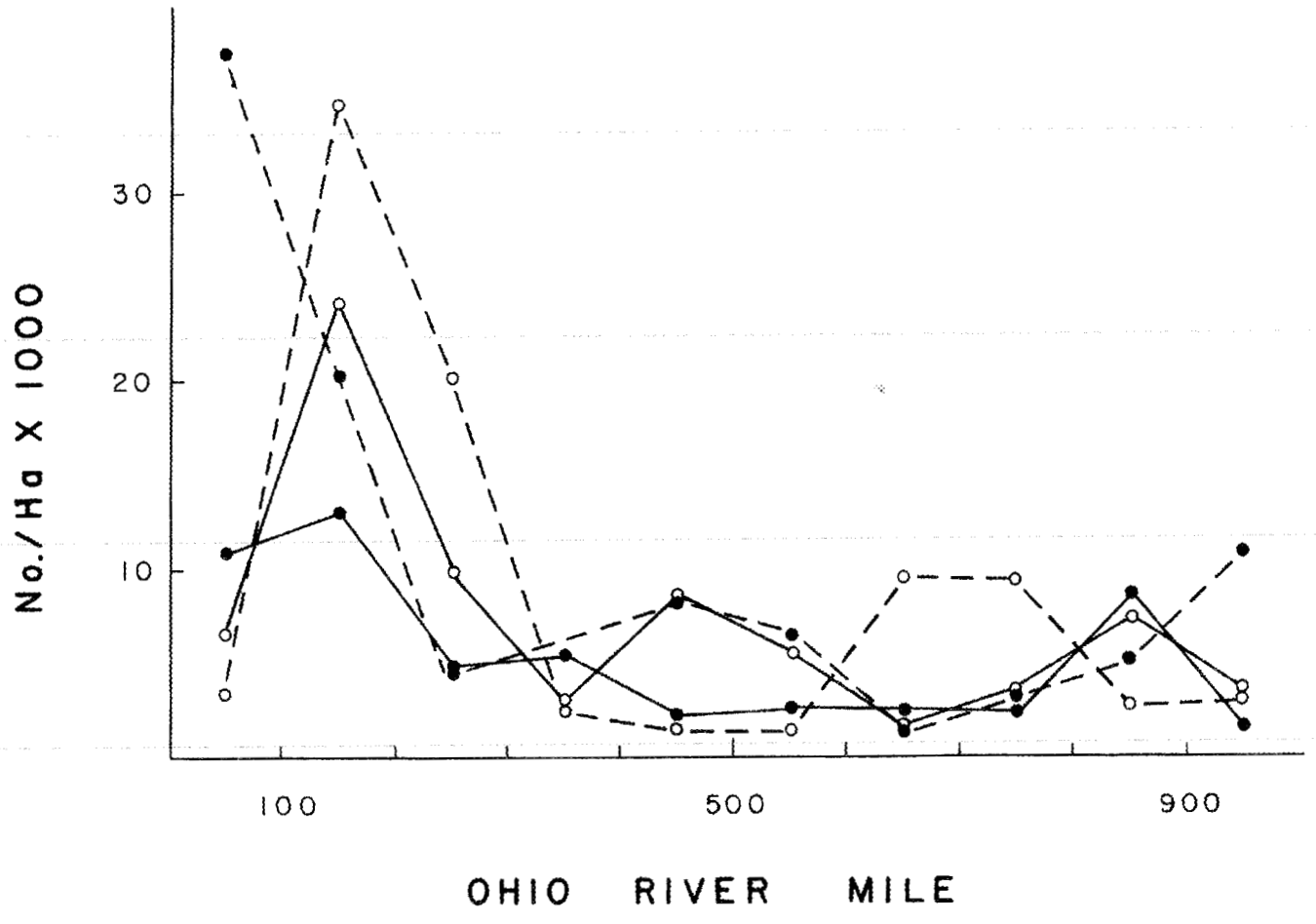

Figure 5. Density of all fishes in lock chamber collections from 100-mile sections of the Ohio River in the four periods: 1957-60 (open circles-dashed line), 1967-70 (open circles-solid line), 1974-77 (solid circles-dashed line) and 1978-80 (solid circles-solid line).

were significantly different at the .05 level according to t tests. Most of the changes between the four periods could easily be accounted for by changes in the density of emerald shiners, which made up 74-88% of the five greatest densities in Figure 5. The variation in numbers of emerald shiners, particularly in the upper third of the river, could be attributed to differences in the willingness of the crews used in different years to collect and count small fishes, or the inherent variability in estimating the density of a schooling species of fish like the emerald shiner.

In a more detailed analysis we considered changes in density over the four time periods within each 100-mile section of the river. This analysis consisted of a series of t tests, which are presented in Table 8. There were significant (.05 level) increases in densities at ORM 0-100 between 1957-60 and the following three periods (1967-70, 1974-77, and 1978-80). There were also significant increases in density after 1957-60 at ORM 400-500, 500-600, and 800-900. There were no significant decreases in density at any location after 1957-60. There were only two statistically significant differences between total densities between 1967-70 and the two later periods. These were an increase in density recorded in 1974-1977 at ORM 0-100 and a decrease in density in the same period at ORM 200-300 (Table 8).

Biomass

The mean biomass (kg/ha) of fishes in the river before 1957 can only be guessed at. The points discussed previously regarding densities could also be applied to biomasses before 1957.

To assess changes in biomass since 1957 we again examined the data from the 243 lock chamber samples. The mean biomass (± one standard

Table 8. Student's t values for tests of significant differences between mean densities and biomasses of all fish species combined in 100-mile sections of the Ohio River between the four time periods of 1957-60, 1967-70, 1974-77, and 1978-80.

ORM and Years	Density Tests			Biomass Tests		
	1967-70	1974-77	1978-80	1967-70	1974-77	1978-80
0-100 miles						
1957-60	-2.14*	-2.37*	-2.95**	-1.00	-0.57	-0.38
1967-70		-2.18*	-1.79		0.36	1.15
1974-77			1.37			.73
100-200 miles						
1957-60	0.33	0.29	0.65	-0.42	-2.53*	-1.11
1967-70		0.18	1.05		-1.65	-1.09
1974-77			0.53			1.47
200-300 miles						
1957-60	0.92	1.08	1.06	-2.68*	-2.98*	-5.02**
1967-70		2.23*	2.03		-0.14	-1.88
1974-77			-0.12			-1.76
300-400 miles						
1957-60	-0.17	—	—	-3.83**	—	—
1967-70		—	—		—	—
1974-77			—			—
400-500 miles						
1957-60	-2.19*	-4.86**	—	-5.32**	-7.66**	—
1967-70		0.12	—		-1.44	—
1974-77			—			—
500-600 miles						
1957-60	-4.14**	-2.83*	-1.34	-18.16**	-5.12**	-5.79**
1967-70		-0.18	2.05		0.64	0.39
1974-77			1.17			-0.15

Table 8. (cont.)

ORM and Years	Density Tests			Biomass Tests		
	1967-70	1974-77	1978-80	1967-70	1974-77	1978-80
600-700 miles						
1957-60	1.13	0.75	—	-0.53	0.64	—
1967-70		0.66	—		0.81	—
1974-77			—			—
700-800 miles						
1957-60	1.23	1.20	0.84	0.42	0.43	0.27
1967-70		0.15	0.34		0.07	0.03
1974-77			0.42			-0.02
800-900 miles						
1957-60	-1.97	-1.40	-4.23**	-2.80*	-3.30**	-21.08**
1967-70		0.39	-0.18		0.06	-1.90
1974-77			-0.87			-2.11
900-981 miles						
1957-60	—	-1.80	—	—	-6.86**	—
1967-70		—	—		—	—
1974-77			—			—

* = significant at the .05 level

** = significant at the .01 level

error) of all fishes in the river increased almost two times between 1957-60 and 1967-70 (from 205 ±33 kg/ha to 391 ±218 kg/ha; Figure 6). By 1974-77 the biomass of all species combined rose to 470 ±76 kg/ha. In 1978-80 the mean biomass declined slightly to 458 ±82 kg/ha. A detailed discussion of changes in biomass of the major species is found in the following sections.

A series of t tests indicated that the elevated biomasses of 1974-77 and 1978-80 were significantly higher (.01 level) than that of 1957-60 (t = -3.35 and -3.09, 157 and 155 d.f.). However, the overall biomass of 1967-70 did not differ significantly from that of any other period, and biomasses of the periods 1974-77 and 1978-80 were also not significantly different.

In a more detailed analysis we examined changes in biomass within each 100-mile section of the river between each of the four time periods by means of a set of t comparisons (Table 8). In this analysis we found significant increases (.05 level) in biomass after the 1957-60 period in each 100-mile section of the river below ORM 100 except for the sections ORM 600-700 and 700-800. There were no significant changes in biomass in the upper 100 miles of the river after 1957-60 according to the t tests. There were no significant increases in biomass after 1967-70. There were no significant decreases in biomass between any of the four periods over the entire river.

Shifts In Diversity And Abundance Of Fishes Along The Ohio River

Changes in the distribution of fishes along the river before 1957 are as difficult to determine as were diversity and species composition changes through time. We must, again, rely principally on the works of Rafinesque, Kirtland, Forbes, Jordan, Call, Trautman, et al. These

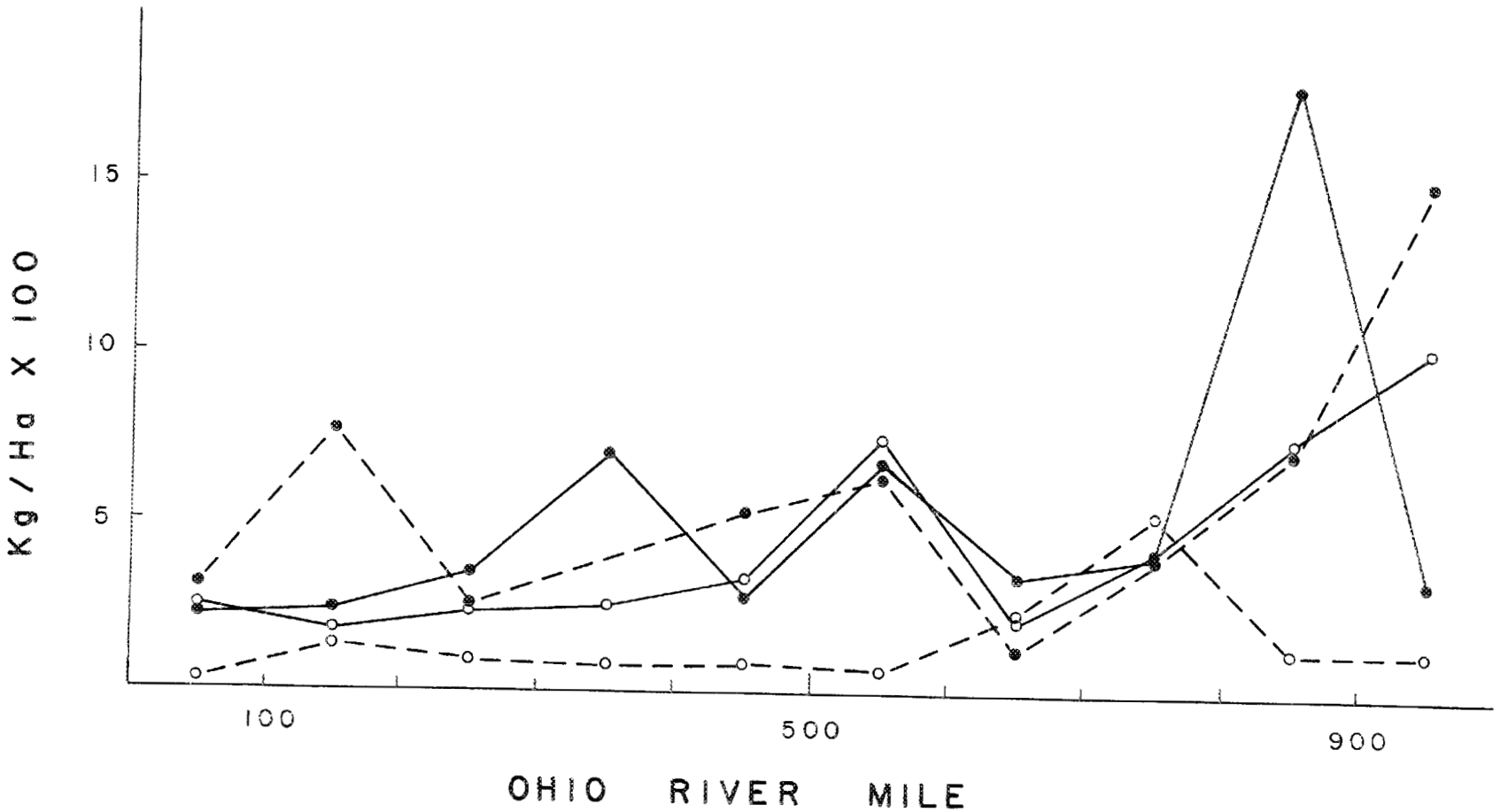

Figure 6. Biomass of all fishes combined in lock chamber rotenone collections from 100-mile sections of the Ohio River in four periods: 1957-60 (open circles-dashed line), 1967-70 (open circles-solid line), 1974-77 (solid circles-dashed line), and 1978-80 (solid circles-solid line).

sources do not, even in total, provide a very uniform picture of fishes present throughout the river. Rafinesque's collecting efforts appear to have been concentrated at Pittsburgh(?), Louisville, and Henderson; Kirtland's at Cincinnati; Forbes' in the Ohio River of Illinois; Evermann's at Louisville; Henshall, Hay, Osburn, and Trautman's in the Ohio River of Ohio; and Call's at Louisville. Rafinesque made many sweeping statements on distribution, i.e., up the river "...as far as Pittsburgh ...." or "...in the lower parts of the Ohio River....". An exact interpretation of these statements is difficult.

Nevertheless, Rafinesque's work, when combined with that of Lesueur at Pittsburgh before him, makes it clear that the upper 100 miles of the river was originally inhabited by a number of species which were either very rare or absent 100-160 years later. The lake sturgeon, which was abundant enough to support commercial fishing before 1900, has not been reported from the Ohio River for over 30 years.

Other fishes which early workers reported from the upper 200 miles of the river, but which were essentially restricted to the lower 700 miles of the river between 1920 and 1970 were: least brook lamprey (actually taken at ORM 216), paddlefish, shovelnose sturgeon, shortnose gar, mooneye, speckled chub (*Hybopsis aestivalis*), blue sucker, lake chubsucker (*Erimyzon sucetta*) eastern sand darter (*Ammocrypta pellucida*), blackside darter (*Percina maculata*), and river darter (*Percina shumardi*).

The muskellunge reported in the upper 200 miles since 1920 may have been the result of stockings rather than resident populations.

Species composition and diversity

Before 1920 a total of 111 species of fish were reported from the Ohio River. In the upper third of the river 37 species were reported,

while in the middle third 89 species were reported, and in the lower third 42 species were reported (Table 6). These numbers probably reflect the distribution of collectors' efforts before 1920 much more than the actual number of fish species present in the different sections of the river. Much of the collecting effort before 1900 was centered at the Falls (Louisville) and in the Cincinnati area. After the work of Rafinesque and Lesueur in 1817-1819 very few collections seem to have been made in the Pittsburgh area, perhaps because of pollution.

Between 1920 and 1969 collecting efforts on the river were much more evenly distributed along the length of the river, although the middle third probably still received the greatest effort. The total number of fish species reported was 121. The numbers of species found during this period were 95, 96, and 90 in the upper, middle, and lower thirds of the river, respectively (Table 6), a much more even distribution of species than that reported before 1920.

Between 1970 and 1983 130 species of fish were reported from the Ohio River. The upper, middle, and lower thirds of the river provided 100, 94, and 91 species, respectively. The large number of power plants in the upper third of the river resulted in the preparation of a number of impact analyses, and several long-term monitoring programs during the 1970's. It is possible that during this decade the upper third of the river received more collecting effort than the remaining two-thirds.

When the data from the three subperiods were combined, the numbers of species reported from the upper, middle, and lower thirds of the river were 120, 122, and 115, respectively (Table 7). Of the 154 species reported from the Ohio River, 86 were found in each third of the river (Table 7). Eleven species were found only in the upper third, 8 species

were found only in the middle third, and 15 species were found only in the lower third. Twenty species were found in the upper two-thirds, 10 species were found in the lower two-thirds, and 4 species were found only in the upper and lower thirds (Table 7).

Shannon-Wiener diversity indices were calculated for lock chamber rotenone samples in each 100-mile section of the river (Figure 4). Although variations in the values were high within and between the four subperiods, a general trend towards increased diversity values with distance downstream was discernible. The mean H values for samples between ORM 0-300, 301-700, and 701-981 were (± SE) 1.26 ±.16, 1.44 ±.15, and 151 ±.18, respectively. None of these values were significantly different from each other at the .05 level according to t tests. In general, diversity values in the upper third of the river increased between 1967 and 1980 when compared to the values for 1957-60 samples. The value of 1.40 for 1957-60 in the uppermost 100 miles of the river would have been only 1.12 if the extremely diverse samples taken by Krumholz, et al. (1962) during the cessation of pollution during the steel strike of 1959 had been omitted. In the lower two-thirds of the river diversity values after 1967 were usually about the same or lower than values in 1957-60 (Figure 4).

Density

None of the studies prior to 1957 were based upon sufficient data to allow even speculation on changes in density along the river, although Lachner (1956) and Trautman (1957) had indicated that numbers and diversity had been reduced in the upper 100 miles due to pollution.

When the 243 lock chamber rotenone samples were divided into 100-mile sections of the river it became clear (Figure 5) that the highest

densities occurred in the upper third of the river in each of the four subperiods considered. The mean density of all fish species combined in all four subperiods between ORM 0 and 300 was (± SE) 14764 ±3197/ha. Between ORM 301 and 700 the mean density was just 6210 ±1240/ha, while between ORM 701 and 981 the overall mean density was 5393 ±1119/ha. Student's t tests indicated that there were significant differences (.05 level) between the overall density in the upper third of the river and each of the two lower thirds (t = 2.64 and 2.30, with 184 and 138 d.f.). However, there was no significant difference between the two lower thirds (t = .44; with 154 d.f.). The higher densities recorded in the upper third of the river were due almost entirely to large catches of emerald and mimic shiners. Detailed accounts of changes in density for each 100-mile section of the river are included in a following portion of this report.

Biomass

When the 243 lock chamber rotenone samples taken between 1957 and 1980 were divided into 100-mile sections and examined (Figure 6), the greatest biomasses were found in the lower 200 miles of the river. The mean biomass of all species of fish combined over all four subperiods between ORM 0 and 300 was (± SE) 251 ±28 kg/ha. The overall biomass in the middle portion of the river (ORM 301-700) was 258 ±28 kg/ha. In the lower portion of the river (ORM 701-981) the overall mean biomass increased to 485 ±85 kg/ha. The biomass of all fishes in the lower third of the river was significantly higher (.01 level) than those in the upper and middle thirds according to t tests (t = -3.06 and -3.10 with 138 and 154 d.f.). However, the mean biomasses in the upper and middle thirds of the river were not significantly different (t = -.17, 184 d.f.).

Biomasses of gizzard shad and common carp exceeded those of all other species in most sections of the river. Detailed accounts of biomass data within each section are included in the following portion of the report.

Variations In The Fish Community Of The Ohio, As Indicated By Lock Chamber Rotenone Collections Between 1957 and 1980.

The earliest report of sampling fishes with rotenone applied to a navigation lock chamber known to us is that of Carter (1954) on the Kentucky River. This practice was initiated on the Ohio River in 1957 and has been continued at irregular intervals up to the present. Table 9 gives the year and location of the 243 such samples known to us. The methods employed have been described by Krumholz (1958), ORSANCO (1962), Preston (1969), and Preston and White (1978). In a typical operation the downstream gates of the lock chamber were left open for a varying period (typically 2-12 hours). Then the lower gates were closed and 5-10 gallons of a commercial, 5% rotenone preparation were added to the chamber to achieve a concentration of 0.5-1.0 ppm. Surfacing fish were then netted by hand and processed. The entire operation was typically completed in one morning.

In the original 1957-59 sample series two basic crews were employed, one from the University of Louisville and one from the Kentucky Division of Fish and Wildlife Resources. In 1960 and 1974 the crews were from the University of Louisville. In all other years the crews were made up primarily of Federal and State agency personnel as described by Preston and White (1978).

We chose to include in the data set five rotenone collections which were made near Lock and Dam 50 and 52, but which were not made within the

Table 9. Locations of 243 lock chamber rotenone collections made on the Ohio River, 1957-1980.

Lock and Dam	Ohio River Mile	Year														
		1957	1958	1959	1960	1967	1968	1969	1970	1974	1975	1976	1977	1978	1979	1980
Emsworth	6.2		1													
Dashields	13.3		1			1	1	1	1		1	1	1	1	1	1
Montgomery Island	31.6	1	1	2	1		1	1	1							
Lock & Dam #8	46.4		1													
New Cumberland	54.4						1	1	1*							1
Lock & Dam #9	56.0		1													
Lock & Dam #10	66.2		1													
Lock & Dam #11	76.9		1													
Pike Island	84.3					1	1	1	1*		1	1	1	1	1	1
Lock & Dam #12	87.4		1													
Lock & Dam #13	96.1				1											
Lock & Dam #14	114.0		1	3												
Hannibal	126.4											1	1	1	1	1
Lock & Dam #15	129.1		1				1	1	1							
Lock & Dam #16	146.5		1													

Table 9. (cont.)

Lock and Dam	Ohio River Mile	Year														
		1957	1958	1959	1960	1967	1968	1969	1970	1974	1975	1976	1977	1978	1979	1980
Willow Island	161.7															1
Lock & Dam #17	167.5		1			1										
Lock & Dam #18	179.9		1													
Lock & Dam #19	192.2		1													
Lock & Dam #20	202.5		1													
Belleville	203.9						1	1	1		1	1	1	1	1	1
Lock & Dam #21	214.5		1													
Lock & Dam #22	220.9		1	1												
Lock & Dam #23	231.4		1			1	1									
Gallipolis	279.2		1			1	1	1	1		1	1	1	1	1	1
Lock & Dam #27	301.0		1													
Lock & Dam #28	311.6		1	1												
Lock & Dam #29	319.6		1	2	1											
Lock & Dam #30	339.4	1	2	1												
Greenup	341.0					1	1	1	1							1

Table 9. (cont.)

Lock and Dam	Ohio River Mile	Year														
		1957	1958	1959	1960	1967	1968	1969	1970	1974	1975	1976	1977	1978	1979	1980
Lock & Dam #31	359.3		1	1	1											
Lock & Dam #32	382.6	1	1	1												
Lock & Dam #33	405.1		1	1												
Lock & Dam #34	434.1		1	1												
Meldahl	436.2					1	1	1	1		1	1		1		
Lock & Dam #35	451.0	1	1	1												
Lock & Dam #36	460.9		1	1												
Lock & Dam #37	483.2	1	1	2	1											
Lock & Dam #38	503.3		1	1												
Markland	531.5						1	1	1		1	1		1	1	
Lock & Dam #39	531.7	1	2	1												
McAlpine (41)	604.4	11	9	8	1		1	1	1	1		1		1		
Lock & Dam #43	633.2	1	1	1	1		1	1	1							
Lock & Dam #44	663.2	1	1	1												
Lock & Dam #45	703.0	1	1	1												

Table 9. (cont.)

Lock and Dam	Ohio River Mile	Year														
		1957	1958	1959	1960	1967	1968	1969	1970	1974	1975	1976	1977	1978	1979	1980
Cannelton	720.7						1	1	1	1	1	1			1	
Lock & Dam #46	757.3	1	2	1						1						
Lock & Dam #47	777.7	2	1	1			1									
Newburgh	776.1							1	1	1				1		
Lock & Dam #48	809.6	1	1	1												
Lock & Dam #49	845.0	1	1	1	1											
Uniontown	846.0							1	1	1		1		1		1
Lock & Dam #50	876.1	1	1	1			1**	1**	1**							
Lock & Dam #51	903.1	1	1	1												
Smithland	918.5											1		1		
Lock & Dam #52	938.9	1	1	1					1**		1**					
Lock & Dam #53	962.9	1	1	1												
Total		29	55	39	8	7	16	16	17	5	8	11	5	11	7	9

Overall Total = 243 samples

*In 1970 the New Cumberland and Pike Island samples were inadvertently combined and are assigned only to Pike Island (Preston 1979).

**Embayment samples next to locks.

lock chambers. These samples were made in small embayments or coves adjacent to the lock chambers because navigation requirements made the chambers unavailable in 1968-70 at Lock and Dam 50, and in 1970 and 1975 at Lock and Dam 52 (Preston, personal communication).

We examined the results of each of the 243 samples and were able to make some additions to the data by comparisons with the Fish Collection at the University of Louisville. In 1957-60 it was common practice for the field workers to preserve most of the minnows and smaller fish for later identification in the lab. We have found a few specimens in the U. of L. fish collection which are clearly labelled as being from some of the lock chamber collections but which were not included in the ORSANCO (1962) report. A more serious omission was found in the 1970 collections from Uniontown and Lock and Dam 50, where a number of species were apparently preserved and sent to the University of Louisville for identification, where they were cataloged into the collection, but the specimens were never recorded on the original data sheets, and do not appear in the records of Preston (1979) and ORSANCO (1981). We have included these specimens in our analysis.

Another problem in interpreting the data is presented by the treatment of minnows in some of the collections. In many of the 1959 collections made by personnel from the State of Kentucky all minnows were lumped together and reported as "miscellaneous minnows". Apparently these specimens were never preserved. This practice was also used a few times in later collections. When we encountered such data we included both the numbers and weights in the sample totals, but the numbers were not included in species diversity calculations. One of the greatest sources of error in this data set is the varying degree of conscientiousness of the different crews in collecting and identifying small fishes

and minnows. In several of the 1959 collections, for example, there are no minnows recorded, a result which is difficult to understand given the ubiquitous presence of emerald shiners and other minnows in all regions of the river.

Nevertheless, we felt that the series of rotenone collections presented the best means of identifying trends in abundance of the major fishes over the past two decades. Therefore, we divided the 243 collections into 10 groups by 100-mile sections of the river, and into four time periods: 1957-60, 1967-70, 1974-77, and 1978-80 for analysis.

The period 1957-60 represented the original set of ORSANCO collections during a period when primary but not secondary sewage treatment facilities were in place. The collections between 1967 and 1970 represent the period just before the implementation of the National Environmental Policy and the Clean Water Act. The 1974-77 and 1978-80 periods give some idea of trends since these two acts were passed.

ORM 0-100

The most abundant fish in the upper 100 miles of the river throughout all four periods has been the emerald shiner (Table 10), which made up 23-82% of the total catch by number in each of the four subperiods. In 1957-60 the second most abundant fish (and the one of the greatest biomass) was the black bullhead (*Ictalurus melas*), which was much reduced in 1967-70, and which was not found in subsequent samples. As Preston and White (1978) have speculated, this may be due to misidentification of fishes which actually appear to be intergrades between black and brown bullheads (*I. nebulosus*) as blacks before 1960 and as browns after 1960. In 1980 we asked Dr. Branley Branson to examine with us a series of the bullheads taken in the upper river in 1957-59, and he

Table 10. Fishes from lock chamber rotenone collections; ORM 0-100; arranged in 4 periods: 1957-60, 1967-70, 1974-77, and 1978-80.

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Longnose gar							1	0.44
American eel			5	0.31	1	0.09	3	0.23
Skipjack herring	81	19.41			13	2.18	23	1.26
Alewife					1	0.01		
Gizzard shad	122	13.98	4382	125.90	6224	159.74	770	32.60
Muskellunge					3	2.22	1	0.22
Goldfish	12	1.28	6	1.52	5	1.32		
Common carp	479	23.42	5443	1039.31	1213	297.91	1213	449.44
Central stoneroller	2	0.01						
Bigeye chub	24	0.03						
Silver chub	23	0.19	2	0.04	11	0.04	2	0.02
Golden shiner	3	0.01	25	0.63			2	0.03
Emerald shiner	9308	12.26	8547	26.08	74603	109.17	27349	26.72
River shiner	1	0.01	14	0.03	2	0.01		

Table 10. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Bigeye shiner					15	0.02		
Ghost shiner	5	0.01	7	0.02	33	0.02	8	0.01
Striped shiner	9	0.01						
Common shiner			1	0.01				
Spottail shiner							1	0.01
Silver shiner	7	0.01						
Rosyface shiner	24	0.02						
Spotfin shiner	3	0.01	424	0.96	125	0.21	24	0.03
Sand shiner	998	1.33	321	0.54	257	0.25	126	0.08
Mimic shiner	1089	0.89	836	0.96	5258	6.84	1003	0.35
Bluntnose minnow	138	0.19	4563	7.78	122	0.11	395	0.34
Creek chub	2	0.01	1	0.01				
Unidentified minnows			2961	10.04				
River carpsucker	1	0.44			1	0.51	1	0.65
Quillback	1	0.11			1	0.23	3	1.95

Table 10. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
White sucker	103	0.84	7	0.63	7	0.93	16	2.41
Smallmouth buffalo	1	0.04					1	0.51
Spotted sucker	5	0.47	1	0.12	2	0.57	1	0.17
Black redhorse			1	0.14	3	0.59	1	0.20
Golden redhorse			1	0.36	7	1.47	2	0.43
Shorthead redhorse							3	0.58
White catfish			570	9.41	527	9.51	69	12.84
Black bullhead	4895	128.58	15	4.59				
Yellow bullhead	3	0.14	488	12.80	67	3.78	95	8.06
Brown bullhead	171	4.90	4231	151.73	476	45.79	213	15.91
Channel catfish	51	9.00	3384	50.28	1549	71.34	1721	123.22
Stonecat							3	0.05
Flathead catfish	1	1.04			2	0.16	11	2.78
Trout-perch							36	0.08
Banded killifish	2	0.01	2	0.02				

Table 10. (cont.)

Species	Years 1957-1960 No.	1957-1960 Kg	1967-1970 No.	1967-1970 Kg	1974-1977 No.	1974-1977 Kg	1978-1980 No.	1978-1980 Kg
White bass	1	0.20			17	0.80	7	0.48
Rock bass			5	0.04	2	0.11	3	0.19
Green sunfish	10	0.21	113	2.51	14	0.46	2	0.02
Pumpkinseed	8	0.09	206	2.58	12	0.02	2	0.04
Warmouth	2	0.07	1	0.01				
Orangespotted sunfish			13	0.13	14	0.08		
Bluegill	18	0.36	193	3.31	31	0.84	27	0.47
Longear sunfish			4	0.11	2	0.04	2	0.01
Redear sunfish			16	0.24				
Smallmouth bass							3	0.05
Spotted bass	1	0.10	15	2.44	61	8.09	8	1.23
Largemouth bass	4	0.68	55	10.74	27	2.85	10	1.19
White crappie	11	0.73	222	2.02	59	3.12	49	5.16
Black crappie	4	0.45	217	7.12	13	1.64	9	1.49
Johnny darter							1	0.01

Table 10. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Yellow perch	3	0.22			30	1.42	4	0.37
Log perch			5	0.07	1	0.01	1	0.01
Sauger			1	0.85	6	2.38	9	2.87
Walleye			8	4.26			8	3.22
Freshwater drum	3	1.64	1	1.32	17	4.32	83	14.76
Total No. and Kg	17629	223.40	37313	1482.69	90834	741.20	33325	713.19
No. Samples	13		14		6		7	
Area sampled (Ha)	4.99		5.60		2.40		3.01	
Total No. and Kg/Ha	3532	44.77	6663	264.76	37847	308.83	11071	236.94

identified these as black bullhead with many intermediate characteristics. The final resolution of this problem should be undertaken by qualified taxonomists.

Brown (black?) bullhead numbers declined through time in the upper river as the other ictalurids (channel and white catfish) increased. The white catfish was introduced to the upper Ohio River in the early 1960's and has established itself in large numbers. Channel catfish densities have increased 10-20 times over the 1957-60 values. Other species which have increased in relative abundance through the four periods include gizzard shad and common carp, which have also come to dominate the biomass, bluntnose minnows, redhorses, yellow bullhead, the sunfishes, the basses, crappies, sauger, and freshwater drum (Table 10). We can only speculate that the reason for these almost universal increases in density in the upper river are due to reduced pollution in this section over the last twenty years. Only the white sucker and sand shiner appeared to decline in abundance, perhaps due to increased competition from other fishes which were increasing.

ORM 100-200

The emerald shiner was the most abundant fish in this section of the river in all four subperiods (Table 11). Mimic shiners were the second most abundant species in 1957-60 and 1978-80, and probably in 1967-70 if the large number of "unidentified minnows" included many of this species. The density of gizzard shad increased over 30 times from 1957-60 to 1967-77, then declined slightly in 1978-80. Channel catfish and black bullhead were the third and fourth most abundant species in 1957-60 but were displaced by gizzard shad, in the later three time periods. Other fishes which increased noticeably in abundance through time were common carp, spotted bass, white crappie, sauger, and drum.

Table 11. Fishes from lock chamber rotenone collections: ORM 100-200, arranged in 4 periods; 1957-60, 1967-70, 1974-77, and 1978-80.

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Ohio lamprey							1	0.02
Paddlefish	1	4.15						
Longnose gar					3	1.60	18	7.80
American eel							5	0.07
Skipjack herring	23	3.82	19	1.89	4	0.75	10	1.81
Gizzard shad	185	19.97	3654	104.23	3282	59.60	1063	59.36
Goldeye	5	0.95						
Goldfish	2	0.78					1	0.27
Central stoneroller	1	0.01						
Common carp	220	408.65	40	36.93	914	699.63	469	339.06
Silverjaw minnow	1	0.01						
Bigeye chub	5	0.01						
Silver chub	550	4.34	3	0.05	2	0.05	76	0.13
Golden shiner	14	0.07					1	0.05

Table 11. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
White crappie	15	0.79	9	0.94	40	0.71	102	3.88
Black crappie	2	0.11	4	0.54	12	0.35	4	0.40
Johnny darter					1	0.01		
Yellow perch	1	0.02	1	0.05	2	0.06	3	0.01
Log perch	1	0.01			2	0.02	2	0.01
Channel darter					1	0.01		
Sauger			1	0.73	33	8.31	37	6.11
Walleye	1	1.18	2	1.32	1	0.77	5	0.92
Freshwater drum	10	2.00	21	0.27	40	11.71	296	33.13
Total No. and Kg	191439	769.72	59053	442.51	26234	956.72	33482	609.25
No. samples	9		4		2		4	
Area sampled (Ha)	5.49		2.44		1.22		2.44	
Total No. and Kg/Ha	34870	140.20	24202	181.36	21503	784.20	13722	249.69

Table 11. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Trout-perch	6	0.02			1	0.01	4	0.01
Brook silverside			1	0.01			1	0.01
White bass	3	0.65			1	0.13	34	2.74
Striped bass					2	0.03		
Rock bass	7	0.07						
Green sunfish	21	0.24	49	0.34	3	0.03	3	0.01
Pumpkinseed	3	0.20	4	0.11	8	0.10		
Warmouth	4	0.20			1	0.07	1	0.01
Orangespotted sunfish	5	0.03	1	0.05	30	0.10	2	0.01
Bluegill	28	1.15	21	0.86	30	0.75	34	0.84
Longear sunfish	8	1.04	3	0.06	7	0.15		
Redear sunfish	1	0.01	2	0.01				
Smallmouth bass	3	0.04	2	0.13	2	0.10	1	0.02
Spotted bass	18	0.86	331	25.21	46	6.97	21	1.88
Largemouth bass	6	0.81	6	0.42	10	2.75	4	0.71

Table 11. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Bigmouth buffalo							1	6.36
Spotted sucker	3	0.82			1	0.68	21	6.68
Silver redhorse	4	0.43						
Black redhorse	15	1.98	1	0.21	5	1.07	5	2.28
Golden redhorse	18	1.32					13	3.16
White catfish					15	0.90	8	1.73
Black bullhead	2001	17.81						
Yellow bullhead			3	0.40	14	0.82	5	0.21
Brown bullhead	260	7.66	78	4.59	276	16.33	71	6.64
Channel catfish	2232	82.00	2120	114.58	1017	85.89	770	73.77
Mountain madtom	1	0.02						
Stonecat			1	0.01			2	0.01
Tadpole madtom	2	0.01						
Brindled madtom	1	0.01						
Flathead catfish	7	0.38	1	0.80	20	8.67	17	14.32

Table 11. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Emerald shiner	168050	183.33	35647	89.45	19441	38.27	17284	21.17
River shiner	66	0.02	2	0.01			2	0.01
Ghost shiner	26	0.03			106	0.04	415	0.30
Common shiner	83	0.14						
Rosyface shiner			1	0.01				
Spotfin shiner	63	0.11	169	0.27	42	0.06		
Sand shiner	742	0.64	52	0.06	1	0.01	26	0.01
Mimic shiner	16492	17.15	1126	1.70	720	0.20	12623	5.34
Bluntnose minnow	205	0.33	168	0.26	87	0.11	12	0.01
Bullhead minnow	6	0.01						
Unidentified minnows			15503	52.19				
River carpsucker	5	1.35			4	2.41	1	0.95
Quillback	2	0.32	3	0.66	2	1.08	1	0.70
White sucker	2	0.04			2	0.42	3	2.48
Smallmouth buffalo	3	1.62	4	3.17	3	4.99	4	3.85

Species which declined noticeably (other than black bullhead, see above discussion) were silver chub (*Hybopsis storeriana*) and sand shiners. The emerald shiner density also declined to 50-30% of the 1957-60 value, although this range of values for the most abundant species could easily be accounted for by a combination of inherent variability in density of a schooling species, and variation in the willingness of personnel to collect and preserve large numbers of minnows.

Common carp represented the greatest biomass in each subperiod except 1967-70, when channel catfish and gizzard shad had greater biomasses.

ORM 200-300

Emerald shiners were the most abundant fishes in this section in 1957-60, but were displaced as the most abundant fish by gizzard shad in 1967-70 and 1974-77, and by mimic shiners in 1978-80, as the density of emerald shiners declined from a high of over 17,000/ha in 1957-60 to a low of 300-400/ha in 1974-80 (Table 12). The abundance of gizzard shad peaked in 1967-70 and declined to about 30% of that value in 1978-80. Common carp increased steadily through the last three subperiods to about 10 times their 1957-60 density. Other fishes which increased noticeably over time were: smallmouth buffalo, white crappie, sauger, and freshwater drum. Species which declined in density were skipjack herring, silver chub, emerald shiner, sand shiner, bluntnose minnow, blue catfish, black and brown bullheads, and black crappie (*Pomoxis nigromaculatus*).

It is interesting to note that over the entire upper 300 miles of the river there seemed to be a decrease in the density of several species of forage fishes (i.e., emerald and sand shiner, silver chub, bluntnose minnow) while many piscivorous species increased in abundance

Table 12. Fishes from lock chamber rotenone collections; ORM 200-300; arranged in 4 periods: 1957-60, 1967-70, 1974-77, and 1978-80.

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Silver lamprey							3	0.09
Longnose gar	5	0.01	6	3.49	12	4.02	11	1.04
Bowfin					1	3.08		
American eel			16	1.42	3	0.22	6	0.86
Skipjack herring	408	20.75	1172	19.35	170	4.90	24	4.68
Gizzard shad	1194	95.27	15243	367.77	7886	242.85	2845	98.87
Goldeye	26	4.61					5	1.61
Mooneye	1	0.15			3	0.07	4	0.58
Goldfish	2	0.30						
Central stoneroller					1	0.01		
Common carp	98	54.47	298	205.93	256	221.85	515	503.18
Speckled chub							1	0.01
Silver chub	865	6.73	52	0.58	194	1.23	59	0.38
Golden shiner	1	0.01						

Table 12. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Emerald shiner	59675	40.64	11129	26.48	1044	1.58	1355	3.63
River shiner	11	.04			14	0.04	21	0.05
Bigeye shiner			1	0.01				
Ghost shiner	50	0.03	601	0.40	18	0.03	428	0.17
Common shiner	1	0.01						
Spotfin shiner	34	0.06	3	0.02	1	0.01		
Sand shiner	88	0.05	1126	0.85			1	0.01
Mimic shiner	2545	1.98	1275	0.93	432	0.28	5806	2.73
Suckermouth minnow	3	0.01						
Bluntnose minnow	55	0.01	208	0.23	10	0.04	4	0.02
Fathead minnow					1	0.01		
Unidentified minnows	4	0.01	1000	3.63			2	0.01
River carpsucker	122	6.87	4	2.36	5	3.16	19	10.94
Quillback	1	0.11	1	0.34			15	6.61
Highfin carpsucker	2	0.65			4	2.86	1	0.68

Table 12. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
White sucker	1	0.07			2	0.21		
Smallmouth buffalo	18	7.80	27	13.87	26	24.92	84	53.81
Bigmouth buffalo					2	3.90	3	9.69
Black buffalo			3	0.95	4	4.55	3	3.32
Spotted sucker	5	1.49			2	0.65	3	1.44
Golden redhorse	3	0.24			2	0.74		
Shorthead redhorse					1	0.45	3	1.09
White catfish					7	1.07		
Blue catfish	70	5.43						
Black bullhead	3	0.15	410	20.18	1	0.45		
Yellow bullhead			5	0.85	6	0.23	1	0.01
Brown bullhead	83	5.96	2250	132.47	325	42.83	16	3.29
Channel catfish	2941	52.32	8245	190.12	1048	112.82	1022	129.15
Flathead catfish	40	1.94	27	0.61	50	6.76	82	32.56
White bass			10	1.14	13	1.65	15	3.28

Table 12. (cont.)

Species	Years 1957-1960 No.	1957-1960 Kg	1967-1970 No.	1967-1970 Kg	1974-1977 No.	1974-1977 Kg	1978-1980 No.	1978-1980 Kg
Striped bass					17	0.97		
Rock bass	1	0.18						
Green sunfish	3	0.05	14	0.48			2	0.01
Pumpkinseed	4	0.06	36	1.13	2	0.06	3	0.01
Warmouth	1	0.09			1	0.01		
Orangespotted sunfish			95	0.40				
Bluegill	89	4.15	88	2.31	38	3.01	30	1.50
Longear sunfish			7	0.13				
Redear sunfish			11	0.28				
Smallmouth bass	2	0.03	1	0.22				
Spotted bass			35	3.01	13	3.73	4	0.70
Largemouth bass	10	1.28	26	7.42	19	4.24	7	1.70
White crappie	120	6.43	189	4.70	231	9.36	258	9.17
Black crappie	25	1.98	183	3.42	41	2.18	17	0.33
Yellow perch			1	0.09	1	0.03	1	0.03

Table 12. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Log perch			5	0.12			1	0.01
Channel darter							1	0.01
Blackside darter					1	0.06		
Sauger	1	0.39	25	7.79	75	17.92	70	16.68
Walleye			3	1.81	3	1.45	4	0.86
Freshwater drum	44	17.63	306	25.55	1366	38.95	1217	153.70
Total No. and Kg	68655	340.53	44137	1052.84	13352	769.44	13972	1058.50
No. of Samples	6		9		6		6	
Area sampled (Ha)	3.42		4.53		2.94		2.94	
Total No. and Kg/Ha	20075	99.57	9743	232.42	4541	261.71	4752	360.03

(i.e., basses, sauger, channel catfish, white crappie, and freshwater drum) or were first found in the collections (i.e., longnose gar, American eel, white bass, walleye, and striped bass). Also, in all three of the upper 100-mile sections of the river the total biomass of the fish community increased between 1957-60 and the following three subperiods, while the total density decreased between ORM 100 and 300.

Gizzard shad represented the greatest biomass of fish in this section of the river in each subperiod except 1978-80 when they were displaced by common carp, which had been second in biomass each of the previous three subperiods. Channel catfish were third in biomass in each subperiod except 1978-80 when they were displaced by freshwater drum, the biomass of which increased 10 times from 1957-60 to 1978-80.

ORM 300-400

Emerald shiners were the most abundant fish in this section of the river in 1957-60, but declined markedly by 1967-70, and none were taken in 1978-80 (although only one sample was made in this subperiod, Table 13). No collections were made in this section of the river in 1974-77. The most abundant fish in 1967-70 and 1978-80 was the gizzard shad (which had been in fourth position in 1957-60, and which increased 25 times over in density), followed by the channel catfish in 1967-70, and the common carp in 1978-80. Increases in density were also noted for longnose gar, common carp, and freshwater drum, while decreases in density were seen for skipjack herring, silver chub, emerald shiner, mimic shiner, smallmouth buffalo, bullheads, and channel catfish.

Channel catfish represented the greatest biomass of fish in this section in 1957-60 and 1967-70, but were surpassed in biomass by common carp, gizzard shad, and freshwater drum in 1978-80. Freshwater drum were second in biomass in 1957-60, but fell to fifth and third places in

Table 13. Fishes from lock chamber rotenone collections; ORM 300-400; arranged in 4 periods: 1957-60, 1967-70, 1974-77, and 1978-80.

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Ohio lamprey	1	0.03						
Silver lamprey			1	0.01			27	0.23
Paddlefish	7	17.63						
Longnose gar	3	0.41	32	6.17			32	8.31
Bowfin							1	0.36
American eel			3	0.14				
Skipjack herring	214	38.12	311	5.73				
Alewife			2	0.05				
Gizzard shad	1920	130.18	2964	85.85			2909	67.83
Goldeye	9	0.84	1	0.66			5	1.33
Mooneye	10	0.73	6	0.81				
Northern pike			1	0.35				
Muskellunge	1	1.94						
Goldfish			1	0.29				

Table 13. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Common carp	71	124.44	445	189.91			155	275.37
Silver chub	230	1.19	21	0.23				
Golden shiner	3	0.02						
Emerald shiner	13085	47.98	215	0.29				
River shiner	27	0.08	3	0.01				
Ghost shiner			11	0.02				
Spotfin shiner	10	0.04						
Sand shiner	8	0.01						
Mimic shiner	3649	6.77	286	0.19				
Steelcolor shiner	1	0.01						
Suckermouth minnow	1	0.01						
Bluntnose minnow	7	0.01	1	0.01				
Bullhead minnow	1	0.01						
Unidentified minnows	2514	6.32	150	0.23				
River carpsucker	57	36.25	24	9.84			3	1.49

Table 13. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Quillback	13	2.89	7	2.46			2	0.95
White sucker			1	0.17				
Smallmouth buffalo	44	72.13	56	42.05				
Bigmouth buffalo	7	5.54					14	18.23
Black buffalo	1	2.47	2	1.52				
Spotted sucker	4	1.95	4	1.90			3	0.87
River redhorse			2	1.16				
Golden redhorse			3	1.02				
Blue catfish	1	4.90						
Black bullhead	35	1.67						
Yellow bullhead	2	0.52	3	0.12				
Brown bullhead	19	1.32	54	2.11				
Channel catfish	2598	258.44	1847	225.85			93	9.82
Unidentified madtom	1	0.01						
Flathead catfish	101	44.48	2	2.59			10	6.44

Table 13. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Trout-perch	1	0.01						
White bass	1	0.32	17	4.08			1	0.24
Rock bass	2	0.43						
Green sunfish	26	0.16	1	0.02				
Pumpkinseed	2	0.01	1	0.05				
Warmouth	7	0.35						
Orangespotted sunfish			2	0.07				
Bluegill	25	1.10	73	4.39				
Longear sunfish	6	0.21	2	0.07				
Redear sunfish	3	0.07	1	0.01				
Spotted bass	2	0.10	8	0.84				
Largemouth bass	5	0.99	6	2.54				
White crappie	49	2.63	76	9.16			15	1.09
Black crappie	9	0.95	58	3.06			3	0.14
Fantail darter	1	0.01						

Table 13. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Log perch	3	0.04						
Sauger	5	2.44	117	15.56			4	0.66
Walleye	3	2.73	3	1.23			3	1.83
Freshwater drum	920	148.58	248	23.38			102	36.29
Total	25725	970.47	7072	646.00			3382	431.48
No. of samples	17		4		0		1	
Area sampled (Ha)	10.99		2.44		0		0.61	
Total No. and Kg/Ha	2341	88.30	2898	264.75	0		5544	707.34

1967-70 and 1978-80, respectively, despite the fact that the biomass of drum actually increased from about 13.5 kg/ha in 1957-60 to 59.5 kg/ha in 1978-80.

Gizzard shad were third in total biomass in 1957-60 and 1967-70, and increased to second position in 1978-80. This increase in position was accompanied by an increase in biomass/area from 11.8 kg/ha to 111.2 kg/ha.

ORM 400-500

Channel catfish, gizzard shad and drum were the three most abundant fishes in this section of the river in 1957-60, 1967-70, and 1974-77. In 1978-80 gizzard shad were displaced to fourth position by white crappie. There were noticeable increases in densities of skipjack herring, common carp, smallmouth buffalo, white bass, white and black crappies, sauger, and freshwater drum over this period. Species which declined in abundance were silver chub, emerald shiner, mimic shiner, and blue catfish. Other species either remained at nearly the same densities or were collected too infrequently to allow comparisons (Table 14).

Channel catfish also represented the greatest biomass followed by gizzard shad and freshwater drum, in the 1957-60 collections. In the subsequent three subperiods channel catfish were displaced by common carp, gizzard shad, and drum in each subperiod, respectively.

ORM 500-600

Silver chub, emerald shiner, and channel catfish were the most abundant species in the 1957-60 collections, but in the subsequent three subperiods the two minnows declined drastically and were replaced in 1967-70 by gizzard shad and skipjack herring. Gizzard shad remained the most

Table 14. Fishes from lock chamber rotenone collections: ORM 400-500; arranged in 4 periods: 1957-60, 1967-70, 1974-77, and 1978-80.

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Silver lamprey			2	0.05				
Paddlefish	3	1.80			26	12.95		
Spotted gar	1	0.53						
Longnose gar	2	0.01	50	13.51	9	3.22	2	0.35
Bowfin	1	1.23						
American eel			19	4.06	6	0.76		
Skipjack herring	133	13.32	131	10.53	20	2.44	93	2.41
Alewife			9	0.22				
Gizzard shad	3467	212.60	18291	236.68	7485	275.75	103	10.64
Threadfin shad	1	0.03	1	0.02				
Goldeye	1	0.21	1	0.15				
Mooneye							1	0.04
Central stoneroller	1	0.01						
Common carp	35	28.31	252	282.27	56	191.33	23	43.30

Table 14. (cont.)

Species	Years							
	1957-1960		1957-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Silver chub	715	3.86	26	0.12				
Golden shiner	1	0.01						
Emerald shiner	2337	6.65	231	0.57				
River shiner	3	0.01						
Ghost shiner	1	0.01	1	0.01				
Sand shiner			1	0.01				
Mimic shiner	5	0.01	163	0.11				
Unidentified minnows	1128	0.58	28	0.04			64	0.19
River carpsucker	10	5.02	4	2.62	1	1.20		
Quillback	2	0.86	6	2.84			1	1.10
Highfin carpsucker							2	0.40
Smallmouth buffalo	6	9.19	18	12.02	9	18.37	13	4.88
Bigmouth buffalo	9	17.70						
Black buffalo			1	1.27				
Spotted sucker			3	1.21				
River redhorse	2	0.11						

Table 14. (cont.)

Species	Years							
	1957-1960		1957-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Golden redhorse	1	0.35	5	2.53			1	0.56
Shorthead redhorse							3	1.85
Blue catfish	26	0.53						
Black bullhead	17	0.73						
Yellow bullhead	1	0.24						
Brown bullhead			10	0.18				
Channel catfish	3915	399.72	820	183.25	581	89.09	232	25.90
Flathead catfish	100	35.59	8	4.89	36	13.75	42	7.40
White bass	2	0.65	23	1.97	29	3.63	5	1.20
Rock bass	4	0.09	1	0.02			2	0.02
Green sunfish	6	0.12	1	0.01	1	0.30		
Warmouth			2	0.01	3	0.05		
Orangespotted sunfish	12	0.10	1	0.03				
Bluegill	7	0.30	214	7.65	41	1.77	7	0.56
Longear sunfish	12	0.27	4	0.20				

Table 14. (cont.)

Species	Years 1957-1960 No.	1957-1960 Kg	1967-1970 No.	1967-1970 Kg	1974-1977 No.	1974-1977 Kg	1978-1980 No.	1978-1980 Kg
Smallmouth bass	1	0.12			1	0.11		
Spotted bass	5	0.88	12	3.07	1	0.11	6	0.57
Largemouth bass	1	0.10	3	0.50	13	4.04		
White crappie	5	0.53	95	5.12	87	6.51	354	3.27
Black crappie	2	0.14	54	3.69	4	1.17	4	0.18
Yellow perch			1	0.02				
Log perch			10	0.09			1	0.05
Sauger	4	1.06	88	14.94	44	14.07	22	3.65
Walleye					2	0.44		
Freshwater drum	1133	72.14	302	43.22	582	20.16	335	72.87
Total No. and Kg	13118	815.72	20892	839.70	9037	661.22	1316	181.39
No. of Samples	14		4		2		1	
Area Sampled (Ha)	8.54		2.44		1.22		0.61	
Total No.and Kg/Ha	1536	95.52	8562	344.14	7407	541.98	2157	297.36

abundant species in 1974-77 and 1978-80, while second and third places went to drum and channel catfish (Table 15).

Species which increased in abundance through time were longnose gar, American eel, skipjack herring, gizzard shad, common carp, buffalo fishes, white bass, white crappie, sauger, and freshwater drum. Again, minnows, including the silver chub and emerald shiners, declined in abundance over the period, as did the blue catfish.

Channel catfish, gizzard shad, and freshwater drum represented the greatest biomass in the 1957-60 collections, but the common carp displaced catfish from first position in each of the subsequent three subperiods. The biomasses of common carp, shad, and catfish all peaked in 1967-70 and have declined somewhat in each subperiod since then. In 1978-80 two unusually large catches of paddlefish and smallmouth buffalo brought these two species into second and third place in biomass.

ORM 600-700

The most abundant fish in this section of the river, which includes Lock and Dam 41 at Louisville, was the emerald shiner in 1957-60, but in the subsequent subperiods the most abundant species were gizzard shad in 1967-70 and 1974-77, and freshwater drum in 1978-80 (Table 16). The decline in emerald shiner density was precipitous, falling from 4572/ha in 1957-60 to 119, 123, and 0/ha in the subsequent subperiods. Gizzard shad were the most abundant fishes in this section of river in 1967-70 and 1974-77, despite their gradual decline in density from 2579/ha in 1957-60 to 114/ha in 1978-80. Freshwater drum increased in density during the period and moved from third in abundance in 1957-60 to first in 1978-80. Other species which increased in abundance through time were paddlefish, white crappie, and sauger. Species which declined in abundance through

Table 15. Fishes from lock chamber rotenone collections; ORM 500-600; arranged in 4 periods: 1957-60, 1967-70, 1974-77, and 1978-80.

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Paddlefish	18	17.52	1	2.31	4	3.20	48	121.19
Longnose gar	2	1.55	8	0.96	11	2.10	25	10.14
American eel			76	5.51	5	0.48	7	0.65
Skipjack herring	7	1.30	545	5.80	33	1.52	263	3.69
Gizzard shad	638	79.69	7773	396.69	5262	182.85	1112	42.12
Threadfin shad			2	0.06				
Goldeye	43	2.14	3	0.85	5	1.58	1	0.57
Mooneye	1	0.11			4	0.35	4	0.03
Goldfish	2	0.11	15	5.22	1	0.14		
Common carp	33	25.27	542	688.41	213	436.99	121	250.96
Silver chub	1791	17.78	15	0.04	12	0.10		
Emerald shiner	1714	5.81	101	0.06	24	0.10	9	0.03
River shiner	4	0.01						
Common shiner	1	0.05						

Table 15. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Mimic shiner	16	0.02			5	0.01		
Unidentified minnows	370	1.12					501	0.50
River carpsucker	4	1.21	13	7.39			4	2.75
Quillback	10	2.15					14	7.51
White sucker	3	0.52						
Smallmouth buffalo	15	10.31	21	17.96	6	5.84	93	143.32
Bigmouth buffalo							49	95.19
Black buffalo			27	41.19				
Spotted sucker	1	0.54	3	1.32	1	0.14	2	1.00
Golden redhorse	1	0.08					1	0.76
Blue catfish	64	2.15	1	0.01			2	0.09
Black bullhead	5	0.31	4	0.02				
Yellow bullhead			6	0.05			2	0.11
Brown bullhead							2	0.15
Channel catfish	1292	118.12	710	160.76	429	40.85	365	61.17

Table 15. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Flathead catfish	33	14.43	9	0.83	20	6.56	38	21.93
White bass	1	0.25			34	2.25	14	2.62
Rock bass	1	0.05			1	0.10		
Green sunfish	4	0.17	1	0.04				
Warmouth	1	0.07			4	0.32		
Orangespotted sunfish	4	0.03						
Bluegill	5	0.01	37	2.08	25	2.14	7	0.55
Longear sunfish	2	0.13			15	1.09		
Redear sunfish	1	0.01						
Spotted bass					3	0.59		
Largemouth bass					4	3.80	1	0.18
White crappie	8	0.60	14	1.53	53	10.35	80	2.76
Black crappie	3	0.12	3	0.23	2	0.38	3	0.20
Log perch					1	0.01		
Sauger	1	0.37	7	0.45	110	27.59	35	5.50

Table 15. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Walleye			2	0.23				
Freshwater drum	552	33.31	399	43.19	1177	46.98	416	61.31
Total No. and Kg	6651	337.42	10338	1383.19	7464	778.41	3219	836.98
No. of Samples	6		3		2		2	
Area Sampled (Ha)	4.28		1.83		1.22		1.22	
Total No.and Kg/Ha	1554	78.84	5649	755.84	6118	638.04	2639	686.05

Table 16. Fishes from lock chamber rotenone collections; ORM 600-700; arranged in 4 periods: 1957-60, 1967-70, 1974-77, and 1978-80.

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Paddlefish	1	1.06			8	2.60	29	7.29
Spotted gar	1	0.56						
Longnose gar	18	7.21	24	16.42	6	1.00	2	0.61
Shortnose gar	1	0.24						
American eel	5	0.34	21	1.19				
Skipjack herring	1643	320.31	147	3.82	114	3.94	75	4.70
Gizzard shad	25227	1298.44	1883	248.92	1416	90.90	70	3.10
Threadfin shad	2019	12.11	1	0.02	36	0.45		
Goldeye	53	10.61			7	1.58	19	3.25
Mooneye	13	0.88						
Goldfish			1	0.82	1	0.43		
Central stoneroller	1	0.01						
Common carp	352	91.94	26	31.86	14	32.26	42	91.37
Mississippi silvery minnow	11	0.04						

Table 16. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Silver chub	1818	11.42	28	0.04	68	0.43		
Emerald shiner	44718	92.13	285	0.29	150	0.80		
River shiner	146	0.23	1	0.01				
Common shiner	6	0.05						
Spotfin shiner	1	0.01						
Mimic shiner	791	0.91						
Bluntnose minnow	31	0.04			1	0.01		
Unidentified minnows	3637	7.58					70	0.62
River carpsucker	168	65.18	10	5.08	8	5.07	2	1.46
Quillback	7	0.44						
Highfin carpsucker	4	1.86	4	2.04				
White sucker	1	0.02						
Smallmouth buffalo	78	7.57	27	19.25	6	4.89	17	12.13
Bigmouth buffalo	4	4.91					6	16.66
Black buffalo	1	0.35	3	2.00	2	3.10		

Table 16. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Spotted sucker	3	0.13					1	0.20
River redhorse	1	0.26	1	0.59				
Blue catfish	404	12.95			1	0.03		
Black bullhead	43	5.06			1	0.25		
Yellow bullhead	1	0.01						
Brown bullhead	10	0.85						
Channel catfish	2214	139.90	635	50.80	27	3.25	218	16.86
Tadpole madtom	2	0.01						
Northern madtom	1	0.01						
Unidentified madtom	1	0.01						
Flathead catfish	170	16.05	9	0.40	2	0.65	8	2.64
White bass	2	0.24			4	0.05	3	0.47
Rock bass	2	0.04	1	0.09				
Green sunfish	94	0.68						
Warmouth	2	0.11						
Orangespotted sunfish	57	0.31						

Table 16. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Bluegill	72	0.74	27	0.39	8	0.28	7	0.19
Longear sunfish	30	0.34	10	0.32	5	0.02		
Redear sunfish			5	0.02				
Smallmouth bass	1	0.05	2	0.05	1	0.01		
Spotted bass	6	0.41	2	0.09				
Largemouth bass	2	0.09						
White crappie	19	3.83	18	1.80	36	1.94	86	8.71
Black crappie	7	0.59	1	0.01			2	0.02
Stripetail darter	13	0.02						
Sauger	14	2.88	13	2.46	15	1.09	7	1.09
Walleye	4	0.59	1	0.15				
Freshwater drum	9815	244.90	1271	102.86	192	7.58	776	44.90
Total No. and Kg	93746	2367.51	4457	491.68	2129	162.61	1440	216.27
No. of Samples	36		6		2		1	
Area Sampled (Ha)	9.78		2.40		1.22		0.61	
Total No. and Kg/Ha	9585	242.08	1857	204.87	1745	133.29	2361	354.54

the period included gizzard shad, threadfin shad, silver chub, emerald shiner, river shiner, river carpsucker, and blue catfish.

Gizzard shad represented the greatest biomass of fish present in this section in the first three subperiods, but were displaced to fifth place in 1978-80 when common carp made up the greatest biomass. Freshwater drum biomasses were either second or third in each subperiod.

ORM 700-800

The gizzard shad was the most abundant fish in this section of the river in the first three subperiods, despite its steady decline in density from a high of 5632/ha in 1957-60 to a low of 172/ha in 1978-80 when gizzard shad fell to fifth place in abundance. Freshwater drum densities were second highest in the first three subperiods and rose to first place in 1978-80, despite their actual reduction in density to about one-third of the 1957-60 density. Emerald shiner were the third most abundant fish in 1957-60, declined rather drastically in the middle two subperiods, and then recovered somewhat to third place again in 1978-80 (Table 17).

Other fishes which increased in density through the period were paddlefish, longnose gar, skipjack herring, mooneye, common carp, silver chub, river carpsucker, smallmouth buffalo, channel catfish, white bass, white and black crappie, and sauger. It is noteworthy that this was the only section of the river in which silver chub densities increased over time. Fishes which declined in abundance were: gizzard shad, threadfin shad, emerald shiner, river shiner, mimic shiner, blue catfish, and freshwater drum.

Gizzard shad represented the greatest biomass of fishes in each of the first three subperiods, but fell out of the top three in 1978-80 when

Table 17. Fishes from lock chamber rotenone collections; ORM 700-800; arranged in 4 periods: 1957-60, 1967-70, 1974-77, and 1978-80.

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Paddlefish			2	8.12	6	7.80	8	11.90
Spotted gar	4	0.86						
Longnose gar	10	0.59	15	2.42	8	5.58	5	1.18
Snortnose gar			1	0.54				
Bowfin			4	9.84	6	10.03		
American eel					26	4.04	2	0.11
Skipjack herring	15	1.75	444	4.56	272	9.21	237	8.22
Gizzard shad	37790	3143.34	8551	861.27	4345	318.72	210	17.40
Threadfin shad	2043	13.44	57	1.65	61	0.95	3	0.08
Goldeye	4	0.34	4	0.73	5	1.09	1	0.40
Mooneye	5	0.39	3	0.32	24	1.27	10	0.14
Goldfish			1	0.50				
Common carp	49	11.95	198	200.99	92	293.10	94	194.54
Silver chub	276	2.16	111	0.06	95	1.80	129	0.20

Table 17. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Golden shiner			1	0.05	1	0.03		
Emerald shiner	4187	14.22	440	1.66	70	0.25	472	1.01
River shiner	98	0.11	25	0.04	10	0.02		
Common shiner	124	0.58						
Red shiner					1	0.01		
Rosyface shiner			1	0.01				
Spotfin shiner					1	0.01		
Mimic shiner	62	0.08	35	0.05				
Steelcolor shiner	1	0.01			1	0.01		
Bluntnose minnow					2	0.01		
Creek chub					1	0.01		
Unidentified minnows	272	0.31						
River carpsucker	51	13.90	120	79.06	108	72.50	44	24.52
Quillback	1	0.51	5	1.00	3	1.41	8	3.41
Highfin carpsucker			10	2.35			5	2.10

Table 17. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Smallmouth buffalo	14	2.79	41	9.95	39	38.07	69	47.15
Bigmouth buffalo	16	2.33	25	30.05	23	42.09	1	3.40
Black buffalo			1	0.18	1	2.45	1	7.17
Spotted sucker			5	3.22			2	0.35
Golden redhorse			1	0.27	1	0.17	2	0.93
Shorthead redhorse					2	1.06		
White catfish					4	0.88		
Blue catfish	1564	27.03	55	2.43	15	0.35	27	1.02
Black bullhead	1	0.17	9	0.58	1	0.11		
Yellow bullhead	3	0.25	1	0.23				
Brown bullhead	1	0.03	1	0.01				
Channel catfish	1493	110.53	535	136.87	1433	87.81	550	44.01
Flathead catfish	142	28.78	46	11.41	43	24.69	38	21.55
Pirate perch	2	0.01	2	0.02	1	0.01		
White bass			1	0.09	19	0.87	15	3.25

Table 17. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Yellow bass			1	0.09				
Striped bass					3	0.06		
Green sunfish	3	0.07	19	0.65	12	0.30		
Warmouth	36	0.41	16	1.06	13	0.40		
Bluegill	48	1.02	262	14.26	132	5.64	8	0.25
Longear sunfish	27	2.05	24	1.11	34	1.32		
Redear sunfish			3	0.30	9	0.39	1	0.07
Smallmouth bass			2	0.05				
Spotted bass			15	2.57	7	2.45		
Largemouth bass	1	0.10	16	4.42	1	0.07		
White crappie	9	0.12	239	28.98	234	35.19	48	5.16
Black crappie	17	1.06	72	4.88	39	4.22	11	1.43
Sauger	19	0.16	9	1.92	102	18.39	37	8.21
Walleye					15	0.95		

Table 17. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Freshwater drum	15685	257.00	1792	98.85	2545	230.19	809	85.09
Total No. and Kg	64073	3638.45	13221	1529.67	9866	1225.98	2847	494.25
No. of samples	11		6		5		2	
Area sampled (Ha)	6.71		3.66		3.05		1.22	
Total No. and Kg/Ha	9549	542.24	3612	417.94	3234	401.96	2334	405.12

carp, drum, and smallmouth buffalo represented the greatest biomasses. Channel catfish had also been in the top three in biomass during 1957-60 and 1967-70.

ORM 800-900

Gizzard shad were the most abundant fish in this section of the river followed by drum in each subperiod except the first, when drum were most abundant and gizzard shad were second in abundance (Table 18). Third place in abundance was occupied by blue catfish, white crappie, and channel catfish in the four subperiods. The great variations in shad numbers probably reflect chance occurrences of large schools in the vicinity of the locks during different collecting dates. Fishes which increased in density during the period included skipjack herring, gizzard shad, common carp, white crappie, white bass, and sauger. Species which declined in abundance through time included: Mississippi silvery minnow, silver chub, mimic shiner, and blue catfish.

Gizzard shad also represented the greatest biomass of fish in the first three subperiods, but were displaced by common carp in 1978-80, the biomass of common carp having increased gradually by a factor of 30 or more through the period. Other fishes included in the top three in biomass in at least one subperiod were freshwater drum, bigmouth buffalo, and channel catfish.

ORM 900-981

Gizzard shad were the most abundant fishes in this last 81 miles of the Ohio River in all four subperiods (Table 19). Although shad numbers seemed to peak in 1974-77, the variability in density, due to the unpredictable movements of large schools of shad in the vicinity

Table 18. Fishes from lock chamber rotenone collections; ORM 800-900; arranged in 4 periods: 1957-60, 1967-70, 1974-77, and 1978-80.

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Silver lamprey							2	0.04
Paddlefish	2	2.35	1	0.95	2	0.75	2	0.11
Spotted gar	2	0.43					1	0.20
Longnose gar	32	1.86	4	1.43	1	0.01	1	0.05
Shortnose gar	1	0.20	17	4.62			1	0.20
Bowfin					1	0.78		
American eel					13	2.63	18	1.96
Skipjack herring	20	2.33	51	3.70	104	3.13	95	7.92
Gizzard shad	3130	317.75	19765	1886.48	5140	610.35	7483	690.51
Threadfin shad	32	0.26	96	1.55	172	3.51	4	0.10
Goldeye	21	4.43			2	0.18		
Mooneye	1	0.12			4	0.31		
Common carp	71	29.58	145	108.39	93	155.55	541	1010.41
Mississippi silvery minnow	183	0.46						

Table 18. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Silver chub	395	2.17	54	0.02	12	0.27	1	0.03
Emerald shiner	377	1.07	12	0.03	2	0.01	615	3.76
River shiner	110	0.27						
Pugnose minnow			3	0.01				
Silverband shiner	7	0.01						
Sand shiner			1	0.01				
Mimic shiner	650	1.32	1	0.01				
Bluntnose minnow			4	0.01	2	0.01	5	0.01
Unidentified minnows	391	0.87						
River carpsucker	47	7.24	112	22.37	20	15.78	23	11.09
Quillback	2	0.81	35	4.81	2	0.77	10	3.07
Highfin carpsucker			29	6.40			8	2.93
Blue sucker	1	0.49						
Smallmouth buffalo	43	6.34	32	15.28	5	11.17	59	40.85
Bigmouth buffalo	81	0.43	88	147.62			49	101.71

Table 18. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Black buffalo			2	0.86			3	4.26
Spotted sucker			18	5.22				
Golden redhorse	1	0.01	1	0.09				
Blue catfish	2908	50.98	1	0.03	19	3.04	135	1.51
Black bullhead			18	2.15				
Yellow bullhead			7	0.64				
Brown bullhead	1	0.20						
Channel catfish	2117	126.96	270	66.65	337	10.29	696	30.95
Mountain madtom	6	0.02						
Unidentified madtom	8	0.05						
Flathead catfish	290	66.74	52	5.05	13	3.47	35	14.69
Pirate perch	2	0.01	71	0.23	3	0.01		
White bass	1	0.15	1	0.18	4	0.75	11	2.66
Yellow bass			11	0.40	2	0.34		
Striped bass					1	0.09		

Table 18. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Rock bass			7	0.13				
Flier			1	0.01				
Green sunfish			41	0.61				
Warmouth			339	3.47	3	0.06	1	0.02
Orangespotted sunfish			60	0.13				
Bluegill	12	0.61	191	4.57	58	1.67	33	1.78
Longear sunfish	11	0.64	72	1.37	20	0.41	2	0.11
Redear sunfish			11	0.22				
Spotted bass	3	0.23	40	1.52				
Largemouth bass			20	8.54	2	0.41	9	1.84
White crappie	5	0.18	876	28.65	91	7.74	49	11.81
Black crappie	4	0.50	691	27.84	5	0.37	14	3.81
Yellow perch			2	0.02				
Log perch	1	0.01						
Blackside darter			1	0.01				

Table 18. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Sauger	4	0.54	133	3.86	9	2.59	62	14.06
Walleye					5	0.45	1	1.04
Freshwater drum	6064	176.00	1303	25.70	415	49.40	917	233.37
Total No. and Kg	17037	804.62	24690	2391.84	6562	886.30	10886	2196.86
No. of samples	10		5		2		2	
Area sampled (Ha)	6.10		3.17		1.22		1.22	
Total No. and Kg/Ha	2793	131.90	7789	754.52	5379	726.48	8923	1800.70

Table 19. Fishes from lock chamber rotenone collections; ORM 900-981; arranged in 4 periods: 1957-60, 1967-70, 1974-77, and 1978-80.

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Paddlefish	3	2.99			36	64.37	25	30.62
Spotted gar	31	0.86	1	0.14				
Longnose gar	4	2.03			13	0.50	3	1.37
Shortnose gar	2	0.53	1	0.14				
Bowfin							1	1.07
American eel	9	1.71	1	0.05				
Skipjack herring	124	12.89	45	0.77	64	1.48	25	3.07
Gizzard shad	4794	152.67	1217	109.77	17417	2192.20	620	74.47
Threadfin shad	3713	33.73			742	18.18	88	1.70
Goldeye	15	1.31			9	2.85	31	3.25
Mooneye	11	0.67			15	1.80	2	0.40
Common carp	236	88.80	104	247.07	49	88.65	37	61.26
Mississippi silvery minnow	493	2.18						
Speckled chub	1	0.01						

Table 19. (cont.)

Species	Years 1957-1960 No.	1957-1960 Kg	1967-1970 No.	1967-1970 Kg	1974-1977 No.	1974-1977 Kg	1978-1980 No.	1978-1980 Kg
Bigeye chub	8	0.01						
Silver chub	242	1.52			12	0.21		
Golden shiner							1	0.04
Emerald shiner	204	0.50			62	0.52	19	0.05
River shiner	205	0.41						
Silverband shiner	496	1.04						
Mimic shiner	351	0.72						
Bluntnose minnow	2	0.01						
Unidentified minnows	42	0.09						
River carpsucker	19	7.12	10	7.21	3	5.50	5	2.31
Blue sucker	4	9.73						
Smallmouth buffalo	69	39.75			8	5.72	19	14.70
Bigmouth buffalo	10	0.74			6	20.32	56	139.00
Golden redhorse			1	1.09				
Blue catfish	867	45.22	76	1.59	66	5.11	57	6.85

Table 19. (cont.)

Species	Years							
	1957-1960		1967-1970		1974-1977		1978-1980	
	No.	Kg	No.	Kg	No.	Kg	No.	Kg
Black bullhead			1	0.14	2	0.27		
Yellow bullhead							1	0.23
Channel catfish	1053	59.76	45	8.89	187	28.56	194	10.36
Stonecat	3	0.02						
Unidentified madtom	8	0.03						
Flathead catfish	427	69.20	13	1.62	49	5.99	26	2.22
Pirate perch	1	0.01						
White bass	24	0.95			9	5.00	5	0.09
Yellow bass	6	0.88	13	0.82	8	1.89	4	0.18
Rock bass							1	0.05
Green sunfish	1	0.02			15	0.73	10	0.32
Warmouth					5	0.18	17	0.35
Orangespotted sunfish							3	0.01
Bluegill	15	0.80	9	0.82	44	3.58	178	5.81
Longear sunfish	9	0.49	3	0.14	12	0.32	52	1.37

Table 19. (cont.)

Species	Years 1957-1960 No.	1957-1960 Kg	1967-1970 No.	1967-1970 Kg	1974-1977 No.	1974-1977 Kg	1978-1980 No.	1978-1980 Kg
Spotted bass	1	0.01			1	0.05	3	0.03
Largemouth bass							17	8.55
White crappie	12	0.74	1	0.14	72	5.85	419	36.70
Black crappie	7	0.61	1	0.23			90	6.77
Greenside darter	1	0.01						
Log perch	1	0.01						
Dusky darter	3	0.01						
Sauger	17	4.96	3	0.59	9	2.67	6	0.97
Freshwater drum	3984	215.23	383	129.91	1239	146.27	140	1.28
Total No.and Kg	17528	760.98	1928	511.13	20154	2608.77	2155	415.45
No. of samples	9		1		2		1	
Area Sampled (Ha)	5.49		0.49		1.72		1.23	
Total No. and Kg/Ha	3193	138.61	3935	1043.12	11717	1516.72	1752	337.76

of the locks, makes it difficult to determine real trends in abundances. The second and third most abundant species in the four subperiods were either freshwater drum, threadfin shad, common carp, channel catfish, or white crappie. Fishes which increased in abundance with time included paddlefish, goldeye, bluegill, and white crappie. Fishes which decreased in abundance included: threadfin shad, Mississippi silvery minnow, silver chub, river shiner, silverband shiner, mimic shiner, blue catfish, and freshwater drum.

Freshwater drum, common carp, gizzard shad, and bigmouth buffalo represented the greatest biomass in each of the four subperiods represented. These four species also occupied the top three positions in biomass rankings in each subperiod.

The twenty most abundant species in all lock chamber samples

The ten most abundant species of fish in the lock chamber samples over the period 1957-80 are given in Table 20. Emerald shiners and gizzard shad were the two most abundant species. However, emerald shiner densities were much greater in the upper third of the river than in the lower two-thirds, while gizzard shad densities were much more uniform throughout the length of the river.

Freshwater drum were third in abundance, and were most common in the lower two-thirds of the river. Mimic shiners were fourth in abundance, but were only found in large numbers in the upper third of the river. Channel catfish were fifth in abundance and were uniformly distributed throughout the length of the river.

The remaining five species on the 10-most-abundant list were: common carp, bullhead (all three species combined), skipjack herring, white crappie, and threadfin shad (Table 19), all of which had mean

Table 20. Standing crops (No./ha) of the ten most abundant fishes in lock chamber rotenone samples from the Ohio River between 1957 and 1980; samples grouped into 100-mile sections of the river.

Species	Years	Ohio River Miles										
		0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-981	$\bar{x}$
Emerald shiner	57-60	1865	30610	17449	1191	274	400	4572	624	62	37	5708
	67-70	1526	14609	2457	88	95	55	119	120	4	0	1907
	74-77	31085	15935	355	—*	0	20	123	23	2	36	5287
	78-80	9086	7084	461	0	0	7	0	387	504	15	1754
Gizzard shad	57-60	24	34	349	175	406	149	2579	5632	513	873	1073
	67-70	783	1498	3365	1215	7496	4248	785	2336	6235	2484	3045
	74-77	2593	2690	2682	—	6135	4313	1161	1425	4213	10126	3926
	78-80	256	436	968	4769	169	911	115	172	6134	504	1443
Freshwater drum	57-60	1	2	13	84	133	129	1004	2338	994	726	542
	67-70	1	9	68	102	124	218	530	490	411	782	274
	74-77	7	33	465	—	477	965	157	834	340	720	444
	78-80	28	121	414	167	549	341	1272	663	752	114	442
Mimic shiner	57-60	218	3004	744	332	1	4	81	9	107	64	456
	67-70	149	461	281	117	67	0	0	10	1	0	109
	74-77	2191	590	147	—	0	4	0	0	0	0	326
	78-80	333	5173	1975	0	0	0	0	0	0	0	748
Channel catfish	57-60	10	407	860	236	458	302	226	223	347	192	326
	67-70	604	869	1820	757	336	388	265	146	85	92	536
	74-77	645	834	356	—	476	352	22	470	276	109	393
	78-80	572	316	348	152	380	299	357	451	570	158	360

Table 20. (cont.)

Species	Years	Ohio River Miles 0-100	1-200	2-300	3-400	4-500	5-600	6-700	7-800	8-900	9-981	$\bar{x}$
Common carp	57-60	96	40	29	6	4	8	36	7	12	43	28
	67-70	972	16	66	182	103	296	11	54	46	212	196
	74-77	505	749	87	—	46	175	11	30	76	28	190
	78-80	403	192	175	254	38	121	69	77	443	30	180
Bullhead (all)	57-60	1016	412	25	5	2	1	6	1	1	0	147
	67-70	845	33	588	23	4	5	0	3	8	2	151
	74-77	226	238	113	—	0	0	1	1	0	1	64
	78-80	102	31	6	0	0	3	0	0	0	1	14
Skipjack herring	57-60	16	4	119	19	16	2	168	2	3	23	37
	67-70	0	8	259	127	54	298	61	121	16	92	104
	74-77	5	3	58	—	16	27	93	89	85	37	46
	78-80	8	4	8	0	152	216	123	194	78	20	80
White crappie	57-60	2	3	35	4	1	2	2	1	1	2	5
	67-70	40	4	42	31	39	8	8	65	276	2	52
	74-77	25	33	79	—	71	43	30	77	75	42	53
	78-80	16	42	88	25	580	66	141	39	40	341	138
Threadfin shad	57-60	0	0	0	0	1	0	206	304	5	676	119
	67-70	0	0	0	0	1	1	1	16	30	0	5
	74-77	0	0	0	—	0	0	30	20	141	431	69
	78-80	0	0	0	0	0	0	0	2	3	72	8

*No collections were made between ORM 300 and 400 during 1974-77.

densities over the entire period of 1957-80 of between 149 and 52/ha.

The following 10 species ranked 11-20 in abundance overall, with mean densities ranging from 42 to 12/ha: silver chub, blue catfish, bluntnose minnow, bluegill, sand shiner, flathead catfish, sauger, ghost shiner (see discussion of this species in Distribution section), black crappie, and smallmouth buffalo.

The twenty species having the greatest biomasses in lock chamber samples

The ten species representing the greatest biomasses in the lock chamber samples taken between 1957 and 1980 are presented in Table 21. Gizzard shad and common carp made up the greatest biomasses (overall mean = 152.76 and 142.79 kg/ha, respectively). Both species were distributed throughout the river but stocks were greatest below ORM 800. The biomasses of freshwater drum and channel catfish ranked third and fourth in abundance overall. The greatest biomasses of drum occurred in the lower half of the river, while channel catfish biomasses were relatively uniformly distributed throughout the river.

The bigmouth buffalo ranked 5th in overall biomass, but this relatively high rank was only achieved by a few unusually high catches made in the lower half of the river during 1978-80. The smallmouth buffalo ranked sixth in overall biomass and stocks were also greatest in the lower half of the river. Emerald shiner biomass ranked seventh overall, and unlike all those ranked above it the biomass of emerald shiner was greatest in the upper 200 miles of the river. Paddlefish biomasses ranked eighth overall and were greatest in the lower half of the river. Flathead catfish biomasses (ninth in rank) were more uniformly distributed over the entire river (excepting the upper 100 miles

Table 21. Biomasses (kg/ha) of the 10 fishes contributing the greatest overall weights in the lock chamber rotenone collections from the Ohio River between 1957 and 1980; samples grouped into 100-mile sections of the river.

Species	Years (inclusive)	Ohio River Miles 0-100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	800-900	900-981	$\bar{x}$
Gizzard shad	57-60	2.80	3.64	27.85	11.85	24.89	18.62	132.76	486.46	52.09	27.81	77.08
	67-70	22.48	42.71	81.19	35.18	97.00	216.77	103.72	235.32	595.10	224.02	165.35
	74-77	66.56	48.85	82.60	—	226.02	149.88	74.51	104.50	500.29	1274.53	280.86
	78-80	10.83	24.33	33.63	111.20	17.44	34.52	5.08	14.26	565.99	60.54	87.78
Common carp	57-60	4.69	74.44	15.93	11.32	3.31	5.90	9.40	1.78	4.85	16.17	14.78
	67-70	185.59	15.14	45.46	77.83	115.68	376.18	13.28	54.92	34.19	504.22	142.25
	74-77	124.13	573.47	75.46	—	156.83	358.19	26.44	96.10	127.50	51.54	176.63
	78-80	149.32	138.96	171.15	451.43	70.98	205.70	149.79	159.46	828.20	49.80	237.48
Freshwater drum	57-60	0.33	0.36	5.15	13.52	8.45	7.78	25.04	38.30	28.85	39.20	16.70
	67-70	0.24	0.11	5.64	9.58	17.41	23.60	42.86	27.01	8.11	265.12	40.00
	74-77	1.80	9.60	13.25	—	16.52	38.51	6.21	75.47	40.49	85.04	31.88
	78-80	4.90	13.58	52.28	59.49	119.46	50.25	73.61	69.75	191.29	1.04	63.57
Channel catfish	57-60	1.80	14.94	15.30	23.52	46.81	27.60	14.30	16.47	20.81	10.89	19.24
	67-70	8.98	46.96	41.97	92.56	75.10	87.85	21.17	37.40	21.03	18.14	45.12
	74-77	29.73	70.38	38.37	—	73.02	33.48	2.66	28.79	8.43	16.60	33.50
	78-80	40.94	30.23	43.93	16.10	42.46	50.14	27.64	36.07	25.37	8.42	32.13
Bigmouth buffalo	57-60	0	0	0	0.50	2.07	0	0.50	0.35	0.07	0.13	0.36
	67-70	0	0	0	0	0	0	0	8.21	46.57	0	5.48
	74-77	0	0	0	—	0	0	0	13.80	0	11.81	2.85
	78-80	0	2.61	0	29.89	0	78.02	27.31	2.79	83.37	113.01	33.70
Smallmouth buffalo	57-60	0.01	0.30	2.28	6.56	1.08	2.41	0.77	0.42	1.04	7.24	2.21
	67-70	0	1.30	3.06	17.23	4.93	9.81	8.02	2.72	4.82	0	5.19
	74-77	0	4.09	8.48	—	15.06	4.79	4.01	12.48	9.16	3.33	6.82
	78-80	0.17	1.58	18.30	0	8.00	117.48	19.89	38.65	33.48	11.95	24.95

Table 21. (cont.)

Species	Years (inclusive)	Ohio River Miles 0-100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	800-900	900-981	$\bar{x}$
Emerald shiner	57-60	2.46	33.39	11.88	4.37	0.78	1.36	9.42	2.12	0.18	0.09	6.61
	67-70	4.66	36.66	5.85	0.12	0.23	0.03	0.12	0.45	0.01	0	4.81
	74-77	45.49	31.37	0.54	—	0	0.08	0.66	0.08	0.01	0.30	8.73
	78-80	8.88	8.68	1.23	0	0	0.02	0	0.83	3.08	0.04	2.28
Paddlefish	57-60	0	0.76	0	1.60	0.21	4.09	0.11	0	0.39	0.54	0.77
	67-70	0	0	0	0	0	1.26	0	2.22	0.30	0	0.38
	74-77	0	0	0	—	10.61	2.62	2.13	2.56	0.61	37.42	6.22
	78-80	0	0	0	0	0	99.34	11.95	9.75	0.09	24.89	14.60
Flathead catfish	57-60	0.21	0.07	0.57	4.05	4.17	3.37	1.64	4.29	10.94	12.60	4.19
	67-70	0	0.33	0.13	1.06	2.00	0.45	0.17	3.12	1.59	3.31	1.22
	74-77	0.07	7.11	2.30	—	11.27	5.38	0.53	8.10	2.84	3.48	4.56
	78-80	0.92	5.87	11.07	10.56	12.13	17.98	4.33	17.66	12.04	1.80	9.44
Bullheads (all)	57-60	26.66	4.64	1.79	0.32	0.11	0.07	0.61	0.07	0.03	0	3.43
	67-70	30.20	2.05	33.89	0.20	0	0.04	0	0.22	0.88	0.29	6.78
	74-77	20.65	14.06	14.80	—	0	0	0.20	0.04	0	0.16	5.55
	78-80	7.96	2.81	1.12	0	0	0.21	0	0	0	0.19	1.23

where they were less). The biomasses of all bullhead species combined ranked tenth overall, and like those of emerald shiner, were greatest in the upper third of the river.

Biomasses of common carp, drum, bigmouth buffalo, smallmouth buffalo, and paddlefish all increased steadily between 1957-60 and 1980. The greatest absolute increase occurred between 1957-60 and 1967-70 for common carp, while the greatest absolute increase for drum, bigmouth buffalo, smallmouth buffalo, and paddlefish occurred between 1974-77 and 1978-80 (Table 21). Biomasses of gizzard shad increased threefold between 1957-60 and 1974-77, but then declined in 1978-80. This same pattern was observed in emerald shiner and bullhead biomasses. Channel catfish biomasses increased noticeably between 1957-60 and 1967-70, but remained relatively stable through the 1970's.

The ten species which ranked 11th through 20th in biomasses (overall mean range = 4.23 to 0.82 kg/ha; Table 22) were, in declining order (Table 22): river carpsucker, white crappie, sauger, skipjack herring, longnose gar, blue catfish, black buffalo, bluegill, black crappie, and largemouth bass. The biomasses of two of these species (skipjack herring and blue catfish) declined between 1957-60, and 1967-80, while the biomasses of the remaining eight increased. The greatest increases within this group occurred in the white crappie and longnose gar.

Table 22. Mean biomasses of species ranked 11th to 20th in overall biomass during four time periods, rotenone lock chamber samples on the Ohio River.

Species	Mean Biomass (kg/ha)			
	1957-60	1967-70	1974-77	1978-80
River carpsucker	1.77	5.51	5.37	4.25
White crappie	0.32	2.65	4.64	7.39
Sauger	0.18	1.89	6.51	4.15
Skipjack herring	5.17	2.05	1.79	3.32
Longnose gar	0.19	1.73	1.11	2.93
Blue catfish	2.46	0.39	0.62	0.77
Black buffalo	0.03	2.43	0.54	1.05
Bluegill	0.21	1.47	1.19	0.91
Black crappie	0.12	1.57	0.52	1.13
Largemouth bass	0.08	0.89	1.30	0.99

REPRODUCTION OF FISHES IN THE OHIO RIVER

The survival rates of early life history stages (eggs and larvae) of fishes have long been considered critical in influencing the subsequent abundance of adult fishes. The concept of a "critical period" during these early stages, which, if survived in large numbers, would result in a strong year-class, was first proposed by the Danish biologist Hjort. Several authors have stated that very little reproduction of fishes takes place in the Ohio River mainstem, and have suggested that fish populations in the river are maintained by the migration of young fishes spawned in tributary streams (i.e., Duquesne Light Co. 1976a; U. S. Nuclear Reg. Comm. 1977; U. S. Army Corps of Engineers 1976a; WAPORA 1971, 1973, 1974a; Westinghouse Electric Corp. 1974b; Butz et al. 1974). Some of these authors seem to imply that since the most vulnerable parts of the life cycle of most fishes (the egg and larvae stages) in the Ohio River occur in tributary streams, there is little chance of harming the fish community by additional, minor degradations of the mainstem. However, in every case we have found these contentions to be based upon no actual evidence, or a very few observations limited to the area surrounding only a few power plants, and nearby tributaries.

In contrast to the above claims, recent studies designed to determine the actual use of tributaries as spawning sites by mainstem fish indicate that smaller tributaries are relatively unimportant, often have substrate and depth combinations unsuitable for the reproduction of most mainstem species, and actually have very low densities of larval

mainstem species (Clark 1979, WAPORA 1978, Clark and Pearson 1979). Even the larger tributaries of the Ohio (i.e., the Little Miami and Great Miami rivers) have been found to have larval densities which are approximately the same as those found in the mainstem (WAPORA 1977a). Therefore, it now appears that the vast majority of fish found throughout the Ohio River, excepting only those rare, small-stream species which stray into the mainstem, have been spawned in the river.

Reproductive Guilds Of Ohio River Fishes

Balon (1975) has recently devised an ecological means of classifying fishes based upon their reproductive behaviors, preferred spawning substrates, and morphological adaptation of the eggs and larvae. Balon's classification scheme, and the principles upon which it is based, provide a framework upon which the known information on spawning habits of Ohio River fish can be arranged to provide a very satisfying understanding of how man's influences on the physical nature of the river have affected the fish community. Balon's scheme begins with the premise that two environmental factors are primary determinants of survival during the critical embryological and larval development of fishes: predators and the availability of oxygen.

The fishes of the Ohio River have, therefore, two primary objectives in spawning: 1) to deposit their fertilized eggs where predators cannot destroy them, and 2) to deposit them where they will not be deprived of oxygen due to siltation, lack of current, or bacterial respiration. That there are many strategies for meeting these objectives is clear when one reviews the 32 reproductive guilds of fishes described by Balon (1975). It is also clear that the best reproductive strategies for fishes to pursue will change as man alters the Ohio River environment.

Although the reproductive habits of many Ohio River fishes are not well known, we have attempted to fit each of the species of fishes reported from the Ohio River into Balon's classification (Table 23). Information on the reproductive habits of the fishes was abstracted largely from Breder and Rosen (1966), Scott and Crossman (1973), Balon (1975), Pflieger (1975), Smith (1979), and Lee et al. (1980).

Of the 154 species of fishes reported from the Ohio River (Table 7) we eliminated the American eel fron consideration because it spawns in the ocean, not the Ohio River. We also ignored the nine introduced species which have not established reproducing populations. Of the remaining 144 species we could not find adequate descriptions of the reproductive habits of 18 species to permit their assignment to a guild. The 126 species which were assigned to reproductive guilds are listed in Table 23. Balon proposed 32 reproductive guilds divided into three major sections, each with two subsections: 1) nonguarders, which ignore eggs and larvae after spawning and either spawn on open substrates or hide their broods, 2) guarders, which protect and/or aerate eggs and larvae after spawning and either choose the substrate on which the brood is reared, or construct a nest to receive the brood, and 3) bearers, which carry their eggs either on or in the parent's body.

Nearly 70% of the fishes in the Ohio River (86 species) were placed in the "nonguarders" section (Table 23), while 29% were placed in the "guarders" section (38 species), and only one species (mosquitofish) was placed in the "bearers" section. Thirteen of Balon's 32 guilds were represented in the Ohio River fish community.

It is particularly interesting that the three most abundant fishes found in the lock-chamber studies between 1957 and 1980 (Table 20), the

Table 23. Reproductive guilds of the 126 species of fish which reproduced in the Ohio River, and for which information on spawning habits is available (after Balon 1975). Numbers in ( ) indicate numbers of species within each group. Definitions of the terms are provided in the text.

Balon's (1975) Subsections	Ohio River Fishes
A. NONGUARDERS	
A.1 Open substrate spawners	
A.1.1 Pelagophils (2)	*Notropis atherinoides* *Aplodinotus grunniens*
A.1.2 Litho-pelagophils (5)	*Acipenser fulvescens* *Dorosoma cepedianum* *Hiodon* (2) *Lota lota*
A.1.3 Lithophils (28)	*Scaphirhynchus platorynchus* *Polyodon spathula* *Alosa* (2) *Clinostomus elongatus* *Hybopsis aestivalis* *Notropis* (3) *Phenacobius mirabilis* *Phoxinus erythrogaster* *Rhinichthys atratulus* Catostomids (12) *Percopsis omiscomaycus* *Stizostedion* (2)* *Cottus carolinae*
A.1.4 Phyto-lithophils (14)	*Dorosoma petenense* *Hybognathus nuchalis* *Hybopsis* (2) *Notropis* (3) *Carpiodes carpio* *Ictiobus bubalus* *Fundulus notatus* *Labidesthes sicculus* *Morone* (2) *Perca flavescens*
A.1.5 Phytophils (17)	*Lepisosteus* (4) *Esox* (3) *Carassius auratus* *Cyprinus carpio* *Notemigonus crysoleucas* *Notropis* (3) *Erimyzon sucetta* *Ictiobus* (2) *Fundulus diaphanus*

Table 23. (cont.)

Balon's (1975) Subsections	Ohio River Fishes
A.1.6 Psammophils (7)	*Ericymba buccata* *Notropis* (3) *Carpiodes cyprinus* *Ammocrypta asprella* *Percina caprodes*
A.2 Brood Hiders	
A.2.1 Lithophils (13)	Lampreys (5) *Nocomis* (2) *Semotilus atromaculatus* *Etheostoma caeruleum* *Percina* (4)
B. GUARDERS	
B.1 Substratum choosers	
B.1.2 Phytophils (1)	*Pomoxis annularis*
B.2 Nest Spawners	
B.2.1 Lithophils (16)	*Campostoma anomalum* *Notropis* (4) *Ictalurus melas* Centrarchids (10)
B.2.2 Phytophils (5)	*Amia calva* Centrarchids (2) *Etheostoma* (2)
B.2.5 Speleophils (16)	*Pimephales* (3) Ictalurids (9) *Etheostoma* (4)
B.2.6 Polyphils (1)	*Lepomis gibbosus*
C. BEARERS	
C.2 Internal	
C.2.3 Viviparous (1)	*Gambusia affinis*

*Recent and convincing evidence indicates that the walleye and sauger belong in the A.1.2, litho-pelagophil guild. (McElman, J. F., 1983. Comparative embryonic ecomorphology and the reproductive guild classifications of walleye, *Stizostedion vitreum*, white sucker *Catostomus commersoni*. Copeia 1983(1):256-250).

emerald shiner, gizzard shad, and freshwater drum, are all either pelagophils (A.1.1) or litho-pelagophils (A.1.2). Balon points out that members of these guilds are usually either marine or recently derived from marine forms. This certainly is the case for the gizzard shad and freshwater drum, which are both recently derived from marine ancestors. The eggs and/or larvae of pelagophils and litho-pelagophils are buoyant or semi-buoyant, are adapted to highly oxygenated waters, and have no or poorly-formed embryonic respiratory organs. Apparently, producing pelagic or semi-pelagic eggs and/or larvae has been a most successful strategy in the Ohio River for these three species (which do not undertake pre-spawning upstream migrations; the grass carp, incidently and ominously, also produces pelagic eggs).

However, four other litho-pelagophils in the Ohio River are today either extirpated (lake sturgeon), rare (burbot), or low in abundance (goldeye and mooneye). The burbot has always been rare in the river, and there is some doubt about whether it ever existed in a naturally-reproducing population (Clay 1975). The other three are known or suspected to undertake significant upstream migrations before spawning. The lake sturgeon spawned far up smaller tributaries, and must have been frustrated by mill dams as well as mainstem navigation dams.

Slightly more than 22% of the fishes in the Ohio River (28 species, Table 23) were considered to be non-guarding lithophils. Non-guarding lithophils, therefore, made up the largest single guild in the Ohio River. Lithophils (A.1.3) deposit their eggs over clean gravel-rock substrates, the larvae are photophobic, and they are adapted for living in well-oxygenated interstitial waters. The embryonic respiratory system is only moderately developed in these fishes. Some representative members of this

guild are the redhorses, white sucker, blue sucker, sauger[a], paddlefish, shovelnose sturgeon, and several minnows (Table 23). Despite the large number of species in this guild only one lithophil (skipjack herring) was found among the 20 most abundant species in the lock chamber samples of 1957-80 (Table 20). It seems likely that the overall reproductive success of this guild has declined with canalization and siltation of the Ohio River in the last 80-100 years.

The non-guarding phyto-lithophil (A.1.4) guild of fish contained 14 Ohio River species. This guild represents an intermediary group midway between the reproductive modes of the lithophils and the nonguarding phytophils (A.1.5). The phytophils deposit their eggs over either live or dead vegetation, flooded plants and vegetable debris. The larvae typically are not photophobic, have cement glands on the head to attach themselves to vegetation off the soft bottom, and have highly developed embryonic respiratory structures which adapt them for survival in poorly-oxygenated situations. Seventeen species of Ohio River fishes belong to the phytophil guild. Three members of these two guilds were represented in the ten most abundant species found in the 1957-80 lock chamber studies: mimic shiner and threadfin shad (phyto-lithophils), and the common carp (phytophil). Some other typical and common members of these two guilds include the buffalofishes, river carpsucker, silvery minnow, silver chub, white bass, and yellow bass. It seems likely that the relative reproductive success of members of these two guilds would have increased following canalization and siltation of the Ohio River.

The non-guarding psammophils (A.1.6) were represented by just seven species, of which only the sand shiner is very abundant. These fishes spawn over clean, coarse sand substrates. The non-guarding brood hiders

[a]Balon recently re-assigned the walleye (and sauger?) to guild A.1.2.

(lithophils -A.2.1) were represented by 13 species, but none of them are very abundant in the river (Table 23).

Members of the "guarder" guilds remain near their spawn and are able to offer protection against predators and provide artificial aeration by cleaning and fanning the eggs. With this strategy fishes are able to reproduce in situations where fine sediments and low oxygen concentrations would otherwise be prohibitive.

The white crappie represents the only Ohio River fish of the guarder-substratum chooser-phytophil (B.1.2) guild. This fish spawns over vegetation, fine roots, or vegetable debris. The spawning site is cleaned and guarded, and the newly-hatched larvae swim constantly to avoid the hypoxic substrate beneath the cleaned vegetation. The white crappie was the ninth most abundant fish throughout the river during 1957-80 (Table 20), and was among the three most abundant fishes in some sections of the lower river (Table 19).

All of the other guarders in the Ohio River (23 species) are nest spawners, that is, they actually construct a cleaned depression on the substratum or clean a naturally-occurring cavity or crevice, where the eggs are deposited. The nest-spawning lithophils (B.2.1; 16 species) include 10 of the 12 centrarchids in the river, five uncommon minnows, and the black bullhead. The larvae of most fishes in this group hide in the gravel at the bottom of the river, may have cement glands, and their embryonic respiratory organs are moderately- to well-developed. Included in this guild are the spotted and smallmouth basses, bluegill, green sunfish, and longear sunfish. Many of the species in this group prefer to spawn in relatively still backwaters, which are not abundant along the Ohio River.

The nest-spawning phytophil (B.2.2) guild includes just five Ohio River species. The bowfin, two darters, and two centrarchids — the largemouth bass and black crappie. The bowfin and the centrarchids also prefer to nest in the relatively still backwaters. It is possible that one reason these fishes are not abundant in the mainstem area is that they do not nest successfully in shallow areas which are constantly disturbed by tow boat wakes. Kramer and Smith (1962) and Summerfelt (1975) have shown that the wave action generated by storms causes nesting failures in largemouth bass populations.

The nest-spawning speleophil (B.2.5) guild includes 16 species of Ohio River fishes: the three *Pimephales* minnows, nine catfish, and four darters (Table 23). These fishes guard their eggs after depositing them on the underside of an object or in a natural cavity. The eggs and larvae are fanned by the parents, and consequently, oxygen supply is seldom a problem. The brown bullhead and channel catfish are two members of this successful guild (both are among the 10 most abundant fishes in the Ohio River, Table 20). The pumpkinseed, a relatively uncommon fish of the upper river, is considered to be a polyphil (B.2.6) because it spawns on nearly any substrate type.

To further clarify relations between reproductive guild success and changes in the river environment we re-read the "Ichthyologia" very carefully and tried to interpret Rafinesque's brief, and sometimes conflicting statements regarding the abundance of the various species. Realizing that our results are suspect, we have categorized each of the 48 species as being rare, occasional, common, or abundant according to Rafinesque, and have assigned them to their respective guilds (Table 24).

An examination of this table shows that the two pelagophils (emerald

Table 24. Reproductive guilds of the 48 fishes (of 52) reported by Rafinesque for which reproductive habitats are known; with Rafinesque's statement of abundance as: rare (R), occasional (O), common (C), or abundant (A).

A. Nonguarders		
A.1 Open substratum spawners		
A.1.1 pelagophils (2)	*Notropis atherinoides*	(A)
	Aplodinotus grunniens	(A)
A.1.2 litho-pelagophils (4)	*Acipenser fulvescens*	(O)
	Dorosoma cepedianum	(C)
	Hiodon alosoides	(O)
	Hiodon tergisus	(C)
A.1.3 lithophils (12)	*Scaphirhynchus platorynchus*	(C)
	Polyodon spathula	(O)
	Alosa chrysochloris	(C)
	Carpiodes velifer	(O)
	Catostomus commersoni	(C)
	Cycleptus elongatus	(O)
	Hypentelium nigricans	(O)
	Minytrema melanops	(R)
	Moxostoma anisurum	(A)
	Moxostoma duquesnei	(C)
	Moxostoma erythrurum	(C)
	Stizostedion vitreum *	(O)
A.1.4 phyto-lithophils (3)	*Carpiodes carpio*	(O)
	Ictiobus bubalus	(C)
	Morone chrysops	(O)
A.1.4 phytophils (7)	*Lepisosteus osseus*	(O)
	Lepisosteus platostomus	(C)
	Lepisosteus spatula	(R)
	Esox americanus vermiculatus	(R)
	Esox masquinongy	(R)
	Notemigonus chrysoleucas	(C)
	Ictiobus niger	(O)
A.1.6 psammophils (1)	*Percina caprodes*	(C)
A.2 Brood hiders		
A.2.1 lithophils (2)	*Lampetra appendix*	(R)
	Nocomis biguttatus	(R)

Table 24. (cont.)

B. Guarders		
B.1 Substratum choosers		
B.1.2 phytophils (1)	*Pomoxis annularis*	(0)
B.2 Nest spawners		
B.2.1 lithophils (7)	*Campostoma anomalum*	(0)
	Notropis cornutus	(0)
	Ictalurus melas	(0)
	Lepomis cyanellus	(0)
	Lepomis macrochirus	(C)
	Micropterus dolomieui	(C)
	Micropterus punctulatus	(0)
B.2.2 phytophils (2)	*Micropterus salmoides*	(0)
	Etheostoma blennioides	(0)
B.2.5 speleophils (7)	*Pimephales notatus*	(0)
	Ictalurus furcatus	(C)
	Ictalurus natilis	(0)
	Ictalurus punctatus	(C)
	Noturus flavus	(C)
	Pylodictis olivaris	(0)
	Etheostoma flabellare	(C)

*See note at bottom of Table 23.

shiner and freshwater drum), which were ranked first and third in abundance in the lock chamber studies of 1957-80, were also among the three species which Rafinesque deemed most abundant in the river (by our interpretation). Many of the non-guarding lithophils, particularly the redhorses, shovelnose sturgeon, and white sucker, were regarded as very common by Rafinesque, while several of the non-guarding phytophils which were abundant in 1957-80, were regarded as only "occasional" by Rafinesque. It is also interesting to note that Rafinesque considered the shortnose gar more common than the longnose (the reverse is true today), and that he considered several fishes, which we might think of as small-stream fishes (i.e., northern hog sucker, stonecat, and three darters), to be rather common in the Ohio.

Rafinesque appeared to consider the silver redhorse to be abundant in the river and the gizzard shad only common, while this relationship was reversed in 1957-80 according to the lock chamber studies.

Spawning Habitats Available In The Ohio River

The macro-habitats available to fishes in a large river can be divided, simplistically, into the following (modified after Sternberg 1971 and Rasmussen 1979):

1. The main channel. This is the area of the river which can be negotiated by commercial barge traffic at normal pool elevation. It will be at least 9' deep and 300' wide by definition and maintenance operations of the U. S. Army Corps of Engineers. In most locations on the river, and at most seasons, it will be deeper and considerably wider. It will often be delineated by navigation buoys. A current of at least 0.5 ft/sec will always be present. Severe scouring due to both high flows and the constant passing of tow boats is a feature of this zone. The

substratum is usually sand, although gravel, rubble, and even bedrock are possible. In some locations, and at low water levels, silt and organic debris may also be found. Rooted aquatic plants are absent.

2. Main channel border. This is the area of the river between the main channel and the shore-debris zone. This area may be very narrow in the upper river, and becomes more extensive in the lower river. Areas where wing dams still exist in the lower river are included in the zone. The substratum is often sand or silt, although occasional extensive deposits of gravel or rubble are found, particularly in the upper third of the river. Rooted aquatic vegetation is absent, and sunken logs are rare enough that bottom trawls may be used. Most fishes in the pelagophil and lithophil reproductive guilds probably spawn in this zone.

3. The shore-debris zone. This zone extends from the shoreline out into the river from 5 to about 150 feet. It is characterized by the presence of occasional "sawyers" and "planters", that is, dead trees which are floating with the bole resting on the substrate or are rooted in the substrate. The substrate is usually sand or silt, but sunken logs and waterlogged branches are widely scattered about and partially buried in the bottom. Smaller pieces of vegetable matter often accumulate on the larger pieces. Rooted aquatic vegetation (*Potamogeton* spp.) is rare in the river, but when present it is found in bands 6-20 feet wide in water 4-6 feet deep, and 15-50 feet offshore. Most fishes in the phytophil, brood-hider, and speleophil reproductive guilds probably spawn in this zone. When gravel deposits occur in this zone some spawning of lithophils may also occur.

4. Tail waters. These areas are found extending 0.5 miles below each of the existing navigation dams. They are characterized by having extensive turbulent areas, elevated oxygen concentration, and sand,

gravel, or bedrock substrates. Extensive silt deposits may occur behind fixed wiers following particular water level histories. No rooted aquatic vegetation is usually present. Although the areas available are small, tail waters may be important spawning areas for local lithophils.

5. Side channels. These areas usually separate near-shore islands from the mainland. They contain running water at normal pool levels. On the Ohio River they are typically steep-sided, soft-bottomed, and are often lined with eroded, slumping banks. Trees which have slumped into the channel are also present. These areas are important spawning areas for speleophils and some phytophils.

6. Sloughs and embayments. These areas are connected to the river at high water but may or may not have a narrow connection with the river at normal water levels (sloughs do not, while embayments do). There is no appreciable current through the area at normal water levels. These areas often contain a great deal of standing and submerged timber, have soft bottoms, and may have rooted aquatic vegetation. They probably represent the most important spawning areas for fishes of the nest-spawning lithophil and phytophil guilds (largemouth bass, bluegill, etc.). Embayments are most abundant in the upper 500 miles while sloughs are most common below ORM 700.

7. Creek mouths and flooded channels. The navigation dams have resulted in the permanent flooding of many creek mouths. The habitat resulting depends largely on the topography of the floodplain crossed by the creek, the gradient of the creek near its mouth, and the mean discharge of the creek. If the gradient is low the creek often forms a steep-banked, soft-bottomed, canal of slack water extending from 600 to 3000 feet up the creek channel. The mouth is often blocked at low water by a silt bar.

If the gradient is higher the creek may maintain a noticeable flow and coarser substratum almost to the mouth, and produce a gravel bar extending into the main channel border. High gradient tributaries prevail above ORM 450, while low gradient creeks are the rule below this point. Creek mouths are not important spawning areas for most river species, but are certainly important for those small-stream species which only stray into the mainstem occasionally.

The available amount of suitable spawning habitat in each of the seven habitat zones described above is closely associated with the substrate types present, as Balon (1975) has pointed out. An actual determination and mapping of substrate types throughout the Ohio River would be an overwhelming task. Nevertheless, we did attempt an analysis of spawning habitat types along the river and employed shoreline type as an approximation of substrate likely to be present.

Photoanalysis Of River Habitats

The U. S. Army Corps of Engineers (Louisville, Huntington, and Pittsburgh Districts) loaned us a complete set of aerial photographs of the Ohio River. Color photographs were taken at normal pool levels between 11 January 1973 and 9 March 1975 on the upper 927 miles of the river. Black-and-white photographs taken between 10 September and 2 October 1979 were used for the lower 44 miles of the river. All photos were printed at a scale of 1:12,000 (one inch = 1000') in a 9" × 9" format, and were examined with the aid of a 10X magnifying glass. Some of the newer high-rise dams were completed after these series of plates were made, so we supplemented the aerial photos with data from U. S. Geological Survey topographic maps, and a series of miscellaneous charts and maps prepared by the U. S. Army Corps of Engineers. All of the

interpretive data taken from these sources was transferred to a set of Ohio River Navigation Charts (U. S. Army Corps of Engineers, 1976d and e; 1978c; scale: 1" = 2000'). For each 100-mile section of the river, we then counted the number of islands, discernible gravel bars, creek mouths dry at normal pool levels, tributary mouths flooded at normal pool levels, and embayments. The surface area of embayments was measured with a planimeter.

We divided the shore-debris zone into five categories based upon the assumption that the visible shore at normal pool level would either constitute the shore-debris zone during the slightly higher water levels often present during the spawning season, or would be the best approximation of the substrate present at the same water level. We realize that large errors are possible in this method, but we believe it allows macro-habitat comparison between large and widely separated sections of the river. The five categories were sand-silt beaches, woody plant cover (trees and/or brush), cutbanks (steep, eroding banks), gravel and/or rubble, and concrete-riprap. We measured the linear distance of each shoreline type on both sides of the river and on islands in the river. Measurements did not extend up tributaries or into embayments.

The results of our analysis for 100-mile sections of the river are presented in Tables 25 and 26. There were 110 islands in the Ohio River according to our analysis. They ranged in size from small towheads of less than 0.5 ha to islands large enough to be inhabited and farmed — such as Neville Island (of 323 ha, at ORM 8), Diamond Island (of 564 ha, at ORM 820), and Wabash Island (of 708 ha, at ORM 848). In the 1814 edition of "The Navigator" Zadok Cramer charted 98 islands on the Ohio River and noted that the river was constantly both creating and eroding-

Table 25. Islands, tributary streams, gravel bars, and embayments in 100-mile sections of the Ohio River.

ORM	Islands	Tributaries		Gravel Bars	Embayments	
		Dry	Flooded		No.	Area (ha)
0-100	18	54	79	12	5	64.8
101-200	20	98	86	13	14	149.7
201-300	6	68	94	2	13	85.6
301-400	3	53	72	3	8	85.4
401-500	1	53	91	1	21	279.9
501-600	5	40	69	11	17	328.3
601-700	6	9	43	5	0	0
701-800	12	2	45	9	2	240.0
801-900	20	15	23	15	0	0
901-981	19	14	30	8	0	0
Total	110	406	632	29	80	1233.70

Table 26. Shoreline types measured along 100-mile sections of the Ohio River. Measurements are in kilometers, although we retain the use of miles for river locations.

	Shoreline Type (km)					
ORM	Silt-Sand	Vegetation	Cutbank	Rock-Gravel	Concrete-Riprap	Total
0-100	274.1	26.1	20.6	34.5	6.5	361.8
101-200	258.7	79.0	7.9	35.5	1.9	383.0
201-300	145.9	43.1	91.2	40.3	1.0	321.5
301-400	153.0	28.0	48.8	92.9	1.2	323.9
401-500	230.3	8.6	18.4	61.4	2.1	320.8
501-600	249.7	30.9	15.1	29.8	0.2	325.7
601-700	188.5	48.4	66.8	19.6	5.6	328.9
701-800	193.1	63.6	61.7	32.7	0	351.1
801-900	187.9	131.8	29.0	22.1	0	370.8
901-981	242.7	33.5	5.1	10.5	0.5	292.3
Total	2123.9	493.0	364.6	379.3	19.0	3379.8

away islands. For example, at Louisville, the first settlement of Europeans was made on Corn Island just above the Falls in 1778. This island was subsequently eroded away, and disappeared shortly after the Civil War. Rafinesque was under contract to Cramer and Spears, Booksellers, to produce a map of the Ohio River (Fitzpatrick 1911). Apparently, the information Rafinesque gathered was actually used to update later editions of Cramer's "The Navigator". Rafinesque (1820b) found 130 islands in the Ohio River. Thus, it appears that there has been a net loss of approximately 20 islands from the river during the last 160 years. These islands have disappeared primarily by erosion (i.e., Goose Island, at ORM 598 disappeared in the 1937 flood), but others have been joined to the mainland (i.e., Dog Island at Smithland Dam), or inundated by the high rise dams. Thwaites (1897) traveled down the Ohio in a skiff in the late 1890's and noticed that many of the islands found in his copy of Cuming's "Western Pilot" (published in Cincinnati, in 1834) had disappeared, while he encountered "few" new islands. Islands were most abundant in the upper 200 miles of the river (18-20/100 mile section), and in the lower 281 miles of the river (12-19/100 mile section, Table 25). In the middle third of the river (ORM 300-600) there were only 1 to 5 islands per 100-mile section.

Islands are important to spawning fishes because: 1) they offer an obstruction to the current which often results in an increase in current speed on one or both sides of the island head, and this often results in the clearing of a coarse sand or gravel bar where lithophils can spawn; 2) most islands are separated from the mainland by a relatively narrow back-channel which is sheltered from waves generated by tow-boats and recreational craft on the main channel, such sheltered areas may be required for nest-guarding lithophils and phytophils (i.e., centrarchids);

and 3) the narrow back-channels are often bordered by undercut banks and fallen timbers, particularly at the lower end of the channel, and these borders provide spawning cavities for the nest-spawning speleophils (i.e., catfishes).

It was very difficult to distinguish and count gravel bars from the aerial photos. Before we could identify a gravel bar it had to be so large and in an obvious location (i.e., at the head of an island, the mouth of a stream, or near a dike) that we are certain that most gravel bars were missed. Field checks of our interpretations were made between ORM 560 and 600, and between ORM 900 and 981 in 1980, and confirmed our belief that gravel bars are much more numerous in the river than our analysis indicates.

The number and area of embayments available to fishes is critically important for successful spawning of many of the centrarchids in the Ohio River, particularly the guarding, nest-spawning lithophils and phytophils which are of most interest to the sport fishermen (i.e., the largemouth and smallmouth basses, and the bluegill). Most of the embayments were formed after the construction of the new high-rise dams began in the early 1960's (Lockard 1966), and 78 of the 80 embayments we measured were above ORM 530. The only two embayments below ORM 530 were located in the Cannelton pool at ORM 717-719 (Table 25). The 17 embayments located between ORM 501 and 530 constituted the greatest total surface area (238.3 ha) in any 100-mile section of the river. There were no embayments between ORM 601-700, and below ORM 719 (Table 25).

Our estimate of the number of embayments in the Greenup and Gallipolis pools (10) was considerably below that (49) of Collins and Harris (1978). We believe this is because we did not consider flooded, linear

creek channels to be embayments, nor did we include embayments which did not connect directly to the mainstem in our counts. Our estimate of the surface area of embayments in the upper river is also considerably below that of Miles (1978) for similar reasons.

Bass fishing tournaments are held each year on those pools which have embayments. Miles (1978) and Jernejcic (1980) have reported that from 90 to 125 tournaments were held on the Ohio River each year between 1975 and 1979. Most of the tournaments have been held on embayments in the Belleville, Willow Island, Racine, Meldahl, Hannibal, and Markland pools. A few tournaments were held in the New Cumberland, Pike Island, Gallipolis, and Newburgh pools. Catch rates in these tournaments are typically 0.05 to 0.23 bass/hour, which equals or exceeds catch rates in lakes and reservoirs in the surrounding area, indicating the presence of fair to good populations of bass in the embayments.

The tributaries to the Ohio River were divided into those in which the mouth was flooded for at least 50 meters from the river (flooded), and those in which no standing water could be observed more than 50 meters from the river (dry) at normal pool levels. At above normal river stages dry creek mouths would be expected to have water backed up into them, and might then provide temporary habitat for mainstem fishes. The number of both dry and flooded tributary mouths/100-mile section declined gradually with distance below Pittsburgh (Table 25). The mean number of dry tributaries was 73/100 miles in the upper 300 miles of the river, 49/100 miles between ORM 301 and 600, and declined to just 10/100 miles below ORM 601. Flooded tributaries also declined from 86/100 miles to 77/100 miles, to 37/100 miles over the same three stretches of river (Table 25).

In our opinion, the primary contribution of tributary streams to the

Ohio River fish community are these: 1) they serve as reservoirs of small-stream-inhabiting species (i.e., stoneroller, creek chub, northern hog sucker, madtoms, topminnows, and darters) which stray only occasionally into the Ohio mainstem; 2) they serve as refugia where mainstem fishes have avoided severe local pollution and thermal events (Krumholz and Minckley 1964); and 3) when embayments are formed on their floodplains they provide protected spawning areas for the guarding, nest-spawning lithophils and phytophils. Tributary streams were also essential as spawning areas for the migratory lake sturgeon before 1920. Although some observers have expressed the opinion that tributary streams are important spawning sites for many, if not most, Ohio River fishes (i.e., Duquesne Light Co. 1976a; U. S. Nuclear Reg. Comm. 1977; U. S. Army Corps of Engineers 1976a; WAPORA 1971, 1973, 1974a; Westinghouse Electric Corp. 1974b; Butz et al. 1974), we find such contentions are, without exception, based upon very little or no actual evidence. Others have pointed out that spawning success is low in some heavily-polluted tributaries and in the mainstem below those tribuatries (i.e., Evans and Tarter 1977).

The width of the Ohio River varies from an average of about 1240 feet in the uppermost 50 miles to 1515 feet at ORM 300-350, 1820 feet at ORM 625-675, and 3600 feet at ORM 950-981. In the upper third of the river maximum depths at normal pool levels typically range from 10 to 31 feet. In the lower two-thirds of the river channel depth usually ranges from 11 to 44 feet. The width of the floodplain also increases from about 0.8 miles at Pittsburgh, to 7.5 miles in the lower third of the river.

The shoreline types along 100-mile sections of the river are given

in Table 26. The most abundant shoreline type in each of the 100-mile sections was the silt-sand beach, which is, in most locations, indicative of a shore-debris zone which is depositional in nature, with a relatively gentle slope towards the main channel border. This shoreline type made up 45 to 83% of the shoreline in each section of the river. The shore-debris zone adjacent to these shorelines are important spawning areas for the litho-pelagophils, pelagophils and phytophils of the non-guarding guilds.

The second most abundant shoreline type was that covered by woody vegetation. Willows and young sycamores, cottonwoods, and box elders grew close enough to the shoreline at normal pool levels to have a portion of their roots and/or boles lapped by water on this shoreline type. This shoreline type made up 3-35% of the total in each 100-mile section of the river, and was most abundant in the upper and lower thirds of the river. This shoreline type provides spawning areas for the phyto-lithophils and phytophils of the non-guarding guilds, and for the substratum choosers and speleophils of the guarding guilds.

The rock-gravel shoreline made up 11% of the total over the entire river (Table 26), ranged from 4 to 29% in each 100-mile section of the river, and was most abundant in the upper half of the river. Rock, gravel, and coarse sand substrates are necessary for the spawning of lithophils and psammophils of both the guarding and non-guarding guilds.

The cut-bank shoreline also made up 11% of the total, and ranged from 2 to 28% in each 100-mile section of the river (Table 26). This shoreline type was most common in the middle portion of the river, between ORM 200 and 800. Eroded, high banks usually indicate a steep slope to the main channel border and unconsolidated substrates. There are

probably very few fish spawning along such shorelines.

Concrete and man-placed riprap shoreline made up less that 1% of the total shoreline along the river, and was probably of little importance to spawning fishes.

Relative Abundance And Distribution Of Larval Fishes

The National Environmental Policy Act of 1969 and PL 92-500 of 1972 mandated the collection of a large quantity of information about larval fishes in the Ohio River which was intended to demonstrate the effects of cooling water withdrawals, power plant construction, dredging, river-port construction, and other major human-induced disturbances on fish populations in the river. We assembled all of the larval fish studies available between 1973 and 1980 and attempted to place these results, for comparison through time and space, into common units of measure and form.

Most of the larval fish collections were obtained with either half-meter or 1-meter nets towed horizontally in the open river. However, some of the collections were made with pumps (either in the intake bays or pipes of power plants, as well as in the open river) and push-nets. Mesh sizes of the filtering nets or buckets ranged from 361 to 1000 μ, but a mesh of around 500 μ was most often used. All collections were made between the months of March and September, but most collectors concentrated on the months of April-July.

The results of the various studies were reported in many different ways, and in several different units, which made our task of extracting data in a form suitable for comparisons very difficult. Our basic unit for comparison was the mean density of larvae (expressed in no./100 m^3 of water filtered) reported by a given author during a given month, at

a given location on the river. In several cases an original data set was included in more than one report, E.I.S., or publication. We used each data set only once in our calculations. We sorted each author's data by month and year of collection, and by location. A mean density value was then calculated from the sample set within each month. A final overall monthly mean was calculated from the sample set mean. Our definition of a "location" was broad. In most studies the investigators took samples from both the plant intake and one or more river locations near the plant. In these cases we considered the intake a separate location, but all river samples reported within a single month were averaged together as one "location", even though they might be taken at the surface and bottom, day and night, and from several transects close to the facility under construction.

Another serious problem arose from the imperfect state of knowledge concerning the identification of larval fish and fish eggs. The willingness and/or ability to classify larval fishes to the generic or specific levels varied widely among the investigators working on the river. Some authors simply reported the density of all larval fishes combined, making no attempt to classify them. Others reported identifications to the specific level within groups of fishes (i.e., redhorses) for which the larvae of many members are undescribed.

We finally selected a series of 24 taxa into which, in our judgement, all of the reported data on larval fish could be reasonably fitted, leaving an additional category for unidentified specimens, and a summary category for all taxa combined. Although a few authors attempted identification of eggs, the vast majority did not, and we simply summed all eggs together. We tried to preserve all lower taxa to which identifications

were taken. Exceptions to this general practice were made for the Hiodontidae, Clupeidae, *Notropis*, Ictaluridae, *Morone*, Centrarchidae, Etheostomatinae, and *Stizostedion*. Although some authors identified members of the genera *Hiodon*, *Notropis*, *Morone*, and *Stizostedion* to species, these identifications were usually based upon relatively few large larvae and/or juveniles. We have greater confidence in simply assigning these specific identifications to genera, and believe that very little useful information has been lost in doing so. Ictalurids were very rare in the larval collections and although they were often identified as *Ictalurus*, *I. punctatus*, and *Noturus* sp., we again believe that little information was lost by placing them together under the family name. Similarly, we combined the relatively few records for darters of the genera *Percina* and *Etheostoma* under the tribe name Etheostomatinae.

The grouping of all clupeids together under the family name was given greater consideration because the clupeids are much more abundant than the other merged groups. Clupeids were often identified to the generic levels of *Dorosoma* and *Alosa*, and occasionally to the specific level. However, we again judged that these identifications were probably based upon relatively few advanced larvae and/or juveniles. The gizzard and threadfin shads are both much more abundant (as adults) than the skipjack herring, and while it seems certain that most clupeid larvae found above ORM 600 will be gizzard shad, while those found below ORM 800 mill be nearly equal mixtures of gizzard and threadfin shads, we believe they are most reliably reported under the family name.

In interpreting the tables of larval fish densities it is important to bear in mind that the mean density values given for genera within a family will not sum to the reported family density because the family

density value was usually calculated from a larger data set which included values from studies which did not identify larva to the generic level. For this same reason, the densities given in our tables for all larvae combined will be different from the sum of all densities given in the table because many studies (particularly those made in the early 70's) merely reported the densities of all larvae combined and these were included in the tabular means.

For comparisons we required complete information on the volume of water sampled, in order to weight our means according to the extent of sampling. However, this information was not provided by many reporters. Therefore, we were able to find only 26 reports containing original data on larval fish densities in the Ohio River in a form suitable for our comparisons. Many of these reports did provide data from several (2-11) localities on the river, and from more than one year of collecting. The reports from which larval fish data was extracted are indicated in the Literature Cited section by an asterisk.

We grouped the mean-monthly-density estimates by 100-mile sections of the river, by months, and by years. The distribution of the data base thus obtained is indicated in Table 27. All collections were made between 1973 and 1980. The number of mean monthly determinations increased from 12 in 1973 to a peak of 57 in 1976 and declined thereafter. This is probably due to most power plant owners having completed requirements for 316a and 316b sections of PL 92-500 in the mid-70's

Since most of the electric generating facilities on the river are located just below Pittsburgh, and in the Cincinnati area, it is not surprising that most larval fish studies were also made in these areas (101 and 52 mean monthly determinations between ORM 0-100 and ORM 401-500,

Table 27. The number (N) of larval fish mean-monthly density determinations by year and 100-mile sections of the Ohio River, as used in our analysis. The 240 determinations were abstracted from 26 different reports.

ORM	Year								Total
	1973	1974	1975	1976	1977	1978	1979	1980	
0-100	5	9	0	24	22	26	19	0	105
101-200	0	0	0	0	2	0	0	0	2
201-300	1	2	0	6	7	0	5	0	21
301-400	0	5	2	0	2	0	0	0	9
401-500	6	9	0	19	3	5	10	0	52
501-600	0	0	0	0	6	0	0	0	6
601-700	0	1	13	0	0	0	0	0	14
701-800	0	0	0	8	0	0	0	0	8
801-900	0	0	0	0	0	0	0	0	0
901-981	0	3	9	0	0	0	0	11	23
Total	12	29	24	57	42	31	34	11	240

respectively; Table 27). Sections of the river which were sampled infrequently were ORM 101-200 (n = 2), ORM 501-600 (n = 6), and ORM 701-800 (n = 8). There were no larval fish collections reported between ORM 801 and 900 (Table 27).

Temporal distributions of fish larvae and eggs

All of the collections we considered were made between the months of March and September of each year. Although the number of location/author sources is low (4) for March, no eggs or larvae were reported in this month (Table 28). Larval fish and eggs first appeared in the river in the month of April, although mean densities of both were low (1.85 and 0.17/100 m^3; Table 27). *Stizostedion* larvae were the most abundant taxa in April (0.34/100 m^3) followed by catostomids (0.28/100 m^3), clupeids (0.19/100 m^3), and *Moxostoma* (0.17/100 m^3).

The calculated peak abundance of all larval fishes combined occurred in May (374.13/100 m^3; Table 28). However, this is misleading because of the bias introduced to the overall totals by the large number of samples collected in May (n = 14) in the lower 81 miles of the river, where larvae were so abundant. Only two samples were collected in June in the lower 81 miles of the river, and thus the combined numbers for the 14 May samples overwhelmed the combined June numbers in the overall analysis. When densities from all species combined were calculated separately for each third of the river (ORM 0-330; 331-660, and 661-981) mean densities were always slightly higher in June than in May (Table 29). We calculated student's t values to compare the mean densities in each third of the river separately during the months of peak density (May and June) and found that mean densities increased significantly (.05 level) or highly significantly (.01 level) from the upper ($\bar{x}$ = 8.96 and 20.55 in May and June)

Table 28. Mean densities (#/100 m^3) of larval fish and fish eggs reported in the months of March-September (1973-80) throughout the river. Totals are ± one standard error.

Item	Month						
	March	April	May	June	July	Aug	Sept
Polyodon spathula			<.01				
Lepisosteus				.04	.01		
Clupeidae		.19	355.02	75.29	4.73	.09	.05
Hiodon			.09	.01			
Esox			.01				
Cypriniformes			.03	.43			.01
Cyprinidae		.01	10.59	9.54	4.10	.13	1.82
Cyprinus carpio		<.01	3.47	.70	.20		
Notropis		.03	3.07	6.13	1.59	.18	
Pimephales			.06	.06	.07	<.01	
Catostomidae		.28	10.10	.38	.02	.02	
Carpiodes-Ictiobus			.74	.02	<.01		
Moxostoma		.17	.16	<.01			
Ictaluridae				.04	.01	.01	
Morone		.04	2.27	.05	.01	<.01	
Centrarchidae			.08	.17	.02	.02	
Lepomis			.03	.24	.12	<.01	<.01
Micropterus				.01	<.01		
Pomoxis			.25	.04	.01	.04	
Percidae			.03	<.01	<.01		
Etheostomatinae		.01	.21	.17	.03		
Perca flavescens		.01	.01	.01	.02	<.01	
Stizostedion		.34	1.64	<.01			
Aplodinotus grunniens		.01	.75	2.97	2.10	.12	0.20
Unidentified larvae		.13	5.96	16.29	2.28	.13	
Total (all larvae)	0	1.85± .71	374.13± 107.13	167.24± 67.22	29.38± 4.92	2.21± .62	2.22± 1.86
Eggs	0	.17	3.36	8.76	8.52	1.07	.02
No. of Location/Month/ Author sources summed	6	41	61	53	40	30	9

Table 29. Mean densities of all larval fishes combined in the upper, middle, and lower thirds of the Ohio River during the peak spawning months of May and June (1973-80). Student's t values were calculated to compare differences between mean densities.

PARAMETER	OHIO RIVER MILES					
	0-330		330-660		660-981	
	May	June	May	June	May	June
$\bar{x}$ (Density #/100 m^3)	8.96	20.55	105.13	112.40	1305.04	
N	29	31	16	18	16	4
S.D.	20.69	29.60	72.53	205.47	1238.85	1054.18

t values

Comparison	t	
	May	June
0-330 vs. 330-660	6.72**	2.46*
0-330 vs. 660-981	5.69**	9.03**
330-660 vs. 660-981	3.87**	5.78**

* - Significant difference at the .05 level.
** - Significant difference at the .01 level.

to the middle third ($\bar{x}$ = 105.13 and 112.40 in May and June) and again from the middle to the lower third ($\bar{x}$ = 1305.04 and 1550.8 in May and June; Table 29). Cluepids made up approximately 85% of the total, followed in abundance by cyprinids and catostomids with about 3% each.

The mean density of all larval fish combined was 167.2/100 m^3 in June. Clupeids, cyprinids, and catostomids were again the most abundant fishes. A few late-spawning species reached their peak densities in June (i.e., *Lepisosteus*, Ictalurids, *Lepomis*, and *Aplodinotus grunniens*; Table 28). The apparent increase in *Notropis* densities probably resulted from the ability of investigators to identify larger larvae in June to genus, whereas in May these same, younger larvae would have been identified only to the family level.

The mean density of all larval fishes combined declined markedly in July (29.38/100 m^3), August (2.21/100 m^3), and September (2.22/100 m^3). Clupeids and cyprinids were the two most abundant taxa in July, but the earlier-spawning catostomids were displaced from third position by the freshwater drum, whose density in July (2.10/100 m^3) was about equal to their peak density (2.97/100 m^3) in June.

The relatively low mean monthly densities of all fish eggs combined (peak density of 8.76/100 m^3 in June) probably reflects the fact that most fish eggs are placed in relatively protected areas where they adhere to the substratum. It seems likely that only the freshwater drum spawn a truly pelagic egg in the Ohio River.

We also compared mean larval fish densities (all species combined) between each year (1973-80). This comparison was difficult because of the uneven distribution of sampling efforts along the river and in various months within the different years (Table 30). For example, there were no

Table 30. Mean densities (#/100 m^3 ± one standard error) of all larval fish taxa combined in the upper, middle, and lower sections of the Ohio River during the spawning seasons (April-July) of 1973-1980. The number in parenthesis is the number of month/location/author samples (N) summed to arrive at the density value.

ORM	Year								Mean of all Years
	1973	1974	1975	1976	1977	1978	1979	1980	
0 - 330	6.0± 5.0 (0)	16.5± 9.1 (9)	— (0)	18.1± 6.5 (25)	10.0± 2.5 (26)	5.4± 1.6 (23)	17.0± 5.8 (20)	— (0)	12.2± 2.1 (108)
331 - 660	9.3± 4.6 (5)	41.2± 17.6 (11)	54.3± 21.5 (12)	167.6± 68.7 (12)	41.6± 21.5 (9)	75.3± 29.6 (3)	57.5± 21.3 (8)	— (0)	70.0± 16.3 (60)
661-981	— (0)	1700.6± (1)	299.0± 168.0 (7(	686.8± 372.2 (8)	— (0)	— (0)	— (0)	1646.6± 395.3 (11)	1014.9± 224.7 (27)

usable samples reported below ORM 661 in 1973 or 1977-79, and the range of samples available within each year varied from 0-26 (Table 30). The effects on variability are obvious when one considers the large standard deviations presented in Table 29.

Distribution of larval fishes and eggs along the Ohio River

We grouped the mean-monthly/author/location densities in 100-mile sections of the river in order to examine distribution along the Ohio River mainstem. We used only samples taken within the peak spawning season (April-July) for this analysis to avoid obscuring any trends with the large number of samples taken in March, August, and September which contained few or no larvae. Most of the collections taken in August and September were made in the upper 100 miles of the river, and their inclusion in the data base would have resulted in underestimates of densities in that region, when compared to the lower river.

Table 31 presents the mean densities of each of the 24 taxa into which larval fish were grouped. The most striking trend in the data is the tremendous increase in the density of larval fish with increasing distance below Pittsburgh. The mean density in the first 100 miles of the river was just 9.67 larvae/100 m^3. Between ORM 300 and 700 the densities of all larva combined increased approximately 10 times from 55.56-77.34/100 m^3, and between ORM 700 and 981 densities increased by another order of magnitude to 686.80-1152.99/100 m^3 (Table 31 and Figure 7).

The mean densities of all species combined over the peak spawning season (April-July) were compared between each 100-mile section of the river by t tests (Table 32). The mean density in the upper 100 miles of the river (9.67/100 m^3) was significantly lower (.01 level) than densities

Table 31. Mean densities (#/100 m^3) of larval fishes and fish eggs reported in 100-mile sections of the Ohio River between 1973 and 1980. Only samples taken between April and July of each year were included in the analysis.

Item	Ohio River Miles										Overall Mean Densities
	0-100	101-200	201-300	301-400	401-500	501-600	601-700	701-800	801-900	901-981	
Polyodon spathula						<0.01					<0.01
Lepisosteus				0.25	<0.01		0.01			0.02	0.03
Clupeidae	0.51		2.44	25.59	21.12	6.33	5.53	209.91		1073.23	149.41
Hiodon						0.13		.13		0.23	.05
Esox								.10			.01
Cypriniformes										1.15	.13
Cyprinidae	6.28		1.75	25.13	2.44	0.05	31.53	17.46		5.00	9.96
Cyprinus carpio	0.32	0.25	1.14	9.60	0.55	2.33	6.92	.24		1.17	2.50
Notropis	1.00		0.51	0.62	8.39	33.19		.04		.16	4.88
Pimephales	0.18					0.03					.02
Catostomidae	0.03	0.15	0.54	0.69	0.46	0.01		.10		29.00	3.44
Carpiodes-Ictiobus	0.01					10.25				<.01	1.14
Moxostoma						3.75					0.42
Ictaluridae	0.04				<0.01		0.01				0.01
Morone	<0.01		0.02		0.04	0.50	0.13			6.46	0.79
Centrarchidae	0.04		0.19		0.10	0.03	0.10			.18	0.07
Lepomis	0.09	0.10	<0.01		0.01	0.16	0.02	.04		.44	0.10
Micropterus	<0.01					0.01		.03		.05	.01
Pomoxis	0.03		0.01	0.04	0.04			.11		.63	0.10
Percidae	0.01									.01	<0.01
Etheostomatinae	0.32		0.08		0.01	0.48				.15	0.12
Perca flavescens	0.05		0.01								0.01
Stizostedion	0.78	0.15	0.03			0.56	0.06	.03		3.27	0.54
Aplodinotus grunniens	<0.01		0.03		0.13	0.48	6.13	13.66		3.69	2.68
Unidentified larvae	0.41		0.24	0.04	1.83		6.14	102.30		9.74	13.41
Total (all larvae)	9.67± 1.82	0.65± .45	26.56± 8.87	61.93± 30.0	77.34± 24.09	58.29± 48.63	56.56± 21.08	686.80± 372.22		1152.99± 278.16	236.75
Eggs	3.90	0.60	3.30	0.40	0.85	14.68	39.13	1.93		4.11	7.55
No. of Location/Month/ Author Sources summed	86	2	17	6	38	4	12	8		0	19

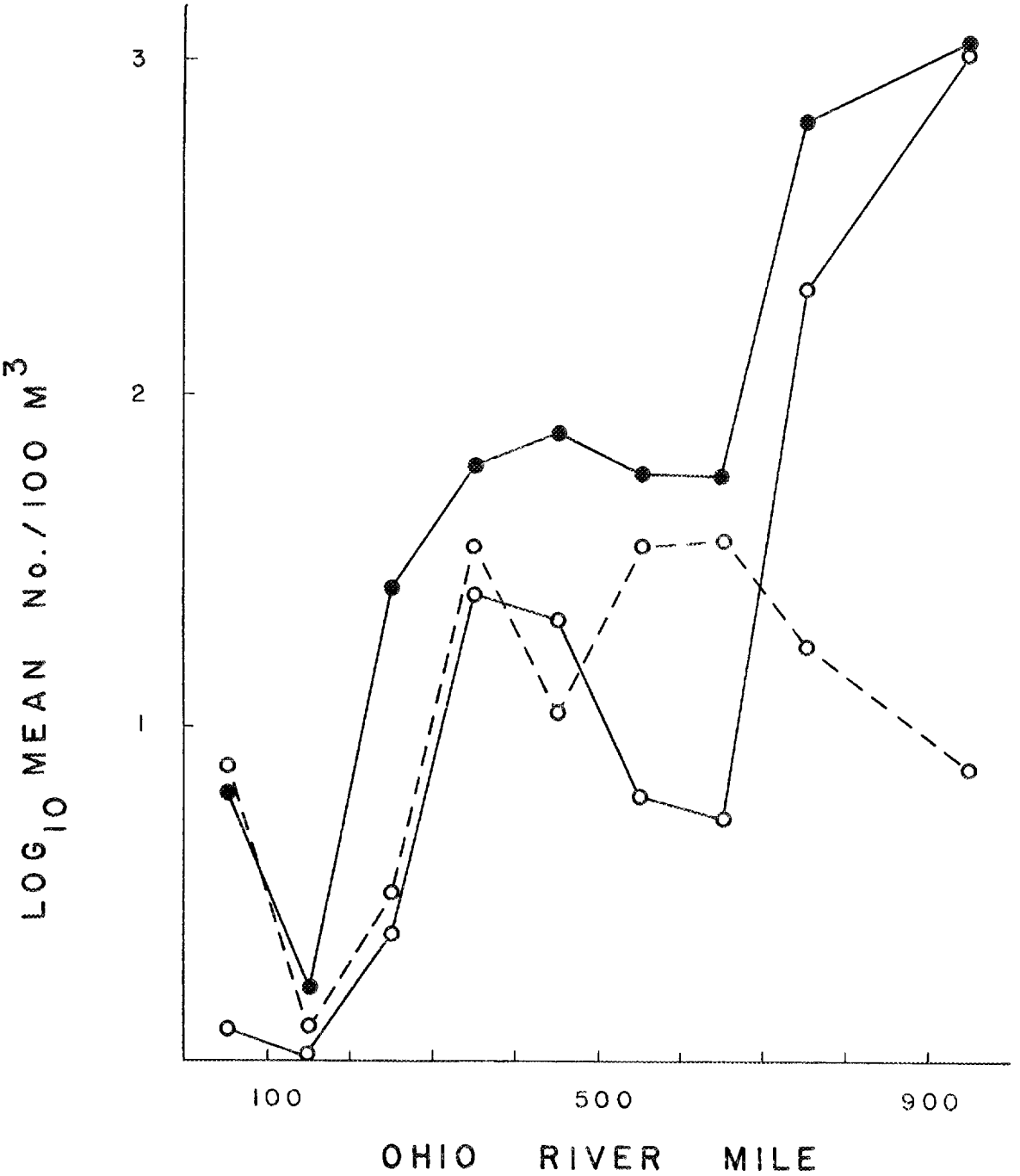

Figure 7. Mean densities ($\log_{10}$ No./100 m^3) of all larval fishes combined (solid circles and line), larval clupeids (open circles and solid line), and larval cyprinids (dashed line) in 100-mile sections of the Ohio River during the peak spawning months (April-July) of 1973-80.

Table 32. Student's t values calculated to test the significance of differences between mean densities of all larval fish species combined (April-July) in 100-mile sections of the Ohio River.

Ohio River Miles	Ohio River Miles								
	100-200	200-300	300-400	400-500	500-600	600-700	700-800	800-900	900-981
0-100	0.74 (89)	-2.99** (104)	-5.19** (93)	-4.25** (125)	-3.89** (91)	-5.21** (99)	-6.41** (95)	NO SAMPLES AVAILABLE	-9.05** (106)
100-200		-0.98 (17)	-1.12 6	-0.72 38	-0.79 4	-1.05 12	-0.88 8		-1.31 19
200-300			-1.55 21	-1.38 53	-1.12 19	-1.46 27	-2.65* 23		-3.82** 34
300-400				-0.25 42	0.07 8	0.15 16	-1.44 12		-2.17 23
400-500					0.25 40	0.46 48	-3.55** 44		-5.44** 55
500-600						0.04 14	-1.16 10		-1.77 21
600-700							-2.10* 18		-3.11** 29
700-800									-0.94 (25)

* - Significantly different at the .05 level.
** - Significantly different at the .01 level.
() = N

at all 100-mile sections downstream except for the 100-200 mile stretch adjacent to it. The density at 100-200 miles did not differ significantly from that of any other stretch of the river, probably because of the very small sample size (n = 2). The density between ORM 700 and 800 (686.8/100 m^3) was significantly higher (.05 level) than densities upstream between ORM 0-100, 200-300, 400-500, and 600-700. The mean density between ORM 900 and 981 (1152.9/100 m) was significantly greater (.01 level) than densities between ORM 0-100, 200-300, 400-500, and 600-700 upstream (Table 32).

Cyprinids were the most abundant larvae in the uppermost 100 miles of the river, followed by percids (darters and sauger-walleye), and clupeids. Only two samples were available between ORM 100 and 200 (Table 31) and the scanty results do not provide much information on relative abundances. Between ORM 200 and 700 the clupeids and cyprinids were roughly equal in density (Figure 7), but below ORM 700, the tremendous increase in total larval fish density was due almost entirely to increases in the clupeidae. It was also below ORM 700 that the threadfin shad became relatively abundant in the Ohio River. Two other taxa which were considerably more abundant in the middle and lower reaches of the river than in the upper were the catostomids, the freshwater drum, and the temperate basses (*Morone*; Table 31).

When the entire data set from all years and localities were averaged, the six families of larval fish exhibiting the greatest overall mean densities were: Clupeidae (149.41/100 m^3), Cyprinidae (17.36/100 m^3), Catostomidae (5.00/100 m^3), Sciaenidae (2.68/100 m^3), Percichthyidae (0.79/100 m^3), and Percidae (0.68/100 m^3) (Table 31).

We also calculated the mean densities of all larval fish combined

in the upper, middle, and lower reaches of the river in each of the years 1973-80 and plotted the results in Figure 8. This figure also indicates the large increase in density from upper to lower thirds of the river. In addition, this figure indicates that densities of larval fish may have peaked in the upper two-thirds of the river in 1976. Although there is a fairly good agreement in trends from year to year in the upper and middle thirds of the river, trends in the lower third are difficult to discern because no samples were available in 1973, and 1977-79.

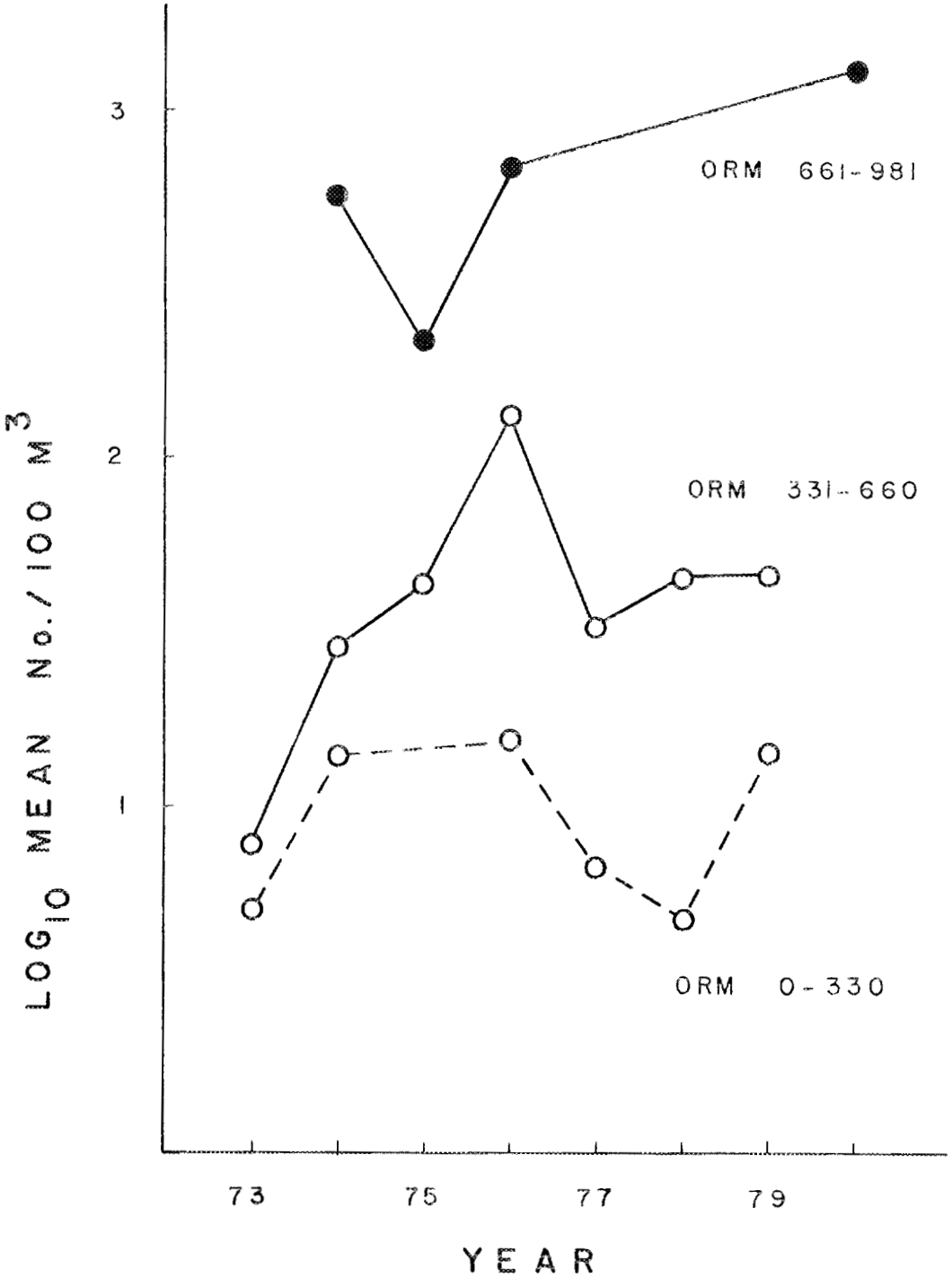

Figure 8. Mean densities ($\log_{10}$ No./100 m^3) of all larval fishes combined in the upper (ORM 0-330, dashed line), middle (ORM 331-660, open circles and solid line), and lower (ORM 661-981, solid circles and line) Ohio River during the peak spawning months (April-July of 1973-80.

DISTRIBUTIONAL CHECK-LIST OF OHIO RIVER FISHES

In preparing a check-list of fishes of the Ohio River one must begin by defining the extent of the river. The river begins at Pittsburgh (ORM 0) and ends at Cairo, Illinois (ORM 981). The major habitat types available to fishes in the river are: 1) the main channel; 2) the main channel border (the region between the main channel and the bank); 3) the shore-debris zone; 4) tail waters; 5) side channels; 6) embayments and sloughs; and finally, 7) mouths of tributary streams.

Our problem, then, was to define the physical limits of the Ohio River. We chose to include only those collections which were made from areas which were directly connected to the river, or which owed their existence to a direct, periodic connection to the river. Therefore, fishes collected in habitat types 1 to 5 above were obviously considered to have been collected in the Ohio River.

Embayments, which are formed over the channels and floodplains of small tributary streams by the navigation dams, are most common in the area between ORM 530 and 100. They are permanently connected to the river channel, and usually contain fishes typical of the large river

fauna, as well as large and important gamefish populations (i.e., largemouth bass and other sunfishes). Therefore, we have considered embayments as extensions of backwater river areas. In reality this inclusion has not affected the distribution maps significantly because the embayments usually contain few species not already present in the main channel, and there has been relatively little collecting effort expended in the embayments. Oxbows, flooded meander channels, and floodplain depression lakes, which are most common along the lower 200 miles of the river, were not considered to be part of the river, and fish collections from them were not included in preparing the distribution maps. These natural, floodplain lakes are occasionally, or even regularly, connected to the river at flood stages, and they do usually contain fishes characteristic of large rivers, i.e., buffalo, gizzard shad, longnose gar, carpsuckers, paddlefish, emerald shiner, and freshwater drum. However, they also contain an assemblage of fish species unique to the heavily-vegetated, clear, standing-water slough environment, i.e., bowfin, spotted gar, pickerels, cypress minnow, spotted sunfish, and the cypress darter. Some of these are rarely, if ever, seen in the river itself.

Creek mouths present a particularly difficult problem. When the lower reaches of a small tributary have an appreciable gradient the delineation between the tributary and the Ohio River can be distinct, and collections made in the tributary within even a few meters of the river often yield species typical of small streams (i.e., central stoneroller, rosefin shiner, and rainbow darter). In this situation, when the tributary, though small, has an appreciable current at its mouth, it is easy to draw an imaginary line across the mouth and not consider specimens collected in the tributary as Ohio River fishes. However, when the lower

reaches of a small tributary stream possess little gradient at low water stages and none at normal or higher river stages, the flooded creek mouth is difficult to distinguish from the river, and the fishes present are usually typical large-river forms. In the ORSANCO (1962) study, this problem was resolved by considering that the Ohio River extended up each flooded creek mouth to the extent of slackwater, or until a definite current could be detected. This sometimes meant that 200-300 meters of flooded stream channel was sampled, with the result that many small-stream species were included in that report [i.e., Ozark minnow, hornyhead chub, ribbon shiner, whitetail shiner (*Notropis galacturus*), pugnose minnow (*Notropis emiliae*), slender madtom (*Noturus exilis*), slough darter (*Etheostoma gracile*), and spottail darter (*Etheostoma squamiceps*)]. For this report we adopted the conservative position of omitting all tributary records.

Determining the actual species of each fish reported from the river also presented some problems. For both scientific and common names we adopted the usage suggested by Robins et al. (1980). In many cases, specimens have been reported (particularly in the last decade) which are outside of the known range of the species. In some cases the identification of the specimen had already been questioned by subsequent authors. We did not have the resources to check all museum specimens nor to even ascertain if voucher specimens were available for the many assessment reports issued in the last decade. Therefore, we simply repeated each citation as we found it. In those cases where the record is doubtful or unusual we have occasionally offered an opinion and have always tried to identify such sources fully so that others may pursue cases of special interest.

The data base from which we extracted fish records consisted of 196

separate publications: 42 were from the period 1817-1919, 39 from the period 1920-1969, and 115 provided records for 1970-83. Some use was also made of unpublished data from a number of agencies and industries, personal accounts, and museum specimens (see previous section). The scattered records of Rafinesque were considered to be a single publication (Ichthyologia Ohiensis, 1820b).

Distribution maps are presented for each species which has been reported from two or more locations on the river. In compiling the distributional data we recorded all specimens examined and literature reports verified within each calendar year and to the nearest river mile. In drafting the maps we found that the scale employed made it difficult for us to render distinctly, records at adjacent river miles. Hence, records at adjacent river miles have, in some cases, been merged into one point.

Three symbols are used on the maps. The large open circles represent collections made before 1920. The smaller open circles represent collections made from 1920 to 1969, while the small solid circles represent collections from 1970 to 1983, inclusive.

The earliest comprehensive works on fishes of the Ohio River basin were typically reported as the fishes of various states (i.e., Indiana - Jordan 1878, 1891, and Eigenmann and Beeson 1893; Illinois - Forbes and Richardson 1920; Ohio - Kirtland 1838-1847 series, and Jordan 1882; West Virginia - Goldsborough and Clark 1908; and Pennsylvania - Cope 1881, and Bean 1892). In these early state works collection sites were rarely described in detail. In many cases there are statements made indicating that a particular species is found "in the Ohio River' of a particular state. On the distribution maps we have included these somewhat nebulous reports by placing the appropriate symbol immediately beneath the name of

the state. In some early reports (i.e., the works of Rafinesque) the locality given is simply "...in the Ohio River...." or "...in the Ohio River as far as Pittsburgh...."! Reports of this broad nature have been included by placing the appropriate symbol beneath the name of Kentucky.

Annotated List Of Species Reported From The Ohio River

This list includes 154 species distributed in 61 genera and 24 families. These species have been reported from the Ohio River (by our definition) or have been captured and/or examined in museums by us. Following the annotated list we have listed 51 additional species which have been reported in tributary streams near the Ohio River and which might occur as strays in the Ohio River.

Petromyzontidae

Ichthyomyzon bdellium (Jordan). Figure 9. The Louisville record is from Call (1896). The other records are from Trautman (1957), ORSANCO (1962), and ORSANCO (1981). The Ohio lamprey is easily confused with *I. castaneus*. Burr (1980) suggests a division between the two species based solely on geography, with *I. bdellium* being in the upper-middle Ohio River, and *I. castaneus* in the lower Ohio River. Smith (1979) reports *I. bdellium* as extinct in Illinois.

Ichthyomyzon castaneus Girard. Figure 10. The older records of the chestnut lamprey in the lower river are from the 1950's (Starret et al. 1960, Page 1980). The recent (1974-76) record is in TVA (1976). The record at ORM 15 (Equitable Environmental Health, Inc. 1979b) is outside the reported range of *I. castaneus* (Lee et al. 1980) and may be *I. bdellium*.

Ichthyomyzon unicuspis Hubbs and Trautman. Figure 11. Occasionally found between ORM 260 and the mouth. A single specimen was collected in the McAlpine Lock (ORM 604) chamber sampling of September 24, 1981. There has been no evident change in silver lamprey distribution in the past decade.

Lampetra aepyptera (Abbott). Type locality: Ohio River. The type locality is ORM 216 before 1860. No specimens reported from the river since. The least brook lamprey is common in small streams tributary to the Ohio River, particularly in the upper reaches.

Lampetra appendix (DeKay). Figure 12. Rafinesque (1820b) reported it (as *Petromyzon nigrum*) "...found as high as Pittsburgh." The recent record at ORM 350 is from Kulik and Gammon (1978). The American brook lamprey is occasional in small tributary streams all along the Ohio River.

Acipenseridae

Acipenser fulvescens Rafinesque. Figure 13. Once abundant throughout the river, no specimens of this large fish have been reported for over 30 years. All of the records between 1920 and 1950 are from Trautman (1957) and many are based upon verbal accounts of fishermen. No lake sturgeon were collected during the ORSANCO (1962) study, and it seems likely that the species only exists as an occasional stray, if at all, in the Ohio River of today. Occasional specimens have been taken in the Cumberland River in 1954 (Clay 1975) and the Mississippi River of Illinois in 1966 (Smith 1979). Trautman (1981) has reported a second-hand observation of a fisherman catching a large sturgeon near ORM 488 in 1971, but the validity of this report must be doubted. This fish was truly migratory,

swimming far up small tributaries to spawn. Trautman (1957) has described the decline of the sturgeon fishery in the Ohio and attributed it to a combination of overfishing on a long-lived, late-maturing species, reduction of molluscan foods through siltation, and obstruction of spawning migration by dams on both the Ohio River and its tributaries. It is listed as a threatened species by Deacon et al. (1979).

Scaphirhynchus platorynchus (Rafinesque). Type locality: Ohio River. Figure 14. Like the lake sturgeon, the shovelnose declined dramatically in numbers between 1900 and 1950. Only one specimen (at ORM 973) was taken in the extensive samplings in 1957-59 reported on in ORSANCO (1962), although Charles (1962) presented reports of commercial fisherman catching sturgeon (presumably shovelnose sturgeon based upon their small size) between ORM 317-535 (1 specimen), ORM 535-742 (1 specimen), and ORM 742-981 (84 specimens) in 1958 and 1959). Only an additional five reports, all below ORM 775, have appeared since 1970 [Electric Energy Inv. (1976) at ORM 952; Axon et al. (1980) at an unspecified location between ORM 846 and 776.1; Cicerello (1981) at ORM 806; and Neff et al. (1981) at ORM 963 and 973]. In July of 1983, I (WDP) examined two shovelnose sturgeon adults collected at the Falls of the Ohio (ORM 604.6). These fish were trapped in isolated pools following a sudden lowering of the gates at McAlpine Dam. Smith (1979) notes the decline of the shovelnose sturgeon in the Mississippi River near the Ohio mouth, and mentions that it seems to be more abundant in the Wabash River than in the Ohio. The shovelnose sturgeon was not an important commercial species, hence its decline in abundance must have been due to changes in the river environment. No extensive spawning migrations have been reported for this species, indicating that siltation of food supplies and/or spawning substrates in the river may have reduced its numbers. The existence of the remnant shovelnose sturgeon

population of the lower Ohio River is, in our opinion, seriously threatened.

Polyodontidae

Polyodon spathula (Walbaum). Figure 15. Originally found from the mouth to at least ORM 95, the paddlefish has not been reported above ORM 429 since 1970. Jordan (1882) noted that the paddlefish was more abundant in the "lower Ohio River of Ohio." Being a large planktivore, which often becomes abundant in large impoundments, the paddlefish may actually prefer the pool habitat created above the navigation dams. The downstream shift in the population may be the result of pollution in the upper river and the inability of adult paddlefish to swim upstream long distances against the swift currents present when the movable dams are raised clear of the dam sill at high water levels. Reproduction certainly has occurred in the upper portion of its range in the 1970's since we captured a larval paddlefish in 1977 at ORM 571 (Clark 1979). Deacon et al. (1979) assigned the paddlefish "special concern" status in the belief that relatively minor disturbances to its large river habitat could move it to endangered status.

Lepisosteidae

Lepisosteus oculatus (Winchell). Figure 16. The spotted gar was probably not distinguished from the shortnose gar by many workers of the last century. Smith (1979) reports that some spotted gar are present in existing collections made by Forbes and Richardson although their 1920 publication does not list *L. oculatus*. The first records of this fish in the Ohio River were those presented in ORSANCO (1962) for 1957-58 collections at ORM 451, 633, and 810 to 939. Since 1970 the spotted gar

has not been taken above ORM 846. The one record for ORM 451 in 1958 may represent a stray individual, or this species may have actually retreated downstream over the past 30 years.

Lepisosteus osseus (L.). Figure 17. The longnose gar is the most common gar in the Ohio River. It was, apparently, common throughout the length of the river before 1920, was reduced in numbers in the upper 150 miles of the river by 1950-70, and has returned to the upper 150 miles since 1970 as water quality improved between Pittsburgh and the Muskingum River.

Lepisosteus platostomus Rafinesque. Type locality: Ohio River. Figure 18. Rafinesque (1820b) reported the shortnose gar in the Ohio River as far as Pittsburgh. Osburn (1901) reported the species at ORM 326. Trautman (1957) recorded verbal accounts of specimens which had been reported to him in the Cincinnati area (record on map) and between ORM 50 and 250, before 1930. In the 1962 ORSANCO study no shortnose gar were taken above Louisville (ORM 605). In a somewhat surprising resurgence, shortnose gar have apparently become more abundant and widespread in the upper Ohio River since 1970, with records at ORM 508 (Zook 1970); ORM 494 (WAPORA 1976a); ORM 436, 406, and 328 (Kulik and Gammon 1978); ORM 395 (U. S. Army Corps of Engineers 1978d); and ORM 161 (Monongahela Power & Light Co. 1976).

Lepisosteus spatula Lacepede. Figure 19. Rafinesque (1820b) reported the alligator gar in the "lower parts of the Ohio." He also reported Audubon's oral account of a large gar, presumably this species, seen near Henderson, KY (the ORM 804 record). Kirtland (1844a) reported a specimen from the Cincinnati area (record at ORM 473) as well as a

specimen taken somewhere above Cincinnati. Trautman (1957) related oral reports of specimens before 1915 at ORM 472; in 1928 at ORM 486; and in 1946 at ORM 424; which we have not plotted in Figure 11. Burr (1980) reports a photograph in the Illinois Natural History Survey of an alligator gar from the mouth of the Ohio River (record at ORM 981). Hoyt (1979) presents the only records since 1946. He found 20 small specimens at ORM 946 between 1974 and 1976. The alligator gar, never a common species, has obviously declined in numbers and is probably restricted to the lower quarter of the Ohio River at present.

Amiidae

Amia calva L. Figure 20. The bowfin is primarily a fish of sloughs, flooded creek mouths, and back channels rather than the main or border channel areas. Although Jordan (1882) and Cope (1881) listed the bowfin in the Ohio River bordering Ohio and Pennsylvania, respectively, they provided no specific locations. Trautman (1957) reported specimens from a tributary and an overflow pool near the Ohio River, but no specimens from the river. One specimen at ORM 483 in 1957 was reported in the ORSANCO (1962) report. The older record at ORM 721 is from a 1968 collection reported by Preston (1969), while the open circle at 846 is an "unverified report" by Gerking (1945). Since 1970 most records have been below ORM 700 (University of Louisville 1974a; Electric Energy,Inc. 1976; Preston 1979; Axon et al. 1980; Starnes 1980; Neff et al. 1981), although there are two records in the upper river [WAPORA (1974a) at ORM 54 and Preston (1979) at ORM 204]. Trautman considered the possibility that the occasional specimens taken near the Ohio River may have been accidental introductions stocked along with more desirable species. The formation of embayments by

the new high-lift dams would seem to favor this species in the future.

Anguillidae

Anguilla rostrata (Lesueur). Figure 21. Since the American eel is a catadromous species, every individual taken in the river has successfully traveled up the Mississippi River to the point of capture despite the obstruction offered by the navigation dams. Records before 1920 are, as usual, sketchy. Comparison of the 1920-1969 and 1970-1980 periods indicate that eels have successfully reached the upper third of the river in both periods. However, the single open circle at ORM 54 represents a 1969 collection. There were no eel records above ORM 172 between 1920 and 1969. Thus, the four records above ORM 100 since 1969 indicate a return to this section of the river due to improved physical conditions.

Clupeidae

Alosa alabamae Jordan and Evermann. Evermann (1902) reported taking this species (as *A. ohiensis*) at Louisville (ORM 605) in 1897 and 1898, it has not been reported since. Clay (1975) gives a good account of the confusion resulting from the misapplication of the term "shad" to several species of fishes at the turn of the century, and the planting of *A. sapidissima* in the Ohio River by the U. S. Fish Commission between 1874 and 1893. Although the Alabama shad has been reported in the Mississippi River above the Ohio mouth (Pflieger 1975, Smith 1979) and in the Cumberland drainage (Lee et al. 1980) it seems unlikely that it exists today in the Ohio River.

Alosa chrysochloris (Rafinesque). Figure 22. The skipjack herring has always been abundant in the Ohio River judging by statements in the

works of Hay, Jordan, Kirtland, Bean, and Call before 1900. The skipjack is another migratory species which has maintained populations throughout the river, even during the years of severe pollution in the upper third of the Ohio. There is even a report (U. S. Army Corps of Engineers 1975a) of skipjack accumulating below locks on the river in the spring until an opportunity to "lock through" with a tow presented itself!

Alosa pseudoharengus (Wilson). Figure 23. The alewife has been reported at ORM 436 in 1970, and ORM 84 in 1977 by Preston (1979). An additional record at ORM 54 in 1977 can be found in WAPORA (1978). Trautman (1981) also records specimens at ORM 342, 440, 450, and 491 after 1969. These records are probably for fish introduced to the upper Ohio River in mixed lots of fish originating in the Great Lakes and transported by bait dealers and fish haulers stocking private pay lakes. It seems unlikely that reproducing populations will develop.

Alosa sapidissima (Wilson). The American shad was stocked in the Ohio River in large numbers between 1874 and 1893, and specimens were recorded for a few years thereafter (Jordan 1882, Bean 1892, Clay 1975). It has not been seen in this century.

Dorosoma cepedianum (Lesueur). Figure 24. One of the most abundant fishes in the Ohio River, the gizzard shad, has been found throughout the length of the river in each of the three time periods represented on the distribution map. The lack of records before 1920 probably reflects the small amount of collecting effort expended, not the true abundance of the fish. Nevertheless, this fish probably did increase in relative abundance after the river was canalized.

Dorosoma petenense (Gunther). Figure 25. The threadfin shad was first discovered in the Ohio River in 1957 by Minckley and Krumholz (1960). They collected specimens at ORM 963, 903, 778, 663, and 607 in that year and from tributaries to the Ohio in the same area. The number of specimens and their distribution indicate that they had probably been in the Ohio River for some time, but had not been noticed. Krumholz et al. (1962) found the threadfin to be most abundant below Louisville in their 1957-59 samplings, although they did capture specimens at ORM 405. The open circle record at ORM 532 is from Preston (1969) representing a 1968 collection. Since 1970 there have been only four additional records above Louisville, extending the known range upstream a few miles to ORM 390 (U. S. Army Corps of Engineers 1976c). This represents the northernmost extent of the threadfin shad's natural range (Lee at al. 1980). Further progress upstream may be temperature-limited since this fish has been observed to suffer mass mortalities during cold periods.

Hiodontidae

Hiodon alosoides (Rafinesque). Type locality: Ohio River. Figure 26. The goldeye was probably never as abundant in the Ohio River as the skipjack herring. Trautman (1957) and Smith (1979) agree that the goldeye has been reduced in numbers and is now regularly seen, but never in abundance. The only records above ORM 167 are those for 1979 and 1981 at ORM 54 and 77 (WAPORA 1980a and Geo-Marine 1982). These specimens may represent either a significant population shift into cleaner waters, or they may simply have been stray individuals. The goldeye has usually been considered to be more tolerant of turbidity than the mooneye and to have increased relative to the mooneye as streams became more turbid in the Ohio Valley.

Hiodon tergisus Lesueur. Type locality: Ohio River at Pittsburgh. Figure 27. The mooneye, like the goldeye, was probably never very abundant in the Ohio River. Its distribution for the three time periods plotted on the distribution map coincided almost exactly with those of the goldeye. Originally distributed throughout the river, between 1920 and 1969 it was not taken above the mouth of the Muskingum River (ORM 172). Unlike the goldeye, there have been no records above ORM 260 since 1970.

Salmonidae

Oncorhynchus kisutch (Walbaum). A single coho salmon was reported from the river at approximately ORM 448 in 1976 (Trautman 1981). Trautman suggests that this individual strayed from one of several known stockings in the Ohio River watershed.

Salmo gairdneri Richardson. The rainbow trout reported at ORM 54 in 1977 (Geo-Marine 1978) and 1979 (WAPORA 1980a) undoubtedly represent escapes from plantings of hatchery fish.

Salmo trutta L. Figure 28. Specimens reported at ORM 54 in 1979 (WAPORA, 1980a), ORM 260 in 1981 (Geo-Marine 1982), and ORM 353 in 1975-77 (Kulik and Gammon 1978) must, again, represent plantings of hatchery fish either in the river, or, more likely, in tributary streams or floodplain ponds. The brown trout reported in ORSANCO (1962) was from a tributary stream, not the Ohio as defined in this report.

Esocidae

Esox americanus vermiculatus Lesueur. Figure 29. The grass pickerel is an inhabitant of clear, well-vegetated waters, either running or still,

ans so finds little suitable habitat in the Ohio River. Kirtland (1844b), Bean (1892) and Call (1896) all list it from the Ohio River before 1900. The only records since 1900 are those at ORM 312 in 1959 (ORSANCO 1962), at ORM 597 in 1972 (White 1974), and ORM 952 in 1972-75 (Electric Energy Inc. 1976). The grass pickerel is occasional in small tributary streams all along the Ohio, and these recent records probably represent strays moving out of tributaries into the mainstem Ohio.

Esox lucius L. Figure 30. Although Kirtland (1844b) and Rafinesque (1820b) both claimed that the northern pike was to be found in the Ohio River, Trautman (1957) expressed the opinion that they may have confused it with the muskellunge, an opinion with which we agree. The record at ORM 341 in 1968 (Preston 1969), and the nine records since 1970 (all above ORM 344: NUS 1976; WAPORA 1976a, 1980a; Duquesne Light Co. 1977b, 1979 a and b; Kulik and Gammon 1978; Geo-Marine 1982, 1983) probably represent hatchery plants in the watershed and in the river by the State of West Virginia (U. S. Nuclear Reg. Comm. 1977).

Esox masquinongy Mitchill. Figure 31. The muskellunge was the large "pike" referred to in early accounts of Ohio River fishes. It was probably found throughout the length of the river, although all records are above Louisville. The specimen at ORM 340 was collected in 1959 (ORSANCO 1962); all other small open circle records are from Trautman (1957) between 1900 and 1950. Since 1970, specimens have been collected at ORM 13 (Preston 1979); ORM 15 (Equitable Environmental Health Inc. 1979b); ORM 35 (Duquesne Light Co. 1979b and 1980); ORM 54 (WAPORA 1974a and Geo-Marine 1978); ORM 77 (WAPORA 1980b); and ORM 368 (Kulik and Gammon 1978). Preston (1979) also reported a tiger muskie (*E. lucius* x *E. masquinongy* cross)

at ORM 84 in 1978. Although these recent fish are probably hatchery releases, they indicate that the upper 100 miles of the Ohio River is capable of supporting adult muskies.

Cyprinidae

Campostoma anomalum (Rafinesque). Figure 32. The central stoneroller was first reported from the Ohio at Louisville by Rafinesque (1820b). It has been found occasionally ever since, throughout the river, but especially in the upper two-thirds. Most specimens found in the Ohio are probably strays from tributary streams. Before construction of the navigation dams, the Ohio probably offered more of the shallow, stony-bottomed riffle and run habitat preferred by the stoneroller.

Carassius auratus (L.). Figure 33. The goldfish is an introduced species which is found throughout the Ohio River, but is most often encountered in the upper two-thirds of the river, particularly near the metropolitan areas of Pittsburgh, Cincinnati, and Louisville. There seems to have been no noticeable change in the number and distribution of goldfish in the Ohio River since 1970 and constant release of aquarium fishes, together with natural reproduction, will insure that the goldfish remains a part of the Ohio River fauna.

Clinostomus elongatus (Kirtland). One specimen reported from ORM 610 in 1975 (Dames & Moore 1975c). The only other known Kentucky record for redside dace is in a tributary of the Licking River. Although this small-creek species is found in Ohio River tributaries in southeastern Ohio and western Pennsylvania, the Ohio River record is at the edge of the reported range of the species (Lee et al. 1980) and may be a misidentification.

Ctenopharyngodon idella (Valenciennes). The introduced grass carp began to be reported from the Mississippi River of Missouri (both above and below the Ohio River mouth) in 1971. Guillory and Gasaway (1978) received an unconfirmed report of a grass carp from "the Ohio River". In the summer of 1980, two commerical fishermen at ORM 963 told me (WDP) that they had caught several large grass carp at that location each year since 1978. On July 29, 1983, I (WDP) examined a grass carp collected at the Falls of the Ohio 4 days before by a commercial fisherman. This fisherman told me that he had selected the specimen from 5 or 6 that were present and that he had seen a few similar fishes several times in the past year. Grass carp have been stocked in many private ponds and lakes in the Ohio River basin over the past 10 years. Recent reports of larval grass carp in the lower Mississippi River (Conner et al. 1980) may indicate established populations. The future impact of the grass carp on dwindling beds of rooted aquatic plants in the Ohio River can only be guessed at. These aquatic plants presently provide valuable spawning and nursery areas for many native fishes (Clark 1979).

Cyrpinus carpio L. Figure 34. The common carp was introduced widely into the Ohio River basin between 1879 and 1896 by the U. S. Fish Commission, It soon found its way into the Ohio River (Evermann 1902 at Louisville) and has been abundant throughout the river to this day. A pollution-tolerant species, the carp was found in abundance in the upper 100 miles of the river throughout the late 1950's and 1960's.

Ericymba buccata Cope. Figure 35. The silverjaw minnow has been reported in the upper half of the river as an occasional stray from smaller tributaries. The first record being that of ORSANCO (1962) in 1957 at ORM 32 and the latest that of WAPORA (1979a) at ORM 260. Apparently, its absence from the lower river is a true reflection of its

disjunct distribution into a northern population whose southernmost extent is Ohio and the middle portions of Indiana and Illinois, and a southern population found south of Tennessee (Lee et al. 1980).

Hybognathus hayi Jordan. The cypress minnow is an inhabitant of the clear, heavily vegetated, floodplain lakes and slow backwaters of the lower Mississippi River drainage. Its range extends up the Ohio valley to western Indiana. Only one record (ORM 791.3) from 1958 (ORSANCO 1962) is acceptable. A specimen listed as *H. hayi* in the University of Louisville collection (U.L. #1290) is actually *H. storeriana*. The single specimen at ORM 791.3 was probably a stray from nearby sloughs.

Hybognathus nuchalis Agassiz. Figure 36. The Mississippi silvery minnow is an inhabitant of clear, slow-moving waters, usually associated with small- to medium-sized rivers. Trautman (1957) could find no Ohio records after 1900 and concluded that its distribution was shrinking towards the west. This does seem to be the case in the Ohio River. Between 1942 and 1962 there are 13 records of the species between ORM 880 and 605. Since 1970 there have been no records above ORM 810 except the single one at ORM 161 (U. S. Army Corps of Engineers 1975b), which needs verification. The range of the fish in the Ohio River has probably contracted to the lower 100 miles of the river.

Hybopsis aestivalis (Girard). Figure 37. The speckled chub inhabits sand and firm gravel bottoms in medium to large rivers. It was probably more abundant in the Ohio River in pre-impoundment days. The three records from 1900 or before are recorded by Henshall (1889) and Osburn (1901). Occasional specimens were taken between ORM 244 and 903 from 1920-1969. In the 1970's specimens were limited to the area between

ORM 260 and 494.

Hybopsis amblops (Rafinesque). Type locality: Ohio River. Figure 38. The bigeye chub is usually found in smaller streams than the Ohio River, and those individuals discovered in the river are probably strays. There appears to be no obvious change in their river distribution in the 1970's when compared to their distribution in the 1920-69 period. The bigeye chub was one of the species which Krumholz and Minckley (1964) observed entering the Ohio River in large numbers from tributaries at ORM 32 following the shutdown of the steel industry due to a strike in 1959.

Hybopsis dissimilis (Kirtland). Figure 39. The streamline chub is a small-stream fish which has been recorded from the Ohio River only by Call (1896) at ORM 605 (date unknown), and by Monongahela Power and Light Company (1976) at ORM 161 in 1973-74. Jordan (1882) considered it to be present in the Ohio River of Ohio.

Hybopsis meeki Jordan and Evermann. The sicklefin chub is known only from the Missouri, Mississippi, and Ohio rivers. In the Ohio it has been reported only in the lower 40 miles of the river by Forbes and Richardson (1920), at ORM 979 in 1880, and by Electric Energy Inc. (1976) in 1972-75 at ORM 952. The 20 specimens reported by Forbes and Richardson as *Platygobio gracilis* (=*Hybopsis gracilis*) were apparently misidentified since their accompanying figure is clearly *H. meeki* (Smith 1979).

Hybopsis storeriana (Kirtland). Figure 40. The silver chub is the most abundant chub in the Ohio River. It was mentioned before 1920 by Jordan (1878), Gilbert and Henshaw (1880; cited in Trautman 1957), Hay

(1894), Call (1896), and Forbes and Richardson (1920) at ORM 276, 468, 605, and 979. It has been reported throughout the length of the river (save the uppermost 31 miles) in both the periods of 1920-69 and 1979-83.

Hybopsis x-punctata Hubbs and Crowe. The gravel chub has been reported from the Ohio River only by Trautman (1957) at dam #29 [3 specimens - OSU #580, T. Cavender (1981)]. Clay (1975) suggests that the *H. dissimilis* reported at the Falls of the Ohio by Call (1896) as *Ceratichthys dissimilis* may have been based upon *H. x-punctata*. This is a small-stream fish which occurs only as a stray in the Ohio River.

Hypophthalmichthys molitrix Val. One specimen of this introduced Asian cyprinid was collected at the Falls of the Ohio at Louisville (ORM 604.6) on July 25, 1983. The specimen (652 mm total length) was picked up from an isolated pool left behind when the gates of McAlpine Dam were suddenly closed. I (WDP) examined the specimen two days after it was frozen by a local resident. The silver carp has been introduced to several fish farms in Arkansas and may have entered the Ohio from the Mississippi River, or it may have escaped from plantings in local ponds.

Nocomis biguttatus (Kirtland). Jordan (1891) listed the hornyhead chub as being present in the Ohio River of Indiana, but no definite locality was given. Fowler (1945) very tentatively considered that the *Catostomus melanotus* Rafinesque (1820b) described from the Falls might have been *N. biguttatus*, a very remote possibility in our view. A catalog entry for this species at ORM 605 in 1983 at the University of Louisville cannot be confirmed as the specimen cannot be found.

Nocomis micropogon (Cope). Figure 41. As Trautman (1957) has pointed out, the river chub was often confused with the hornyhead before 1925. The river chub is distributed somewhat to the south of the hornyhead

(Lee et al. 1980) and in the upper half of the Ohio River. It is encountered too frequently to be called a stray, but it is never reported in large numbers in the river. Records since 1970 have been reported by WAPORA (1973, 1975, 1976a, 1980a), U. S. Army Corps of Engineers (1976a), Monongahela Power and Light (1976), Kulik and Gammon (1978), and Geo-Marine 1982).

Notemigonus crysoleucas (Mitchill). Figure 42. The golden shiner is a large and generally-distributed minnow in the Ohio River basin. It has been found throughout the length of the Ohio including the upper, polluted, quarter between 1920 and 1969.

Notropis atherinoides Rafinesque. Figure 43. It seems a shame that Rafinesque described the emerald shiner from Lake Erie, rather than the Ohio River, for it is the most abundant fish in the river and has been distributed from source to mouth both before and after 1970.

Notropis blennius (Girard). Figure 44. The river shiner has been found throughout the length of the river in each of the three time periods considered, but has been most frequently found in the lower third of the river.

Notropis boops Gilbert. Figure 45. The bigeye shiner is usually found in small, clear streams over silt-free bottoms. Records from the Ohio River almost certainly represent stray individuals. Between 1955 and 1967 specimens were reported at only three localities, all below ORM 203. Since 1974 specimens have been recorded at four localities, all above ORM 103. This appearance of a rather pollution-intolerant species in the upper 100 miles of the river, even if as occasional strays, indicates favorable changes in water quality (Gilbert 1981).

Notropis buchanani Meek. Figure 46. The ghost shiner has been reported occasionally throughout the Ohio River. Although the center of its geographic distribution is to the west of the Ohio River basin, most records from the Ohio are in the upper, or eastern third of the river. Since 1969 only two collecting sites have been reported below ORM 341, while collections have been made at nine sites above ORM 341. Recently, Gilbert (1982) examined two specimens (U.L. #11463 at ORM 32) preserved from the ORSANCO (1962) study and found them to be hybrids between *N. atherinoides* and *N. volucellus*. In a paper presented at the 62nd annual meeting of the American Society of Ichthyologists and Herpetologists in Dekalb, Illinois, D. A. Mayhew described this hybrid from the lower Monongahela River. It is a pallid fish with many intermediate meristic characters which could easily lead to its confusion with *N. buchanani*. Therefore, we have doubts about the correct identification of those records not backed by extant specimens.

Notropis chrysocephalus (Rafinesque). Type locality: Probably the Ohio River. Figure 47. The striped shiner was considered a subspecies of *N. cornutus* until elevated to specific status by Gilbert in 1961, a decision accepted by Robins et al. (1980), but disputed by Clay (1975) and others. The first Ohio record of the fish under the new specific status was made in 1963 (Page 1980) at ORM 921. All subsequent records have been from the upper half of the river, above ORM 518. The open circles on the Ohio border of the river represent records from Trautman (1957) who clearly identified the subspecies *N. cornutus chrysocephalus*. The striped shiner is primarily a fish of small and medium streams, found only occasionally in the Ohio River. According to Trautman (1957) the adults move downstream during drought

and may then enter the Ohio River more frequently.

Notropis cornutus (Mitchill). Figure 48. The common shiner was apparently distributed throughout the Ohio River except for the upper 100 miles (Lee et al. 1980). Before 1961, as explained under *N. chrysocephalus*, the striped shiner was considered a subspecies of *N. cornutus*. Therefore, based on the current distribution of *N. cornutus* and *N. chrysocephalus*, it seems clear that most of the records of *N. cornutus* before 1961 were actually *N. chrysocephalus*. Also, many investigators have either not accepted or have not been aware of the elevation of *N. chrysocephalus* to specific status, since reports of *N. cornutus* in the Ohio River far outside of its generally accepted range have been made between 1970 and 1977 (i.e., Kulick and Gammon 1978; U. S. Army Corps of Engineers 1978b; WAPORA 1973, 1974a, 1975, 1978). Because of the confusion between the two fishes we have elected to simply report the records as given in the original reports, although it is our belief that most, if not all, records should be assigned to *N. chrysocephalus*. This fish, reported as *N. cornutus*, seems to be concentrated in the upper two-thirds of the river, with no apparent shift in its distribution in the three time periods considered.

Notropis emiliae (Hay). Figure 49. The pugnose minnow has been reported sporadically from the extreme lower reaches of the Ohio River (below ORM 878). Although it was found in small tributaries near the Ohio River of Ohio before 1950 (Trautman 1957), no specimens were reported from the river. The ORSANCO (1962) specimen reported at ORM 263 in 1958 was taken from a tributary, not the river. The pugnose minnow is usually found in small, clear streams amongst aquatic vegetation. It occurs only as strays in the lower river.

Notropis fumeus Evermann. Figure 50. The ribbon shiner is commonly found in the western third of Kentucky and southern Illinois, but has only been reported from the Ohio River at two locations (ORM 333 and 880) in 1978 (Charles et al. 1979). The record in ORSANCO (1962) at ORM 898 was from a tributary stream, not the Ohio River.

Notropis heterolepis Eigenmann and Eigenmann. Figure 51. The blacknose shiner has been reported from just two river locations (ORM 58 and 102 in 1974 (WAPORA 1977b and c). Other records of this fish in the Ohio River basin are at least 50-100 miles to the north of the river in Ohio (Trautman 1957), Indiana and Illinois (Lee et al. 1980), or scattered to the south of the Ohio (Lee et al. 1980, Clay 1975).

Notropis hudsonius (Clinton). Figure 52. The spottail shiner has been reported thrice in the Ohio River at ORM 979 by Forbes and Richardson (1920) before 1904, by Geomarine (1978) at ORM 54 in 1977, and by ORSANCO (1981) at ORM 13 in 1980. The last two records are not unlikely since a few specimens have been taken in tributaries to the upper river, as well as in the Mississippi River near the Ohio River mouth (Lee et al. 1980). Raney (1938) cited Evermann and Bollman (1886) as having recorded it in the upper Monongahela of Pennsylvania. The ORSANCO (1962) record in 1957 was from a tributary entering at ORM 910.

Notropis lutrensis (Baird and Girard). Figure 53. The red shiner is primarily distributed to the west of the Mississippi River. It is usually found in turbid, quiet sections of medium-sized streams. It has occasionally been found in the Ohio River since 1957. The three records between ORM 940 and 961 are from Smith (1979) and Page (1980). The record at ORM 877 is from ORSANCO (1962) in 1957, while the uppermost

record (ORM 721) in 1974 is from the University of Louisville (1974b). These reports have also been summarized by Burr et al. (1980).

Notropis nubilus (Forbes). The record of Forbes and Richardson (1920) at Cairo (ORM 979) is the only one known to us. The ORSANCO (1962) record at ORM 940 in 1957 was from Seven Mile Creek in Illinois. The Ozark minnow distribution is centered in southern Missouri and northern Arkansas.

Notropis photogenis (Cope). Figure 54. The silver shiner is common in medium-sized rivers of the upper Ohio River basin, and is occasionally taken in the Ohio River. The record at ORM 946 (Hoyt 1979) represents an extension of the previously known range of about 150 miles to the west. The open circle records between ORM 487 and 633 represent four lots of specimens taken in 1960 by J. Williams and others and housed in the University of Louisville collections. Only one of the lots is currently available and it contains only *N. atherinoides*. Therefore, the three records are suspect. The same may be said for the open circle record at ORM 32 by the same collectors in 1961. Although Trautman (1957) found no specimens in the Ohio River, he expressed the opinion that it must have been present before impoundment of the river since it was common in many small tributaries of the river in Ohio. The records at ORM 102, 161, and 390 are from WAPORA (1977b), and U. S. Army Corps of Engineers (1976b, 1976c); all taken in 1973-74.

Notropis rubellus (Agassiz). Figure 55. Although common to the north and south of the Ohio River, the rosyface shiner seems to be rare in tributaries along the mainstem (Lee et al. 1980). Nevertheless, Krumholz and Minckley (1964) reported that the rosyface shiner was one of

the species which quickly moved from tributary and backwater sanctuaries into the Ohio River at Montgomery Lock and Dam (ORM 32) following the cessation of pollution associated with the prolonged steel strike of 1959. It has been recorded sporadically throughout the length of the Ohio River. It appears that records in the upper third of the river have become slightly more numerous since 1970.

Notropis shumardi (Girard). Figure 56. The silverband shiner is a large-river species found most commonly in the Mississippi and its larger, western tributaries. Apparently it is declining in abundance in the lower Ohio River, and its range seems to be contracting towards the Mississippi. There were 13 records in the river between ORM 845 and 972 (4 in ORSANCO 1962 and 9 in Smith 1979 and Page 1980) during the years 1957-64; but only one record (Starnes 1980, at ORM 968 in 1979) has been reported since 1970.

Notropis spilopterus (Cope). Figure 57. The spotfin shiner is common in many streams in the Ohio River basin. It is moderately common throughout the Ohio River although fewer records have been reported below ORM 500 in 1970-80 than in the period 1920-1969. The spotfin seems to have been collected with increasing frequency in the upper 100 miles of the river since 1970. This fish is probably a permanent resident of the river, although it is seldom taken in large numbers.

Notropis stramineus (Cope). Figure 58. The sand shiner's distribution is generally to the north and west of the Ohio River mainstem, although the fish is common in the upper 90 miles of the river. It has not been reported below Louisville in the 1970's, however, and is most abundant in the upper 100 miles of the river. This fish seems to move

about a good deal in schools, and travels freely between small and medium-sized tributaries and the Ohio mainstem. Krumholz and Minckley (1964) found this minnow entering the Ohio River (at ORM 32) in large numbers from tributaries within weeks of an abrupt cessation of pollution associated with the steel strike of 1959.

Notropis umbratilis (Girard). We have only one record of the redfin shiner in the Ohio River (ORM 939 in 1970) in Preston (1979). It has also been reported in tributaries near the Ohio River between miles 90-315 (Trautman 1957) and 896-965 (Smith 1979). It is a fish of small to medium-sized streams and should be expected only as strays in the Ohio River.

Notropis venustus (Girard). We have only two collection sites in the extreme lower reaches of the river at ORM 951 and 961, both in 1964 (Smith 1979 and Page 1980). The blacktail shiner, although a fish of larger streams, reaches its northernmost distribution in the Mississippi River valley at the Ohio River mouth.

Notropis volucellus (Cope). Figure 59. The mimic shiner is probably the second most abundant minnow in the Ohio River after the emerald shiner. It has been found throughout the river, but in the period 1970-1980 fewer collections were made in the lower half of the river than in previous years. In the upper half of the river the species was still reported in large numbers at many individual sites within each 100-mile section of the river. The mimic shiner was another of the species which Krumholz and Minckley (1964) found entering the Ohio River at ORM 32 from tributaries and backwaters following the steel strike of 1959.

Notropis whipplei (Girard). Figure 60. The steelcolor shiner was occasionally reported between ORM 304 and 703 before 1970. Since 1970 its occurrence in the river has expanded downstream slightly to ORM 744 (U. S. Army Corps of Engineers 1980b), and, more dramatically, upstream to ORM 54. The steelcolor shiner is a fish of medium-sized rivers, and there are probably few permanent residents of the Ohio River. The appearance of this temporary visitor to the upper 300 miles of the river since 1970 reflects, again, improved water quality in this section.

Phenacobius mirabilis (Girard). Figure 61. The suckermouth minnow is usually an inhabitant of smaller, turbid streams. It has been recorded sporadically throughout the length of the river, but since 1970 only five collection sites, at ORM 494 (Geo-Marine 1982), ORM 453 (WAPORA 1978), ORM 260 (Geo-Marine 1983), ORM 234 (Trautman 1981), and ORM 168 (Preston 1979) have been reported.

Phoxinus erythrogaster (Rafinesque). Figure 62. The southern redbelly dace is usually considered a small-upland-stream species. Jordan (1878 and 1891) listed it as in the Ohio River of Indiana, without providing a specific location. The only recent record is that of ORSANCO (1962) at ORM 312 in 1959. This collection (1 specimen) was made in a "backwater behind the esplanade at Lock and Dam 28." Although this backwater area had recently been connected to the river and seems to have met our criteria of an "Ohio River site", many of the species from this collection (i.e., stoneroller and creek chub) indicate that the site may have actually been a small tributary mouth rather than a backwater.

Pimephales notatus (Rafinesque). Type locality: Ohio River. Figure 63. The bluntnose minnow probably shows up in a higher percentage of fish collections in all sections of the river than any other species

except the emerald shiner. It seems to have been more frequently collected, particularly in the lower half of the river, since 1970.

Pimephales promelas Rafinesque. Figure 64. The fathead minnow is usually found in small to medium, muddy streams. It does not compete well with the bluntnose minnow according to Trautman (1957), and is seldom found where the bluntnose is abundant. In the Ohio River the fathead is found only occasionally in the upper half of the river. Since 1970 it has only been reported from the upper 300 miles and in only four collections. It is even possible that these reports are the result of releases from bait buckets since the fathead is imported and sold extensively throughout the Ohio River Basin.

Pimephales vigilax (Baird and Girard). Figure 65. The bullhead minnow is commonly encountered only in the lower 200 miles of the Ohio River. The four uppermost records since 1970 are from WAPORA (1975 and 1980a) and Geo-Marine (1983).

Rhinichthys atratulus (Hermann). Figure 66. Another small-stream fish which occurs as strays in the Ohio River, the blacknose dace has been reported from the Ohio River of Indiana (no specific locality given) by Jordan (1891) and Hay 1894). There are two records at ORM 35 in the 1970's by Duquesne Light Co. (1977b and 1980), and at ORM 54 and 77 in 1981 (Geo-Marine 1982). The record at ORM 312 is from the same "backwater behind esplanade at L & D #28" collection which produced the southern redbelly dace record (ORSANCO 1962).

Semotilus atromaculatus (Mitchill). Figure 67. The creek chub is probably seldom, if ever, a permanent resident of the Ohio River, but

like other large minnows found in small streams, it seems very willing to venture into the river during times of drought and low water. It has, therefore, been reported occasionally throughout the length of the river.

Catostomidae

Carpiodes carpio (Rafinesque). Type locality: Falls of the Ohio River. Figure 68. The river carpsucker is found throughout the length of the river in abundance, except for the upper 150 miles where it seems to have been reported less frequently. Before 1970 only one collection was reported above ORM 100, whereas since 1970 11 collections have been reported in the same stretch (only four solid dots appear on the distribution map because the collections reported were made at just four sites in different years).

Carpiodes cyprinus (Lesueur). Figure 69. The quillback, like the river carpsucker, is distributed throughout the Ohio River, but seems to be most frequently encountered in the middle portions of the river. The river carpsucker is usually 5 to 8 times more abundant than the quillback. The quillback has also become more abundant in the upper 100 miles of the river since 1970.

Carpiodes velifer (Rafinesque). Type locality: Ohio River. Figure 70. The highfin carpsucker has been reported from ORM 172 to the mouth of the Ohio River. There are many more records since 1970 than before, which may indicate an increase in abundance. The highfin carpsucker is usually considered to be less tolerant of turbidity and pollution than either the river carpsucker or the quillback, a fact which is

substantiated by its absence from the upper 172 miles of river, and by its occurrence in lower numbers than the other two carpsuckers. Rafinesque (1820b) reported in his rather sweeping, and perhaps unreliable manner, that the highfin carpsucker was found "...as far as Pittsburgh." Bean (1892) also reported the highfin carpsucker as present in the Ohio River of Pennsylvania. If these early accounts are true, it would appear that the highfin was driven from the Ohio River above the Muskingum River by pollution before 1900, and has not returned.

Catostomus commersoni (Lacepede). Figure 71. The white sucker is common in the Ohio River above Louisville. The only record below ORM 626 is that of Electric Energy Inc. (1976) at ORM 952 in 1972-75. In the ORSANCO (1962) study of 1957-59 the white sucker was third in abundance amongst the suckers, and its distribution and abundance appear to be little changed since then. The white sucker was another species which Krumholz and Minckley (1964) found invading the Ohio River at ORM 32 from tributaries and backwaters following the prolonged steel strike of 1959 in which the steel mills of Pittsburgh were shut down, and pollution was drastically reduced.

Cycleptus elongatus (Lesueur). Type locality: Ohio River. Figure 72. The blue sucker was described in 1817 by Lesueur after a visit to Pittsburgh where Lesueur's specimens were probably collected (Raney 1938). The blue sucker has always been considered the best of the suckers, for eating, and was abundant in the early fish markets found in communities along the river. According to Smith (1979) the blue sucker has declined dramatically over most of its range, probably due to the interference of dams with spawning migrations, siltation of

preferred spawning and feeding substrates, and pollution. There have been only five records of blue sucker in the Ohio River between 1970 and 1982: Aquatic Control (1975) at ORM 560 in 1974; Kulik and Gammon (1978) at ORM 356 in 1975-77; U. S. Army Corps of Engineers (1980b) at ORM 744 in 1973-78; Geo-Marine (1982) at ORM 54 and 494 in 1981; and Geo-Marine (1983) at ORM 453 in 1982. In the period 1920-1969, 15 year-site collections were reported. In our opinion the blue sucker was probably a common fish of the Ohio River before 1850, declined rather dramatically between 1900 and 1950, continued its slow decline into the 70's, but may have increased in abundance after 1975. In 1980, commerical fishermen at ORM 964 told me (WDP) that they still caught a few "gourd seeds" each winter, but not as many as they did 20-30 years ago. Smith (1979) reports similar verbal accounts from fishermen on the Mississippi River of Illinois.

In September of 1981, I(WDP) examined three blue suckers which were found dead on the shore at ORM 604.6 at the Falls of the Ohio by Mr. Brainard Palmer-Ball, a student at the University of Louisville. Mr. Palmer-Ball selected the three specimens from a group of 15-20 which had been stranded in an isolated pool at the Falls following closure of the McAlpine Dam gates. While electrofishing in the same area in September 1981 and May 1982, students and I saw, but did not capture, what appeared to be two blue suckers approximately 50 cm total length. Finally, on May 11, 1982, Chris Holdren and I (WDP) captured a single adult blue sucker and saw two others at the Falls. We have subsequently captured, by electrofishing, 17 specimens below the Falls in the summer of 1983, and have on two separate dates in July 1983, counted 43 and 228 specimens stranded in pools below McAlpine Dam.

Erimyzon oblongus (mitchill). Figure 73. The creek chubsucker is usually found in small streams with gravel bottoms. Before 1880 the Ohio River may have had suitable shallow areas for this fish, but records since 1900 are almost certainly strays. Rafinesque (1818a) reported it from the Ohio River, as did Henshall (1889) at ORM 465, and Osburn (1901) at ORM 95 and 324. Trautman (1957) has discussed the questionable validity of these reports and their possible confusion with *E. sucetta*. Since Osburn's report there have been only two records, both in the lower Ohio River. Electric Energy Inc. (1976) reported two specimens at ORM 952 in 1975. The record by TVA (1976) at ORM 946 refers to the same specimen reported as *E. sucetta* by Hoyt (1979), who made the original collections and identifications. Personal communication with Hoyt and TVA personnel failed to resolve the discrepancy, and based upon other recent reports of *E. oblongus* near the Lower Ohio (Burr 1980) we agree with Hoyt's determination of *E. sucetta*. The ORSANCO (1962) records for this species were in tributaries at ORM 232 and 902, not in the Ohio River.

Erimyzon sucetta (Lacepede). Figure 74. The lake chubsucker is usually found in still waters, sloughs, and small lakes. The reports by Henshall (1889) and Osburn (1901) have been questioned by Trautman, but are, nevertheless, plotted on the distribution map. The records in ORSANCO (1962) at ORM 499 and 902 are from tributaries, not the Ohio River. The only recent, acceptable report is that of Hoyt (1979) at ORM 946 between 1974 and 1976.

Hypentelium nigricans (Lesueur). Figure 75. The northern hog sucker was first reported "below the Falls" at Louisville by Rafinesque (1820b), and was mentioned in the general works of Jordan (1891), Hay (1894), and Call (1896). It was probably much more common in the Ohio

River before navigation improvements removed or inundated the shallow riffle areas of the river. Between 1920 and 1969 it was found occasionally between ORM 172 and 630. Since 1969 it has been found more frequently, and its reported range has extended up the river to at least ORM 35 (Duquesne Light Co. 1977b, 1979b, 1980; WAPORA 1974c, 1974d, 1976a, 1978, 1979a, 1980a; Geo-Marine 1978; U. S. Army Corps of Engineers 1978b). These records probably reflect a return of this pollution-intolerant species, albeit in small numbers, to a portion of the river which has improved in quality since 1970.

Ictiobus bubalus (Rafinesque). Type locality: Ohio River. Figure 76. The smallmouth buffalo is probably the most abundant sucker in the Ohio River, and is certainly the most abundant of the buffalo fishes. It is found throughout the length of the river, but is most abundant below the Muskingum River. It does not appear to have increased in the upper river as pollution has abated, as many other fishes have, and it has not been reported above ORM 53. Raney (1938) reported that although Rafinesque (1820b) had stated that "it comes as far as Pittsburgh" it had not been seen there since. Trautman (1957), Smith (1979), and others have reported that commercial fishermen feel that the smallmouth buffalo declined in abundance during the late 1800's and the first half of this century. Speculative causes for the decline have included the building of navigation dams, siltation, pollution, and the introudction of the common carp.

Ictiobus cyprinellus (Valenciennes). Figure 77. The bigmouth buffalo is most abundant in the lower Ohio River. It is never as abundant as the smallmouth buffalo, and has been reported above ORM 200 only once (Preston 1979), at ORM 126 in 1978. Trautman (1957) related accounts

of fishermen catching bigmouth buffalo between ORM 40 and 179 before 1950, but we have not plotted these on the distribution map. Trautman (1957) and Smith (1979) both consider the bigmouth to be more tolerant of turbidity than the smallmouth buffalo, but its relative scarcity in the upper 200 miles of the river may indicate that it is less tolerant of pollution.

Ictiobus niger (Rafinesque). Type locality: Ohio River. Figure 78. The distribution of the black buffalo in the Ohio River is nearly identical to that of the smallmouth, although the black is much less common than either the smallmouth or bigmouth buffaloes. The black buffalo is most common in the middle third of the river. Before 1969 there was only a single record of this fish above ORM 150 (U.L. collection at ORM 112 in 1959). Actually, even this record is suspect since the specimen (U.L. #11002) is no longer available, and another specimen (U.L. #11285) from ORM 312 in the same year is clearly a misidentified *I. bubalus*. The single record at ORM 35 since 1970 is from Duquesne Light Co. (1977b) between 1970 and 1975.

Minytrema melanops (Rafinesque). Type locality: Ohio River. Figure 79. The spotted sucker is fairly common in the upper two-thirds of the Ohio River, and has been reported occasionally in the lower third. The large number of reports since 1970 may indicate that the spotted sucker is either holding its own or increasing in the Ohio River.

Moxostoma anisurum (Rafinesque). Type locality: Ohio River. Figure 80. Trautman (1957) considered the silver redhorse to be declining in abundance between 1900 and 1950 in Ohio, but an examination of the distribution map indicates that this species may have increased in

abundance since 1970. Between 1920 and 1969 specimens were known only between ORM 114 and 491, but since 1970 the known continuous range in the Ohio has expanded to between ORM 35 and 597, and there is one record at ORM 880 (Charles et al. 1979).

Moxostoma carinatum (Cope). Figure 81. The river redhorse has been collected throughout the length of the Ohio River, but is most commonly encountered in the middle third of the river. When the ORSANCO study was conducted in 1957-59, 40 river redhorse were found in 4 collections while only 11 silver redhorse were found in 3 collections. Since 1970 the river redhorse has appeared at slightly fewer collection sites than the silver redhorse.

Moxostoma duquesnei (Lesueur). Type locality: Ohio River at Pittsburgh. Figure 82. The black redhorse is thought to be intolerant of pollution and siltation, as is the river redhorse (Trautman 1957, Pflieger 1975, Smith 1979). Between 1920 and 1969 collections of this sucker were made at only four sites on the Ohio River between ORM 114 and 464. Since 1970 collections have been made at 22 sites between ORM 13 and 597.

Moxostoma erythrurum (Rafinesque). Type locality: Ohio River. Figure 83. The golden redhorse is certainly the most common redhorse in the Ohio River. It is found throughout the length of the river, but is most common in the middle third. Like the other redhorses, it seems to have been collected more frequently in the last decade than in the 1920-1969 period, particularly in the upper 100 miles of the river. The golden redhorse is usually considered the most pollution-tolerant member of the genus *Moxostoma*.

Moxostoma macrolepidotum (Lesueur). Figure 84. The shorthead redhorse is also distributed throughout the Ohio River, but is most frequently encountered between ORM 300 and 500. Between 1920 and 1969 it was not found above ORM 244. Since 1970 it has been found upstream as far as ORM 13, and its frequency of occurrence throughout the river seems to be increasing.

Moxostoma valenciennesi Jordan. The greater redhorse has been reported at ORM 463 in 1963 (Tebo 1965) and at ORM 336, 356, 377, 411, 416, 436, 470, and 500 between 1975-1977 by Kulik and Gammon (1978). Gammon (personal communication) has expressed doubts that the 1970's specimens were identified correctly and since the specimens are not available, and no other recent reports have been made, we can only conclude that the greater redhorse could only occur as a rare stray in the Ohio River. Most literature records of this species are from the Great Lakes area, and above the northern third of Illinois, Indiana, and Ohio (Lee et al. 1980).

Ictaluridae

Ictalurus catus (L.). Figure 85. The white catfish has been introduced to the upper Ohio River Basin from the eastern seaboard states. Pay-lake operators and catfish farmers have imported large numbers, particularly from Maryland, and some of these fish have escaped into other waters, including the Ohio River. The first report from the Ohio River was made in 1968 at ORM 54 (Preston 1969). Most of the subsequent records have been from the upper 300 miles of the river, but there is one record from ORM 721 (Clay 1975 - U.L. #1879). Whether these records represent an established and reproducing population is not known as yet.

Ictalurus furcatus (Lesueur). Figure 86. The blue catfish is characteristic of large rivers throughout the Mississippi drainage. It has been reported from the mouth of the Ohio up to ORM 54 (Geomarine 1978). Evermann and Bollman (1886) did report it from the Monongahela River. It appears to increase in abundance with distance below Pittsburgh, and is actually rare in the upper third of the river. There appears to have been little change in its distribution since 1970 although it has declined in abundance in the upper half of the river.

Ictalurus melas (Rafinesque). Type locality: Ohio River. Figure 87. The black bullhead is common throughout the length of the Ohio River. It was the second most abundant ictalurid, after *I. punctatus*, in the ORSANCO (1962) study. A comparison of the 1920-69 and 1970-80 periods indicates that the distribution seems to have shifted downstream. Before 1969, and particularly in the ORSANCO (1962) study, black bullheads were most abundant in the upper third of the river. Since 1969 more records have been reported in the lower half of the river, and relatively few records have been reported above ORM 400.

Ictalurus natalis (Lesueur). Figure 88. The yellow bullhead is also found throughout the length of the Ohio River. In the ORSANCO (1962) study the yellow bullhead seemed to be distributed rather evenly throughout the river, however, since 1970 there seem to be many more records in the upper 150 miles of the river.

Ictalurus nebulosus (Lesueur). Figure 89. The brown bullhead, like the black and yellow bullheads, is found throughout the length of the Ohio River. However, the brown seems to be less common in the lower half of the river than its two close relatives. The brown bullhead has

also shown a definite increase in the upper third of the river over the last 20 years. When the ORSANCO study was conducted in 1957-59, the black bullhead was roughly 10 times more abundant in the upper river. An examination of lock chamber studies conducted between 1967 and 1980 show that this situation has been reversed, and the brown bullhead is now the most abundant bullhead in the upper third of the river (Preston and White 1978), while the yellow bullhead has become second in abundance. The brown bullhead is usually considered to prefer clearer, more heavily-vegetated water than the black. We considered the possibility that the earlier identifications of black bullhead may have been in error, so in 1980 we examined approximately 20 collections of black bullhead (about 80 specimens) which had been preserved during the ORSANCO (1962) study in the upper Ohio River, with the aid of Dr. Branley A. Branson, and confirmed that they were indeed *I. melas*, although they showed some characteristics of *I. nebulosus*. Therefore, we can only conclude that there has been a shift in the bullhead population of the upper river from *I. melas* to *I. nebulosus*, perhaps in response to better water quality. Trautman (1981) in discussing a series of bullheads collected by H. Ronald Preston from the Ohio River, considered most specimens to be hybrids and backcrosses.

Ictalurus punctatus (Rafinesque). Type locality: Ohio River. Figure 90. The channel catfish is easily the most abundant and ubiquitous ictalurid in the Ohio River. It has been found in abundance throughout the river in all three time periods considered.

Noturus eleutherus Jordan. Figure 91. The mountain madtom is typically found in medium and large rivers. It has been collected sporadically

in the Ohio River on gravel deposits, and despite its rarity, is probably a permanent resident of the river. Older records are those of ORSANCO (1962) at ORM 114, 845, 877, and 973 between 1957 and 1959. There are only three records since 1969: Hoyt (1979) at ORM 946, Neff et al. (1981) at ORM 961 in 1980; and Geo-Marine at ORM 453 and 494 in 1981.

Noturus flavus Rafinesque. Type locality: Ohio River. Figure 92. The stonecat is an inhabitant of small and medium-sized rivers and streams. It was probably much more abundant on the "rapids" of the Ohio River before impoundment (three localities are known before 1900). Today it probably occurs in the Ohio River only as strays. The six records since 1970 are from ORSANCO (1981) at ORM 13, 54, and 126; Duquesne Light Co. (1977a) at ORM 34; Hoyt (1979) at ORM 946; and Geo-Marine (1982) at ORM 77 and 260.

Noturus gyrinus (Mitchill). Figure 93. The tadpole madtom has been found occasionally in the lower half of the Ohio River. Only one record is known above ORM 530 (ORSANCO 1962, at ORM 114 in 1959). The tadpole madtom is usually found in smaller, quiet streams, and individuals found in the Ohio are probably strays.

Noturus miurus Jordan. Figure 94. The brindled madtom is fairly common in small tributaries all along the Ohio River, and is occasionally found in the river as stray individuals.

Noturus nocturnus Jordan and Gilbert. Figure 95. The freckled madtom is usually found in medium-sized rivers of the lower Mississippi drainage basin, and up the Ohio River basin only into Indiana and Kentucky. Three reports (probably all as strays from tributaries) are known: Hay (1894) at ORM 792; Smith (1979) at ORM 962; and Electric Energy Inc.

(1976) at ORM 952.

Noturus stigmosus Taylor. Figure 96. The northern madtom is rare in medium-sized streams all along the Ohio River, and has been collected just twice in the river: Clay (1975) at ORM 663 in 1957 (U.L. #8954); and Hoyt (1979) at ORM 946 in 1974-76.

Pylodictis olivaris (Rafinesque). Type locality: Ohio River. Figure 97. The flathead catfish is found throughout the length of the Ohio River, although it is only occasionally taken in the upper 150 miles. It is probably third in abundance amongst the ictalurids, behind the channel and blue catfishes. There seems to have been no major change in its distribution during the three time periods considered.

Aphredoderidae

Aphredoderus sayanus (Gilliams). Figure 98. The pirate perch is usually found in quiet, vegetated waters. It has been found occasionally in the lower Ohio River (below ORM 720) where it probably occurs as escapees from floodplain sloughs and creek mouths. Geo-Marine (1982) reported a specimen at ORM 543 in 1981.

Percopsidae

Percopsis omiscomaycus (Walbaum). Figure 99. The trout-perch is a rare inhabitant of small and medium-sized streams to the north of the Ohio River above ORM 600. Before 1900 it may have been a permanent inhabitant of the rocky riffles of the upper Ohio, but since impoundment of the river it probably occurs only as a stray. The records below ORM 320 are from Hay (1894) who cites Jordan at ORM 605; and Tebo (1965) at ORM 463 in 1963. The appearance of this inhabitant of clear waters in

the upper 100 miles of the Ohio since 1970 attests, once again, to the improved water quality of the upper river.

Gadidae

Lota lota (L.). Figure 100. The burbot is usually considered to inhabit deep, clear, and cold lakes or larger, cold rivers. Records from the Ohio River represent the southernmost extension of the range for this species. Jordan (1888 and 1891) reported it from the Ohio at ORM 608. Forbes and Richardson (1920) claim it was "...occasionally taken in the Ohio...." before 1900, but did not report any specimens seen by themselves. Clay (1975) identified the photo of a fish taken at ORM 663 in 1953 as a burbot, and reported three specimens captured in 1960 at ORM 480. Trautman (1957) expressed the opinion that the burbot has probably never been established in the Ohio River, and that the records of Jordan (1891) and Forbes and Richardson (1920) were probably based upon strays which found their way down the upper Mississippi River and into the Ohio. The more recent records of Clay probably represent escaped individuals from pay-to-fish lakes, which are commonly stocked with mixtures of wild fish seined in Michigan and the northern regions of Indiana and Ohio.

Cyprinodontidae

Fundulus diaphanus (Lesueur). Figure 101. The banded killifish was introduced from the Atlantic coast drainage of Pennsylvania into the upper Ohio River drainage of Pennsylvania before 1938 (Raney 1938). Trautman (1957) mentions a letter in which E. C. Raney told him of finding the banded killifish in the Ohio River (ORM 28) in 1942. Apparently

the banded killifish is now well-established in tributaries of the Ohio River above ORM 300, and it has been reported as strays between ORM 13 and ORM 260 many times. The records at ORM 260 are from WAPORA (1974a, 1980a) in 1973 and 1979.

Fundulus heteroclitus (L.). The only known record of the mummichog in the Ohio River is that of E. C. Raney, cited in Trautman (1957). Raney found the mummichog at ORM 28 in 1942 together with the banded killifish (see above), both having been introduced to the area from the Atlantic coast drainage of Pennsylvania. The mummichog has not been reported since in the Ohio River, and apparently did not succeed in establishing itself, as did the banded killifish.

Fundulus notatus (Rafinesque). Figure 102. The blackstripe topminnow is usually found in small, slow-moving streams, or in sloughs and backwaters. It occasionally strays into the Ohio River, particularly in the lower third of the river. The only two records in the upper river are both at ORM 54 by WAPORA (1974a), and U.L. #1738 which was collected at New Cumberland Lock and Dam, and may be the same specimen reported as *F. diaphanus* by Preston and White (1978). Unfortunately, the specimen cannot be located. The specimens reported in ORSANCO (1962) were all from tributaries, not the Ohio River.

Fundulus olivaceus (Storer). The only acceptable record of the blackspotted topminnow in the Ohio River is that of Smith (1979) at ORM 940 (location verified by Page 1980). The record by ORSANCO (1962) at ORM 942 in 1957 was from a tributary to the Ohio. The mouth of the Ohio River is near the northernmost extent of the natural range of this fish.

Poeciliidae

Gambusia affinis (Baird and Girard). Figure 103. The mosquitofish is usually found in ponds, roadside ditches, and sloughs. The lower third of the Ohio River represents the limit of its natural range into the Ohio River basin, although it has been stocked to the north and east of this area for mosquito control. All records are below mile 596, and probably represent strays from adjacent waters. All of the ORSANCO (1962) records were from tributaries, not the Ohio River.

Atherinidae

Labidesthes sicculus (Cope). Figure 104. The brook silverside is found in small and medium-sized streams throughout most of the Ohio River basin, and is occasionally found in the river itself. An active, schooling species, this fish may move purposefully between tributaries and the mainstem in response to local conditions. Before 1968 all records were from below ORM 870, except for Call's (1896) record at Louisville. Since 1968, all records have been in the upper 260 miles of the river, where cleaner waters may have encouraged movement from tributaries into the Ohio mainstem. The ORSANCO (1962) record at ORM 975 was from a tributary, not the Ohio River.

Percichthyidae

Morone chrysops (Rafinesque). Type locality: Ohio River. Figure 105. The white bass is found throughout the length of the river, but is most commonly encountered below ORM 300. There seem to have been many more locality records in the middle river since 1970 than before 1970, but this may be due to the increased use of boat-mounted electrofishing

gear in recent years, a type of gear to which the white bass is particularly susceptible. On the other hand, Pflieger (1975) reports that the white bass has increased in the Mississippi River since impoundments have reduced turbidity, and the turbidity of the Ohio has declined since 1970 as well.

Morone mississippiensis Jordan and Eigenmann. Figure 106. The yellow bass is restricted to the lower half of the Ohio River, and is most frequently encountered in the last 100 miles of the river. It is much less common than the white bass. Although there are more records for the fish since 1970 than before 1970, as in the case of the white bass, this may reflect increased usage of electrofishing boats by collectors, rather than a change in abundance. The record at ORM 490 is from WAPORA (1976b). The three records at or just below Louisville (ORM 610, 617, and 626) are from Dames and Moore (1975c, 1976c). Jordan (1882) was the first to mention yellow bass in the Ohio River: "...extending up the Ohio to the mouth of the Wabash or beyond."

Morone saxatilis (Walbaum). Figure 107. The striped bass has been stocked in the larger impoundments of Kentucky since 1957 (Clay 1975). Beginning in 1967 is has also been stocked in the Ohio River of Kentucky (Axon et al. 1980) and West Virginia (U. S. Nuclear Reg. Comm. 1977). Occasional individuals from these stockings have been captured and reported, beginning in 1975 (Kulik and Gammon 1978; Hoyt 1979; Preston 1979; Smith 1979; WAPORA 1980; Neff et al. 1981; Trautman 1981). Commercial fishermen at Dam #53 told me (WDP) in the summer of 1980 that they have been able to catch large striped bass with hook-and-line gear every spring since 1975 in the fast water below the dam. In the summer of 1983, I (WDP) electrofished 14 specimens (all less than 200 mm TL) at the Falls of the Ohio at Louisville.

Centrarchidae

Ambloplites rupestris (Rafinesque). Figure 108. The rock bass has occasionally been reported in the upper two-thirds of the Ohio River, and rarely in the lower third. The only discernible trend on the distribution map is the increase in the number of records reported above ORM 80 since 1970.

Centrarchus macropterus (Lacepede). Figure 109. The flier is usually considered an inhabitant of clear, heavily-vegetated, still waters. In the Ohio River Basin it is found in sloughs, oxbow lakes, and standing waters on the floodplains of large streams in the western third of the basin. Jordan (1878) reported it in the "lower Ohio". The only other records are all below ORM 845 since 1957 (ORSANCO 1962, ORM 877; U. L. #1885, ORM 846; Electric Energy Inc. 1976, ORM 952; Hoyt 1979, ORM 946; and Starnes 1980, ORM 968). These reports probably represent strays from lentic floodplain waters.

Lepomis cyanellus Rafinesque. Type locality: Ohio River. Figure 110. Although the green sunfish is usually found in smaller streams and ponds, it is regularly reported from the Ohio River, and many individuals are probably permanent residents of the river. It has been found throughout the length of the river. There are no evident changes in its distribution or abundance in the river since 1970.

Lepomis gibbosus (L.). Figure 111. The pumpkinseed is usually found in lakes, ponds, and clear, well-vegetated backwaters. It is fairly common in the upper third of the Ohio River, occasional in the middle third, and only a few strays enter the lower third. All of the small-open-circle records between ORM 499 and 529 represent specimens

taken in embayments by Lockard (1966). It appears that the creation of the many embayments in the upper half of the river by the construction of the high-lift dams in the 1960's and 1970's, provided habitats favorable to the pumpkinseed at least as far downstream as Markland Dam (ORM 531.5). Therefore, it appears that the records below ORM 400 are not the result of stockings (Burr 1980), but strays from the embayments. The extreme downstream record (ORM 754) is from Dames and Moore (1976a).

Lepomis gulosus (Cuvier). Figure 112. The warmouth is found throughout the Ohio River, but is most frequently encountered in the lower two-thirds. Although it is usually found in smaller rivers, lakes and ponds, it is encountered often enough in the Ohio to be considered a permanent resident. Many more records have been made in the middle third of the river since 1970 than before 1970 but it is unclear if this is a result of larger numbers of fish in the river or a greater number of investigators working on the river with gear more efficient for collecting this species (i.e., electrofishing gear).

Lepomis humilis (Girard). Figure 113. The orangespotted sunfish is also found throughout the length of the Ohio River, but never in large numbers. Although the overall distribution center of the species lies to the west of the Ohio River, the species seems to be encountered most frequently (after 1970 at least) in the upper 150 miles of the river.

Lepomis macrochirus Rafinesque. Type locality: Ohio River. Figure 114. The bluegill is distributed throughout the length of the Ohio River, and is the most common centrarchid in the river. It may be most abundant in the middle third of the river, responding to the creation of the embayment habitat in much the same manner as the pumpkinseed.

Lepomis megalotis (Rafinesque). Figure 115. The longear sunfish is the second most abundant centrarchid in the Ohio River. It is found throughout the length of the river, but is most often encountered in the lower and middle thirds. The number of reports of this species in the middle third of the river, near the embayments, increased dramatically after 1970.

Lepomis microlophus (Günther). Figure 116. The redear sunfish is taken only occasionally in the Ohio River. It has been reported from each 100-mile segment of the river between ORM 13 and 952. Unlike the bluegill, longear, pumpkinseed, and other sunfishes, it does not appear to have increased since the creation of embayments in the upper half of the river.

Micropterus dolomieui Lacepede. Figure 117. The smallmouth bass prefers clear, flowing streams with gravel bottoms. It was probably more abundant in the Ohio River before impoundment, but it is now the least abundant of the three basses in the river. It has been reported between ORM 13 and 952, but is most abundant in the upper two-thirds of the river. Records since 1970 indicate that it is particularly abundant between ORM 350 and 500, but this may be an artifact resulting from the large amount of electrofishing effort expended in this section of the river between 1975 and 1977 (Kulik and Gammon 1978).

Micropterus punctulatus (Rafinesque). Type locality: Ohio River. Figure 118. The spotted bass is usually found in larger, slower, and more turbid streams than the smallmouth, and was probably the most abundant of the three basses in the Ohio River at the time of Rafinesque. It has commonly been reported throughout the length of the Ohio River

both before and after 1970. At present it is only slightly less abundant than the largemouth bass, the latter species having been favored in the habitat alterations associated with impoundment of the river.

Micropterus salmoides (Lacepede). Figure 119. The largemouth bass probably became the most abundant of the *Micropterus* in the Ohio River before 1950, following the completion of the original set of 46 navigation dams in 1937. The largemouth bass is found in almost any aquatic habitat within its range, but seems to favor large, still waters. In the Ohio River it is commonly found from Pittsburgh to Cairo. On the distribution map it appears to have been most common after 1970 in the middle third of the river, an impression which may be due to the favorable embayment habitat created there, to increased use of electrofishing gear in the area, or both.

Pomoxis annularis Rafinesque. Type locality: Ohio River. Figure 120. The white crappie is common throughout the length of the Ohio River. It is probably the third most abundant centrarchid (after the bluegill and longear sunfish) in the river, and has demonstrated no obvious changes in distribution since 1970.

Pomoxis nigromaculatus (Lesueur). Figure 121. The black crappie, which is usually considered to prefer clearer waters than the white crappie, is only slightly less abundant than the white crappie in the Ohio River. It is found throughout the length of the river and there have been no obvious changes in its distribution in the river since 1970.

Percidae

Ammocrypta asprella (Jordan). Figure 122. Known from only two

locations on the Ohio River (ORM 327, Osburn 1901; and ORM 506, Jordan 1899) before 1900. The crystal darter apparently prefers large river habitats with expanses of clean sand and gravel. This type of habitat has been almost eliminated by human activity in the Mississippi River Basin, and hence the crystal darter has been classified as of "special concern" by Deacon et al. (1979), and is considered extirpated in Illinois (Smith 1979), Kentucky (Burr 1980), and Ohio (Trautman 1957 and 1981). The chances of this species being in the Ohio River of today seem remote at best.

Ammocrypta pellucida (Putnam). Figure 123. The eastern sand darter requires large expanses of clean sand and gravel, a type of habitat which became much less available in the Ohio River, as well as throughout the range of the species, after 1900. The earlier records on the distribution map are from Call (1896) and Trautman (1957). The single record at ORM 260 in 1977 is from WAPORA (1978). Deacon et al. (1979) considered the eastern sand darter to be of "threatened" status.

Etheostoma asprigene (Forbes). The only accepted record is that of Forbes and Richardson (1920) at ORM 979 (as *E. jessiae*). The mud darter is found, rarely, in sloughs on the floodplains of the Mississippi River and its larger tributaries near their mouths. Smith (1979) reports it from several sloughs and creek mouths near the lower Ohio River. The records in ORSANCO (1962) were all from tributaries between ORM 890 and 902, not the Ohio River.

Etheostoma blennioides Rafinesque. Type locality: Falls of the Ohio River. Figure 124. The greenside darter is usually found in medium-sized streams with swift, clear water running over coarse gravel-

rubble riffles. These conditions were certainly present in the Ohio River of Rafinesque's day, but no more. Therefore, the few records between 1920 and 1969 in the lower half of the river probably represent individuals straying from tributary streams. Only one of the ORSANCO (1962) records was taken from the Ohio River (at ORM 903 in 1959) rather than tributary streams. Since 1970, specimens have been reported at eight locations, all above ORM 453. This upstream shift in records probably resulted from improved water quality in the upper river, which encourages occasional individuals to stray into the river from tributaries.

Etheostoma caeruleum Storer. Figure 125. The rainbow darter occurs in the Ohio River only rarely, as stray individuals from small tributaries. It has been reported only between ORM 54 and 518.

Etheostoma flabellare Rafinesque. Figure 126. The fantail darter is one of the most common darters in small streams all along the Ohio River, but it is rarely encountered, as strays, in the Ohio mainstem. It has been reported between Louisville (Rafinesque 1820b, Call 1896, ORSANCO 1962, Trautman 1981) and ORM 54.

Etheostoma kennicotti (Putnam). The stripetail darter has been reported from just one location (ORM 607) on the Ohio River in 1957 (ORSANCO 1962). There are two other collections in the ORSANCO (1962) report, at ORM 902 and 898, but they are both from tributaries.

Etheostoma nigrum Rafinesque. Figure 127. The johnny darter is widely distributed in small streams all along the Ohio River, but particularly those along the upper two-thirds of the river. Individual specimens have been reported between ORM 13 and 605. None of the

specimens reported in ORSANCO (1962) were taken from the Ohio River mainstem. Since 1970 most of the reports have come from the upper 300 miles of the river, another reflection of more favorable water quality conditions.

Etheostoma spectabile (Agassiz). Figure 128. The orangethroat darter is usually found in very small streams along the lower two-thirds of the Ohio River valley (Trautman 1957, Clay 1975, Lee et al. 1980). However, the only two reports of this species straying into the Ohio River are by WAPORA (1979a and 1980b) at ORM 54 and 77.

Etheostoma variatum Kirtland. Figure 129. The variegate darter is occasional in small to medium-sized tributaries of the upper two-thirds of the Ohio River. It has been reported from the river by Woolman (1892) at ORM 605, and by Osburn (1901) at ORM 98. Geo-Marine (1982) reported specimens at ORM 54, 77, and 494 in 1981.

Etheostoma zonale (Cope). Figure 130. The banded darter is usually found in riffle areas of medium-sized streams. Since 1970 it has been reported from five localities in the upper Ohio River (ORM 34, 54, 77, 260, and 494) by Duquesne Light Co. (1980), WAPORA (1977a, 1980a), and Geo-Marine (1982). The ORSANCO (1962) record at ORM 499 was from a tributary. The appearance of these recent strays in the upper river probably reflects both increased collector efforts and better water quality.

Perca flavescens (Mitchill). Figure 131. The yellow perch has been collected occasionally in the upper two-thirds of the Ohio River since at least 1878. Jordan (1878) mentioned its presence in the Ohio River of Indiana, and Call (1896) recorded it at the Falls near Louisville.

Trautman (1957) agrees with Kirtland's earlier conclusions that the yellow perch found its way from the Great Lakes to the upper Ohio River through the many connecting canals constructed before 1825. After 1900 yellow perch were also stocked in many lakes, ponds, and streams adjacent to the upper Ohio River. Reports of larval perch in the upper Ohio River (i.e., Duquesne Light Co. 1977a; WAPORA 1977a; Evans and Tarter 1977; Geo-Marine 1978, 1983) indicate a reproducing population.

Percina caprodes (Rafinesque). Type locality: Ohio River. Figure 132. Rafinesque found the logperch or "hogfish" to be "the most common species" of all the darters in the Ohio River, and so it probably still is today, although, relative to other fishes, it can only be said to be found occasionally. It seems to be distributed from Pittsburgh to Cairo, although it is slightly more abundant in the middle third of the river.

Percina copelandi (Jordan). Figure 133. The channel darter is typically found on clean sand and gravel bars in larger tributaries of the Mississippi River below Wisconsin (Lee et al. 1980). Trautman (1957) expressed the opinion that the channel darter should have been present in the riffles of the Ohio River before 1900, but he could find no records. He did report populations in the Muskingum River from its mouth at ORM 172 upstream, and in several other tributaries between ORM 276 and 490. The first specimens from the Ohio River were reported in 1976 (Duquesne Light Co. 1977a, at ORM 35; and Preston 1979, at ORM 126). Additional specimens have subsequently been reported by Equitable Environmental Health (1979b) at ORM 15, Preston (1979) at ORM 279, WAPORA (1980a) at ORM 54 and 260, and Geo-Marine (1983) at ORM 77 and 494. Apparently, as water quality in the upper Ohio River improved in the 1970's, the channel darter

strayed from the Muskingum River, and other sanctuaries, back onto the remaining sand and gravel substrates in the upper Ohio River.

Percina evides (Jordan and Copeland). An inhabitant of smaller streams, the gilt darter has been reported just once from the Ohio River at ORM 276 in 1888 (Henshall 1889). If it exists in the river of today it would only be as a rare stray.

Percina macrocephala (Cope). Jordan (1878) reported the longhead darter as being in the Ohio River of Pennsylvania, but it is not clear if this general statement was backed by actual specimens. It has been found in tributaries of the Ohio River in Pennsylvania, Ohio, West Virginia, and Kentucky, but usually at some distance above the mouths of the tributaries (Lee et al. 1980).

Percina maculata (Girard). Figure 134. The blackside darter is customarily found in the pools of small streams, but there are three records of strays in the Ohio River at ORM 98 (Osburn 1901), and ORM 204 and 877 (Preston 1979). The ORSANCO (1962) records were all from tributaries between ORM 499 and 910, not the Ohio River mainstem.

Percina sciera (Swain). Figure 135. The dusky darter is usually found in medium to large rivers in the lower Mississippi River drainage. It is found occasionally in tributaries all along the Ohio River, but there are only two records of strays in the Ohio River proper: Henshall (1889) at ORM 337 in 1888 and ORSANCO (1962) at ORM 963 in 1957. The ORSANCO record at ORM 902 in 1957 was from a tributary, not the Ohio River.

Percina shumardi (Girard). Figure 136. The river darter is usually found in deep, swift chutes of medium to large streams. It may have been a permanent resident of the Ohio River before 1850, but since 1900 it has rarely been collected. Trautman (1957) reports three records between ORM 94 and 325 before 1900, and one at ORM 491 between 1920 and 1950. The records at ORM 597-598 and 606 are from ORSANCO (1962) in 1957 and 1959 and Williams (1963). Since 1970 there have been eight additional reports: at ORM 54 (Geo-Marine 1982), at ORM 260 (Geo-Marine 1983), at ORM 395 (U. S. Army Corps of Engineers 1978d), at ORM 494 (WAPORA 1978, 1979a, 1980a), at ORM 946 (Hoyt 1979), and at ORM 952 (Electric Energy Inc. 1976).

Stizostedion canadense (Smith). Figure 137. The sauger is common throughout the length of the Ohio River where it is known to many fishermen as the jack salmon. There have been far more reports of sauger since 1970 than before, particularly in the middle third of the river. Before 1970 the sauger was only occasionally taken in the upper 200 miles of the river, but since 1970 it has become more abundant in that region.

Stizostedion vitreum (Mitchill). Figure 138. The walleye is also distributed throughout the length of the Ohio River, but has, apparently, always been less abundant than the sauger. The walleye has continued to decline relative to the sauger since 1970. In the river-wide ORSANCO study of 1962, only three sauger were captured for each walleye taken. In recent studies, conducted at ORM 570-580, and 918-981, we have typically taken 30-50 sauger for each walleye captured. A comparison of the number of locality reports for the sauger between 1920-69 and 1970-80 shows an increase from 42 to 99, respectively, while a similar comparison for the walleye shows a decrease from 33 to just 26. Although

the walleye is by no means rare in the Ohio River of today, it does seem to be declining steadily.

Sciaenidae

Aplodinotus grunniens Rafinesque. Type locality: Ohio River. Figure 139. The freshwater drum is found from Pittsburgh to Cairo, as it was in the days of Rafinesque. It is common everywhere in the river, although there are noticeably fewer records in the upper 200 miles of the river. There have been no definite changes in distribution between the three time periods considered, excepting, possibly, a slight encroachment into the upper 50 miles of the river after 1970.

Cottidae

Cottus carolinae (Gill). Figure 140. The banded sculpin is usually found in smaller, lowland streams, and probably occurs in the Ohio River only as a rare stray. Records on the map are from Jordan (1878) for "the Ohio River of Indiana", Call (1896) at ORM 605, ORSANCO (1962)at ORM 660, and Smith (1979) at ORM 921 in 1963.

Fishes Which Could Occur In The Ohio River

Many of the 154 species of fish which have been reported from the Ohio River, as defined and accepted by us in the preceeding section, are species which usually complete their life cycles in smaller streams, sloughs, oxbow lakes, or other aquatic habitats, and have been found only occasionally in the Ohio River after straying into the river, drifting into the river while dead or moribund, being driven into the river by floods, pollution, or dewatering of the preferred habitat, after being

stocked in the river or nearby waters, or by other imaginable events.

Therefore, it is certainly conceivable that any species of fish which has been reported from waters near the Ohio River could eventually be found in the mainstem. We prepared a list of fishes which have been reported from waters within 50-100 miles of the Ohio River (based largely upon the distributions reported by Gerking 1945, Trautman 1957, ORSANCO 1962, Clay 1975, Pflieger 1975, Smith 1979, Burr 1980, and Lee et al. 1980), and divided the fish on the list into two categories: A) those deemed likely to occur in the Ohio River, and B) those for which occurrence in the Ohio River seems to be possible but unlikely.

An annotated list of fishes likely to occur in the Ohio River

Acipenseridae

Scaphirhynchus albus (Forbes and Richardson): The pallid sturgeon has been found in the Mississippi River above and below the Ohio River mouth since 1950 (Pflieger 1975, Smith 1979). It is a large-river species and probably strays into the lower portion of the Ohio River.

Salmonidae

Salvelinus fontinalis (Mitchill). The brook trout has been stocked extensively in small tributaries of the Ohio River in Pennsylvania, eastern Ohio, and western West Virginia. Like the rainbow and brown trouts, it should eventually be recorded as an introduced stray in the upper 150 miles of the Ohio River.

Umbridae

Umbra limi (Kirtland). The central mudminnow has been reported from sloughs and sluggish tributaries near the Ohio River in southern

Illinois, western Kentucky, and the upper 100 miles of the river in Ohio and Pennsylvania. It could occur as a stray in the Ohio River.

Esocidae

Esox niger Lesueur. The chain pickerel has been found in oxbow lakes along the lower 100 miles of the Ohio River in Illinois and Kentucky. Although rare, it could easily find access to the Ohio mainstem.

Cyprinidae

Hybognathus argyritis Girard. The western silvery minnow has been collected in the Missouri River and in the Mississippi River downstream to a point just a few miles above the Ohio River mouth. It is a riverine species which could easily stray into the lower end of the Ohio River.

Hybognathus placitus Girard. The plains minnow, is, like *H. argyritis*, found in the Missouri River and down the Mississippi. It has been found in the Mississippi River at Cairo, Illinois, and very likely occurs in the lower end of the Ohio River.

Hybopsis gelida (Girard). The sturgeon chub is also a riverine species found in the Missouri River, which is also found down the Mississippi River to about the mouth of the Ohio River. It may enter the lower few miles of the Ohio River.

Hybopsis gracilis (Richardson). The flathead chub, like the above three minnows, is found in the Missouri River, and down the Mississippi. The flathead chub, however, is found below the mouth of the Ohio River as well. Pflieger (1975) makes the point that these four species do not ascend the Mississippi River above the Missouri River mouth, an indication that they prefer turbid waters. The Ohio River is much clearer at

its mouth than the combined Mississippi-Missouri waters into which it empties, and hence, these four species may also be reluctant to enter the Ohio.

Notropis ardens (Cope). The rosefin shiner is found in abundance in many small tributary streams close to the Ohio River between ORM 300 and 700. It surely strays occasionally into the Ohio River.

Notropis texanus (Girard). The weed shiner has been found in tributaries of the Wabash and Mississippi rivers near the Ohio River. A definite locality for the ORSANCO (1962) specimen could not be determined, but was probably a tributary between ORM 850 and 981.

Atherinidae

Menidia beryllina (Cope). The inland silverside has been reported from the Mississippi River just below the mouth of the Ohio River, and from streams emptying into the Mississippi River in western Kentucky. It will probably be found in the lower Ohio River.

Centrarchidae

Lepomis punctatus (Valenciennes). The spotted sunfish is found in bottomland lakes and sloughs near the Ohio River in Illinois and western Kentucky. It probably finds its way from these habitats into the lower Ohio River (ORM 850-981) at high water periods.

Percidae

Etheostoma camurum (Cope). The bluebreast darter is still found occasionally in larger tributaries of the Ohio River between ORM 50 and 700, sometimes fairly close to the mainstem. Trautman (1957) believed it was probably in the Ohio River before 1900, and it may yet turn up

as a stray.

Etheostoma chlorosomum (Hay). The bluntnose darter is common in small tributaries near the Ohio River of Illinois. It probably strays into the river between ORM 800 and 981.

Etheostoma gracile (Girard). The slough darter is commonly found in small tributaries of the lower Ohio River in both Illinois and Kentucky. The ORSANCO (1962) records (3) for this fish were all from tributaries between ORM 898 and 942. This fish could occur, as strays, between ORM 800 and 981.

Etheostoma proeliare (Hay). The cypress darter is occasionally taken in bottomland lakes and sloughs bordering the Ohio River between ORM 850 and 981. The ORSANCO (1962) record was from a tributary at ORM 898. It could stray into the Ohio River.

Etheostoma squamiceps Jordan. The spottail darter is abundant in several small tributaries to the Ohio River between ORM 800 and 981, as well as in the upper Green River drainage (Smith 1979, Burr 1980). The ORSANCO (1962) reports were from tributaries at ORM 898 and 902. Although this is a small-stream species it probably strays into the Ohio River occasionally.

Percina phoxocephala (Nelson). The slenderhead darter is found in small tributaries near the Ohio River between ORM 165 and 981. The ORSANCO (1962) record was from a tributary at ORM 499.

Cottidae

Cottus bairdi Girard. The mottled sculpin can be found in small

tributaries of the Ohio River between ORM 0 and 633, often close to the tributary mouth. The locality of the ORSANCO (1962) specimen could not be determined, but was probably a tributary.

An annotated list of fishes whose occurrence in the Ohio River is possible but unlikely

This list includes species which have been reported within 50-100 miles of the Ohio River, but because of habitat requirements, rarity, and/or a lack of recent reports, we consider the likelihood of their being in the Ohio River less than that of fishes on the previous annotated list.

Petromyzontidae

Ichthyomyzon fossor Reighard and Cummins. The northern brook lamprey is an uncommon, headwater inhabitant of the Ohio River Valley.

Ichthyomyzon gagei Hubbs and Trautman. The southern brook lamprey was listed from the Ohio River in Tennessee Valley Authority 1976, at ORM 946. However, these were the same specimens Hoyt (1979) reported as *I. greeleyi*, and which Burr (1980) concluded were *I. castaneus*. The southern brook lamprey is known, in the Ohio River basin, only from the Tennessee River system in the extreme southwestern portion of the basin, where it is uncommon.

Ichthyomyzon greeleyi Hubbs and Trautman. The mountain brook lamprey has been reported from the Ohio River (Hoyt 1979; see above species account), but the identification has been questioned. This species is an uncommon, headwater inhabitant at scattered locations in the Ohio River Valley.

Osmeridae

Osmerus mordax (Mitchill). The rainbow smelt has recently (1978 and 1979) been captured in the Mississippi River both above and below the mouth of the Ohio River (Burr 1980).

Cyprinidae

Campostoma oligolepis Hubbs and Greene. The largescale stoneroller seems to favor large to medium, turbid streams. It has been reported from tributaries of the Mississippi River within 50 miles of the Ohio River mouth (Lee et al. 1980).

Clinostomus funduloides Girard. The rosyside dace is typically an upland species. It has been reported near the Ohio River in both Ohio and northeastern Kentucky, but is apparently rare in these locations (Trautman 1957, Clay 1975, Lee et al. 1980).

Exoglossum laurae (Hubbs). The tonguetied minnow is known from three widely-scattered, upland populations in the Ohio River basin. The population closest to the Ohio River mainstem (in Ohio) has declined markedly in the last 30 years (Lee et al. 1980).

Notropis amnis Hubbs and Greene. The pallid shiner is a very rare species, formerly in small tributaries of the lower third of the river. In recent years it has declined almost to extinction in the northern part of its range (Pflieger 1975).

Notropis ariommus (Cope). The popeye shiner is an uncommon resident of upland streams at several scattered locations throughout the Ohio River basin. Gilbert (1981) has suggested that the records of *Notropis boops* in the Ohio River of Pennsylvania may be based upon this species.

Notropis chalybaeus (Cope). The ironcolor shiner has been found within 50 miles of the mouth of the Ohio River in southeastern Missouri. It is a lowland species, found in slow-moving, vegetated streams and ditches (Pflieger 1975).

Notropis galacturus (Cope). The whitetail shiner is an upland species reported from the upper reaches of southern tributaries of the Ohio River in southern Kentucky. The record for this species in ORSANCO (1962) was for specimens from Grand Pierre Creek in Pope County, Illinois (ORM 898 in 1957). The specimens could not be located, and may have been misidentified *N. spilopterus*

Notropis hubbsi Bailey and Robison. The bluehead shiner is known from tributaries of the Mississippi in southern Arkansas, and was formerly known from a floodplain lake in southern Illinois. The Illinois population may have been extirpated (Smith 1979) and the chances of this fish being found in the Ohio River are remote at best.

Notropis zonatus (Putnam). The bleeding shiner has been reported in tributaries of the Mississippi River in Missouri above the mouth of the Ohio River.

Rhinichthys cataractae (Valenciennes). The longnose dace is common in the center of its distribution in southern Canada and the northern tier of states in the United States, but has been reported only occasionally in the Ohio River basin; always in small, upland streams. Most of the records are from before 1900, and it seems unlikely that this species will be found in the Ohio River.

Catostomidae

Lagochila lacera Jordan and Brayton. The harelip sucker was collected at scattered localities in the Ohio River basin before 1900. It is now considered extinct.

Ictaluridae

Noturus exilis Nelson. The slender madtom is rare in smaller tributaries of the lower half of the Ohio River.

Cyprinodontidae

Fundulus catenatus (Storer). The northern studfish has been reported in the headwaters of the Wabash, Salt, Tennessee, Cumberland, Green, and Barren rivers (Burr 1980, Lee et al. 1980). It is fairly common and could occur in the Ohio River, although there are no records within 30-40 miles of the river.

Fundulus notti (Agassiz). The starhead topminnow has been found in a few clear, well-vegetated floodplain lakes in southern Illinois and western Kentucky near the Ohio River (Clay 1975, Smith 1979, Burr 1980).

Gasterosteidae

Culaea inconstans (Kirtland). The brook stickleback can be found in northern and central Ohio in small, cool streams (Trautman 1957). It appears to have declined in abundance since 1900, and would be an unlikely inhabitant of the Ohio River even as a stray.

Centrarchidae

Elassoma zonatum Jordan. The banded pygmy sunfish is found in floodplain lakes and streams of southern Illinois and western Kentucky (below the mouth of the Wabash: Clay 1975, Smith 1979). Its exacting

habitat requirements are not met in the lower Ohio mainstem, but it may stray into the river under unusual conditions.

Lepomis symmetricus Forbes. The bantam sunfish is found in the floodplain lakes of southern Illinois and western Kentucky below ORM 850. It is uncommon and an unlikely inhabitant of the Ohio River.

Percidae

Ammocrypta clara Jordan and Meek. The western sand darter has been reported from the western tip of Kentucky as recently as 1940 (Clay 1975), but its increasing rarity in the Ohio River drainage probably precludes its occurrence in the Ohio River mainstem.

Etheostoma exile (Girard). The Iowa darter has been recorded in headwaters of Ohio River tributaries in Ohio (Trautman 1957), but at over 50 miles from the Ohio River proper.

Etheostoma histrio Jordan and Gilbert. The harlequin darter is very rare in western Kentucky and southern Illinois (Clay 1975, Smith 1979, Burr 1980). It would be a most unusual stray in the Ohio River.

Etheostoma maculatum Kirtland. The spotted darter is an uncommon fish with a sporadic distribution in the Ohio River drainage. Records are known from central Ohio, northwestern Pennsylvania, northern Indiana, southern Kentucky, and West Virginia (Lee et al. 1980).

Etheostoma microperca Jordan and Gilbert. The least darter has been reported from small creeks in northern and central Ohio and Indiana, usually over 50 miles from the Ohio River. One record for Beargrass Creek, Kentucky is close to the Ohio River (Clay 1975, Burr 1980) but the occurrence of this species in the Ohio mainstem is unlikely.

Etheostoma neopterum Howell and Dingerkus. The lollipop darter is known only from tributaries of the lower Tennessee River (Burr and Mayden 1979). It would seem to be an unlikely stray in the Ohio River.

Etheostoma rufilineatum (Cope). The redline darter is occasionally taken in the Cumberland and Tennessee river drainages of western Kentucky (Clay 1975).

Etheostoma smithi Page and Braasch. The slabrock darter is uncommon in lower tributaries of the Cumberland and Tennessee rivers in western Kentucky and Tennessee. Its slabrock habitat requirements make it an unlikely stray in the Ohio River.

Etheostoma tippecanoe Jordan and Evermann. The Tippecanoe darter is uncommon in smaller streams throughout the upper 800 miles of the Ohio River valley and would seem to be an unlikely stray in the Ohio River.

Percina ouachitae (Jordan and Gilbert). The saddleback darter has been collected in the extreme western corner of Kentucky in recent years, and before 1900 was collected up the Ohio River valley as far as the Wabash and Green rivers. It may stray into the lower 100-150 miles of the Ohio River.

Percina oxyrhyncha (Hubbs and Raney). The sharpnose darter is present in the upper reaches of several southern Ohio River tributaries above ORM 800.

Fishes which have been erroneously reported from the Ohio River

Coregonus johannae (Wagner). The deepwater cisco was reported in Kulik and Gammon (1978) at ORM 530.6 in 1977-78. The deepwater cisco

is endemic to Lakes Michigan and Huron, was last reported in 1951, and is now considered extinct (Lee et al. 1980). Gammon (personal communication 1980) believes the 1978 report was due to an error in a computer-generated list.

Gobiosoma molestum Girard. In 1891 Jordan reported "a specimen taken in the Ohio River at Louisville is in the Agassiz Museum." This was undoubtedly a mis-labeled specimen.

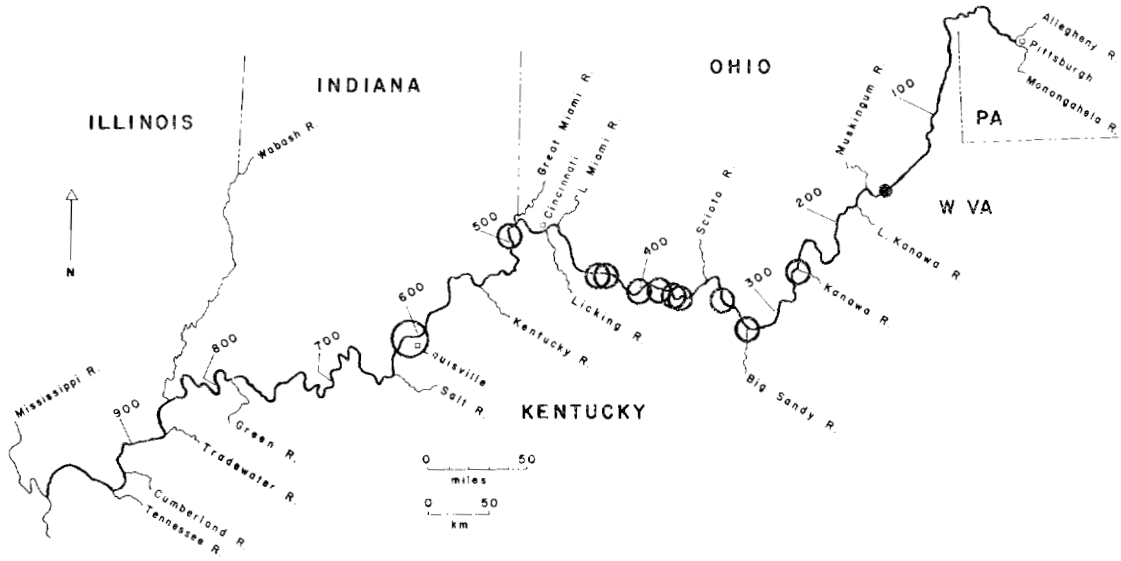

Figure 9. Distribution of *Ichthyomyzon bdellium* in the Ohio River.

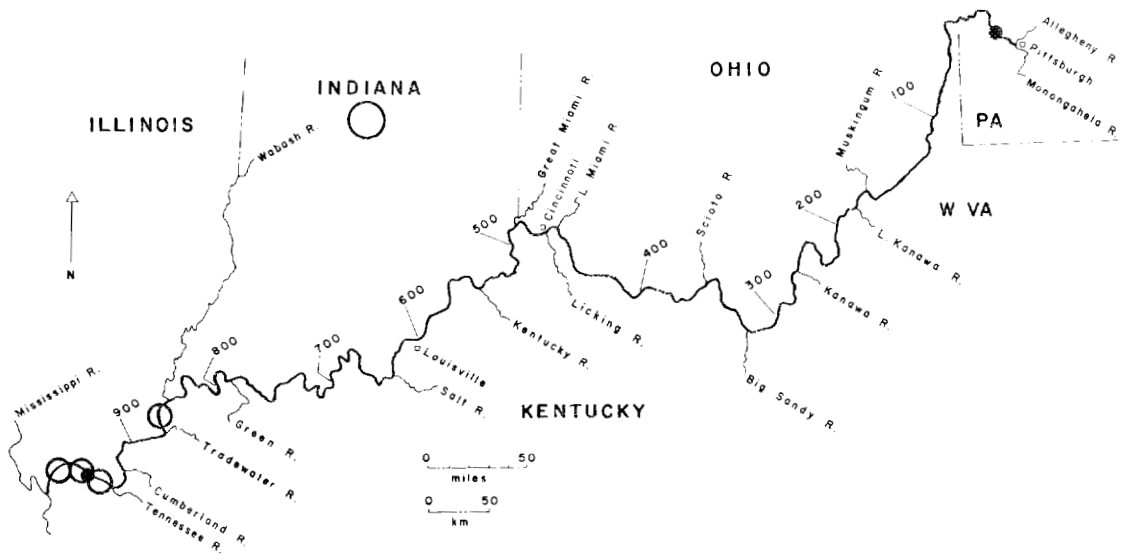

Figure 10. Distribution of *Ichthyomyzon castaneus* in the Ohio River.

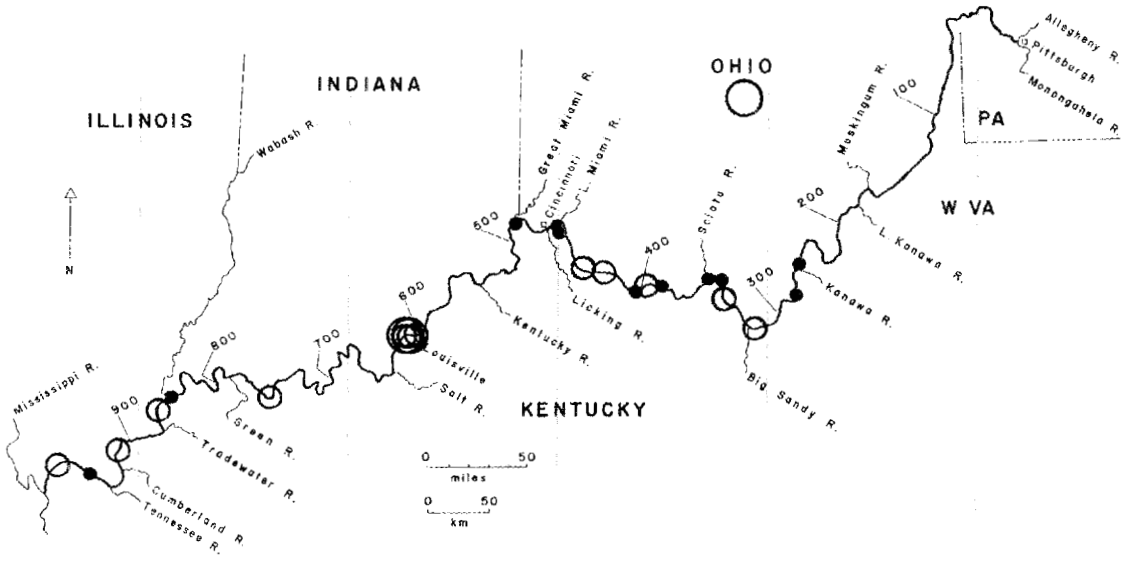

Figure 11. Distribution of *Ichthyomyzon unicuspis* in the Ohio River.

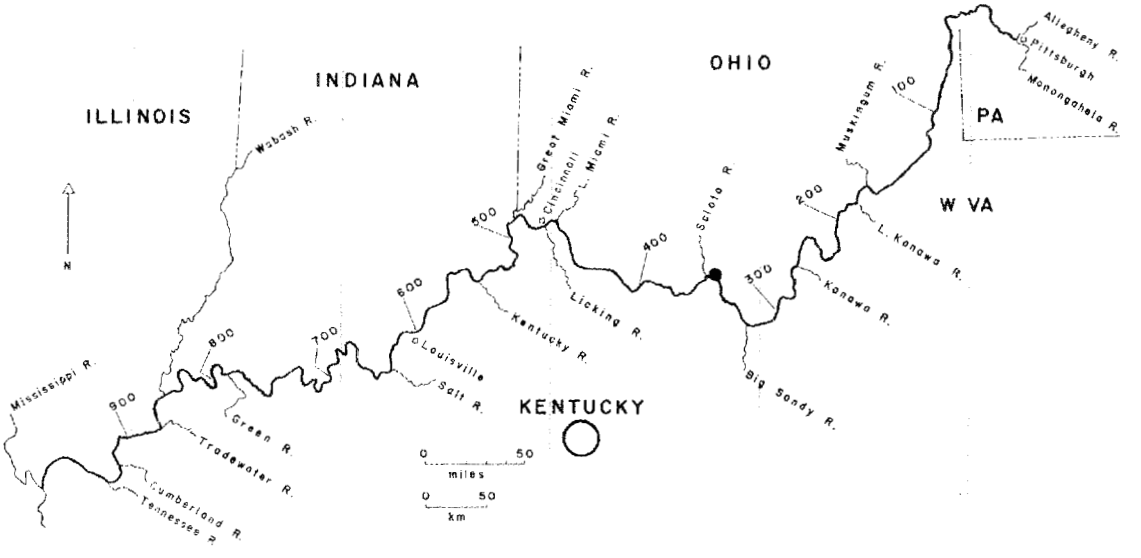

Figure 12. Distribution of *Lampetra appendix* in the Ohio River.

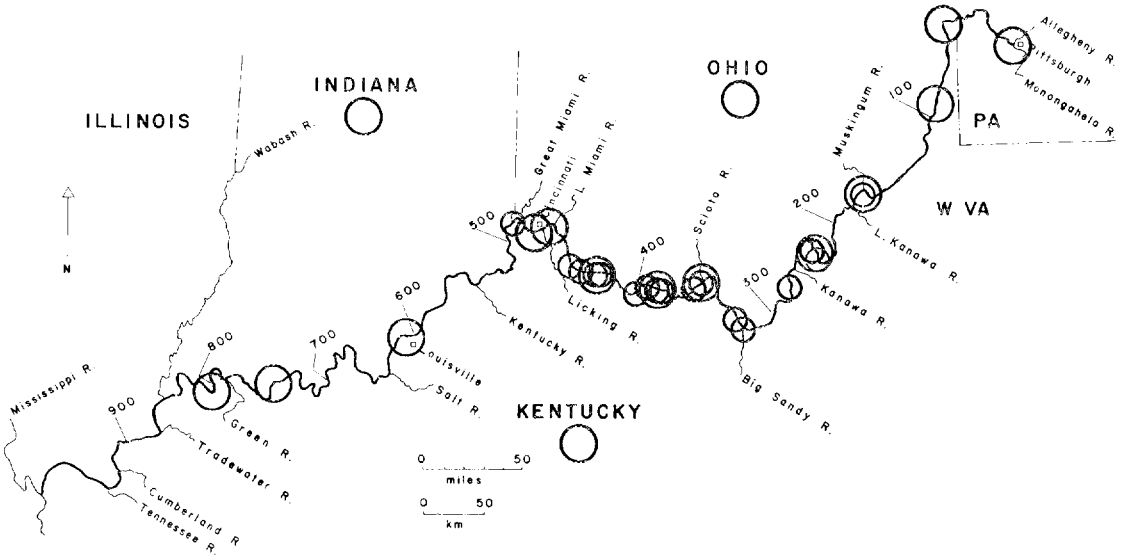

Figure 13. Distribution of *Acipenser fulvescens* in the Ohio River.

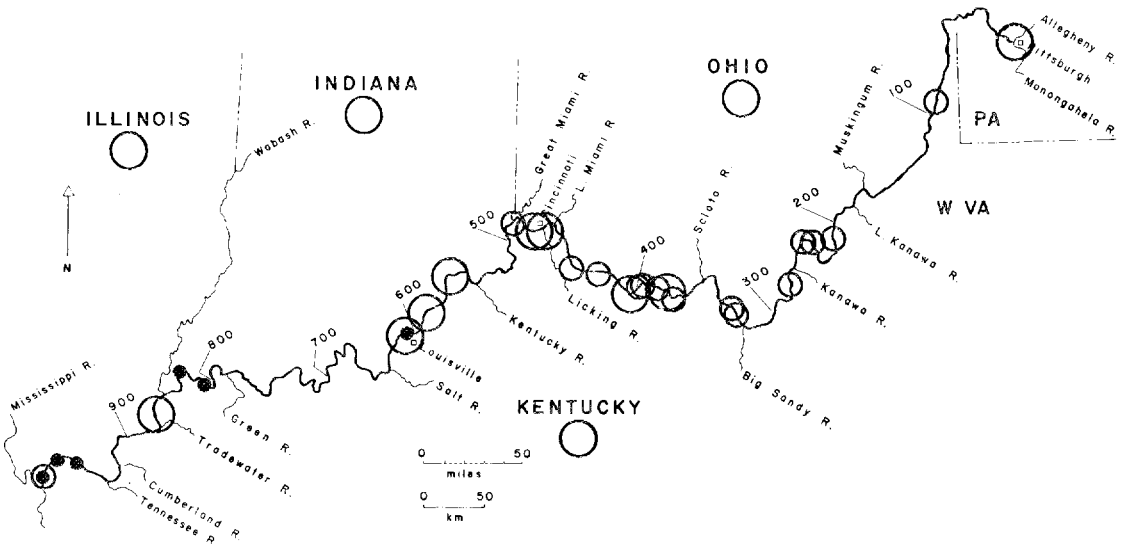

Figure 14. Distribution of *Scaphirhynchus platorynchus* in the Ohio River.

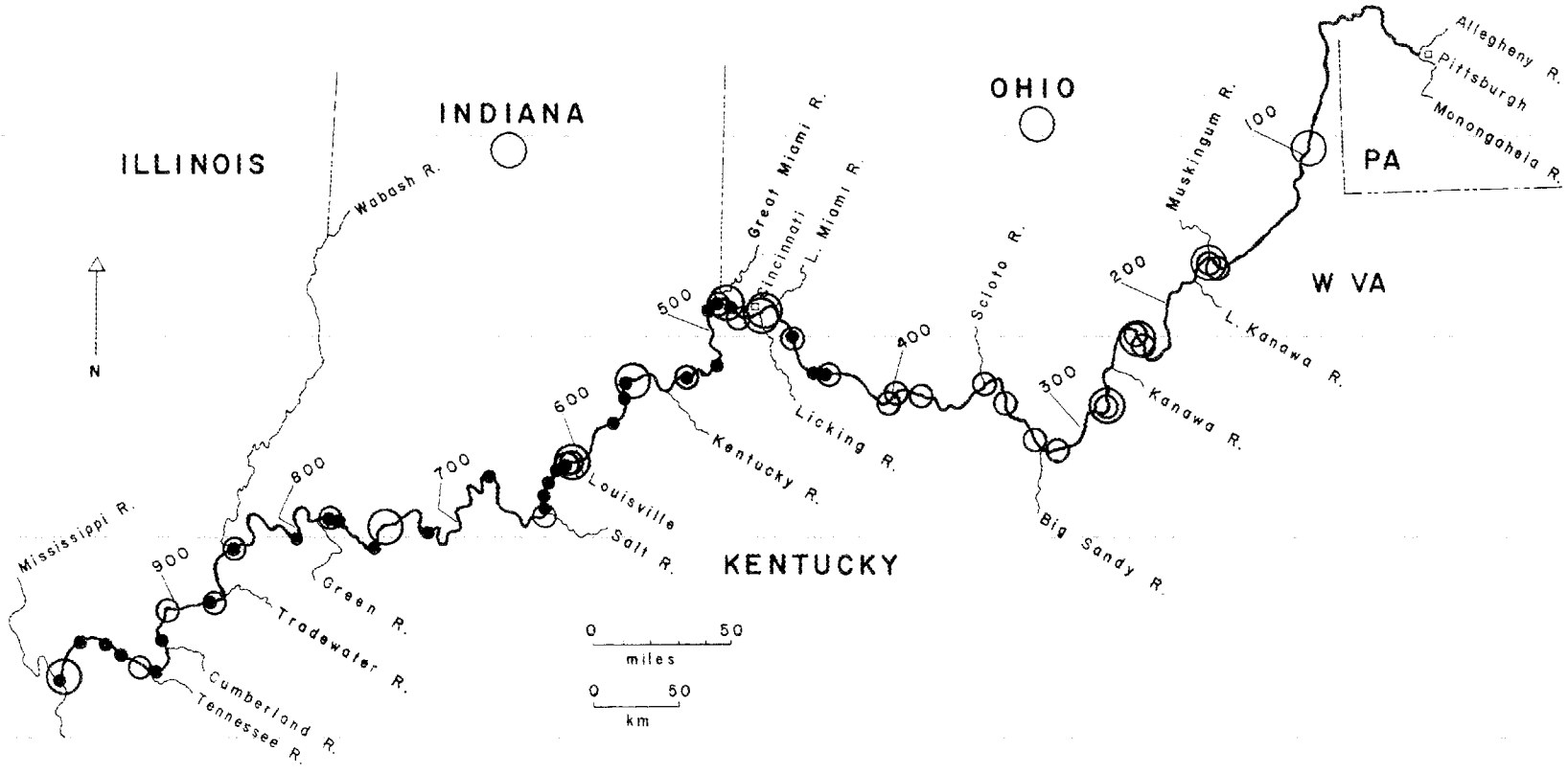

Figure 15. Distribution of *Polyodon spathula* in the Ohio River.

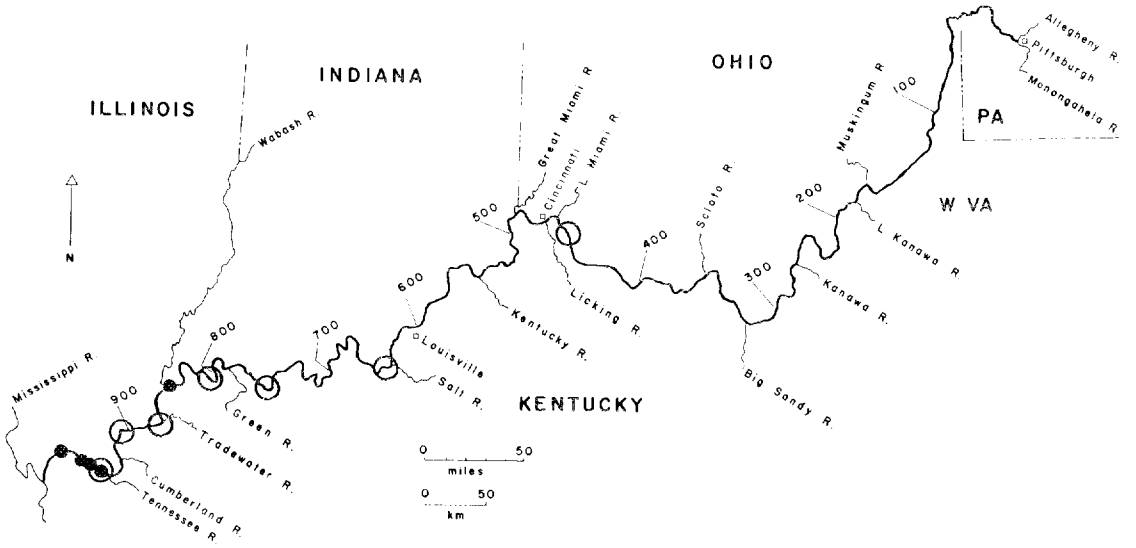

Figure 16. Distribution of *Lepisosteus oculatus* in the Ohio River.

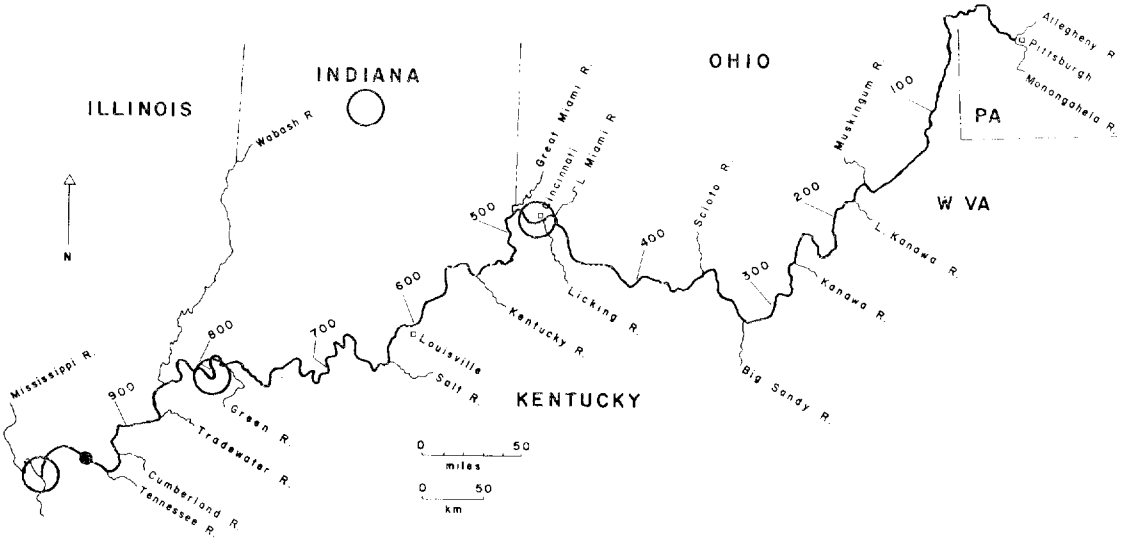

Figure 19. Distribution of *Lepisosteus spatula* in the Ohio River.

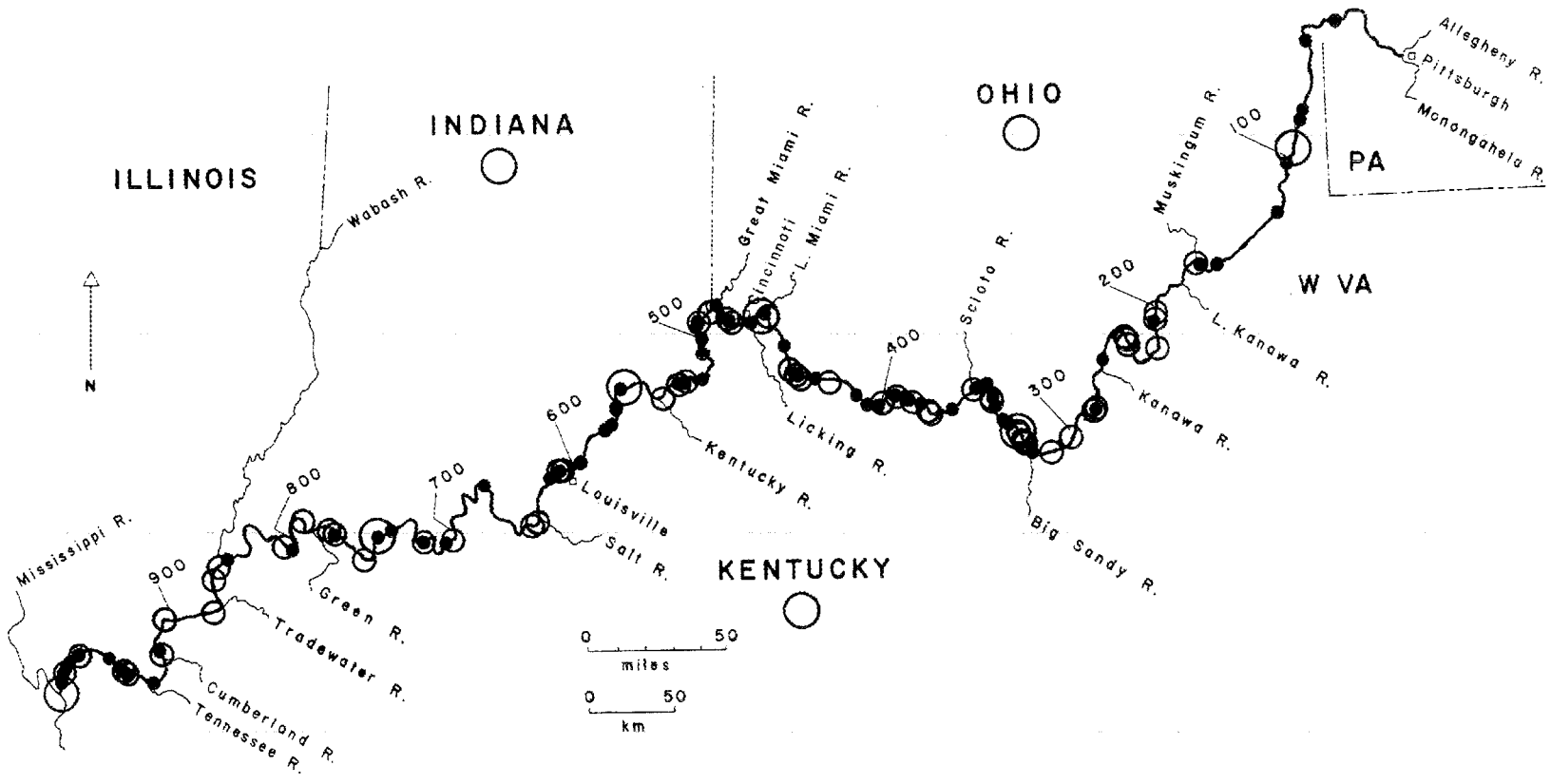

Figure 17. Distribution of *Lepisosteus osseus* in the Ohio River.

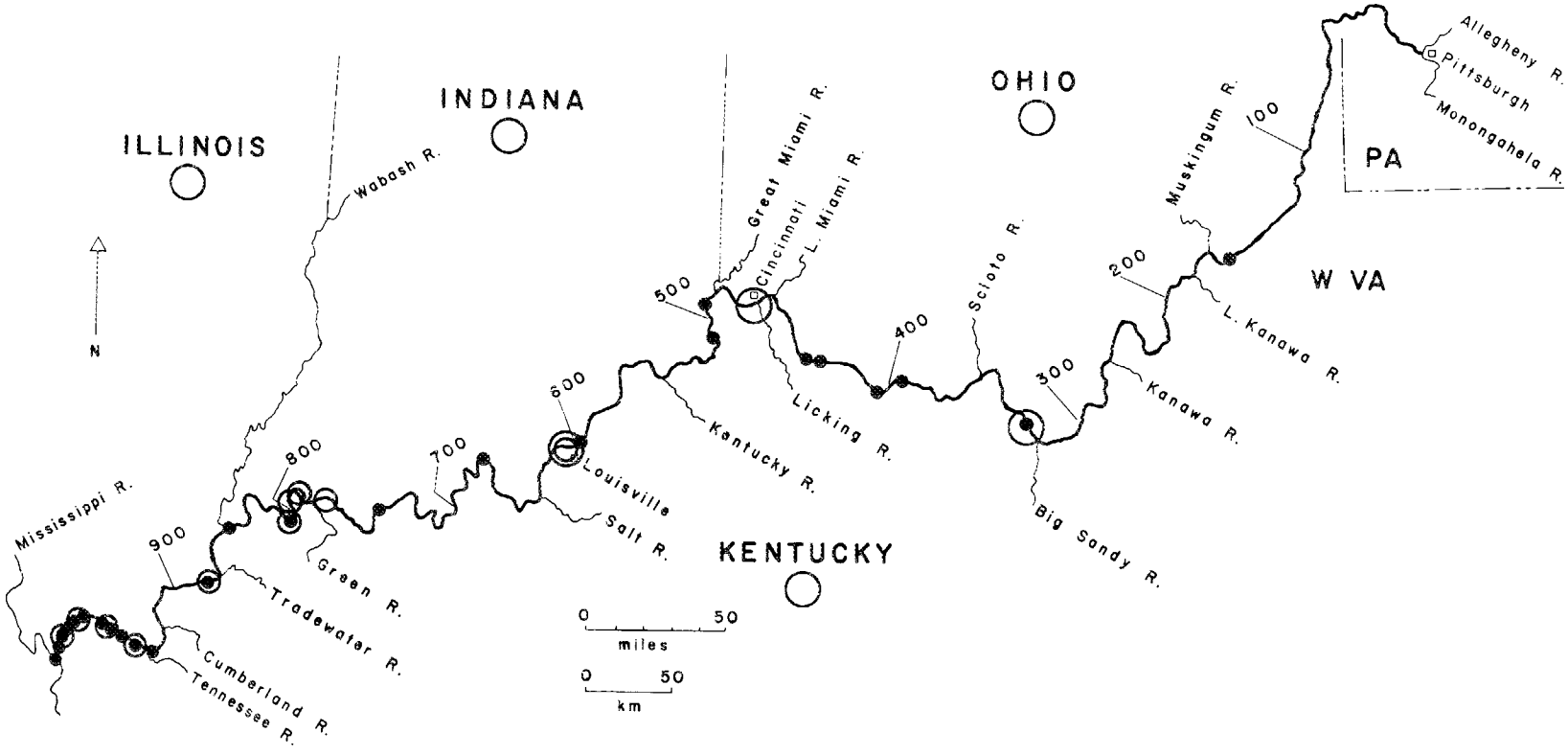

Figure 18. Distribution of *Lepisosteus platostomus* in the Ohio River.

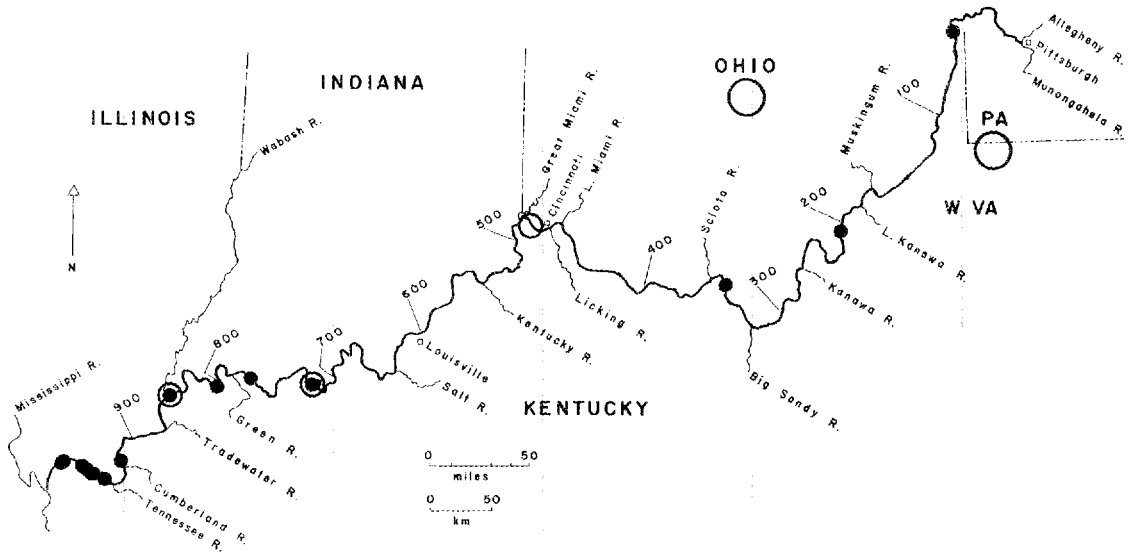

Figure 20. Distribution of *Amia calva* in the Ohio River.

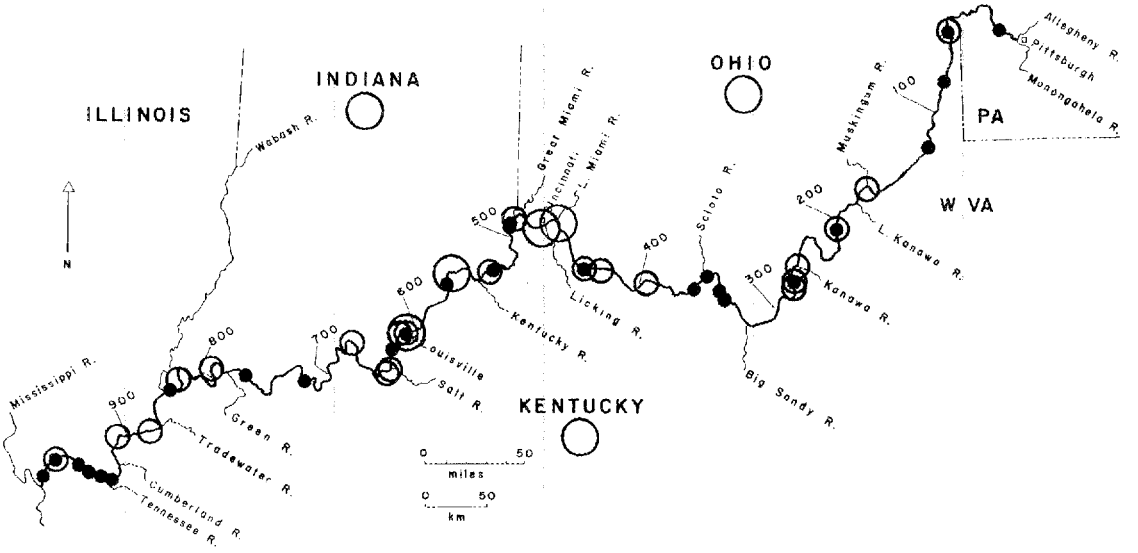

Figure 21. Distribution of *Anguilla rostrata* in the Ohio River.

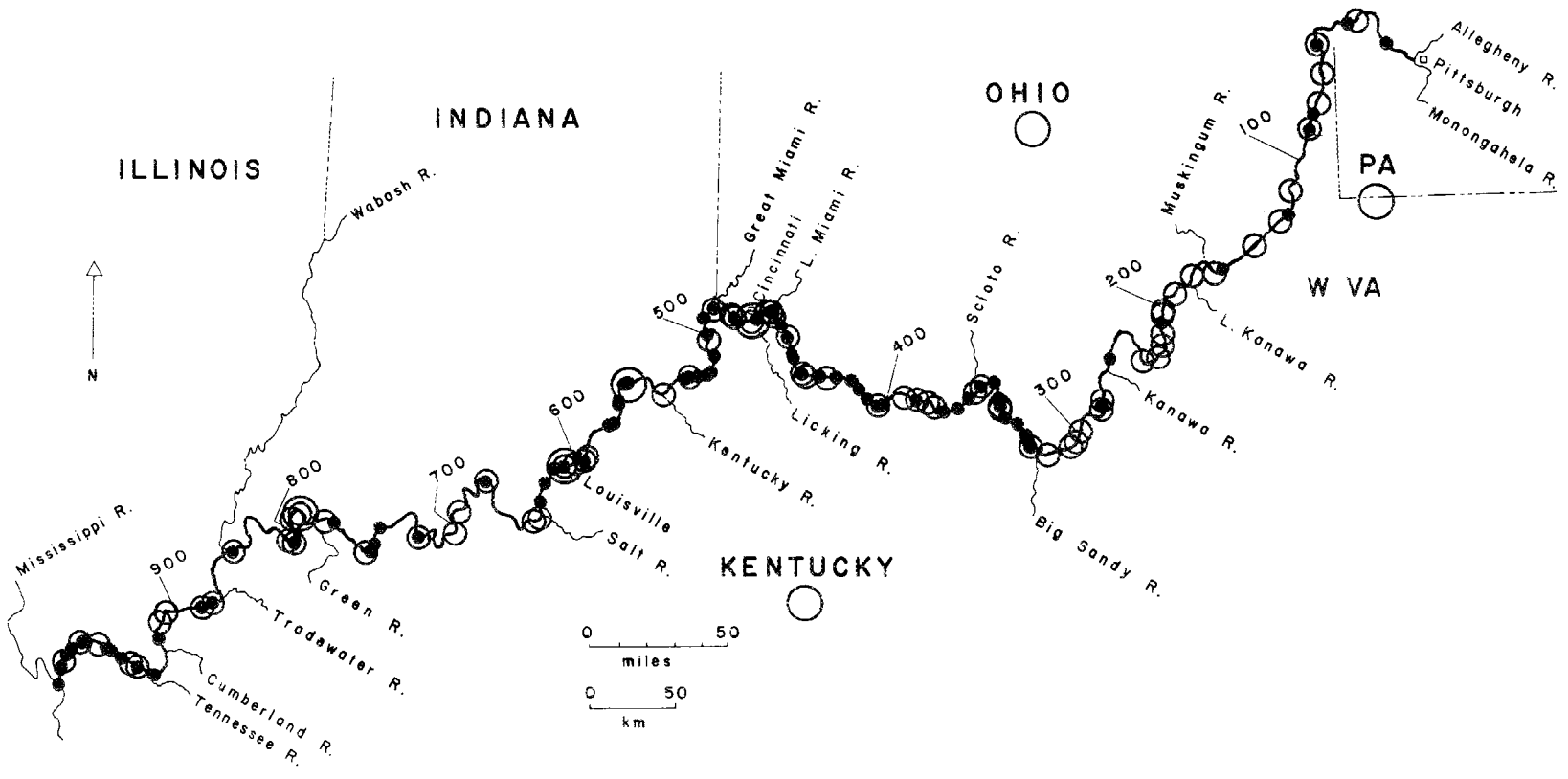

Figure 22. Distribution of *Alosa chrysochloris* in the Ohio River.

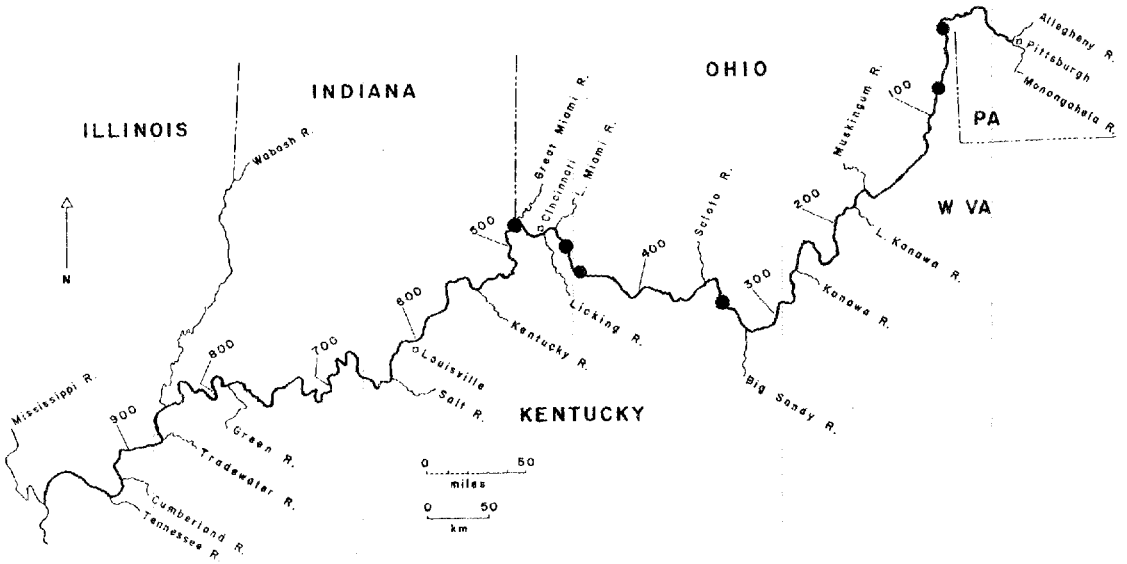

Figure 23. Distribution of *Alosa pseudoharengus* in the Ohio River.

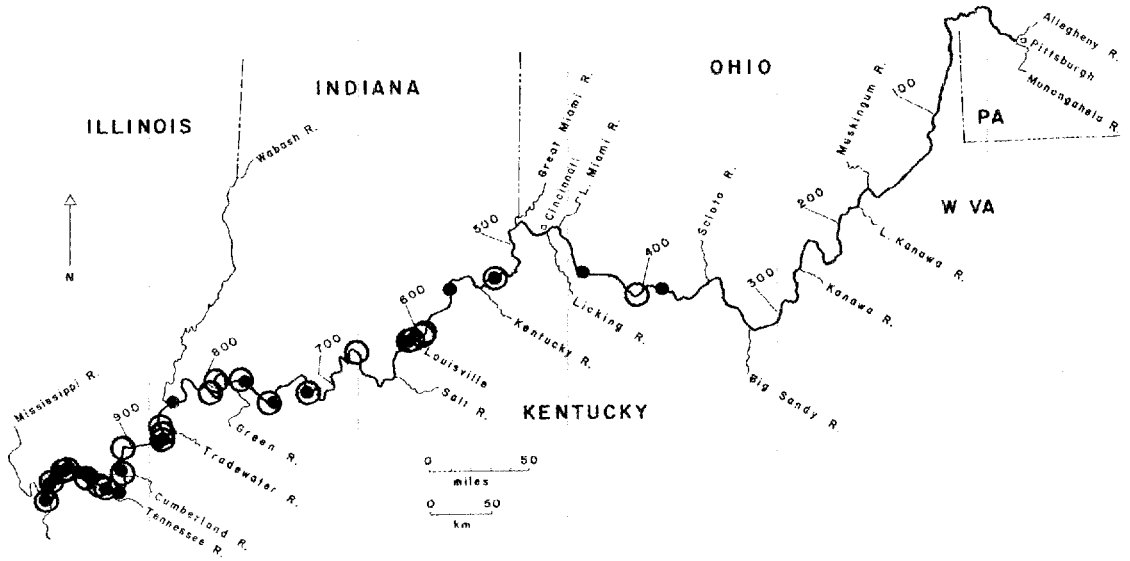

Figure 25. Distribution of *Dorosoma petenense* in the Ohio River.

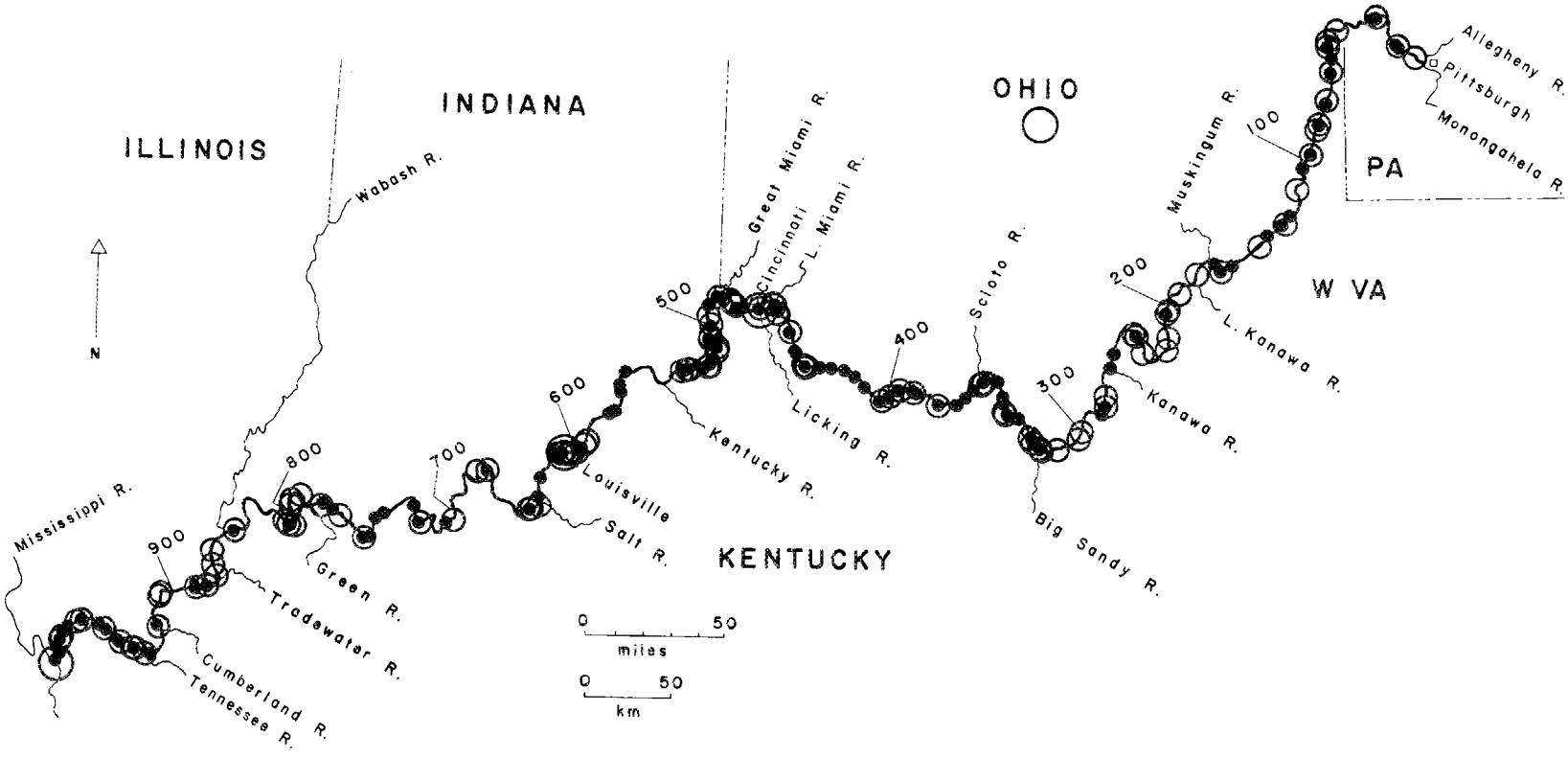

Figure 24. Distribution of *Dorosoma cepedianum* in the Ohio River.

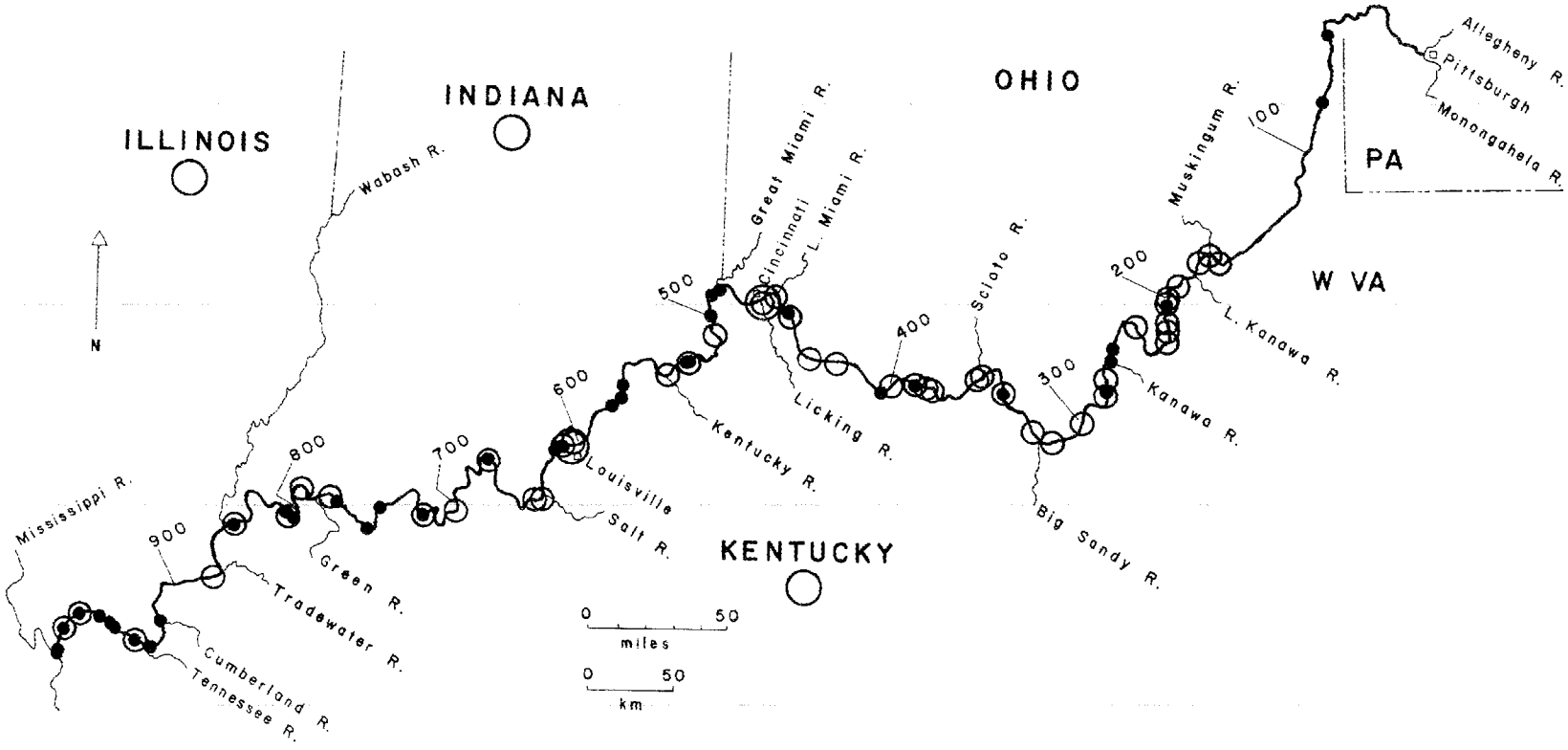

Figure 26. Distribution of *Hiodon alosoides* in the Ohio River.

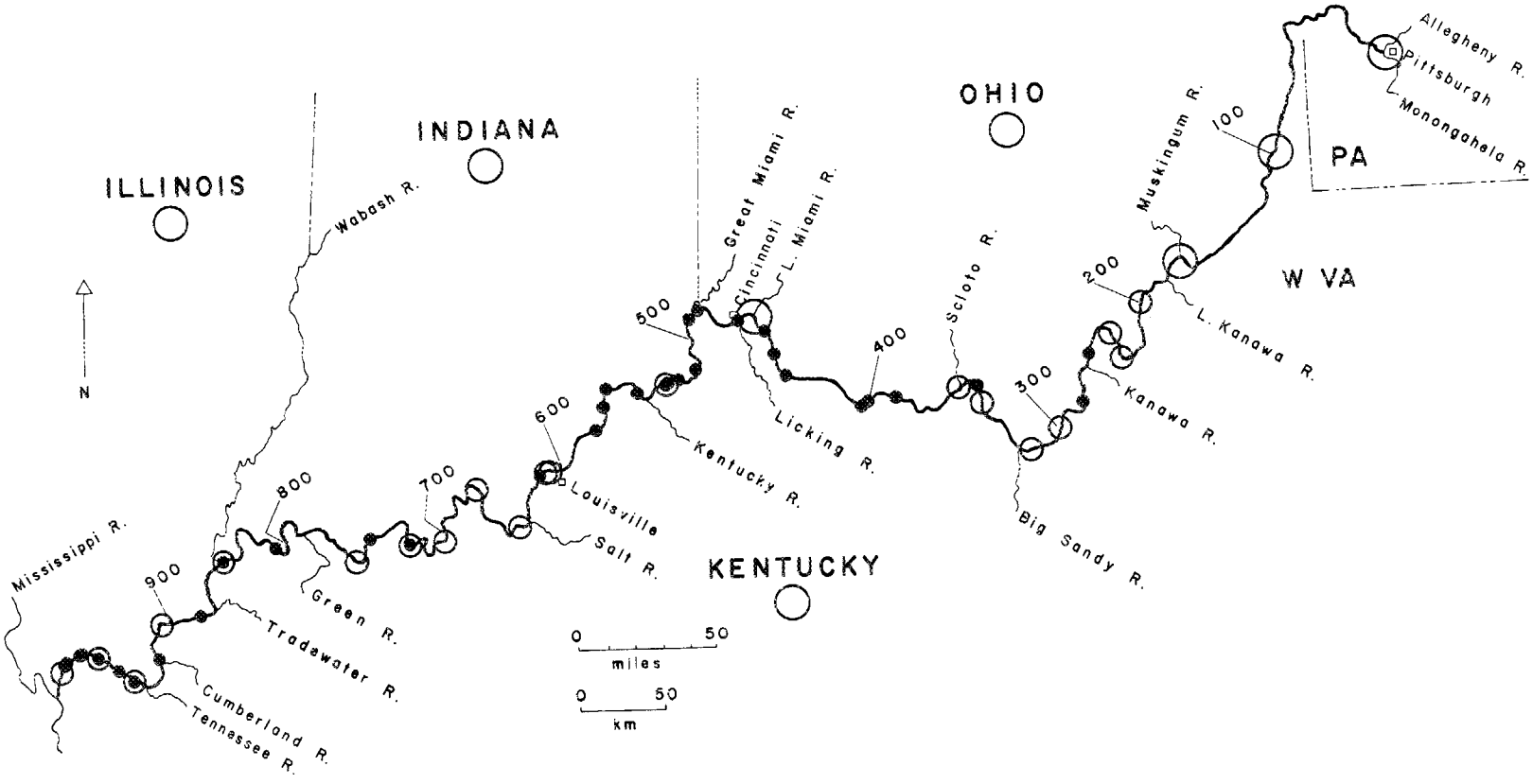

Figure 27. Distribution of *Hiodon tergisus* in the Ohio River.

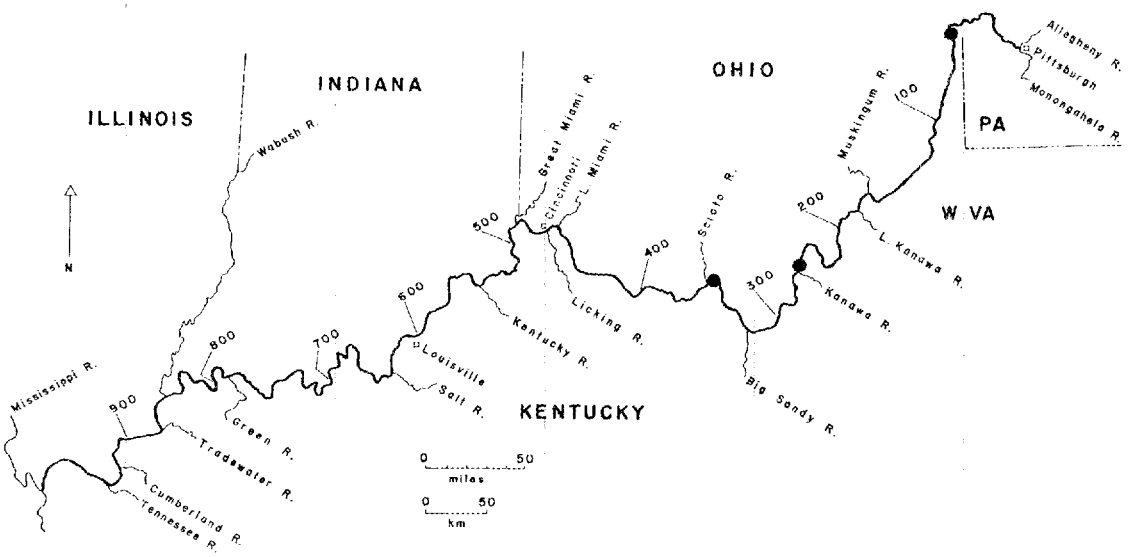

Figure 28. Distribution of *Salmo trutta* in the Ohio River.

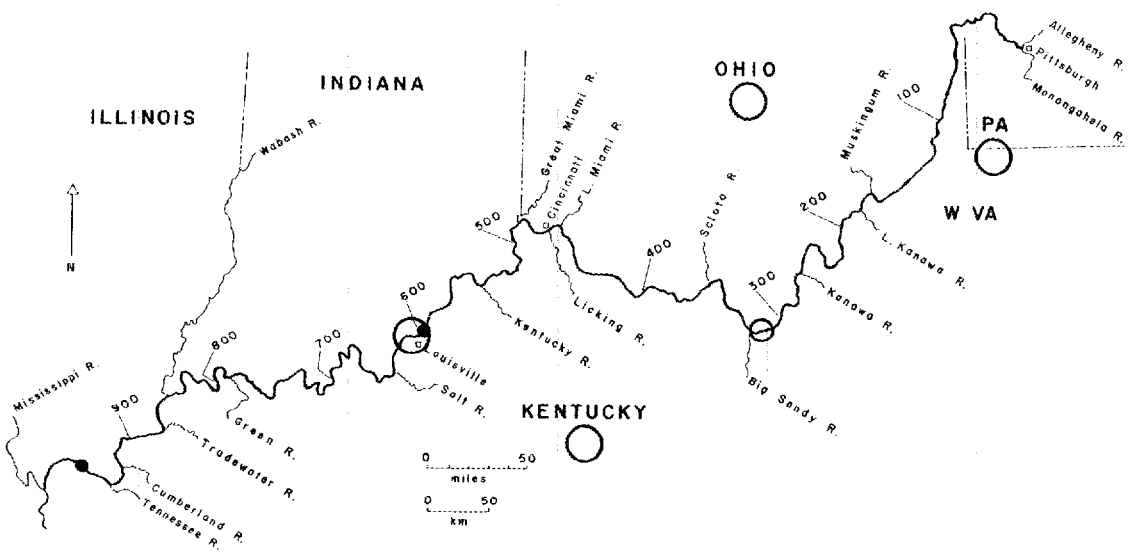

Figure 29. Distribution of *Esox americanus vermiculatus* in the Ohio River.

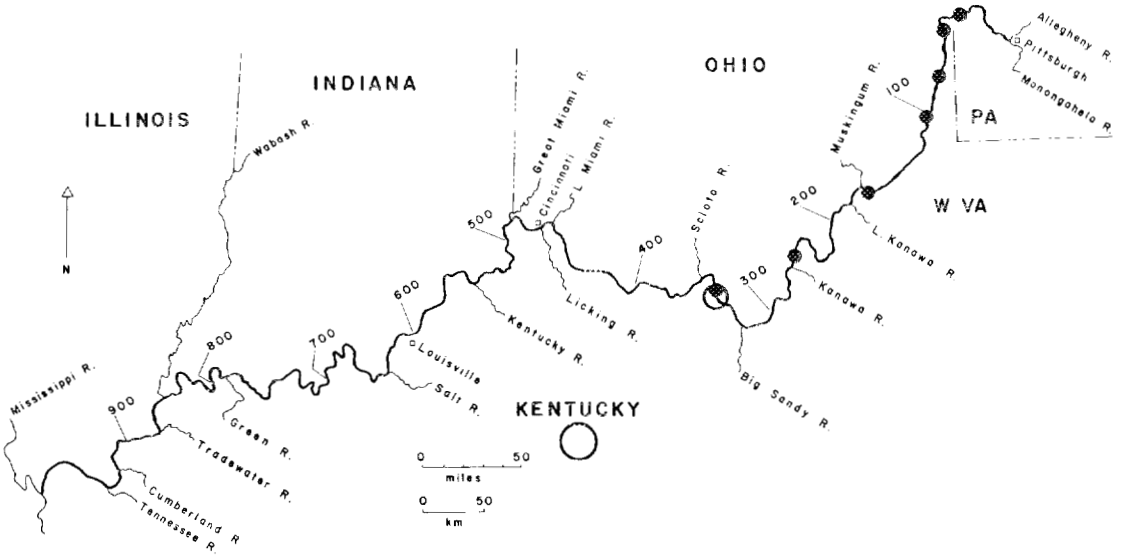

Figure 30. Distribution of *Esox lucius* in the Ohio River.

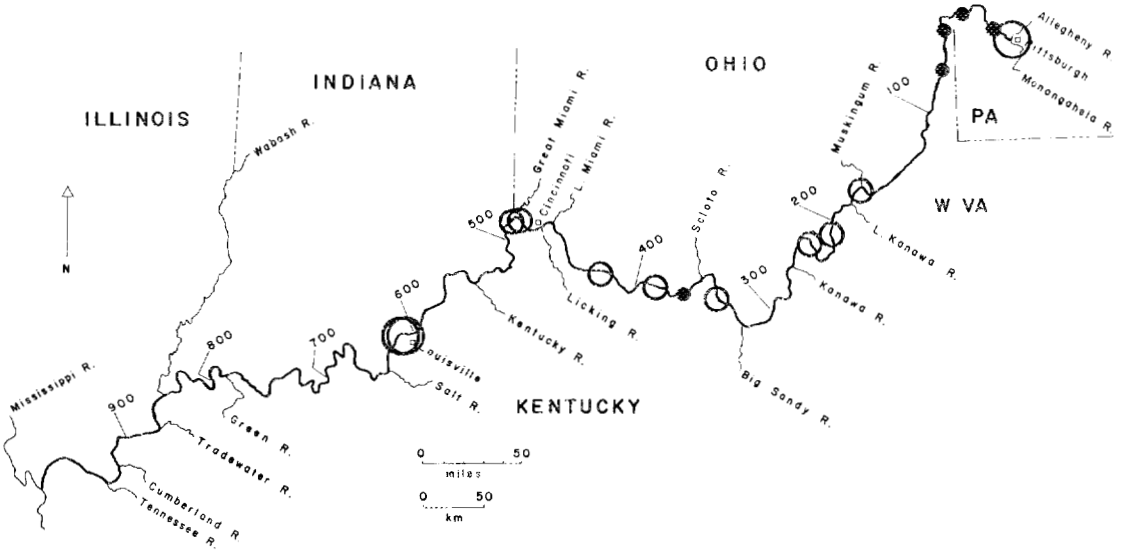

Figure 31. Distribution of *Esox masquinongy* in the Ohio River.

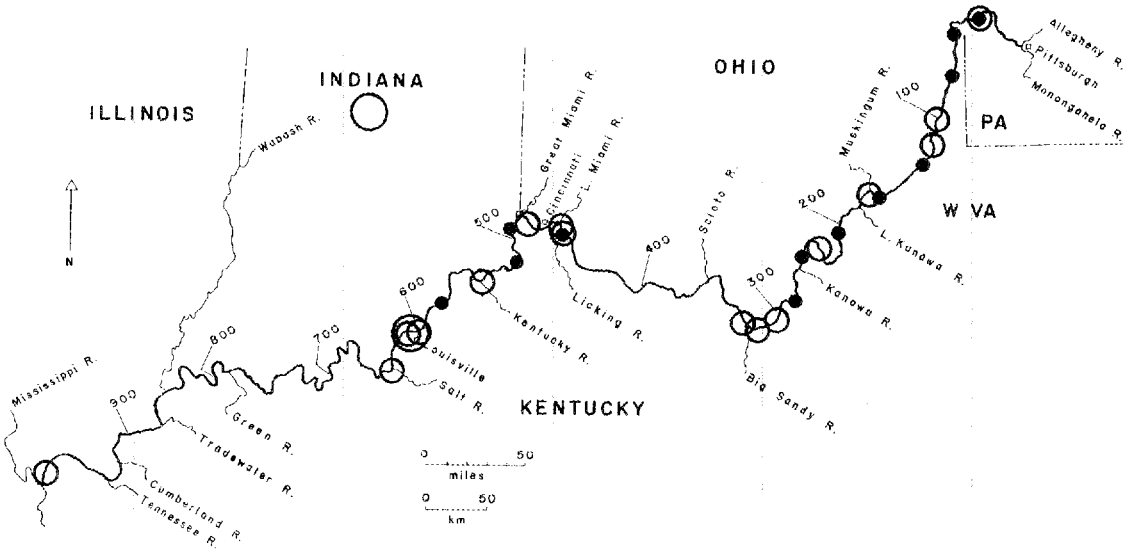

Figure 32. Distribution of *Campostoma anomalum* in the Ohio River.

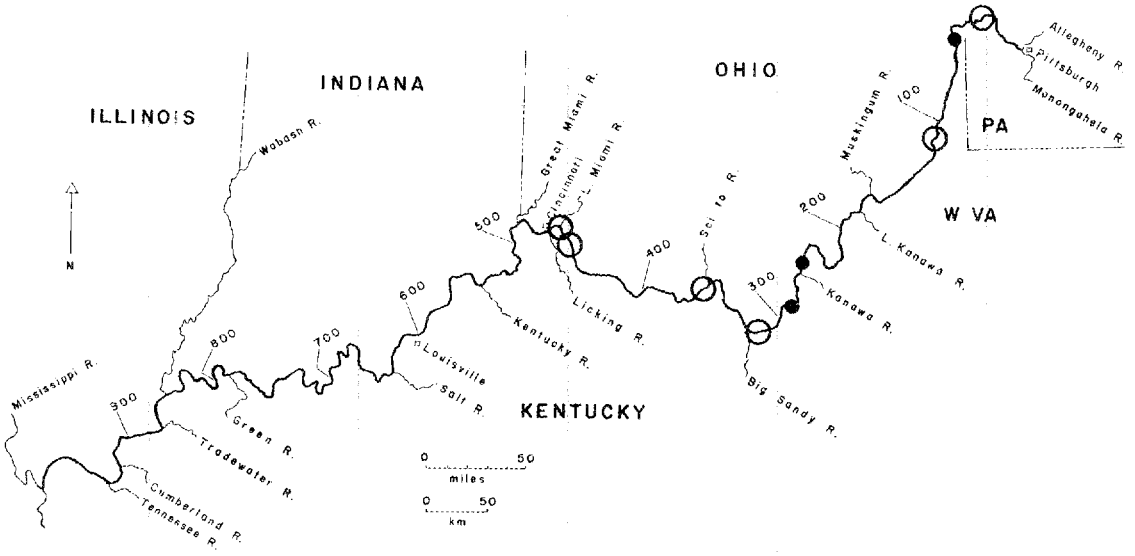

Figure 35. Distribution of *Ericymba buccata* in the Ohio River.

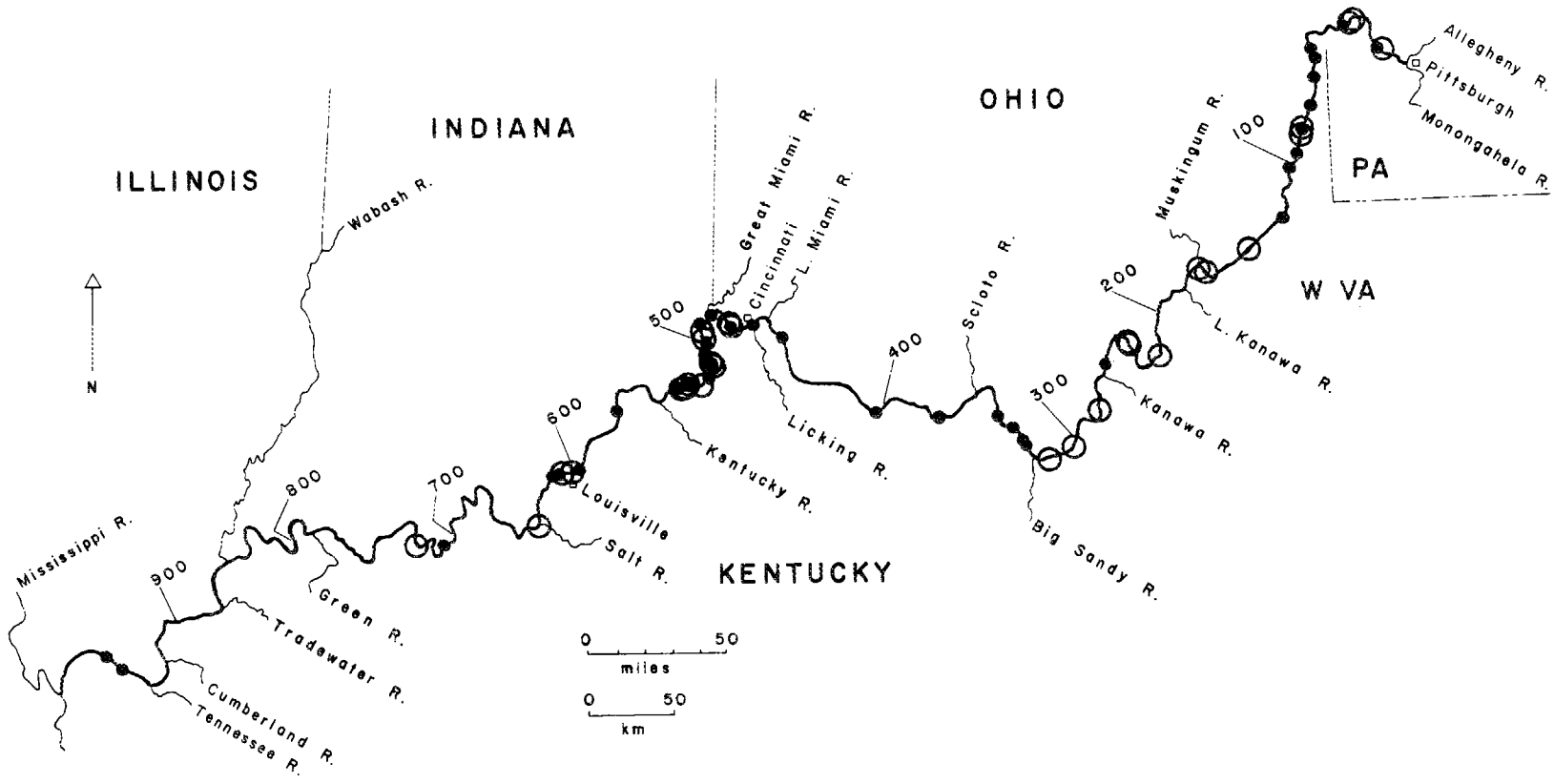

Figure 33. Distribution of *Carassius auratus* in the Ohio River.

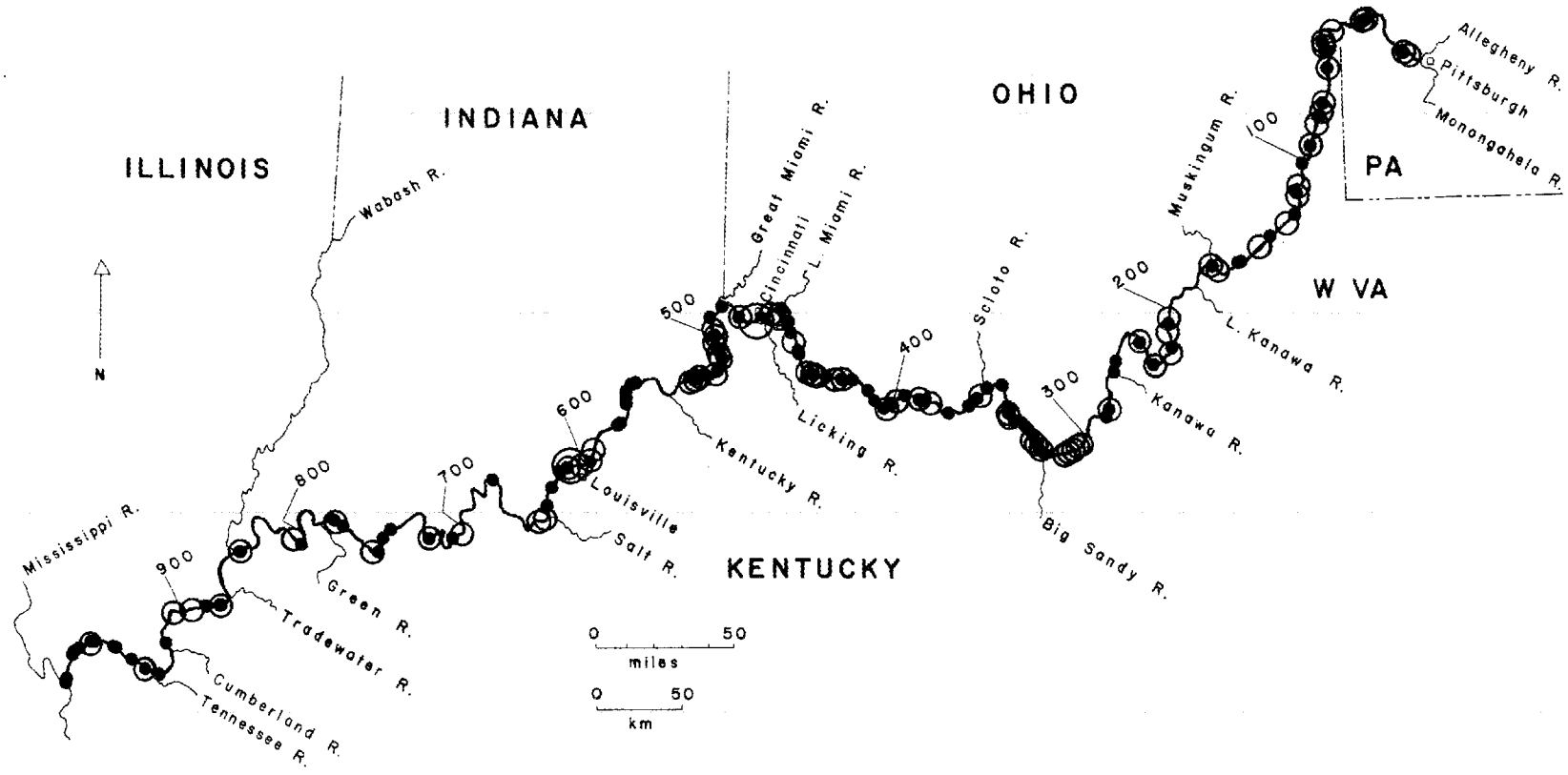

Figure 34. Distribution of *Cyprinus carpio* in the Ohio River.

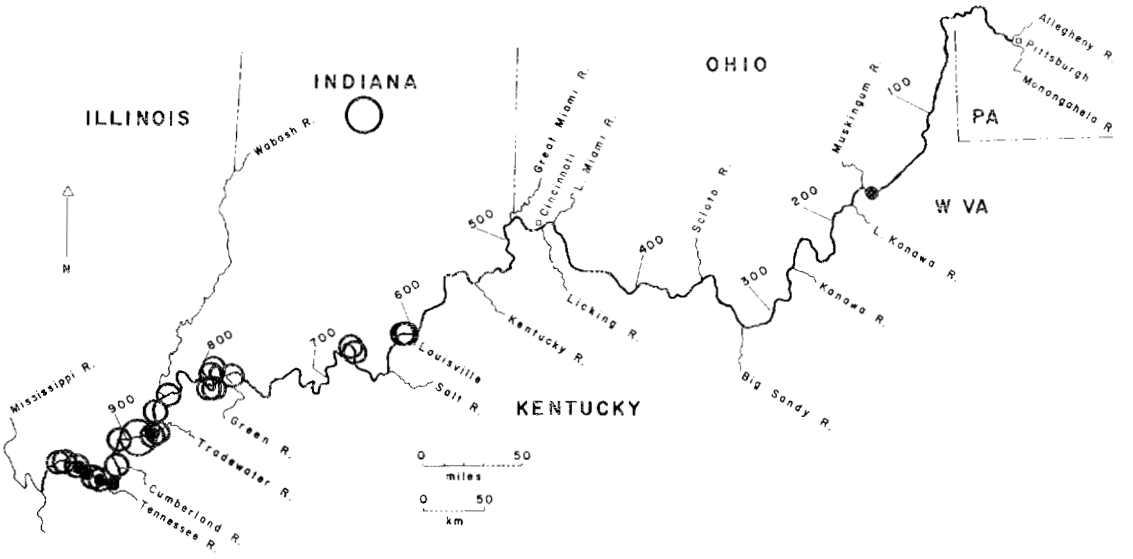

Figure 36. Distribution of *Hybognathus nuchalis* in the Ohio River.

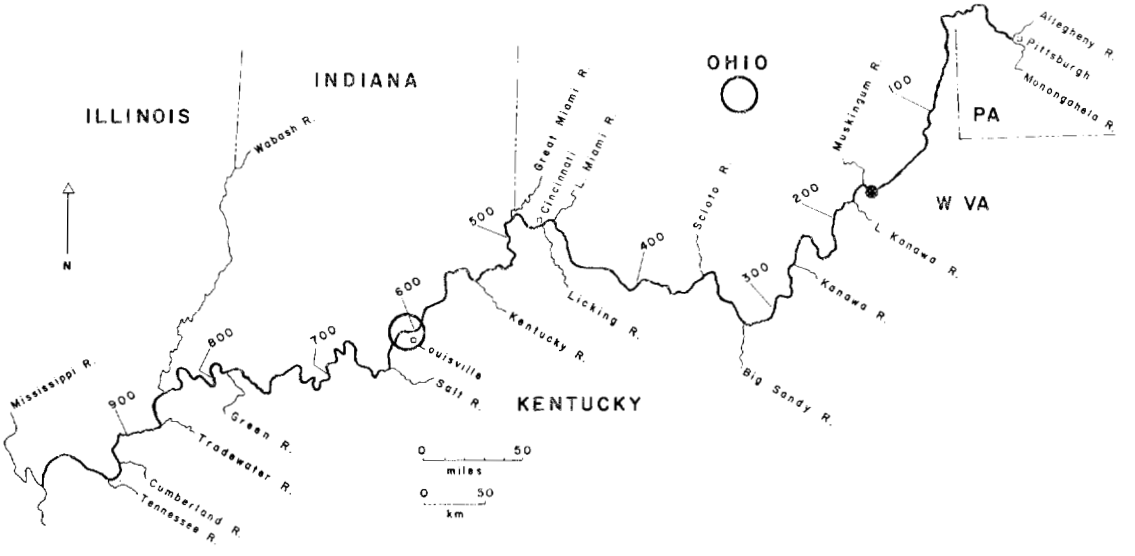

Figure 39. Distribution of *Hybopsis dissimilis* in the Ohio River.

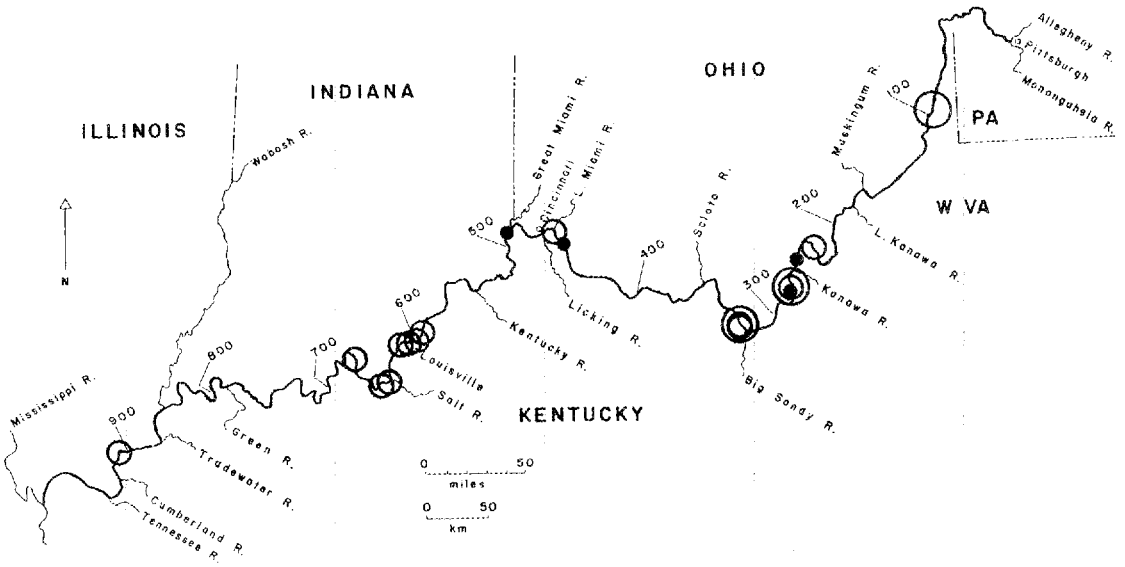

Figure 37. Distribution of *Hybopsis aestivalis* in the Ohio River.

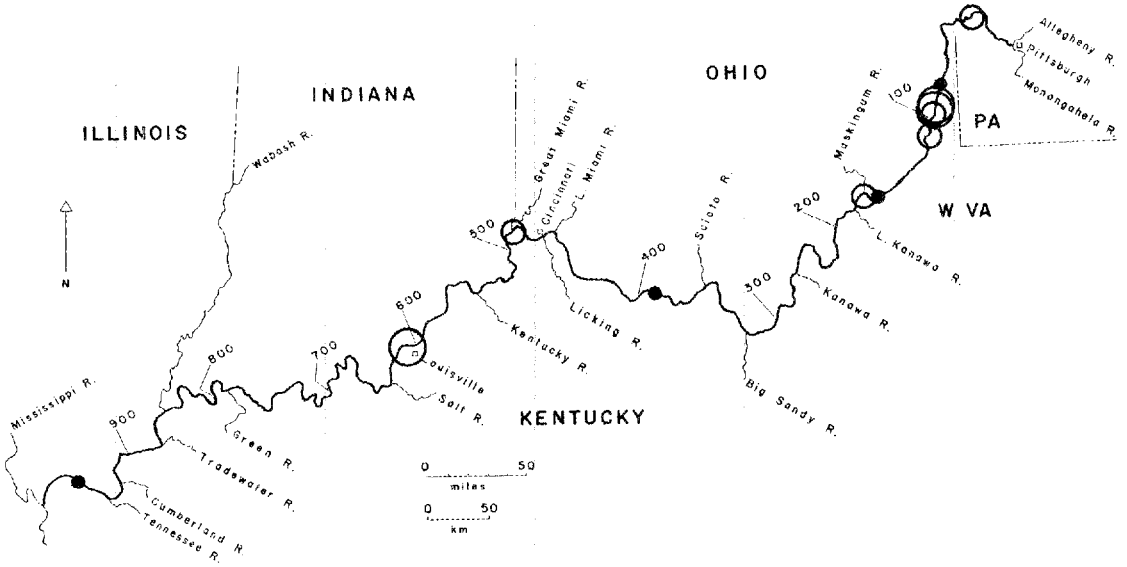

Figure 38. Distribution of *Hybopsis amblops* in the Ohio River.

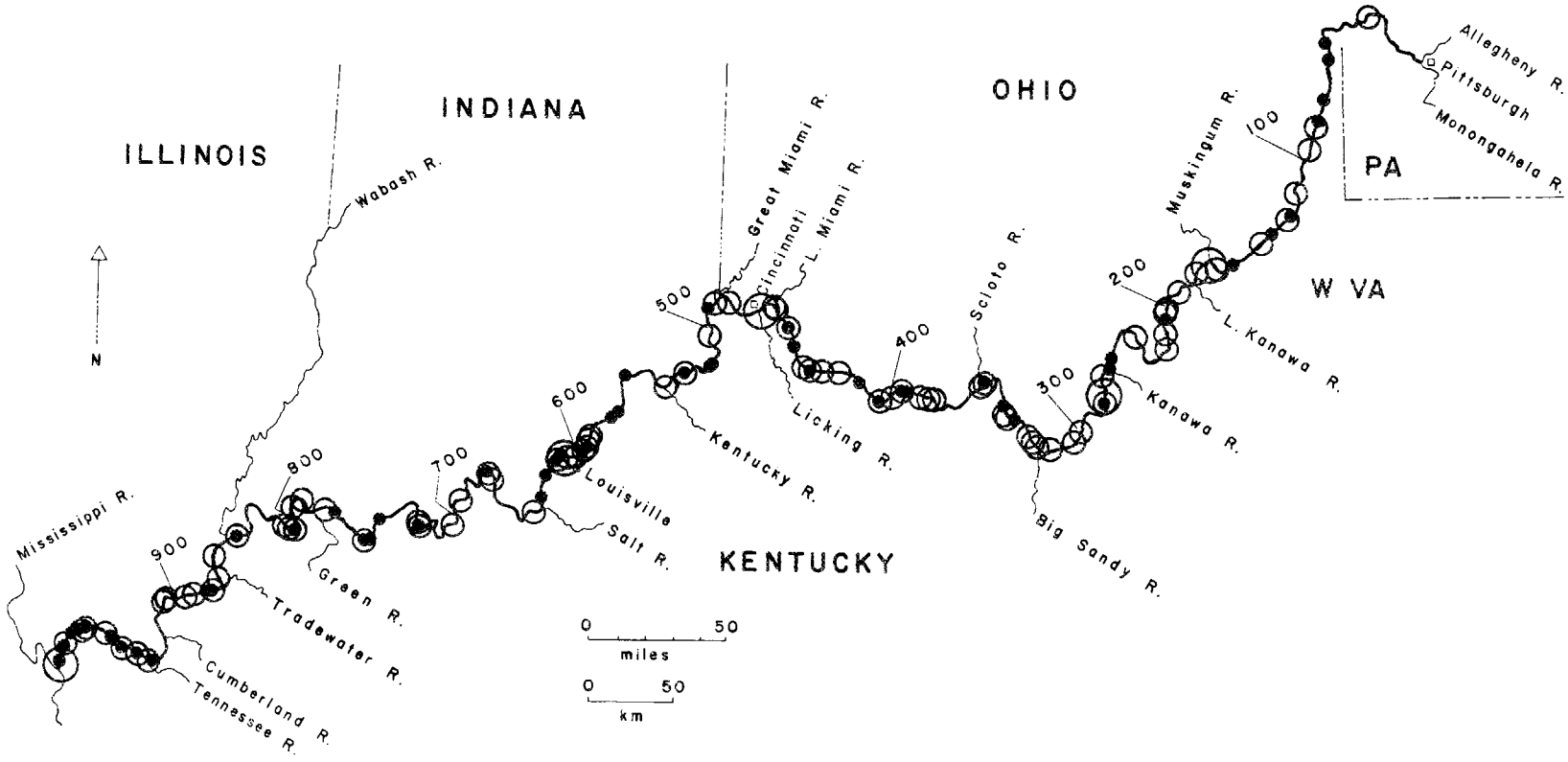

Figure 40. Distribution of *Hybopsis storeriana* in the Ohio River.

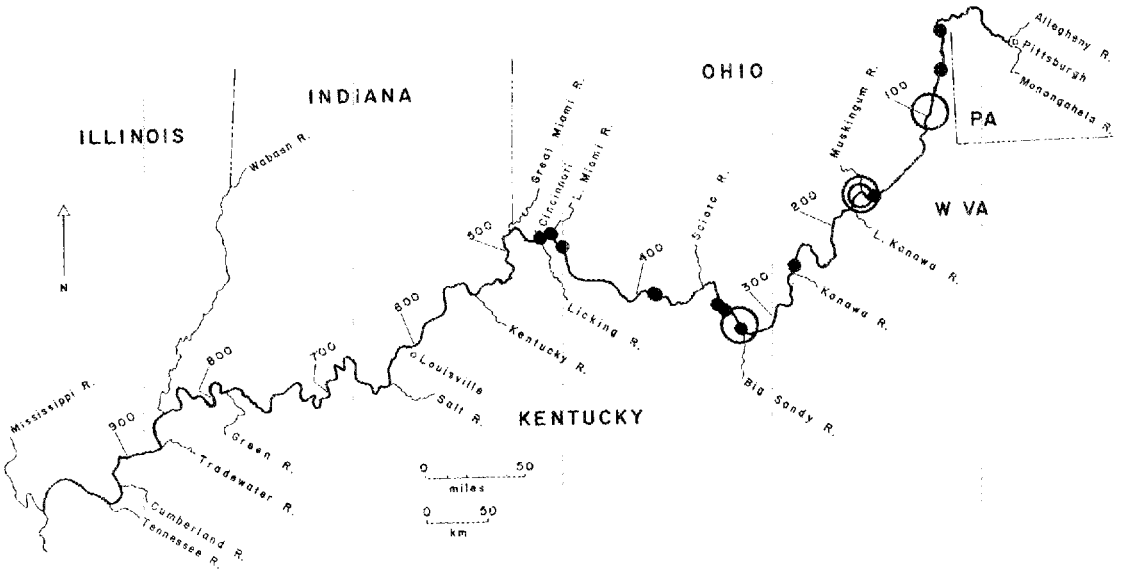

Figure 41. Distribution of *Nocomis micropogon* in the Ohio River.

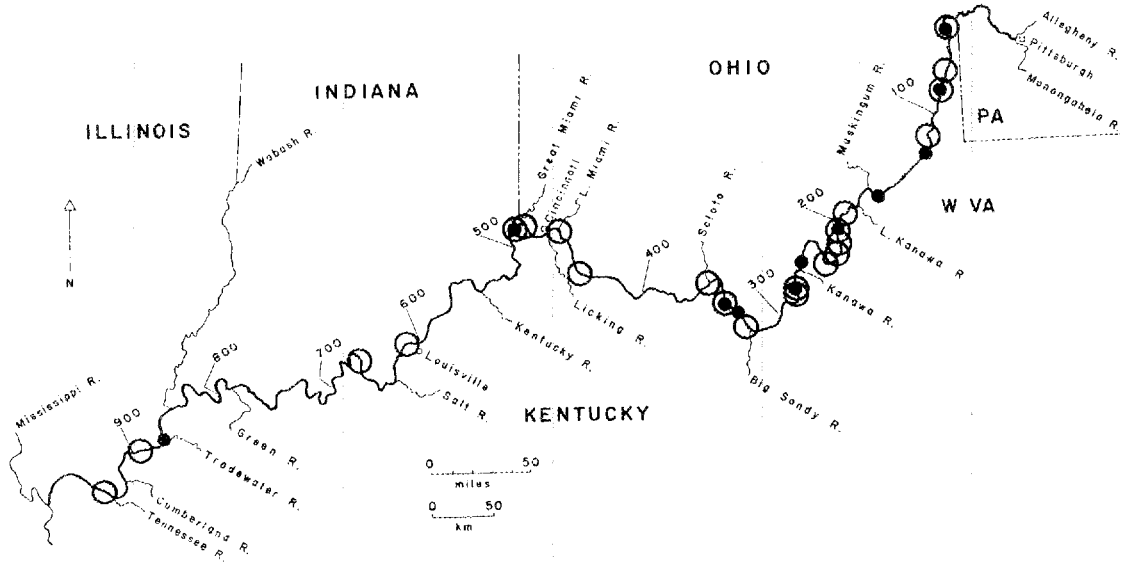

Figure 46. Distribution of *Notropis buchanani* in the Ohio River.

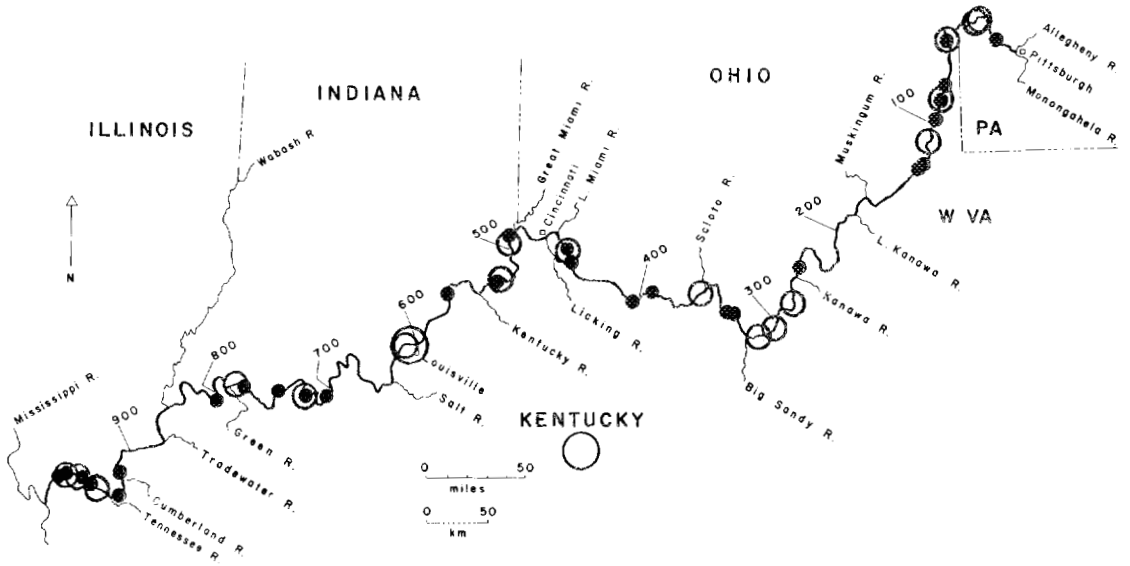

Figure 42. Distribution of *Notemigonus crysoleucas* in the Ohio River.

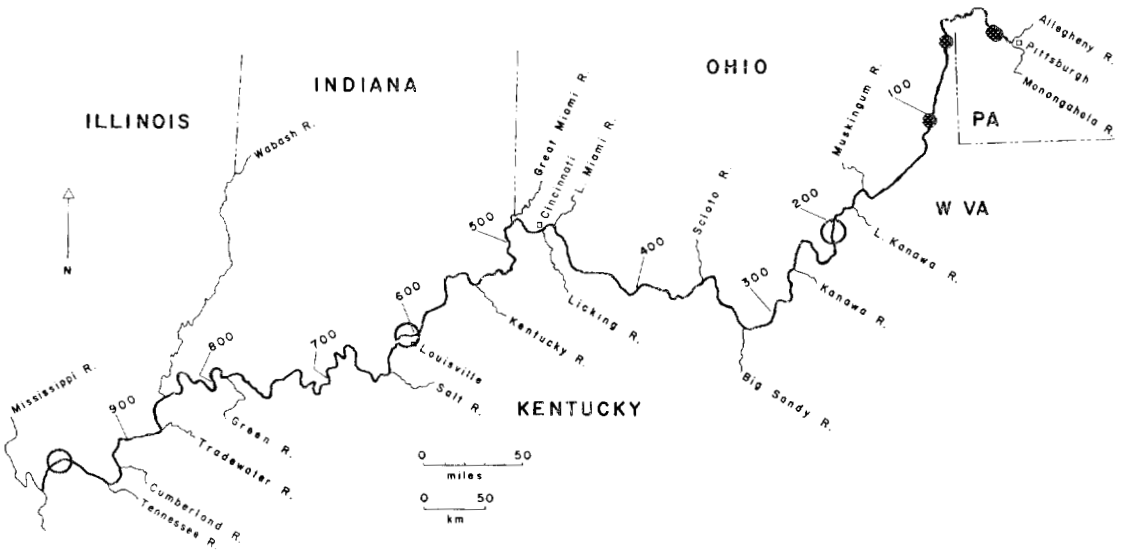

Figure 45. Distribution of *Notropis boops* in the Ohio River.

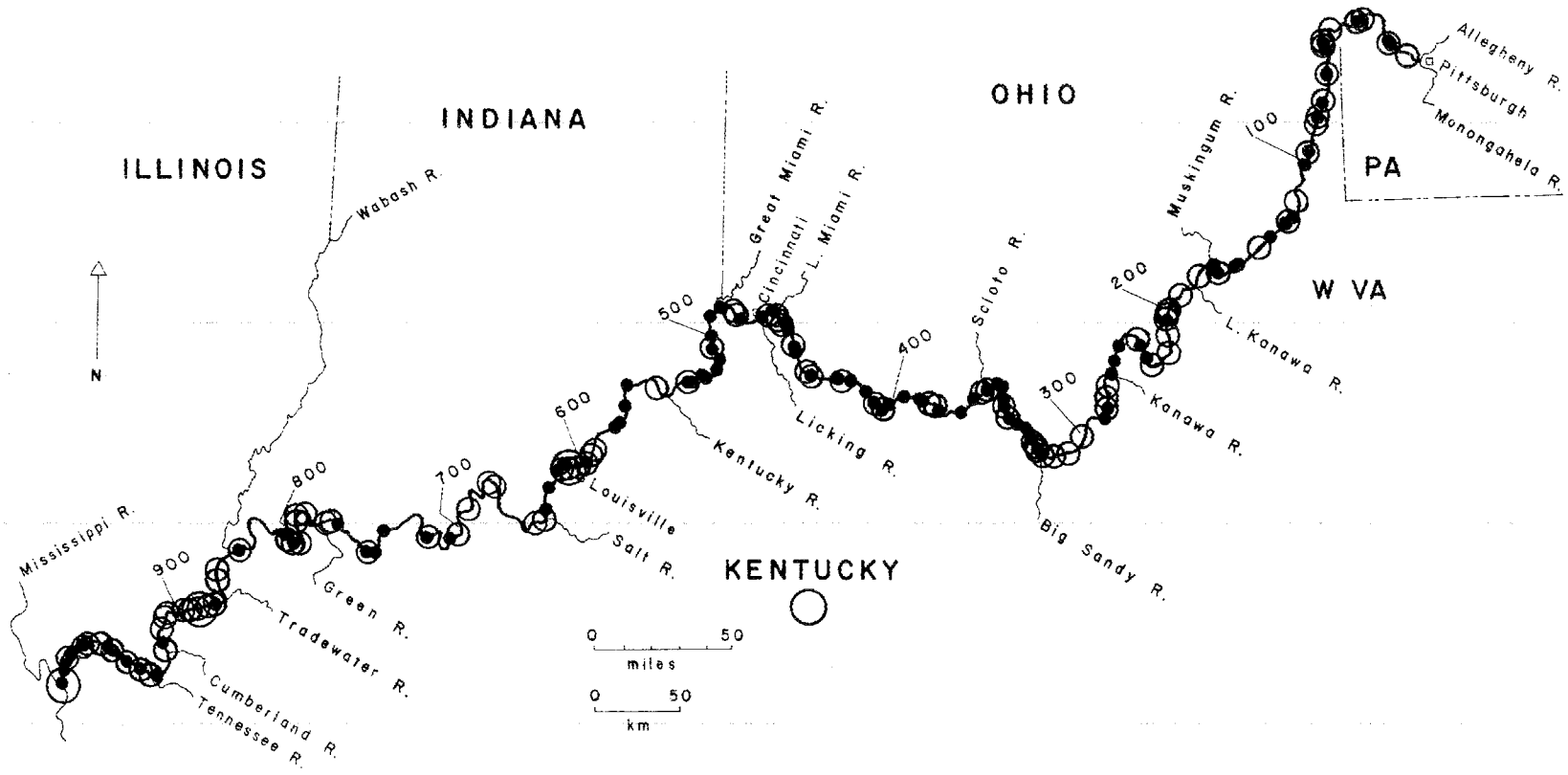

Figure 43. Distribution of *Notropis atherinoides* in the Ohio River.

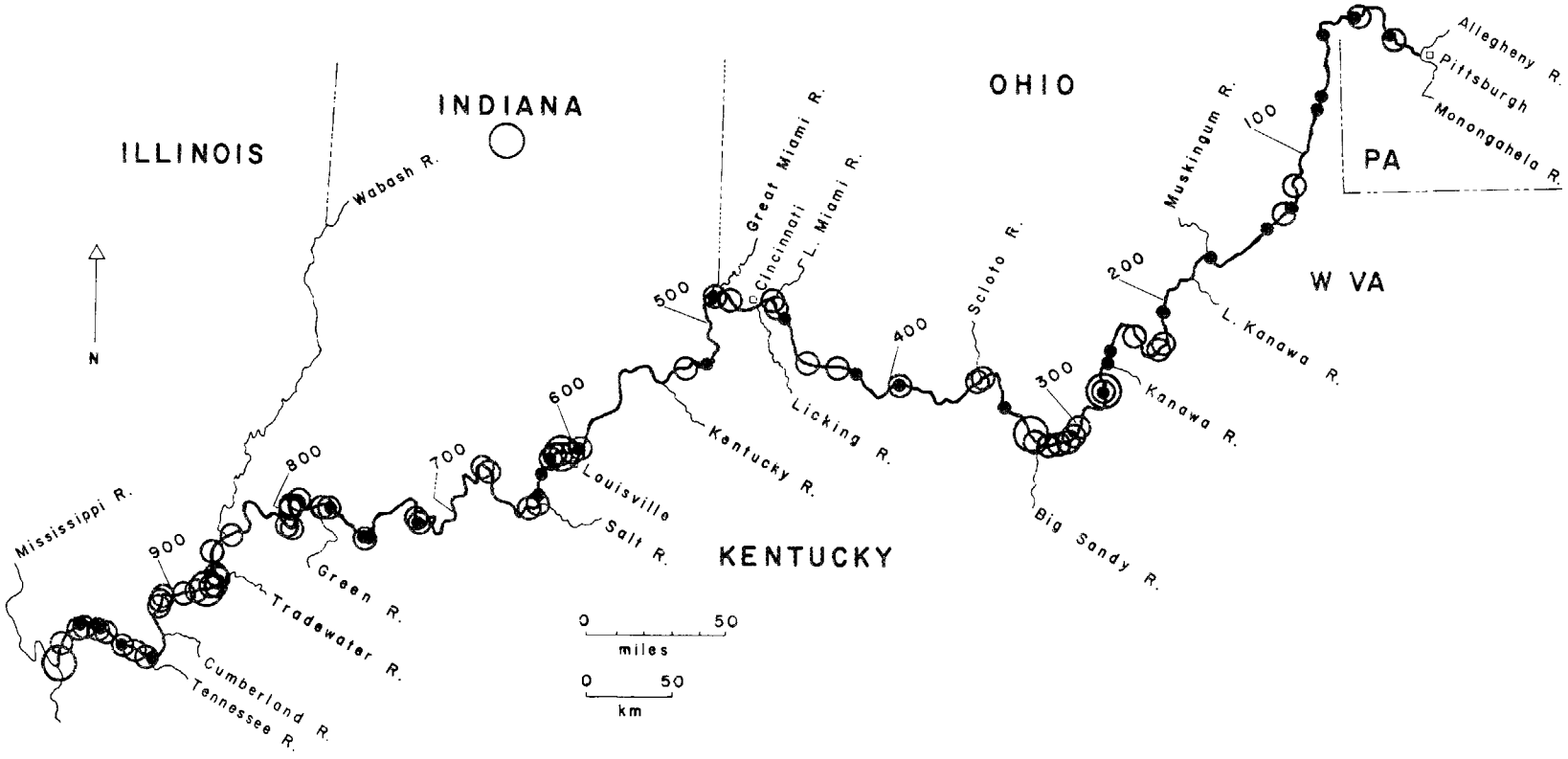

Figure 44. Distribution of *Notropis blennius* in the Ohio River.

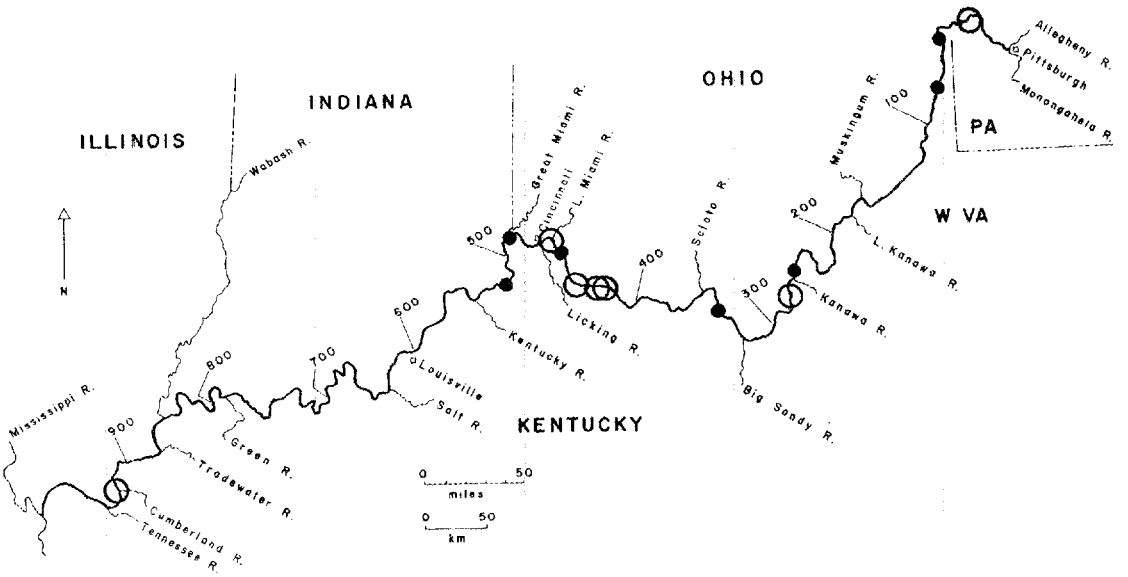

Figure 47. Distribution of *Notropis chrysocephalus* in the Ohio River.

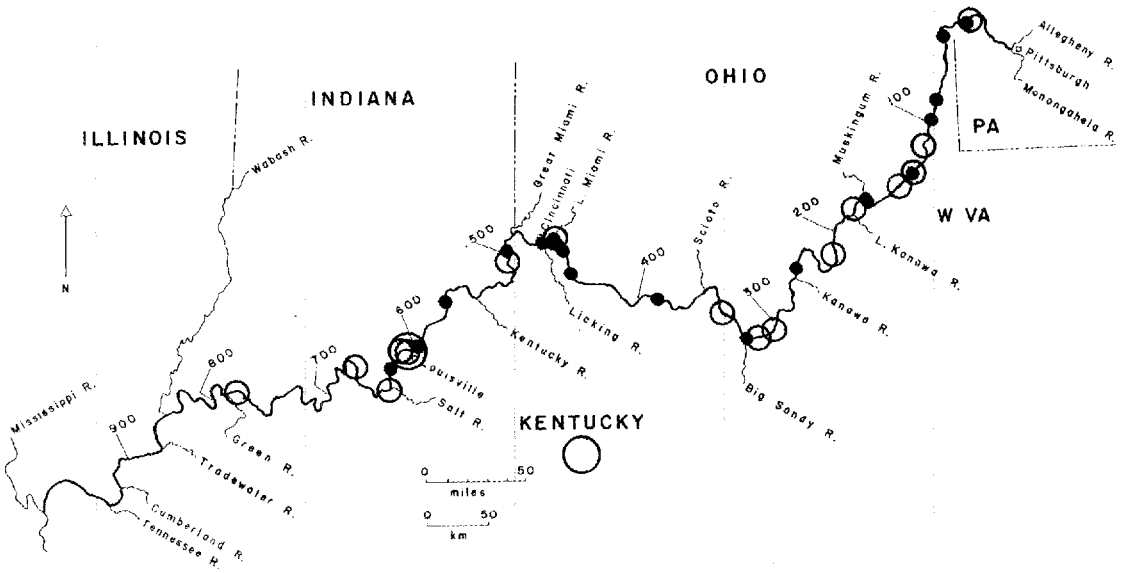

Figure 48. Distribution of *Notropis cornutus* in the Ohio River.

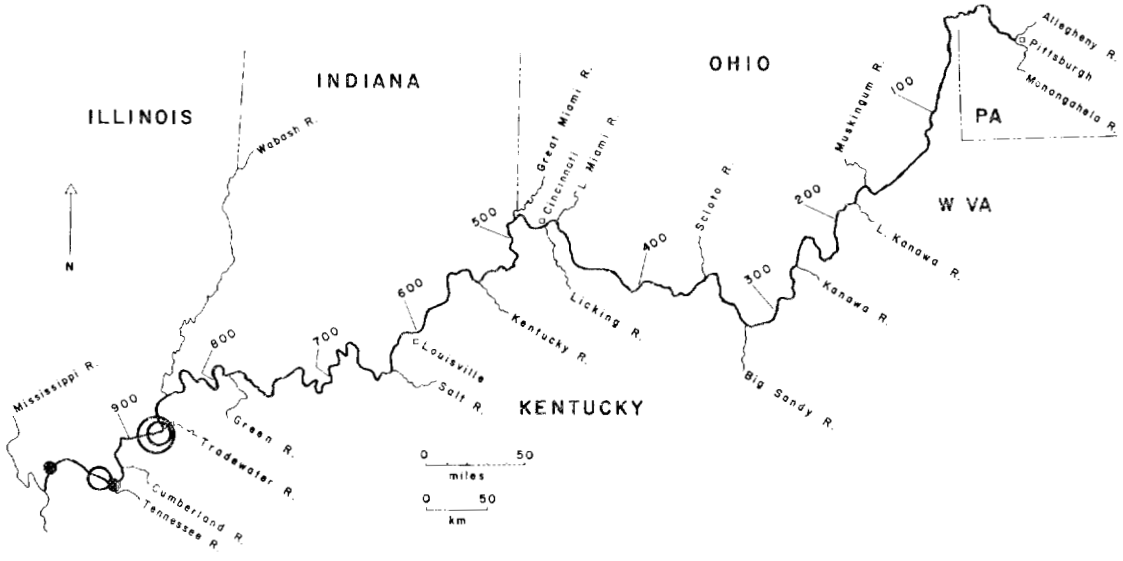

Figure 49. Distribution of *Notropis emiliae* in the Ohio River.

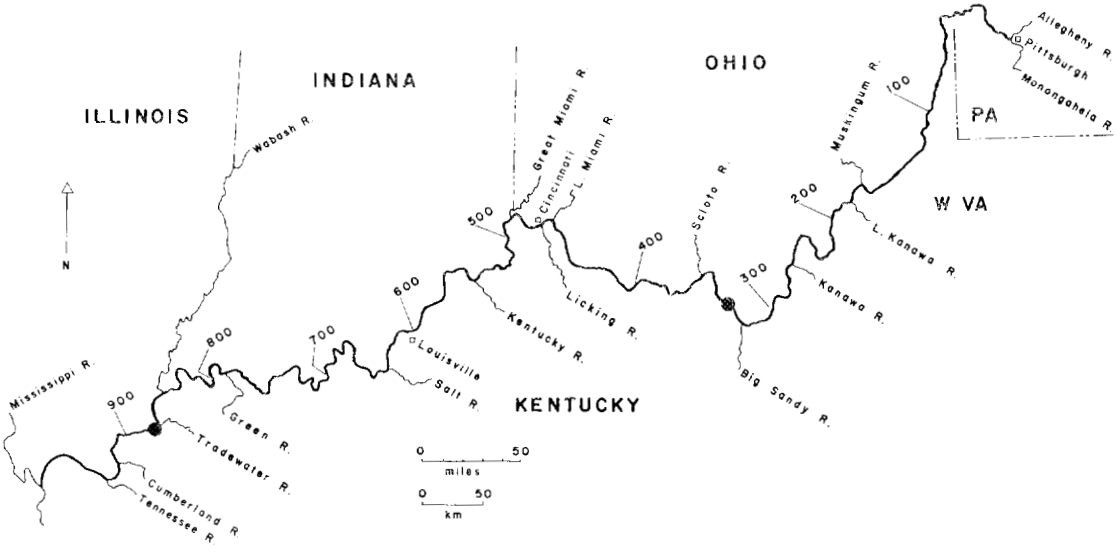

Figure 50. Distribution of *Notropis fumeus* in the Ohio River.

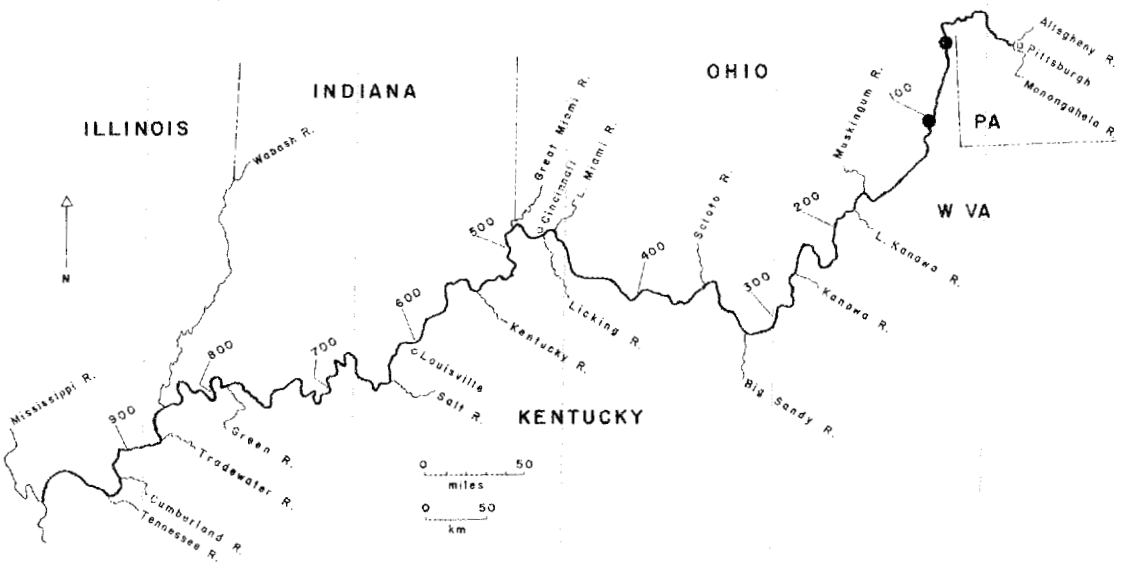

Figure 51. Distribution of *Notropis heterolepsis* in the Ohio River.

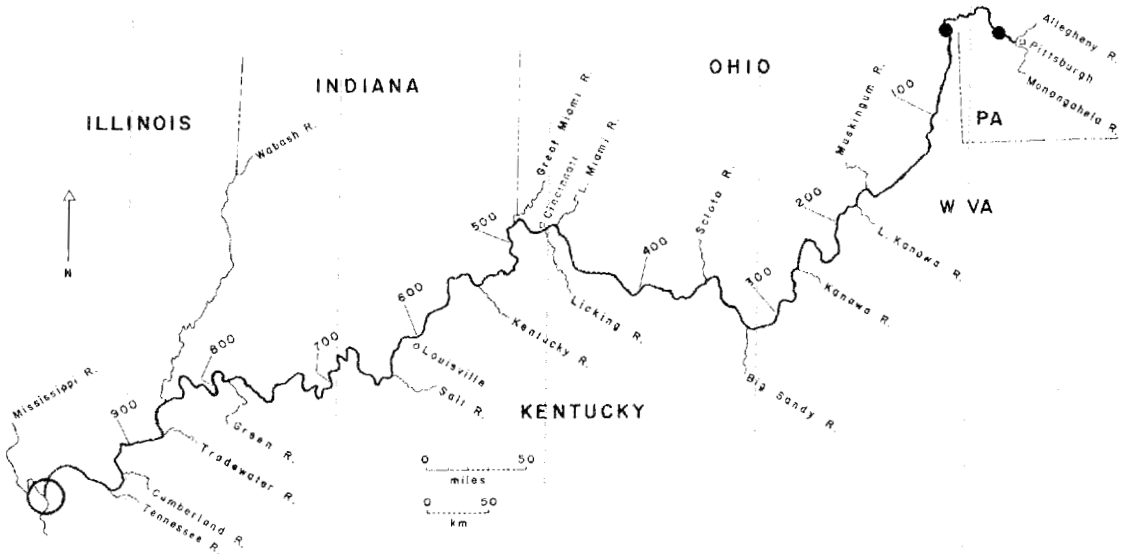

Figure 52. Distribution of *Notropis hudsonius* in the Ohio River.

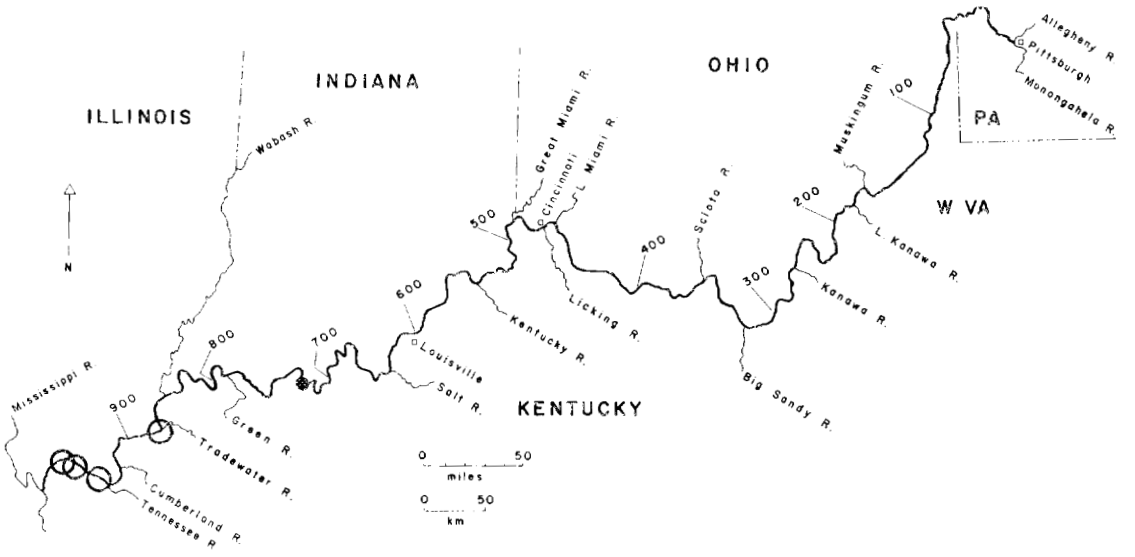

Figure 53. Distribution of *Notropis lutrensis* in the Ohio River.

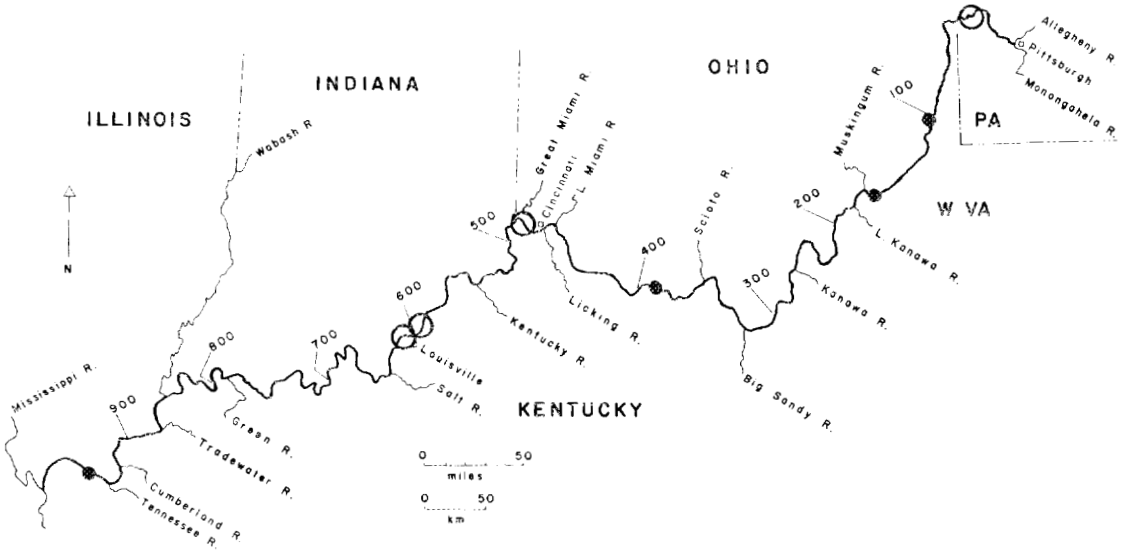

Figure 54. Distribution of *Notropis photogenis* in the Ohio River.

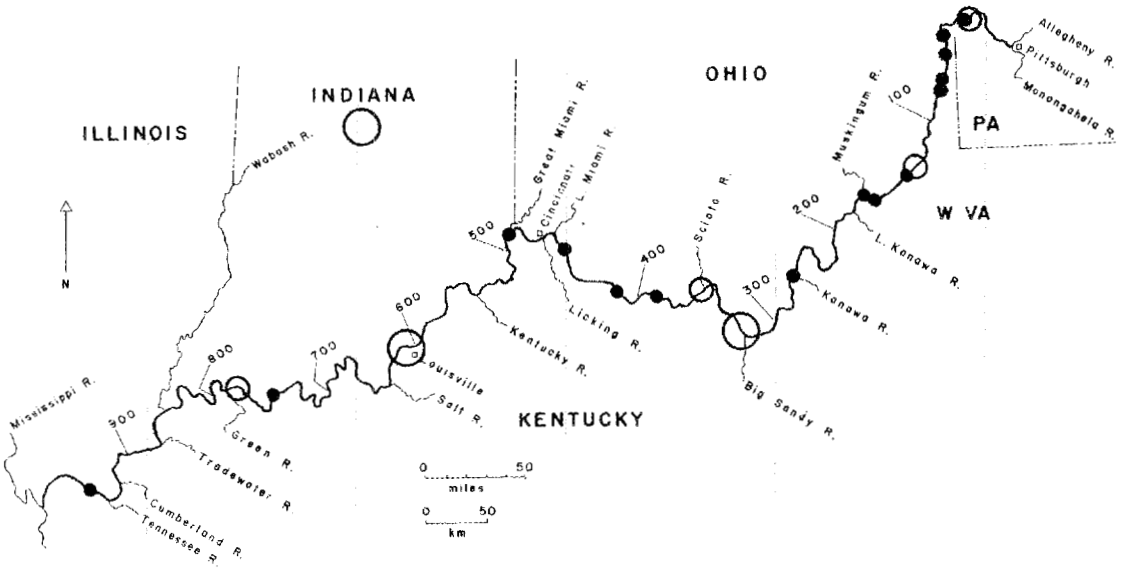

Figure 55. Distribution of *Notropis rubellus* in the Ohio River.

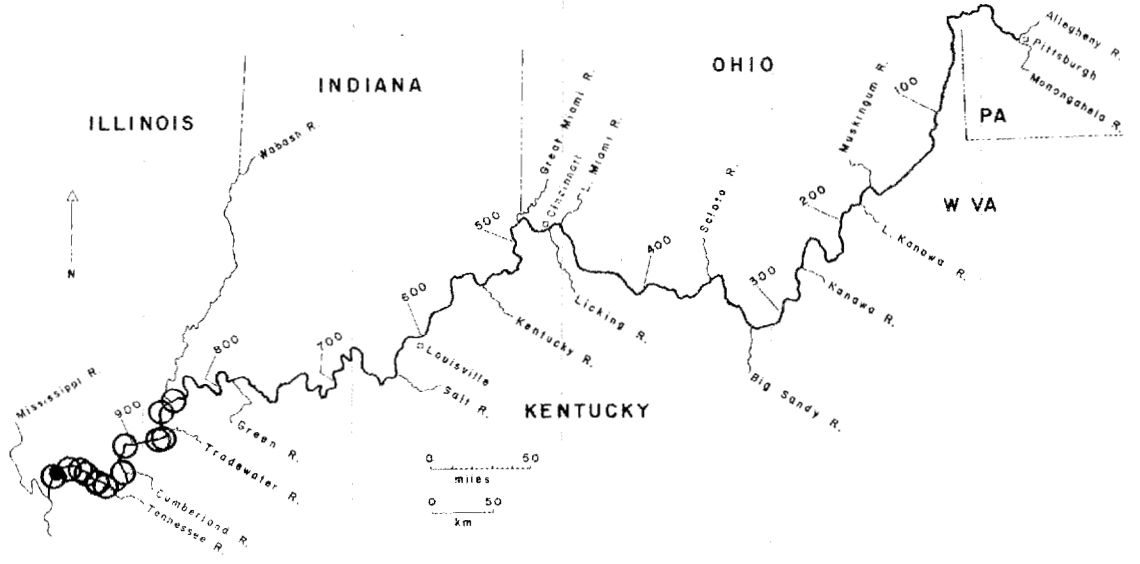

Figure 56. Distribution of *Notropis shumardi* in the Ohio River.

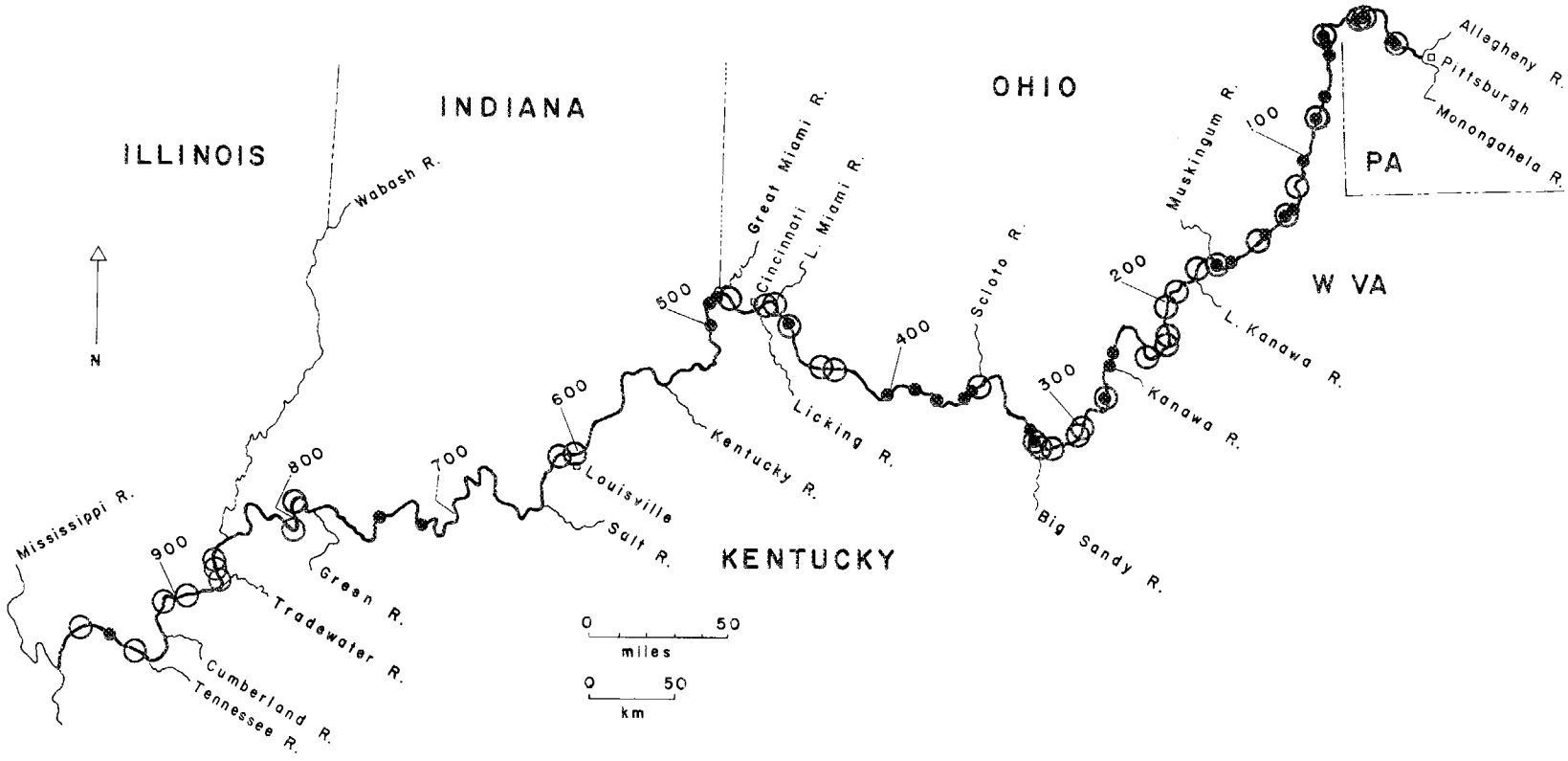

Figure 57. Distribution of *Notropis spilopterus* in the Ohio River.

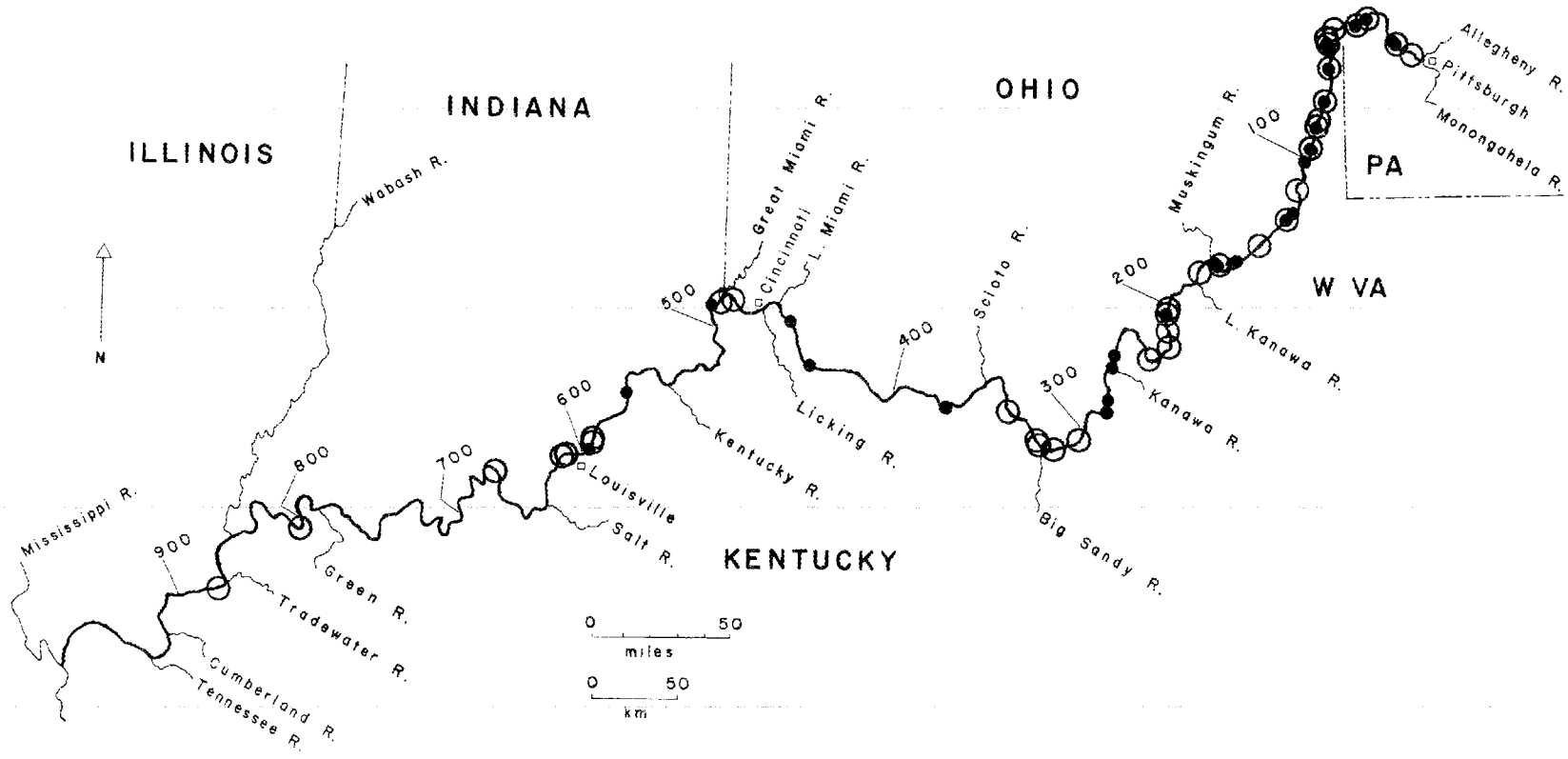

Figure 58. Distribution of *Notropis stramineus* in the Ohio River.

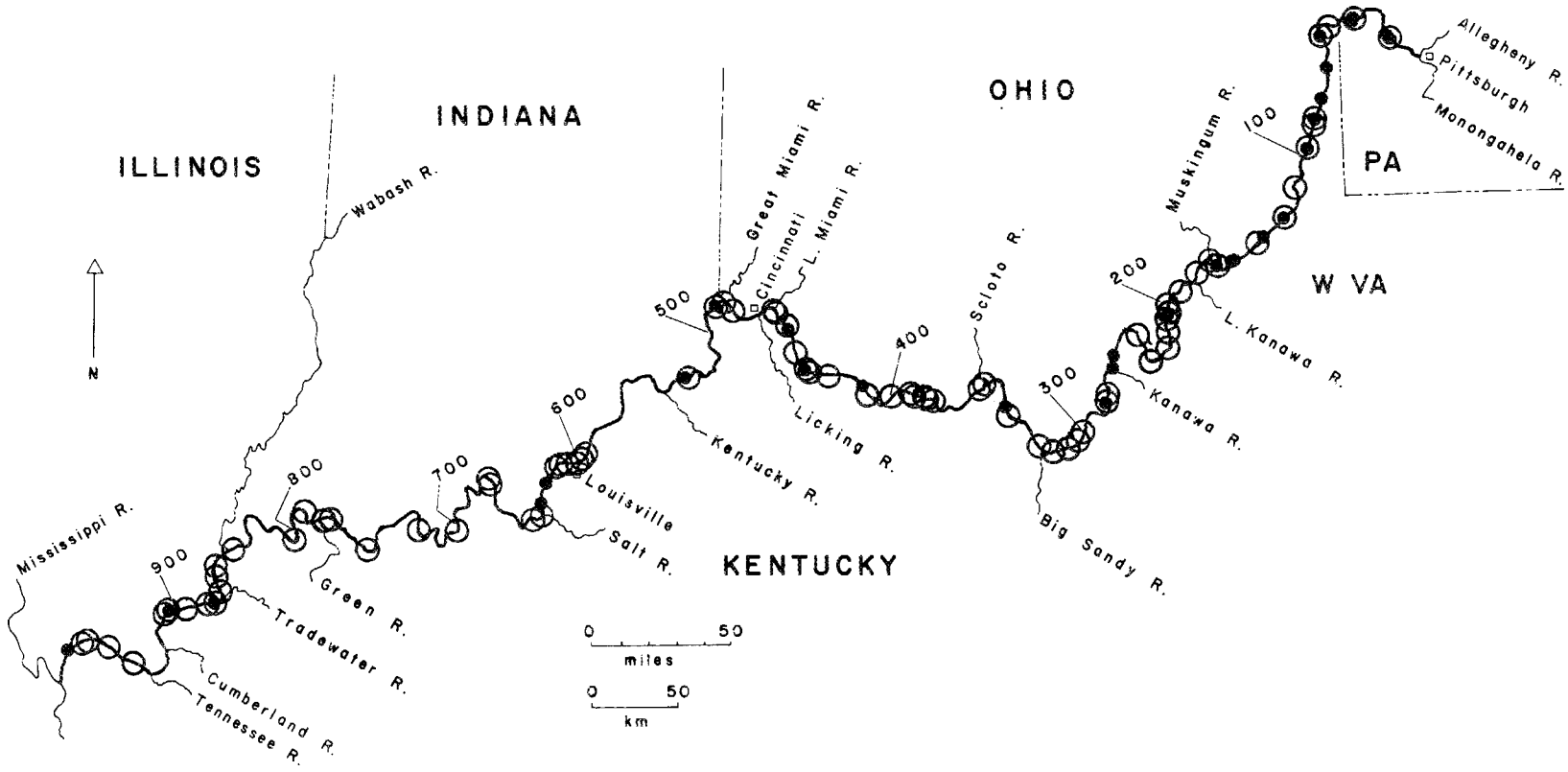

Figure 59. Distribution of *Notropis volucellus* in the Ohio River.

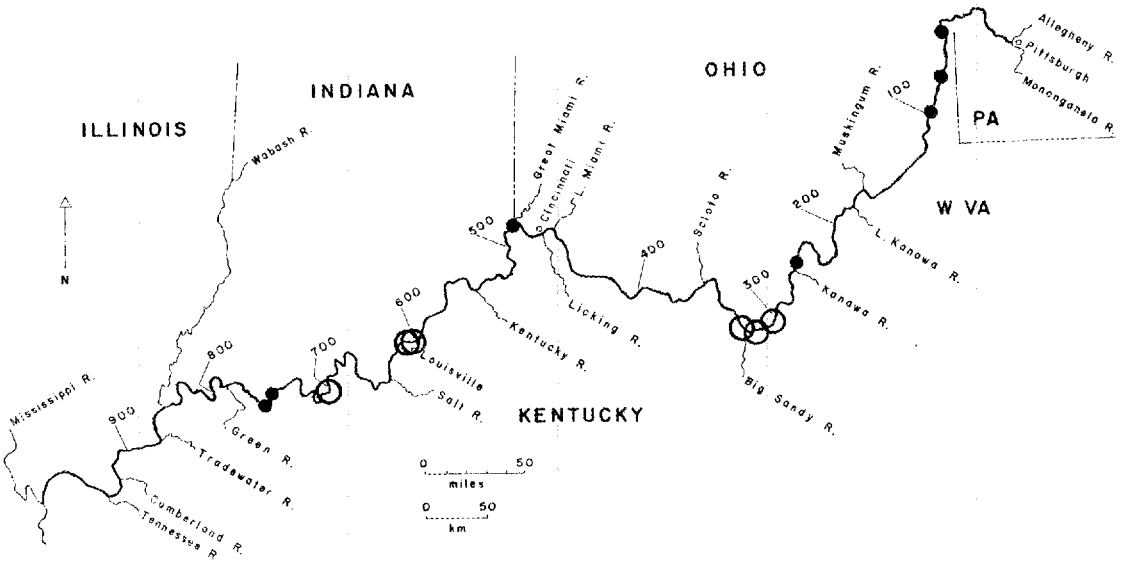

Figure 60. Distribution of *Notropis whipplei* in the Ohio River.

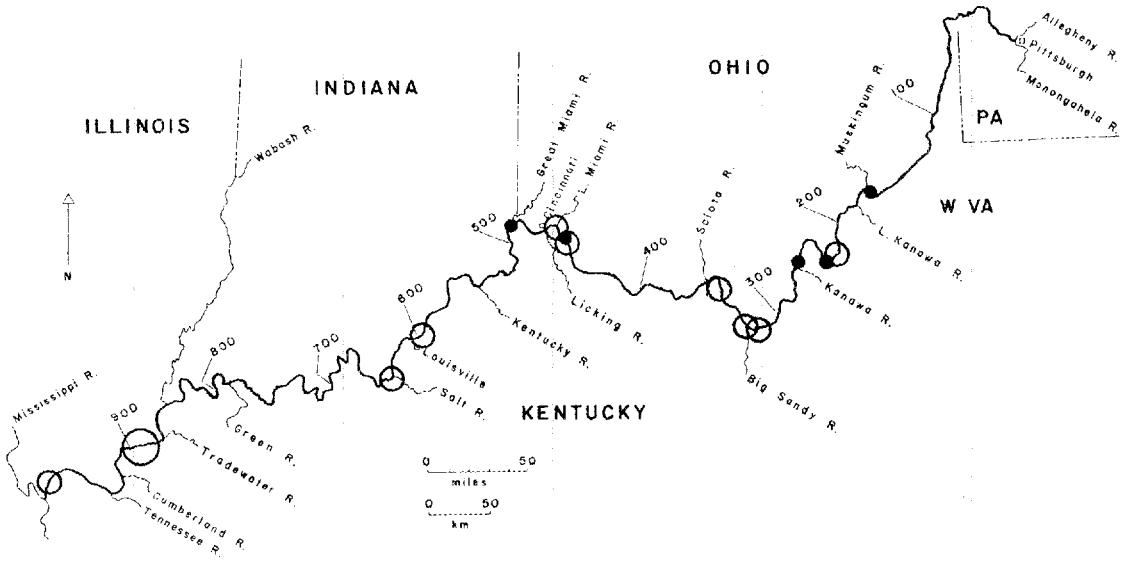

Figure 61. Distribution of *Phenacobius mirabilis* in the Ohio River.

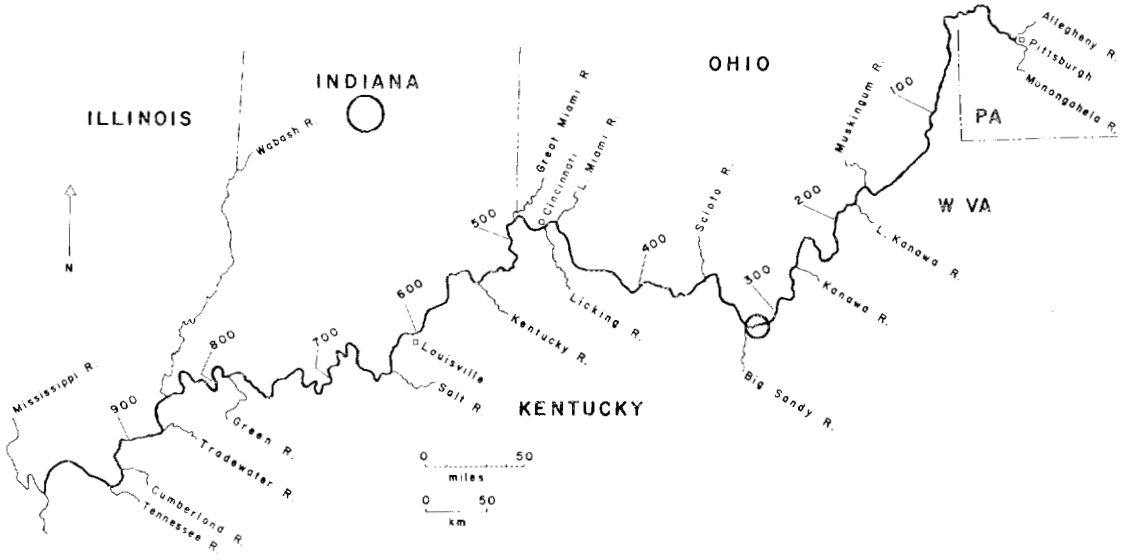

Figure 62. Distribution of *Phoxinus erythrogaster* in the Ohio River.

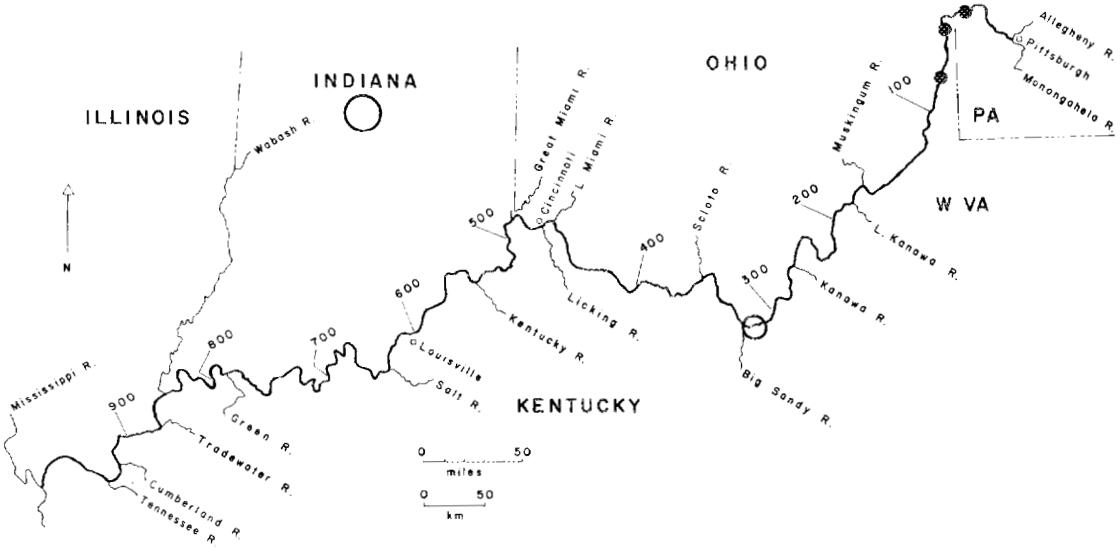

Figure 66. Distribution of *Rhinichthys atratulus* in the Ohio River.

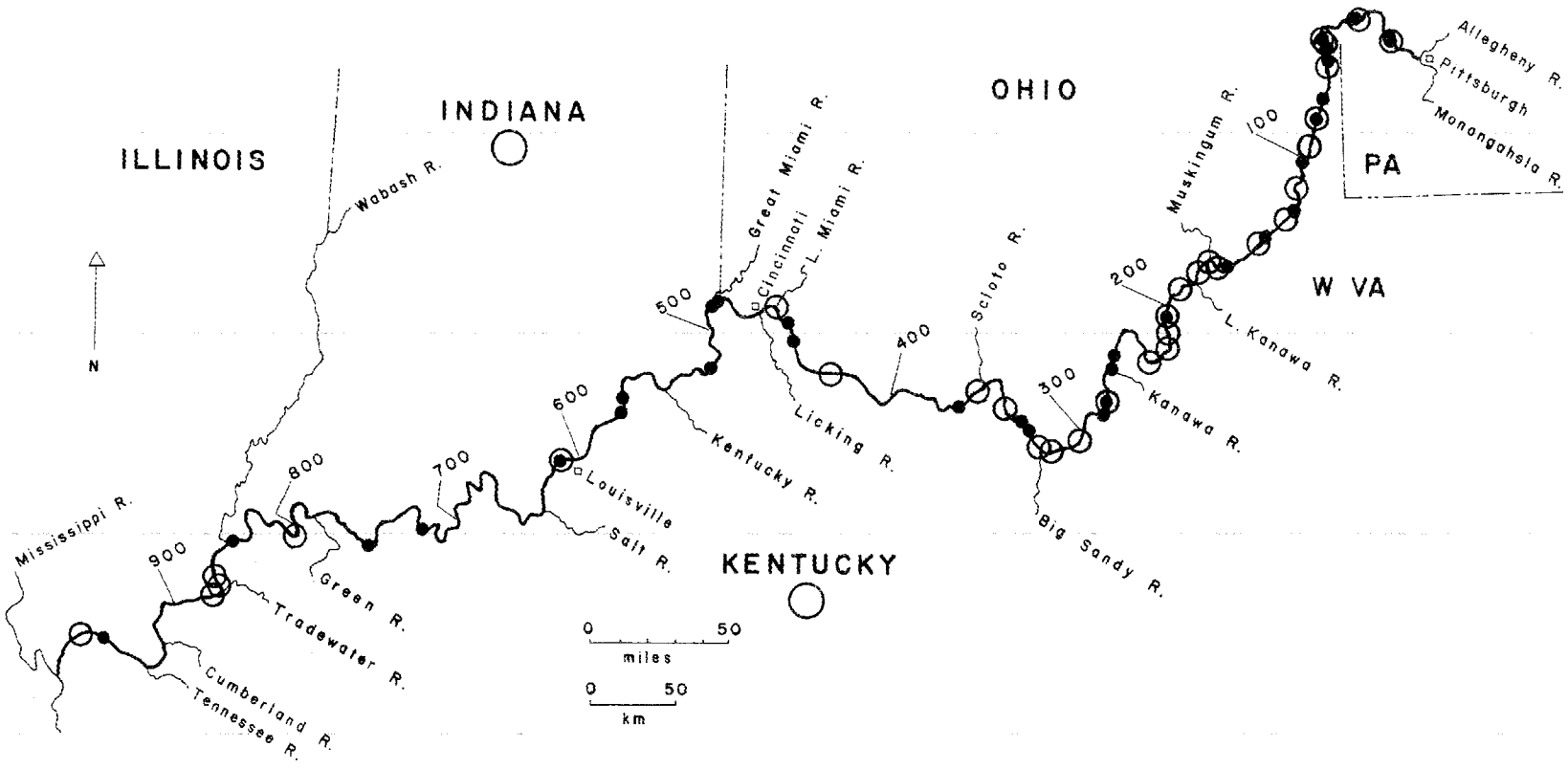

Figure 63. Distribution of *Pimephales notatus* in the Ohio River.

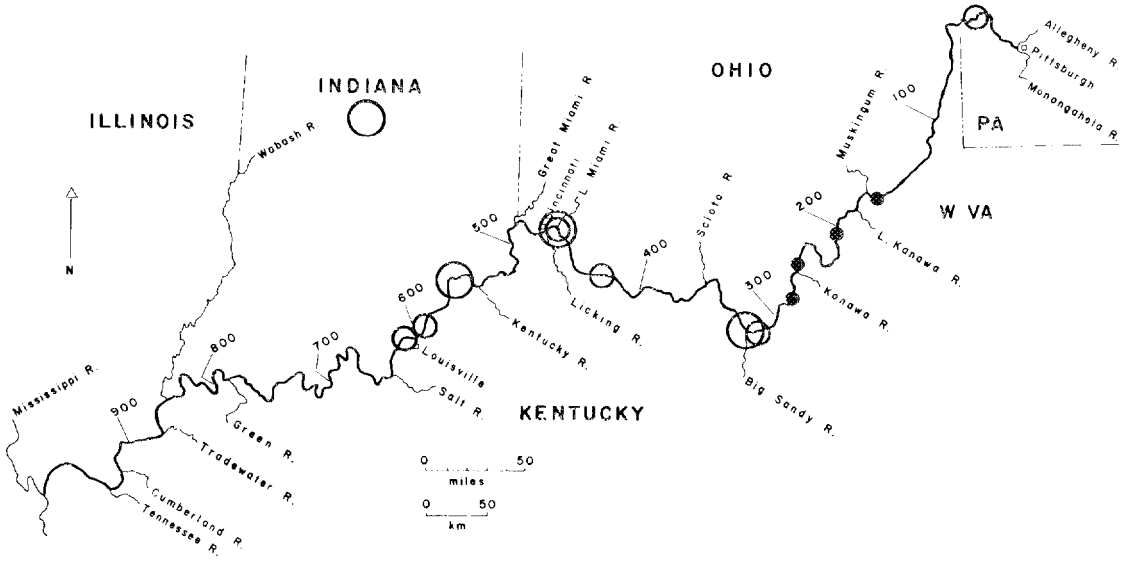

Figure 64. Distribution of *Pimephales promelas* in the Ohio River.

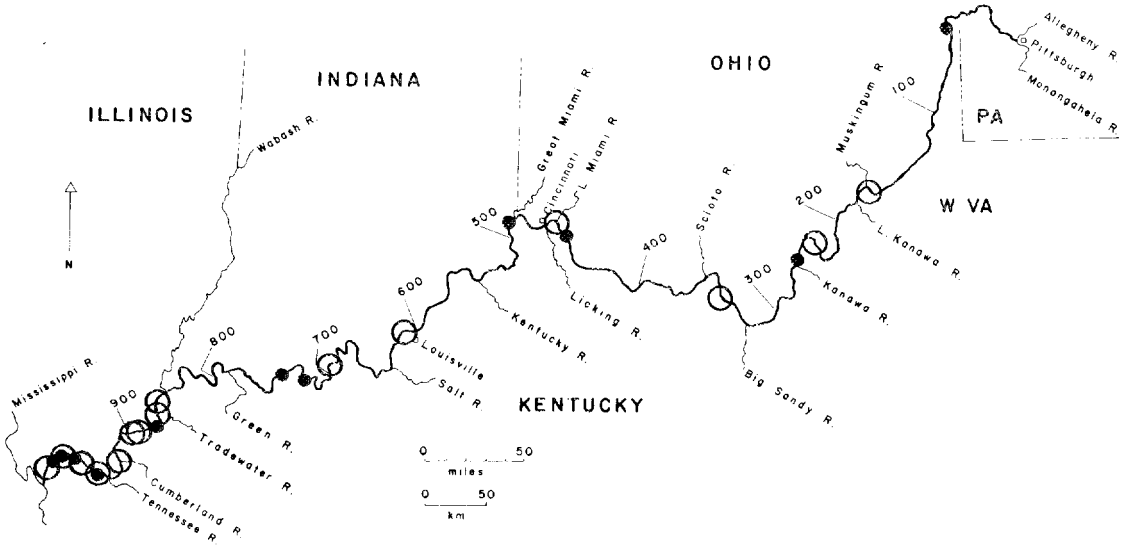

Figure 65. Distribution of *Pimephales vigilax* in the Ohio River.

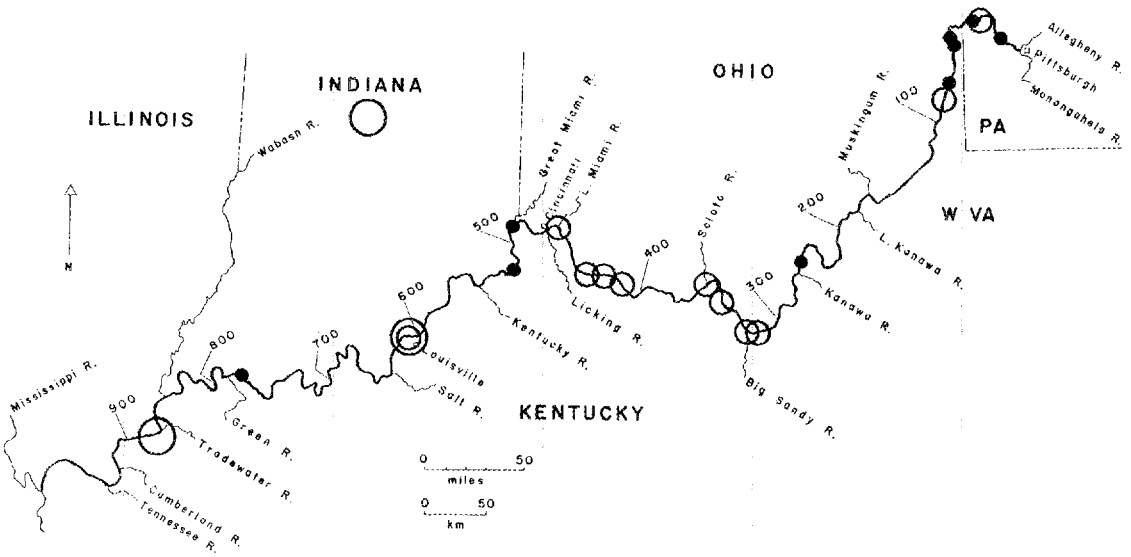

Figure 67. Distribution of *Semotilus atromaculatus* in the Ohio River.

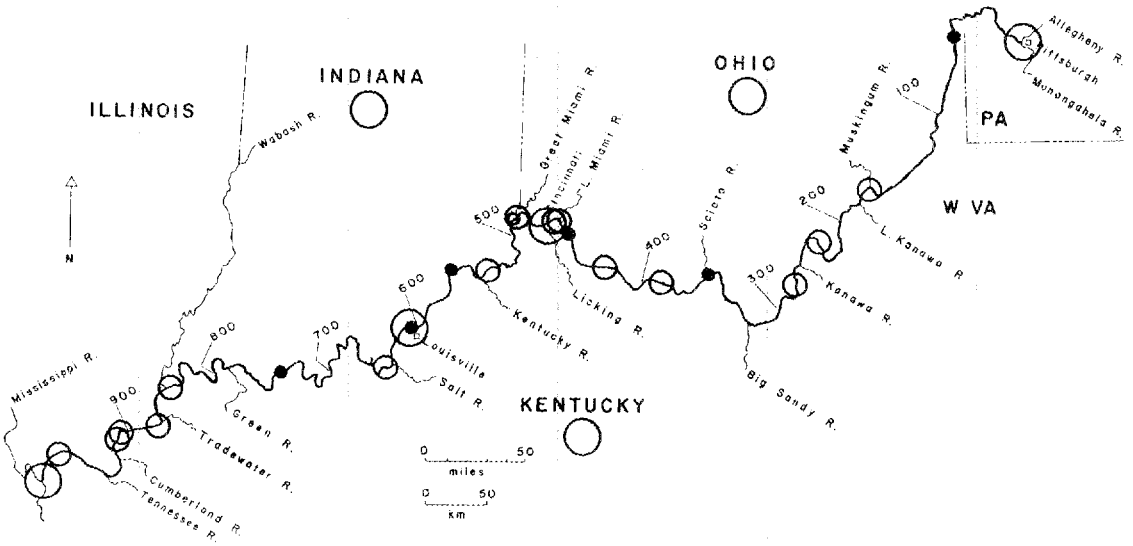

Figure 72. Distribution of *Cycleptus elongatus* in the Ohio River.

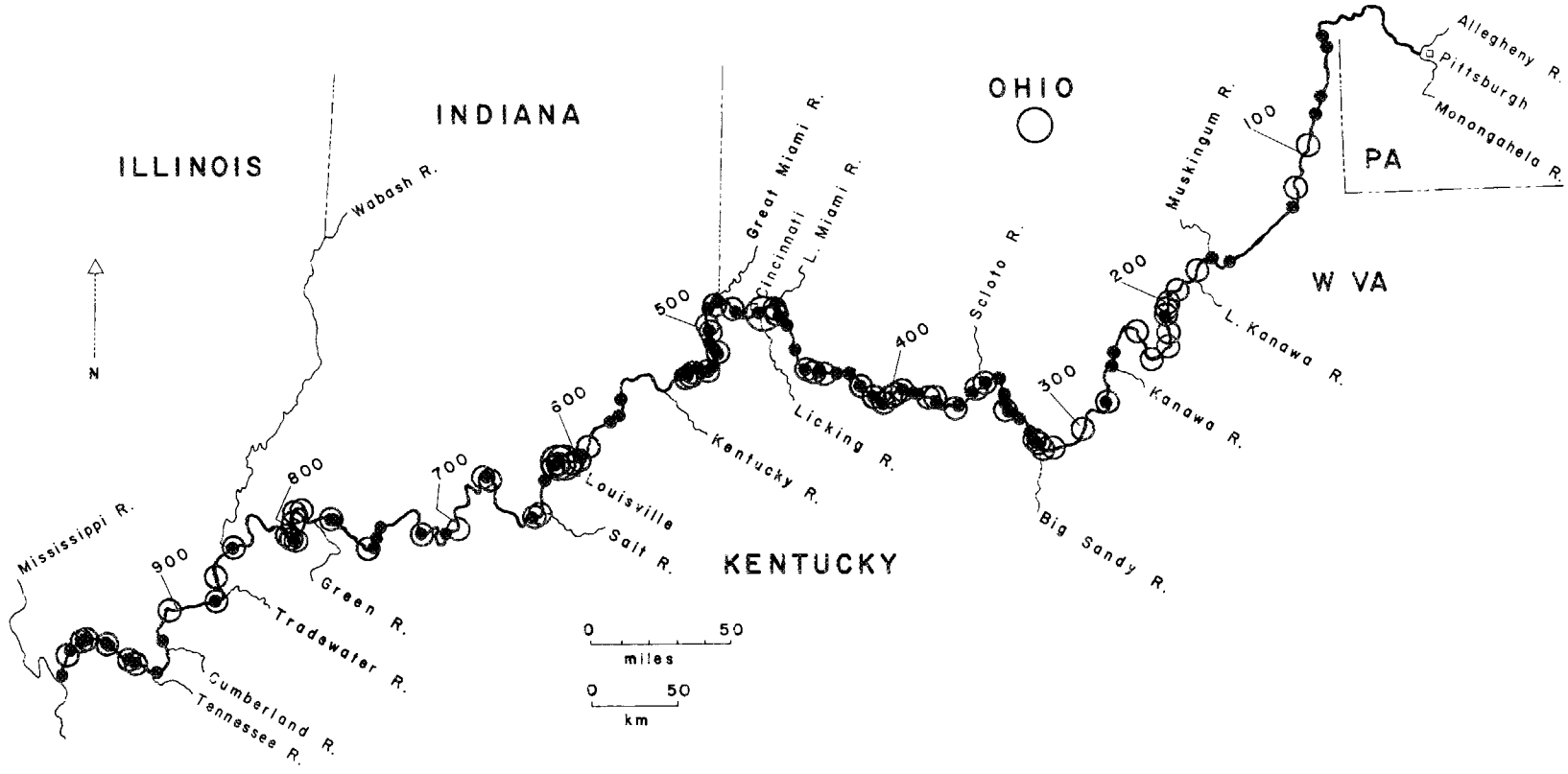

Figure 68. Distribution of *Carpiodes carpio* in the Ohio River.

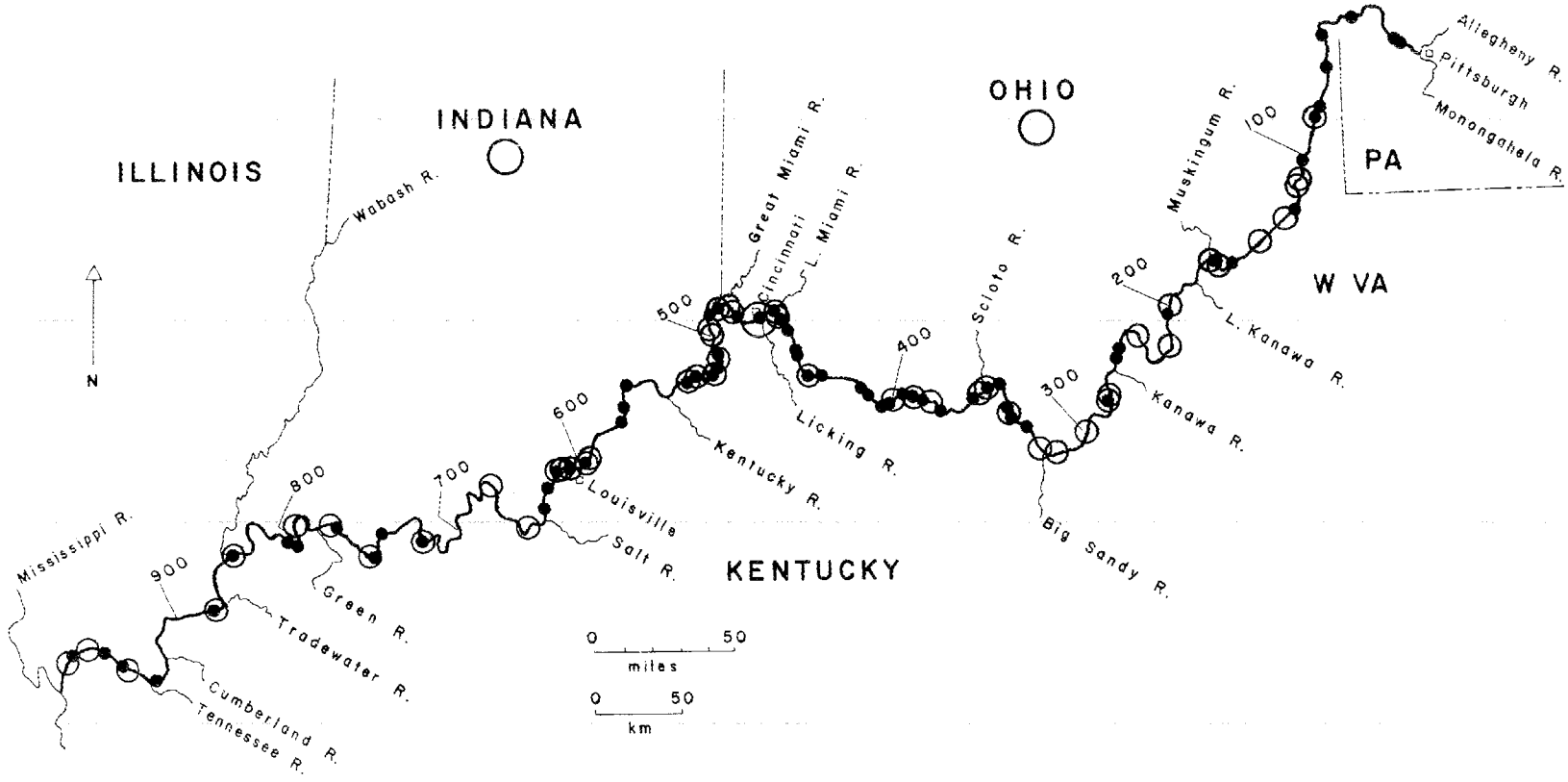

Figure 69. Distribution of *Carpiodes cyprinus* in the Ohio River.

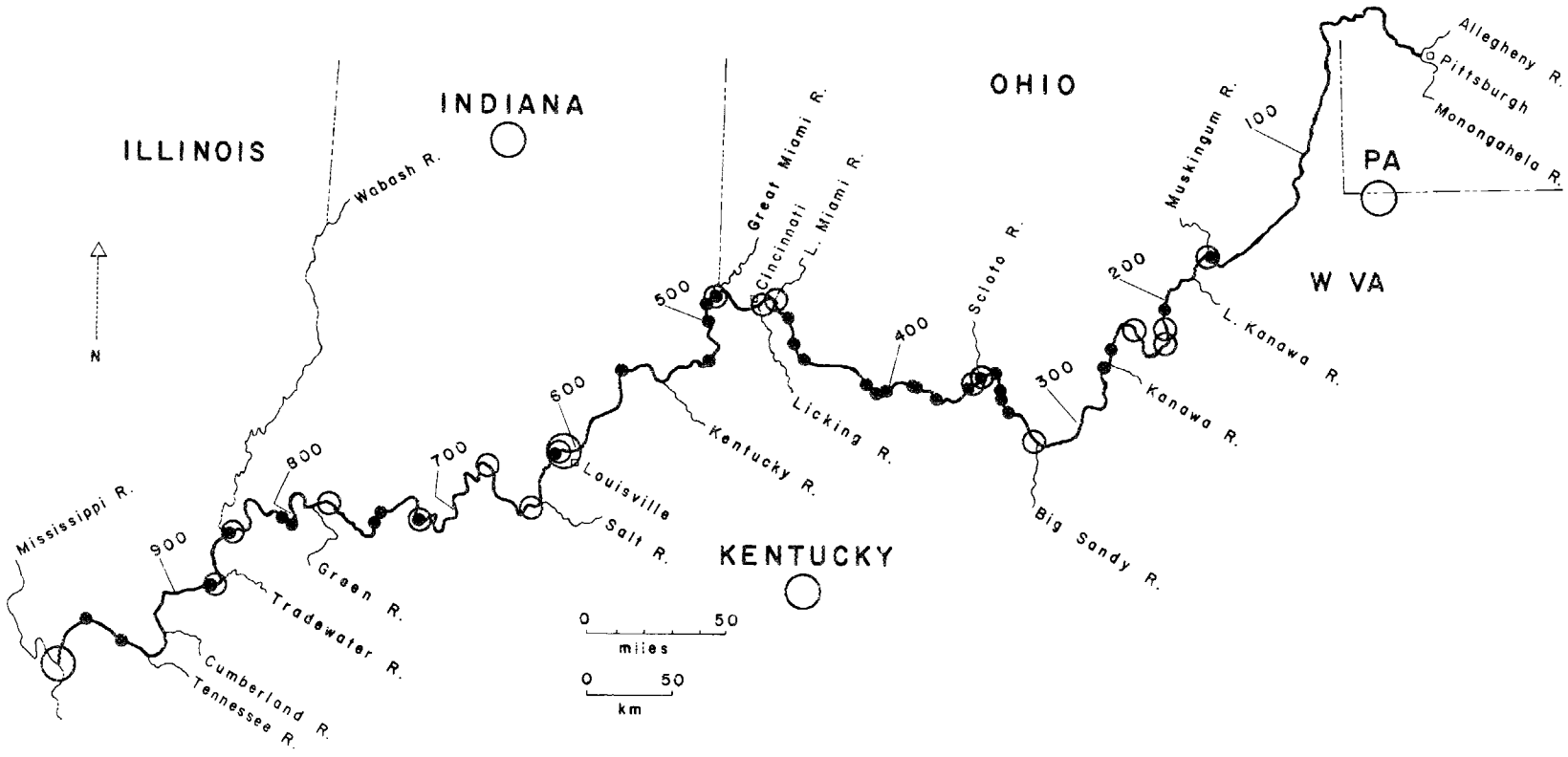

Figure 70. Distribution of *Carpiodes velifer* in the Ohio River.

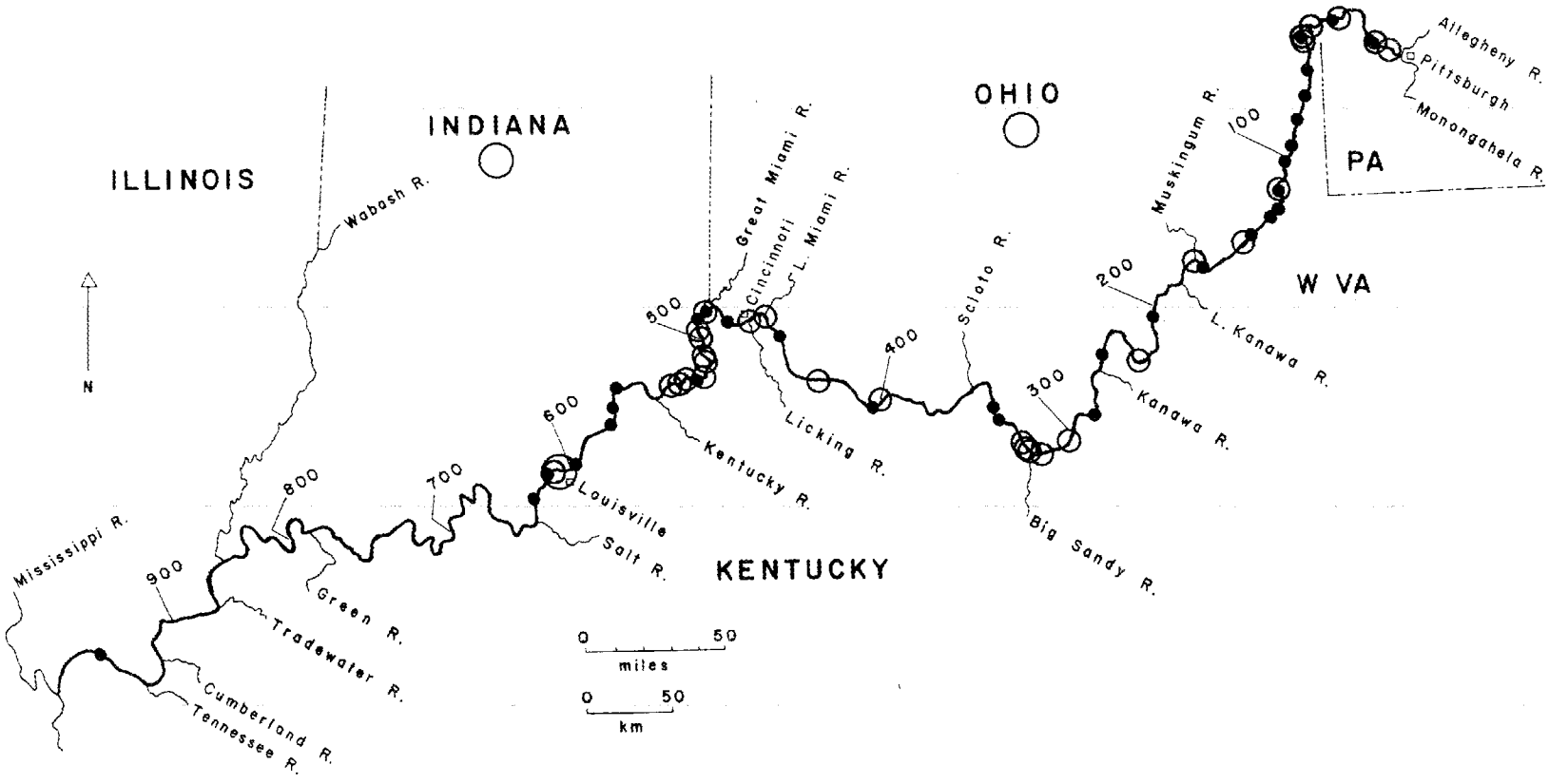

Figure 71. Distribution of *Catostomus commersoni* in the Ohio River.

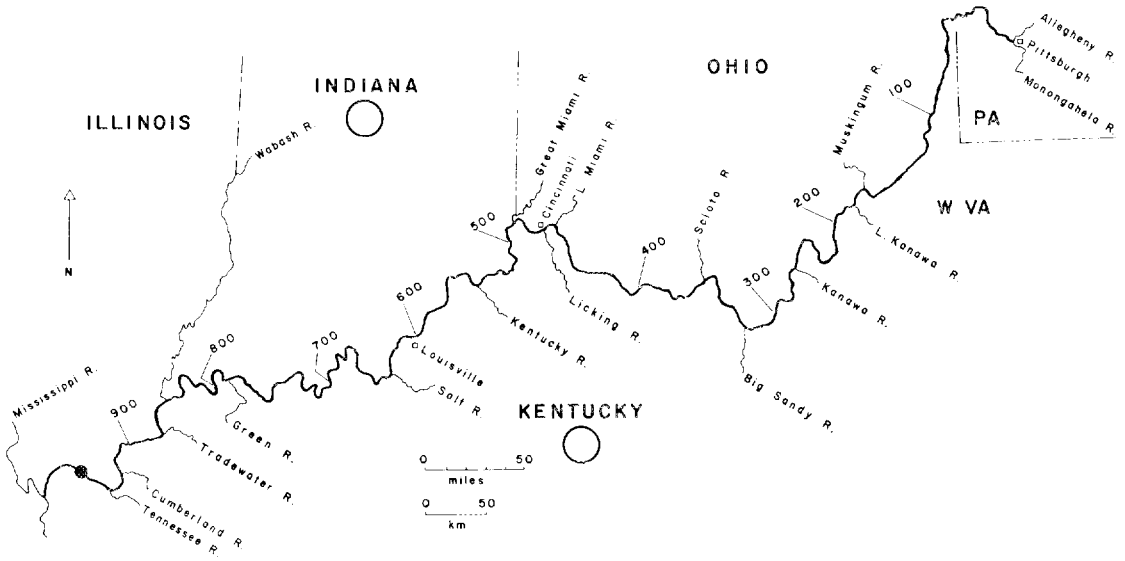

Figure 73. Distribution of *Erimyzon oblongus* in the Ohio River.

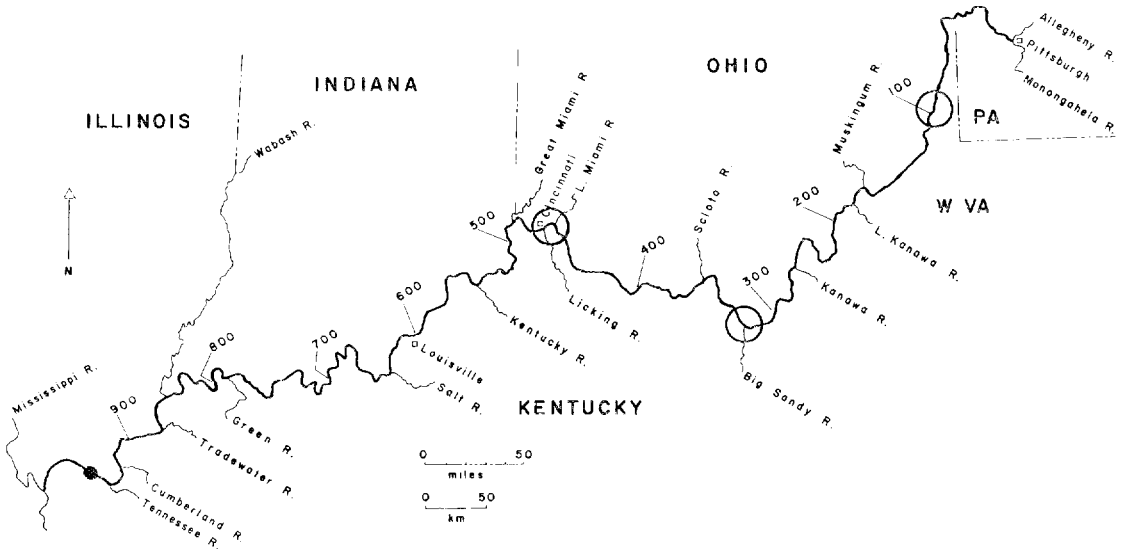

Figure 74. Distribution of *Erimyzon sucetta* in the Ohio River.

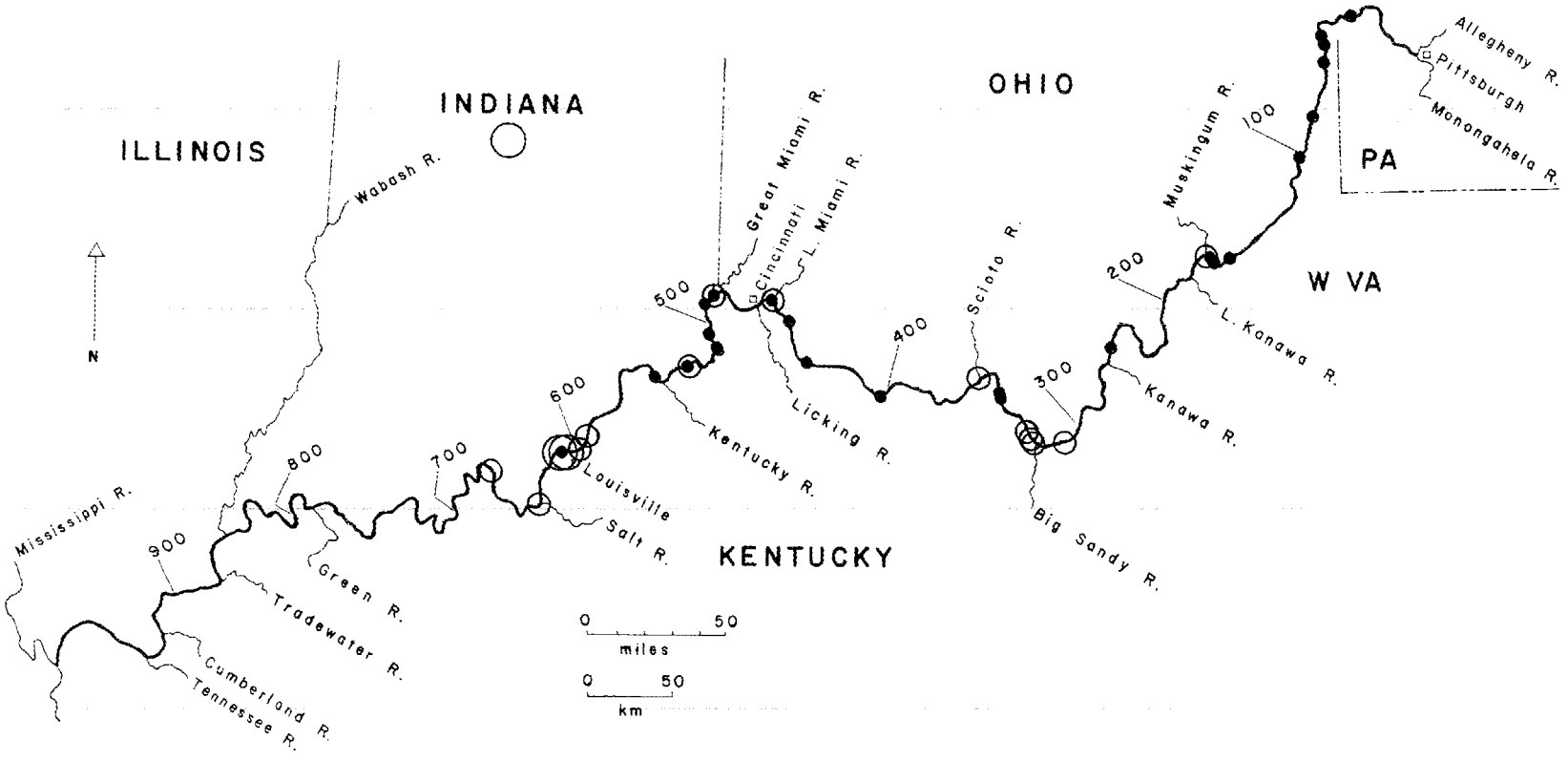

Figure 75. Distribution of *Hypentelium nigricans* in the Ohio River.

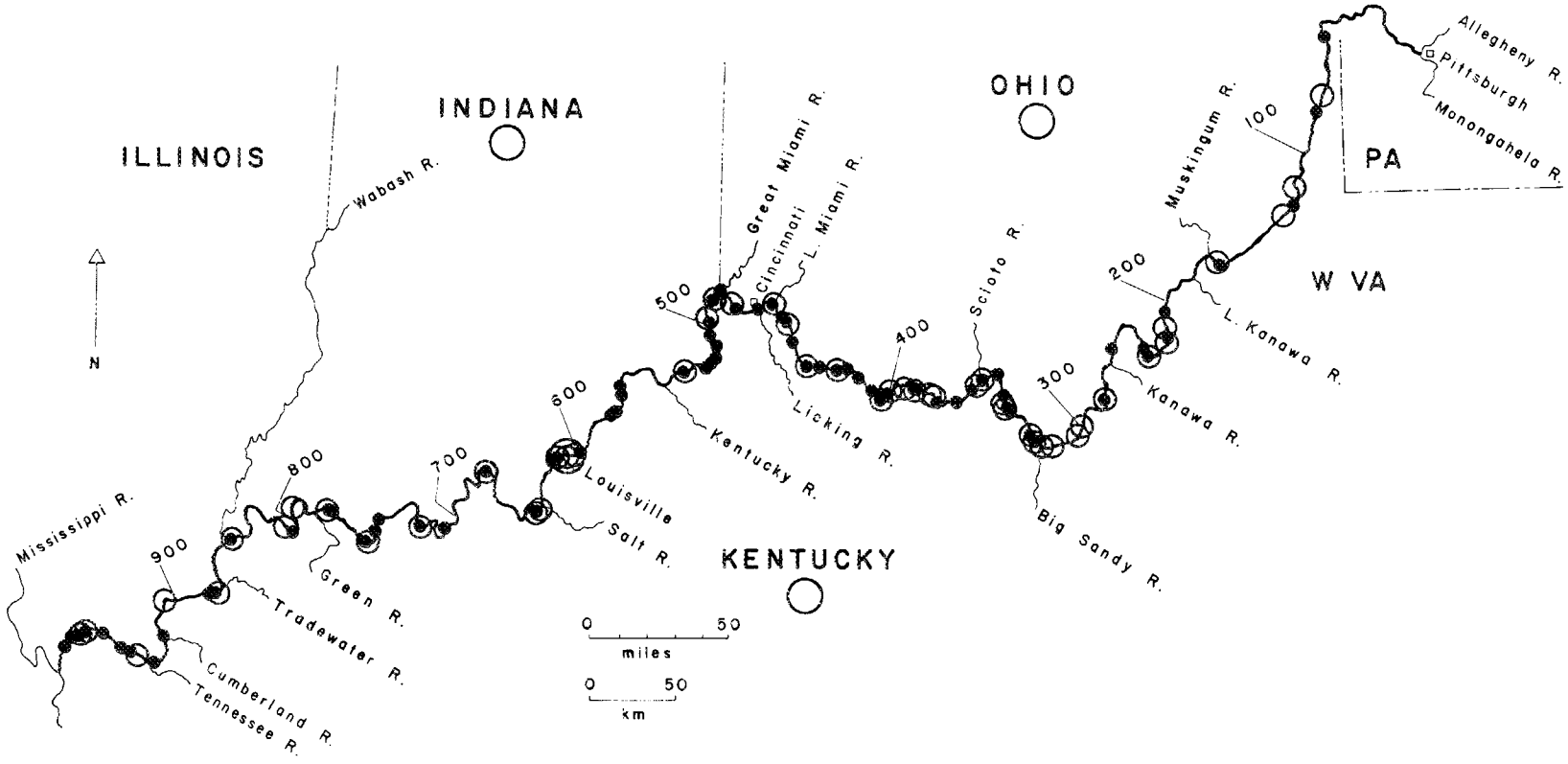

Figure 76. Distribution of *Ictiobus bubalus* in the Ohio River.

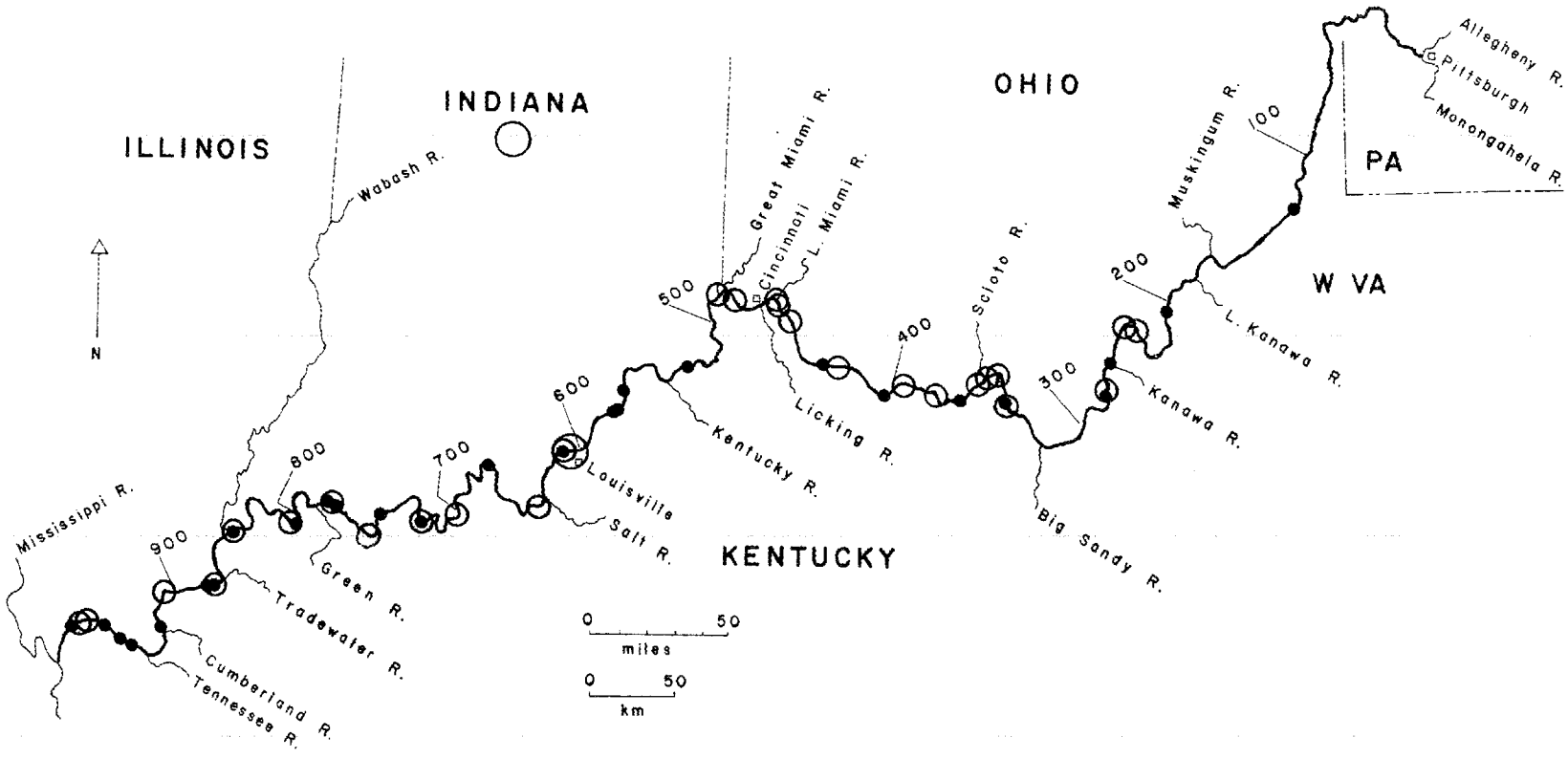

Figure 77. Distribution of *Ictiobus cyprinellus* in the Ohio River.

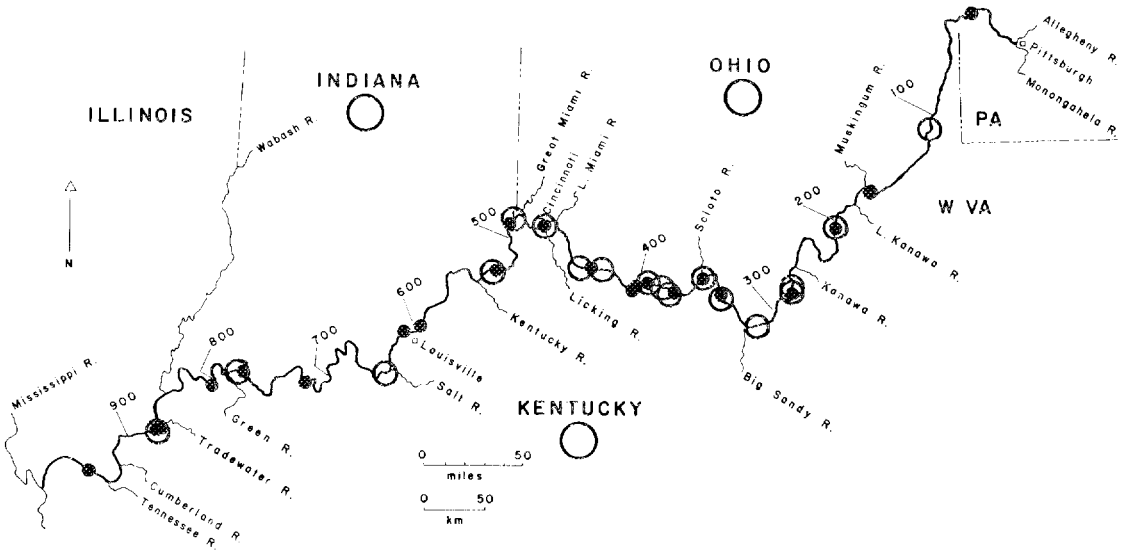

Figure 78. Distribution of *Ictiobus niger* in the Ohio River.

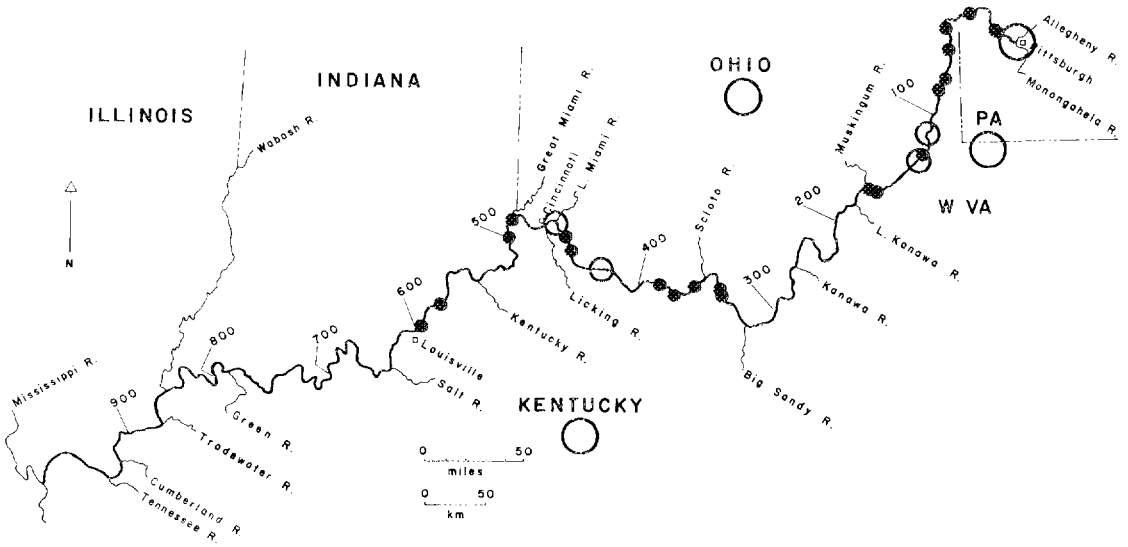

Figure 82. Distribution of *Moxostoma duquesnei* in the Ohio River.

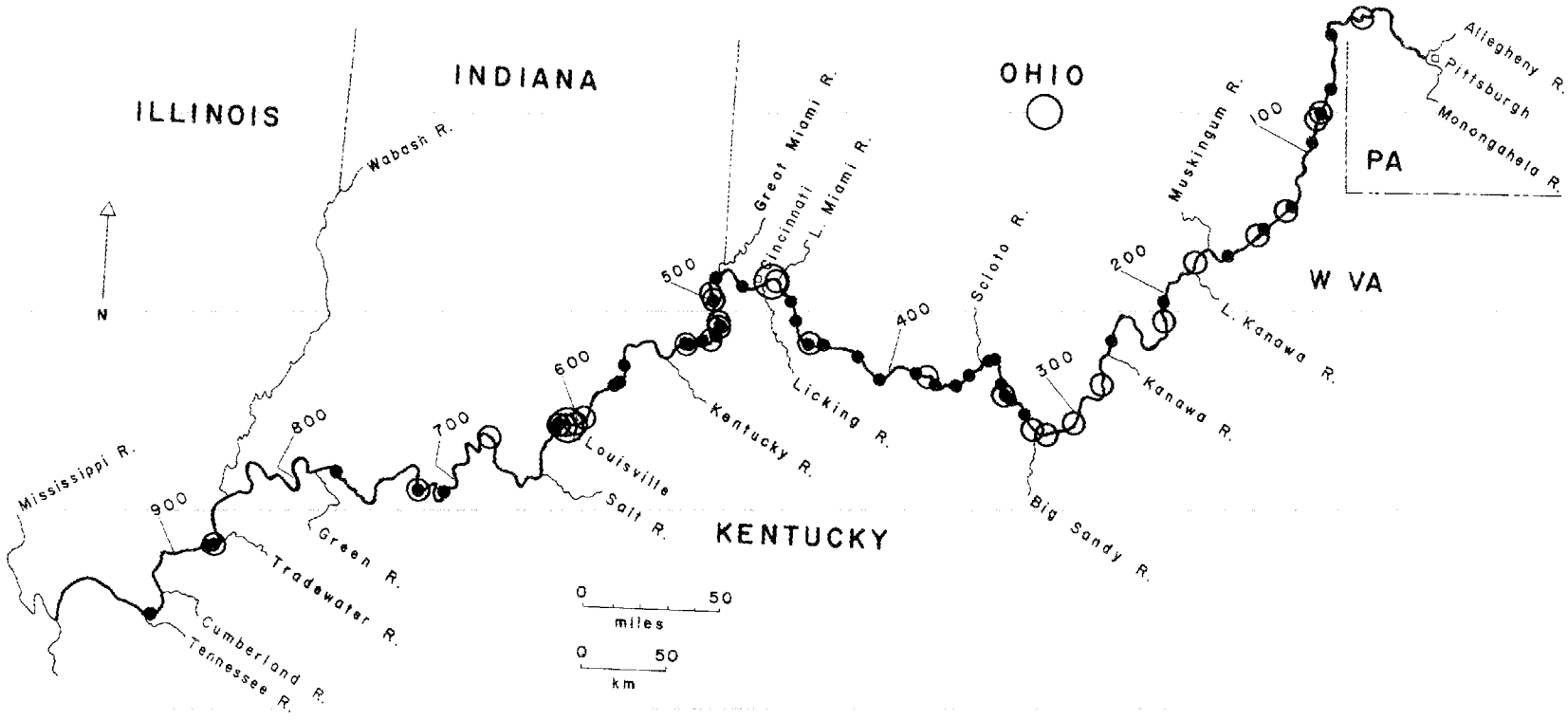

Figure 79. Distribution of *Minytrema melanops* in the Ohio River.

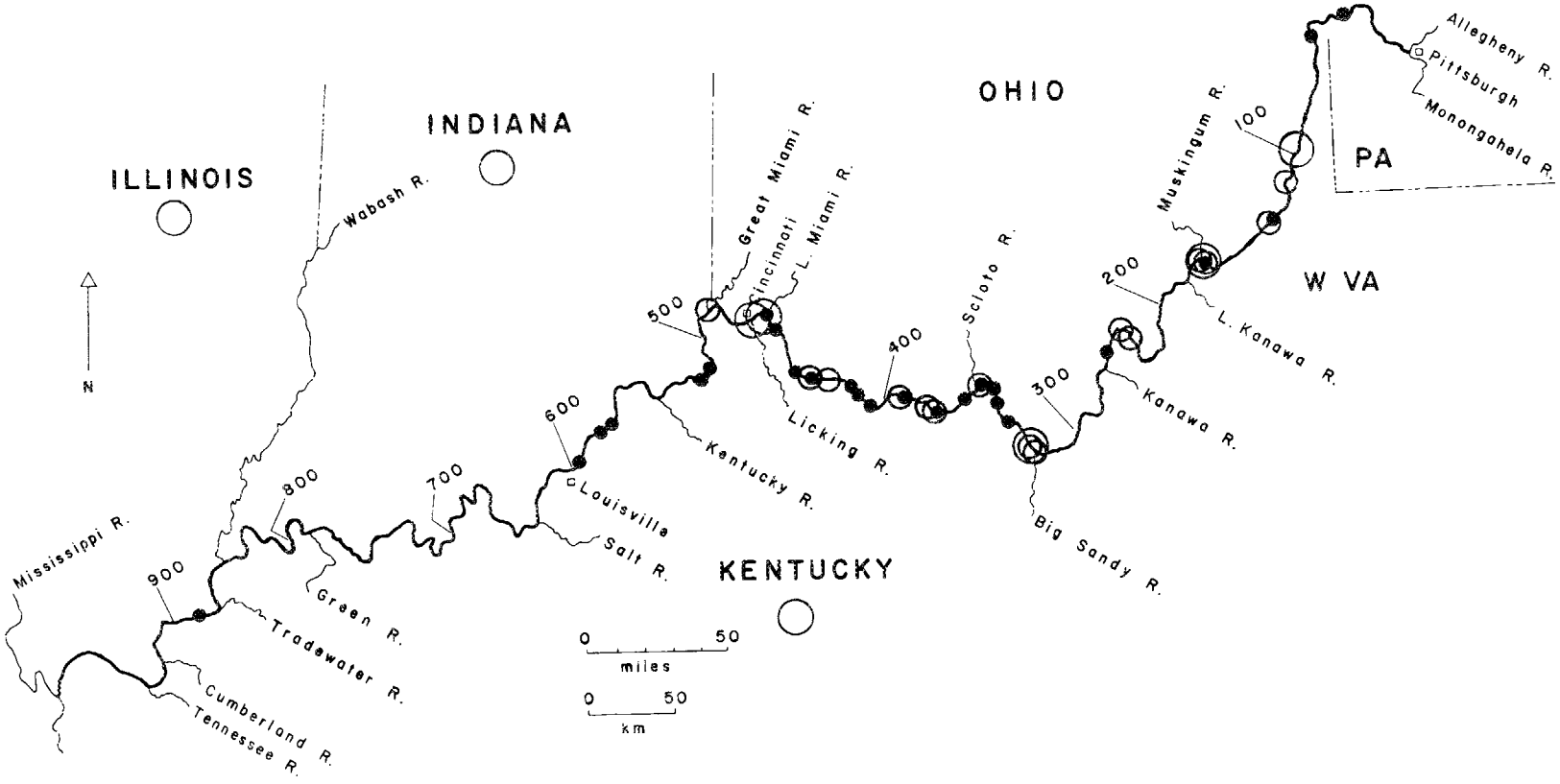

Figure 80. Distribution of *Moxostoma anisurum* in the Ohio River.

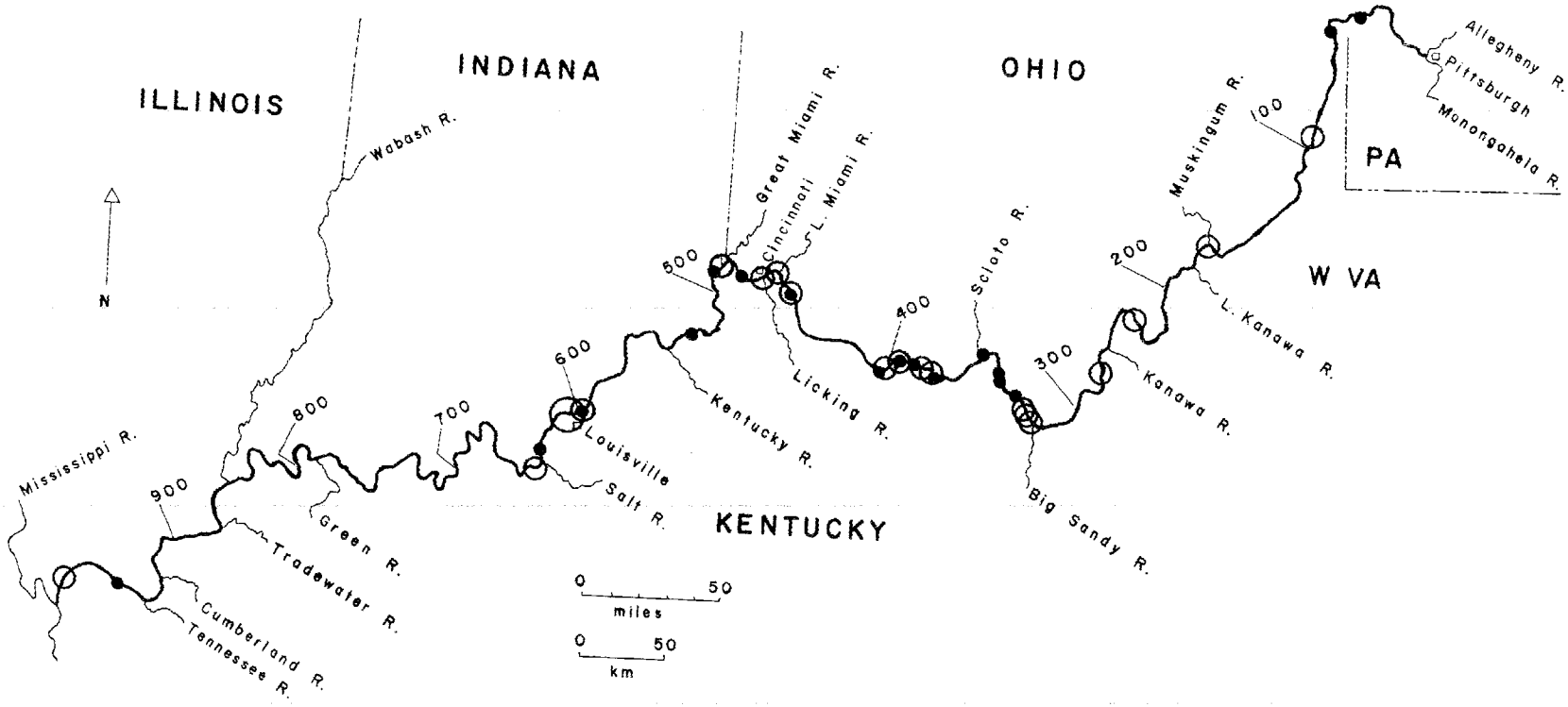

Figure 81. Distribution of *Moxostoma carinatum* in the Ohio River.

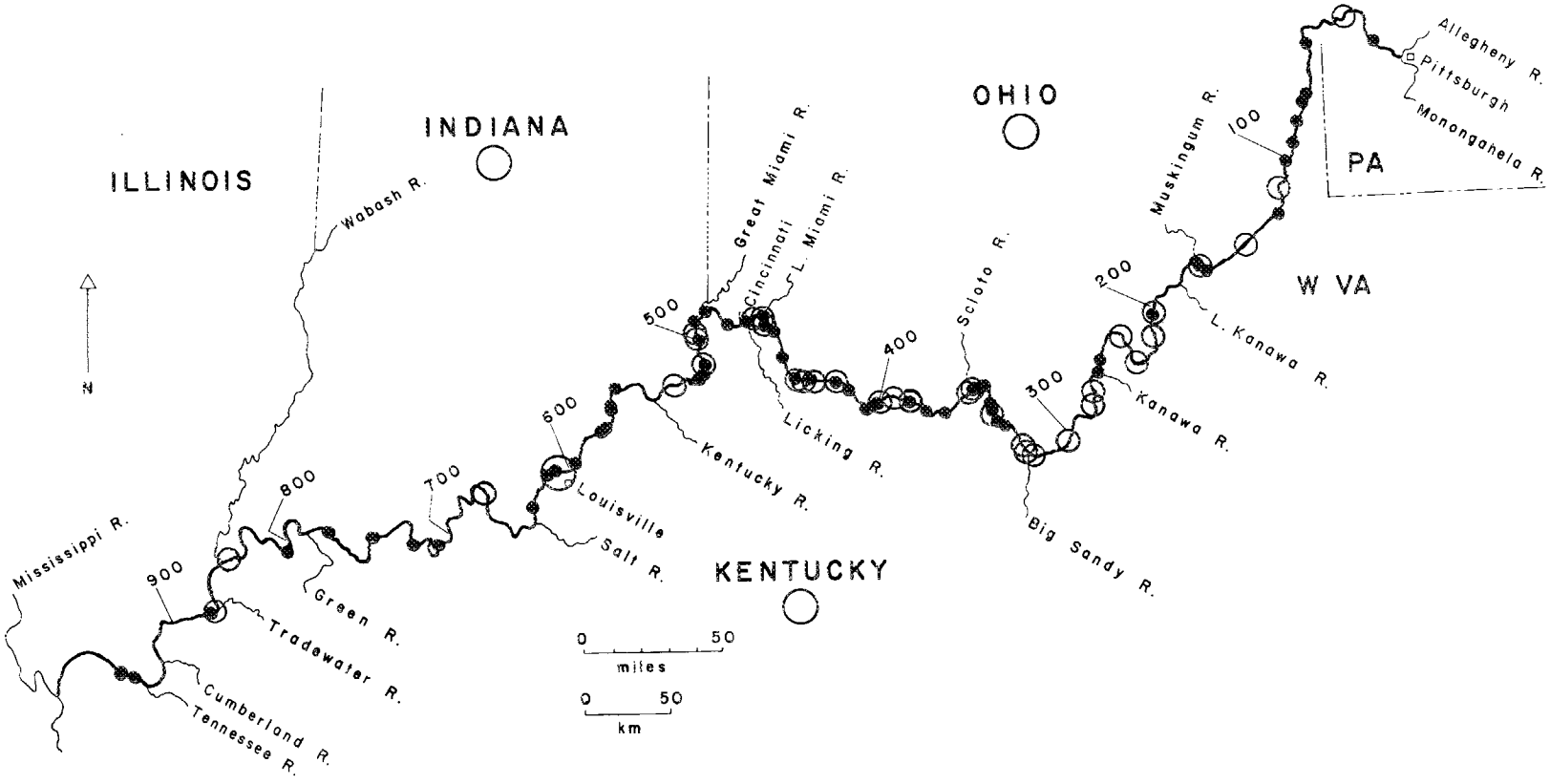

Figure 83. Distribution of *Moxostoma erythrurum* in the Ohio River.

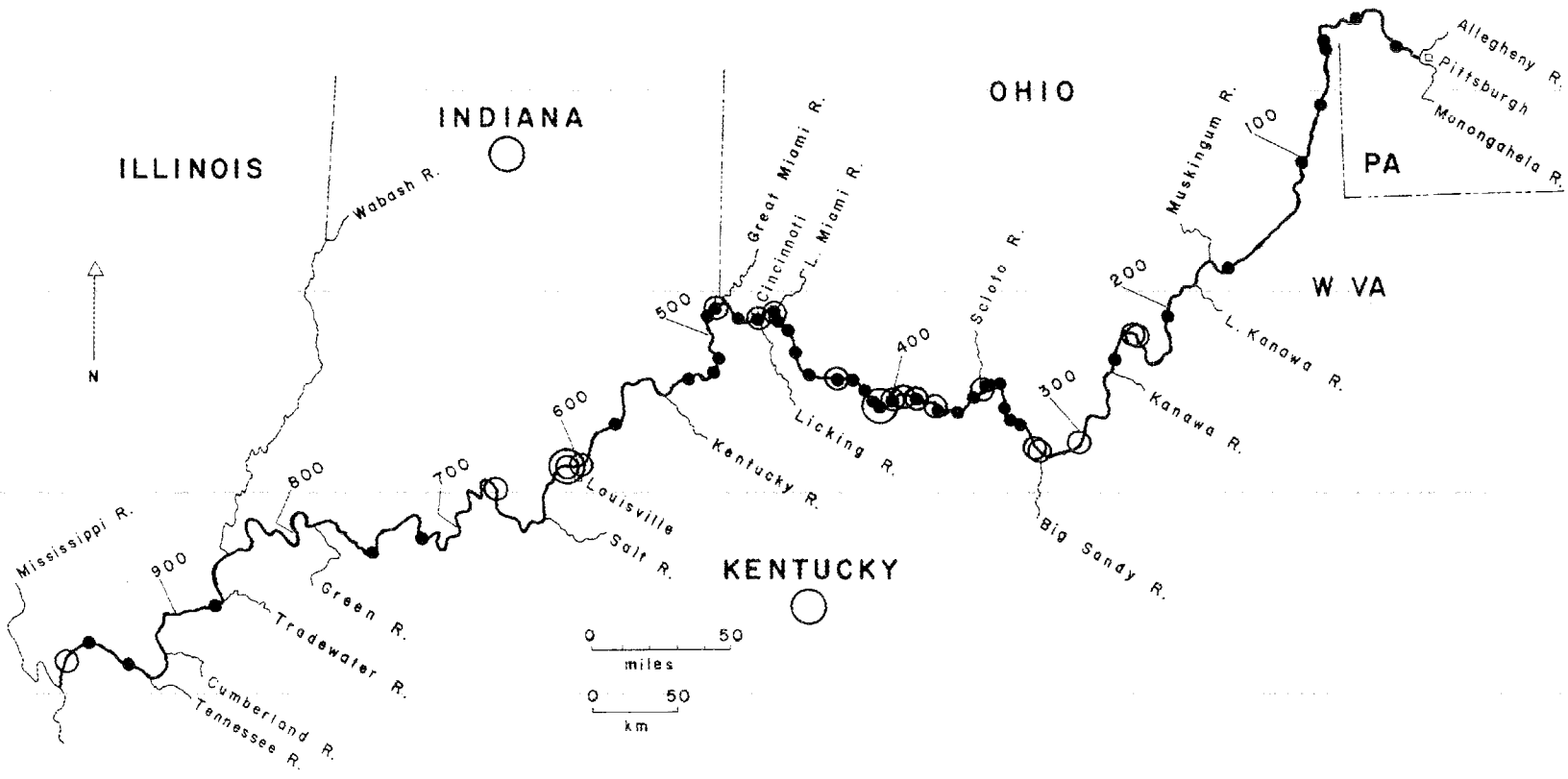

Figure 84. Distribution of *Moxostoma macrolepidotum* in the Ohio River.

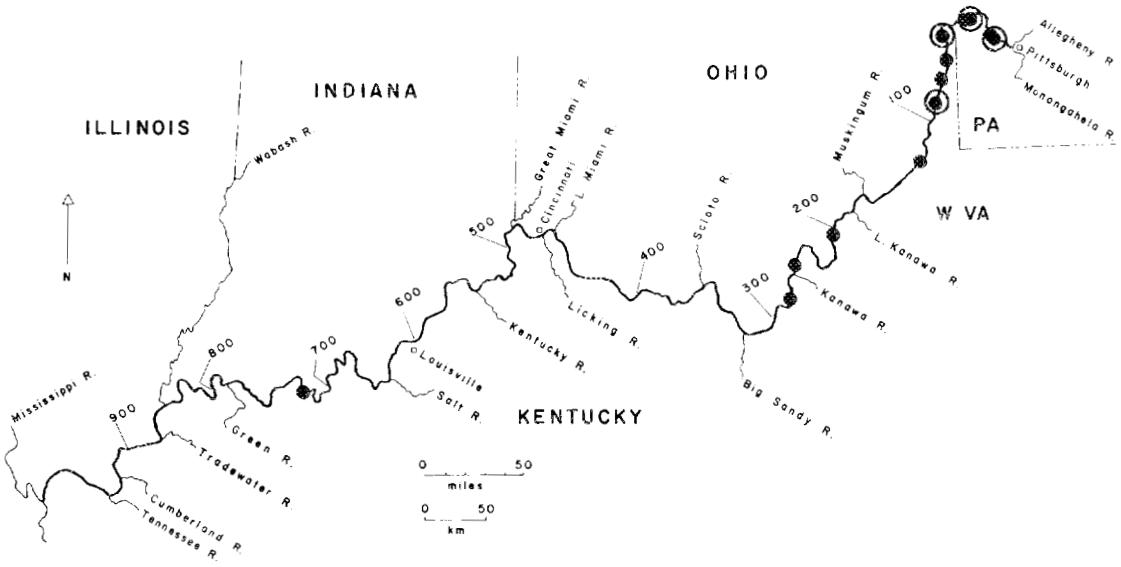

Figure 85. Distribution of *Ictalurus catus* in the Ohio River.

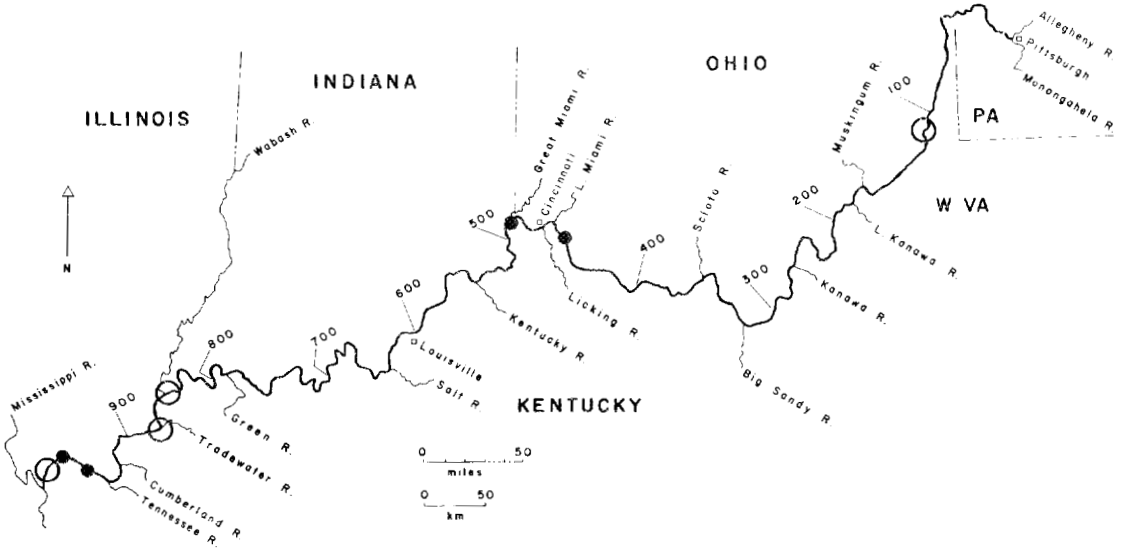

Figure 91. Distribution of *Noturus eleutherus* in the Ohio River.

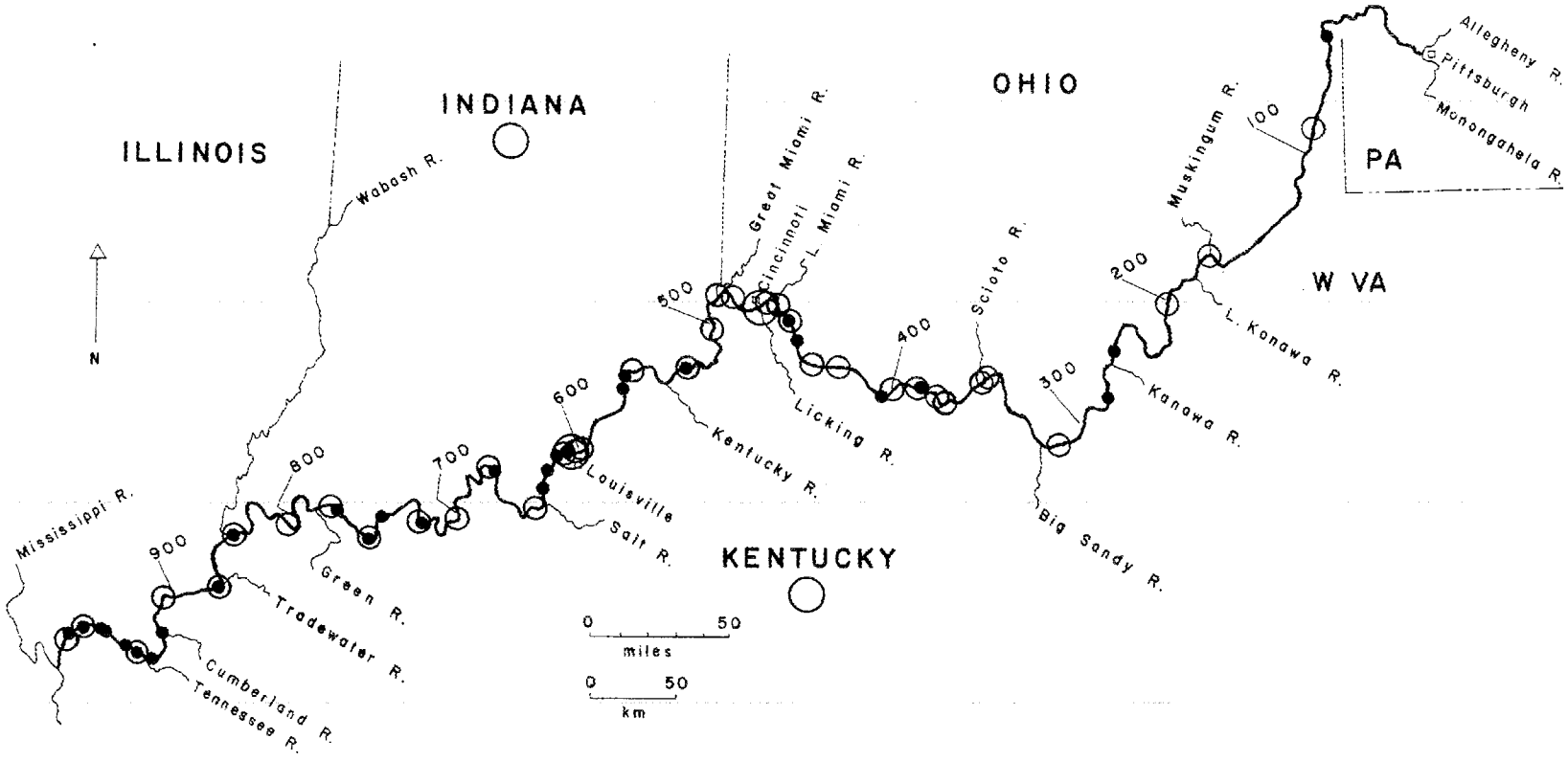

Figure 86. Distribution of *Ictalurus furcatus* in the Ohio River.

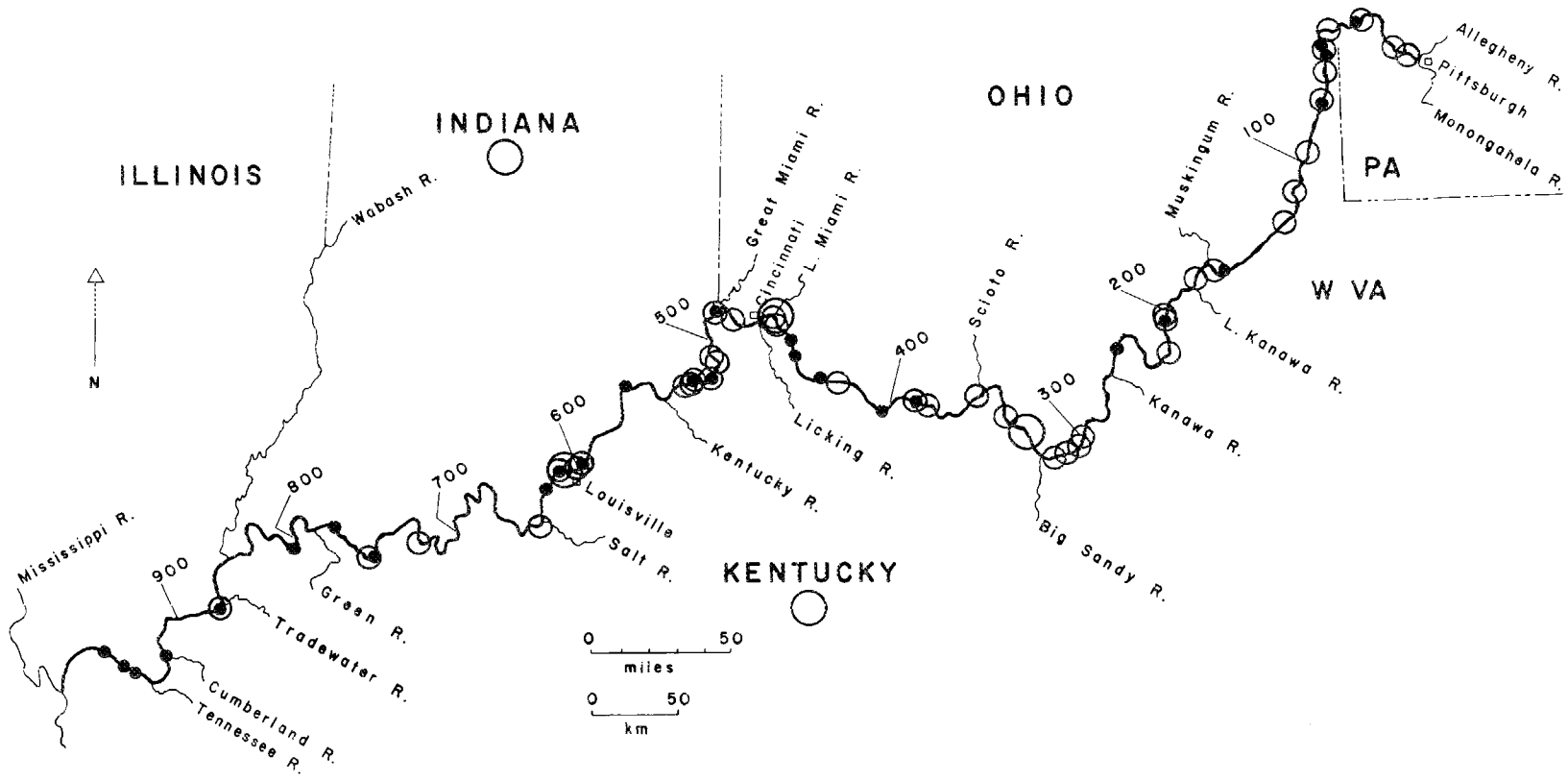

Figure 87. Distribution of *Ictalurus melas* in the Ohio River.

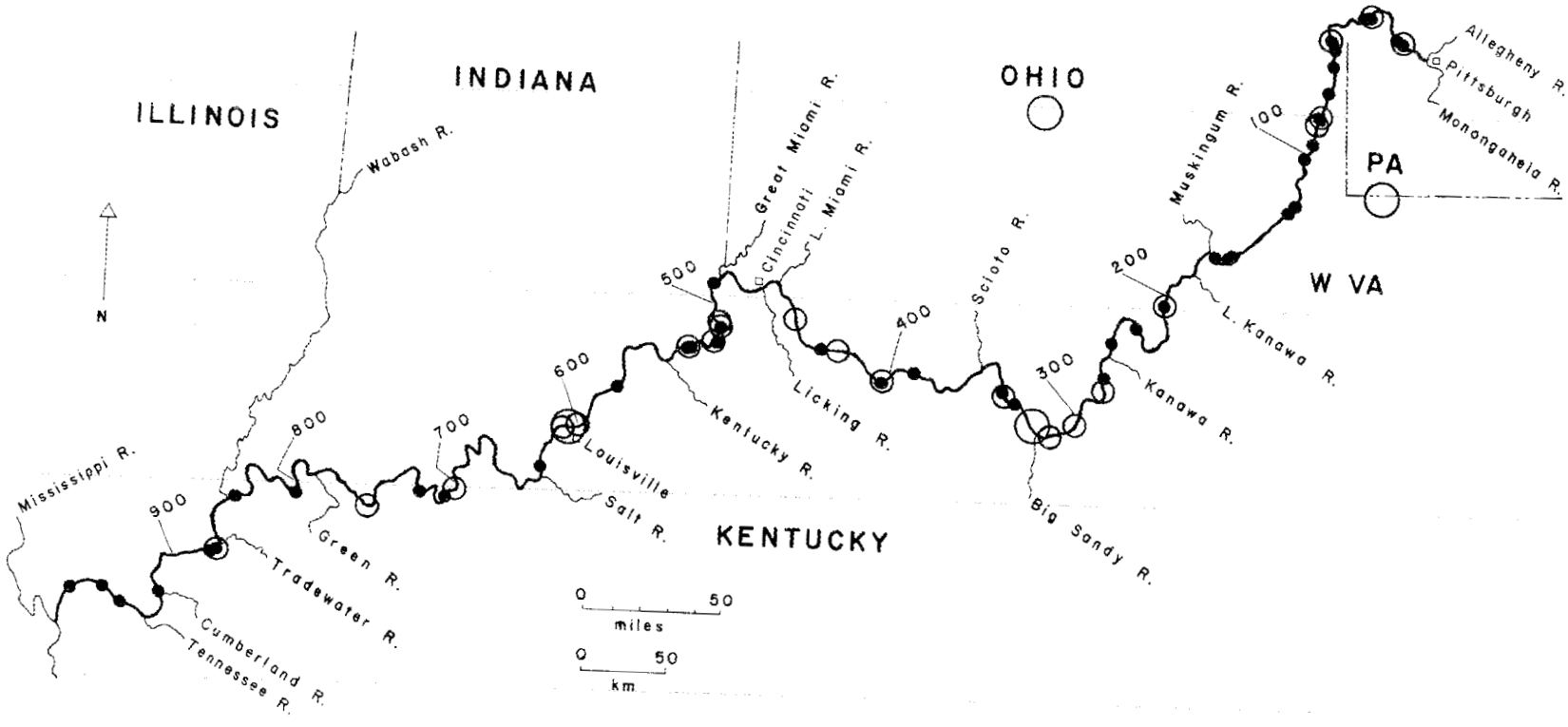

Figure 88. Distribution of *Ictalurus natalis* in the Ohio River.

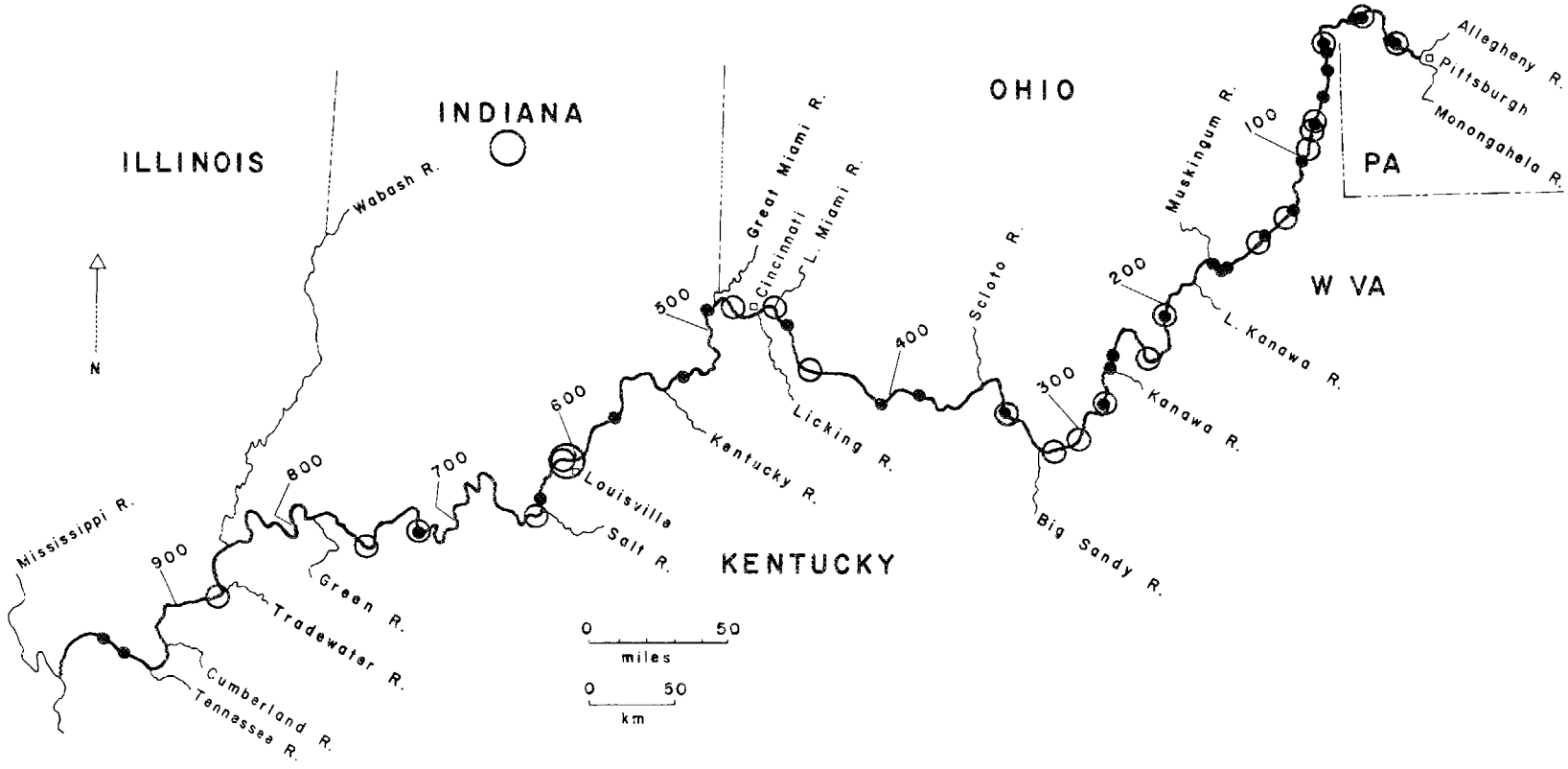

Figure 89. Distribution of *Ictalurus nebulosus* in the Ohio River.

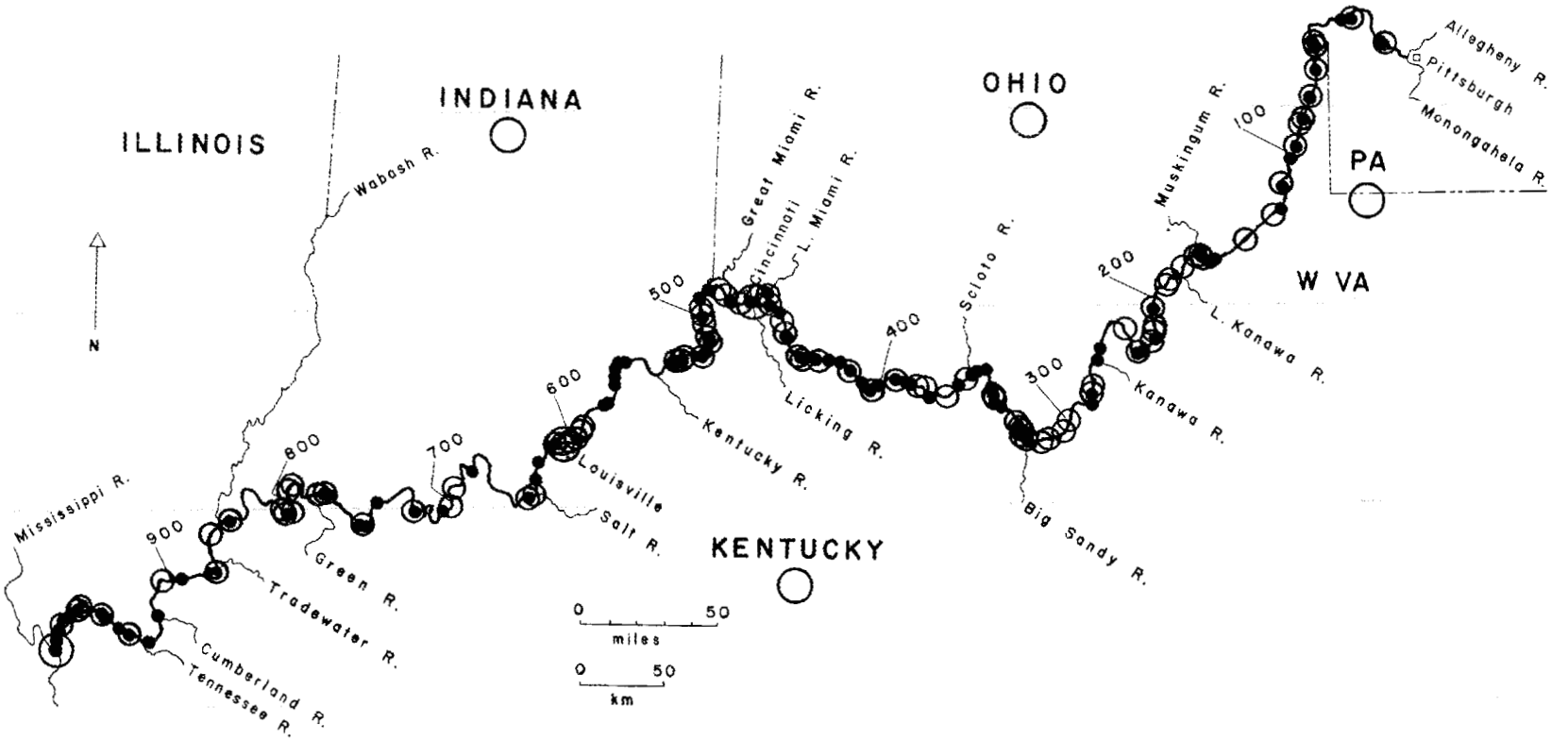

Figure 90. Distribution of *Ictalurus punctatus* in the Ohio River.

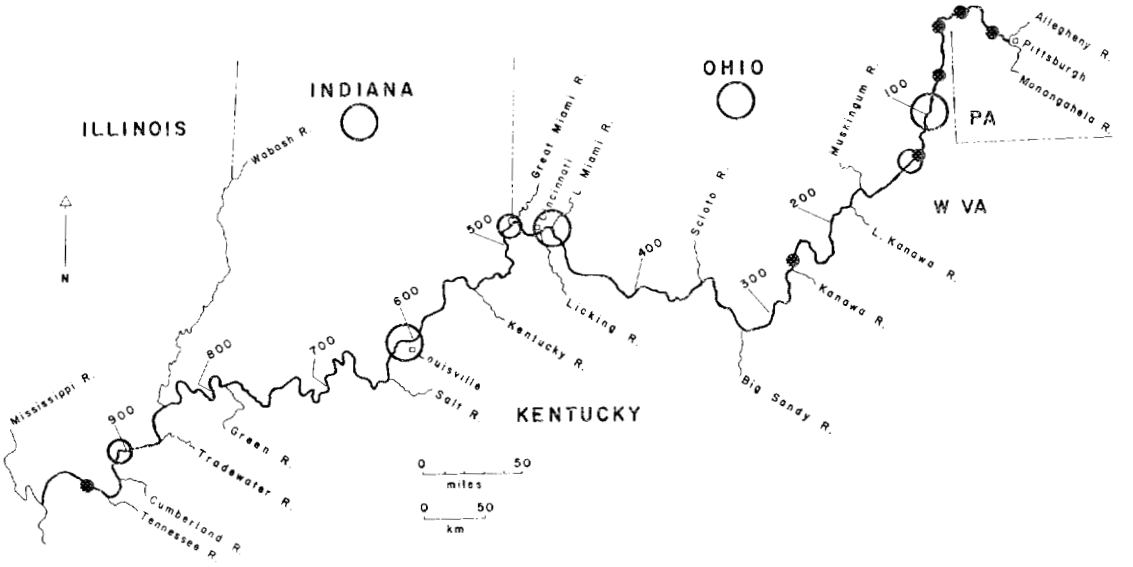

Figure 92. Distribution of *Noturus flavus* in the Ohio River.

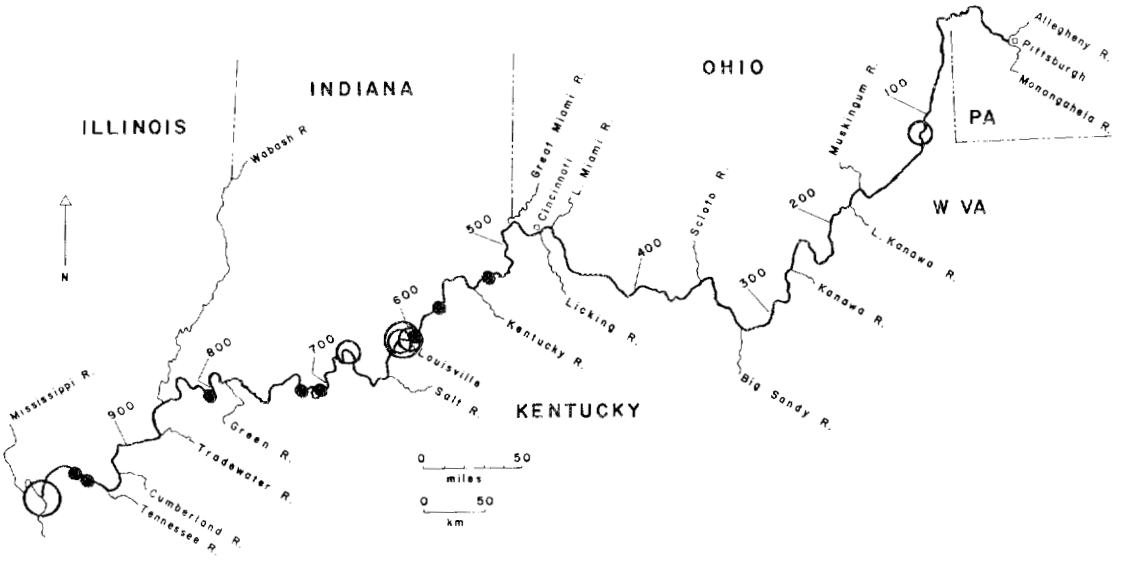

Figure 93. Distribution of *Noturus gyrinus* in the Ohio River.

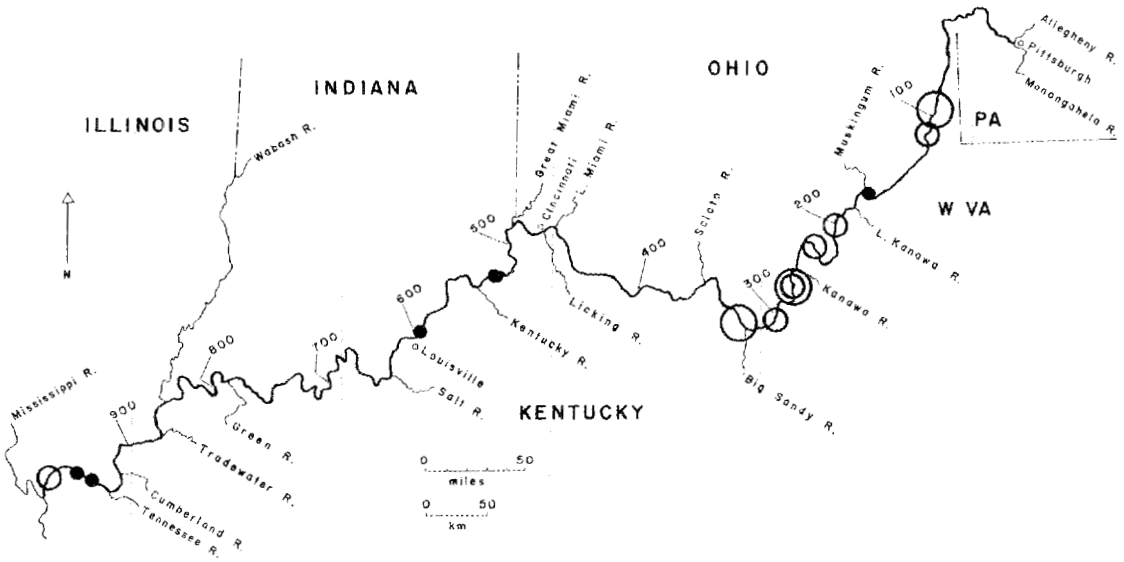

Figure 94. Distribution of *Noturus miurus* in the Ohio River.

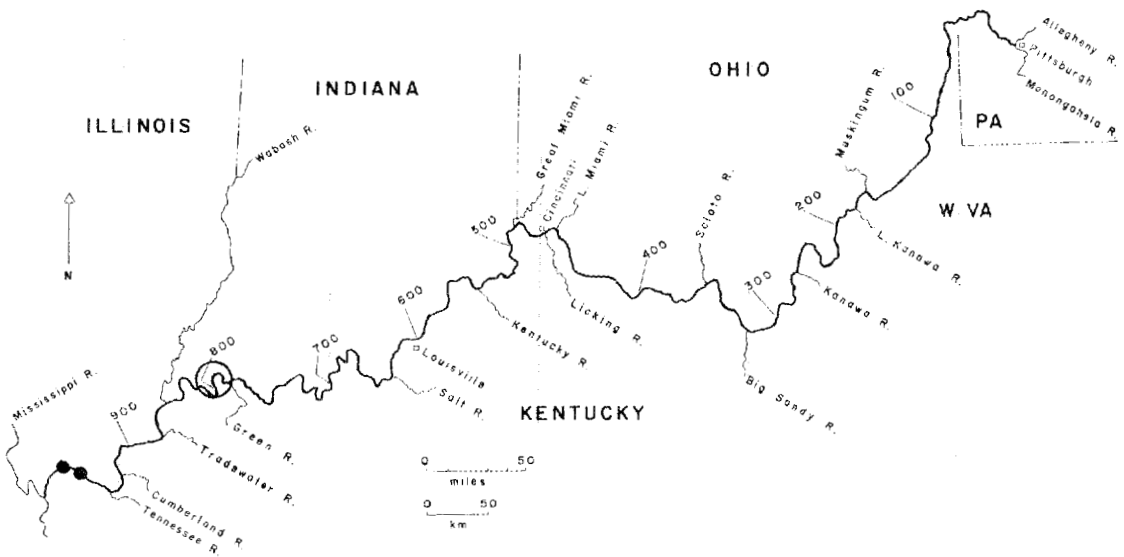

Figure 95. Distribution of *Noturus nocturnus* in the Ohio River.

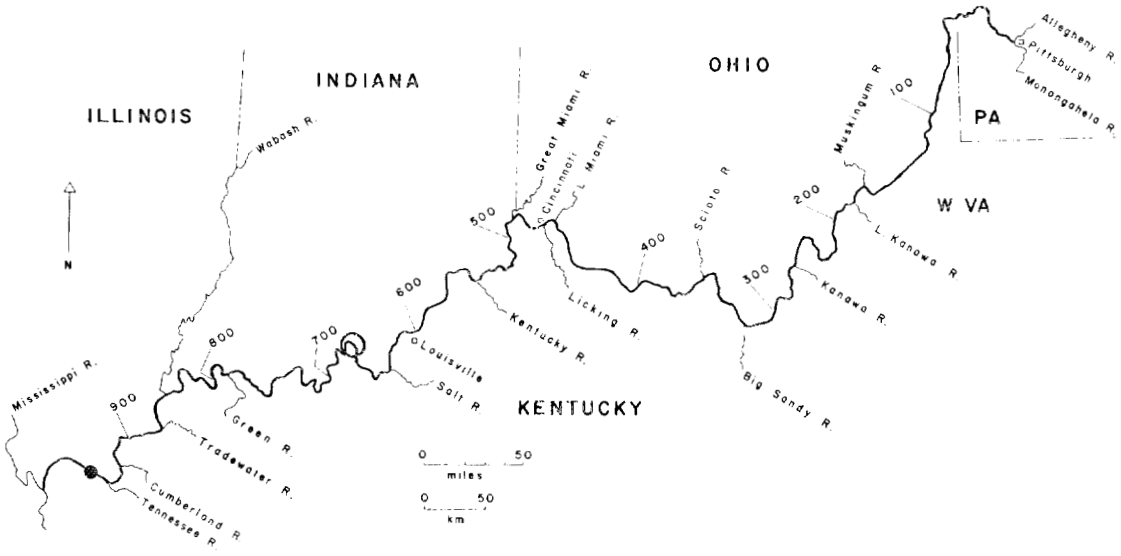

Figure 96. Distribution of *Noturus stigmosus* in the Ohio River.

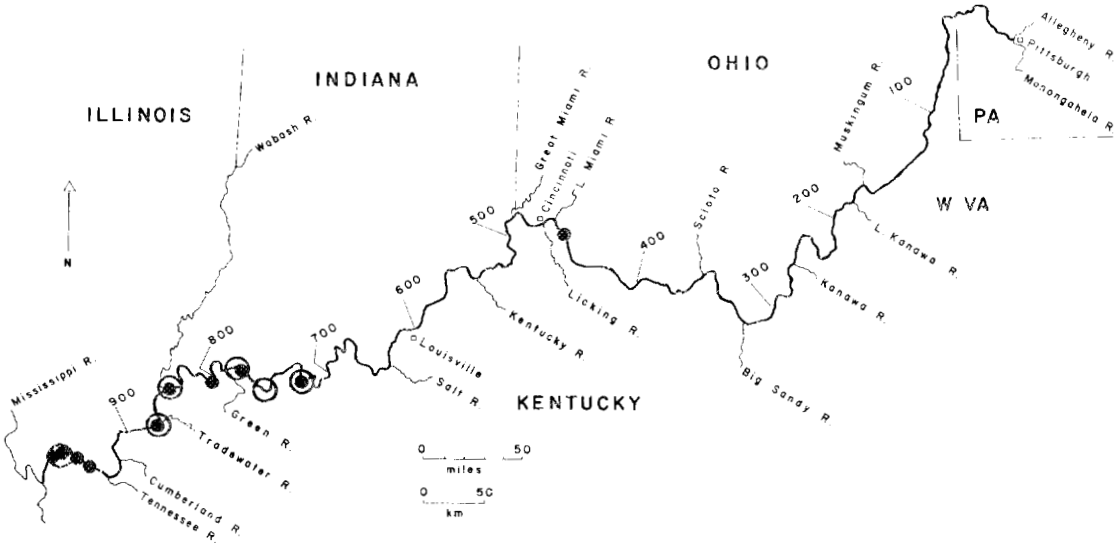

Figure 98. Distribution of *Aphredoderus sayanus* in the Ohio River.

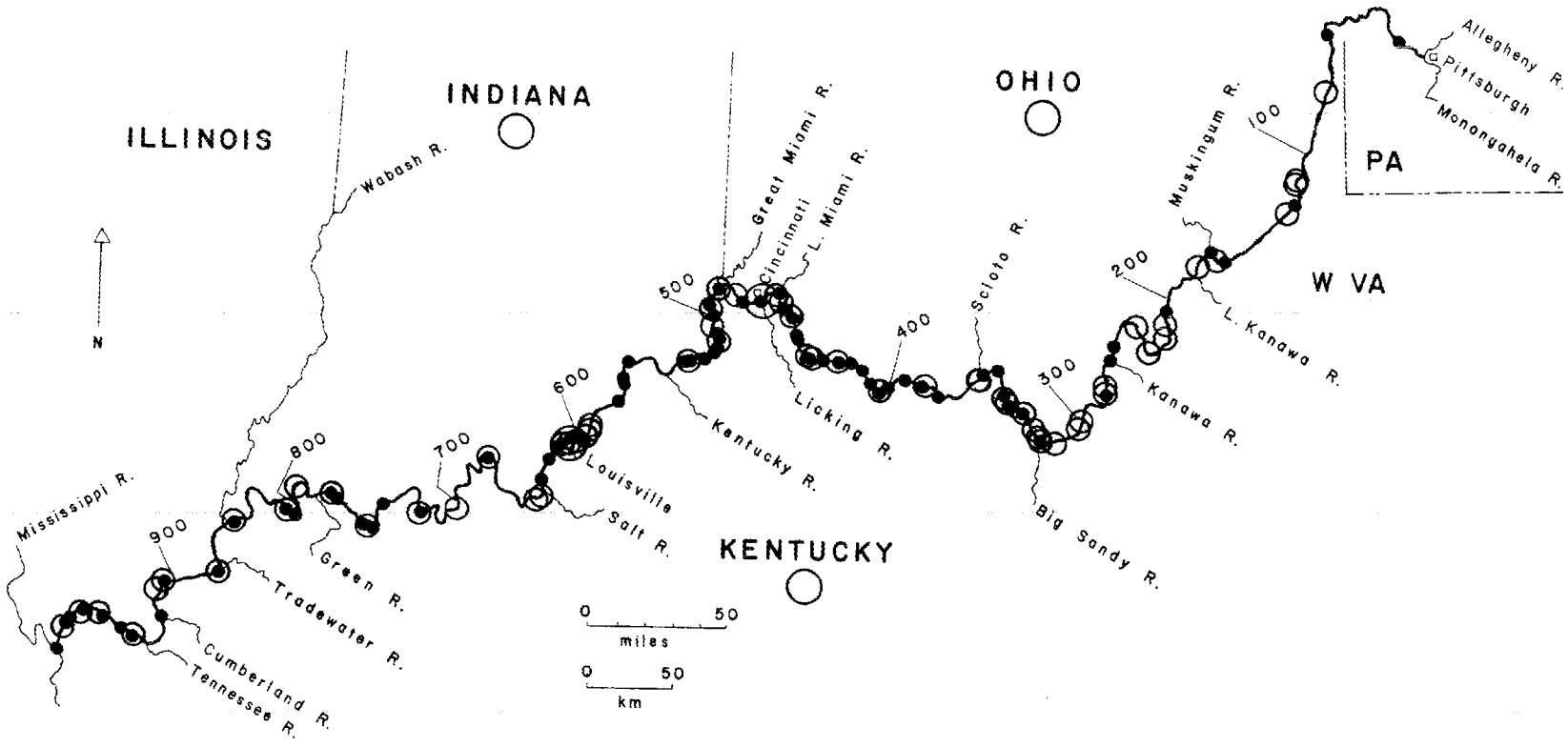

Figure 97. Distribution of *Pylodictis olivaris* in the Ohio River.

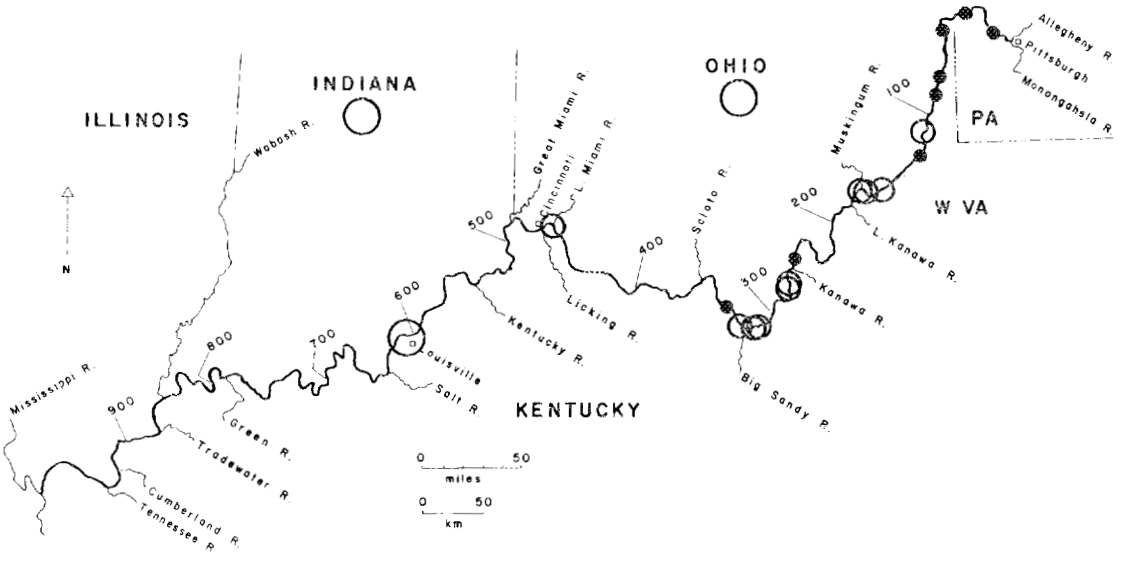

Figure 99. Distribution of *Percopsis omiscomaycus* in the Ohio River.

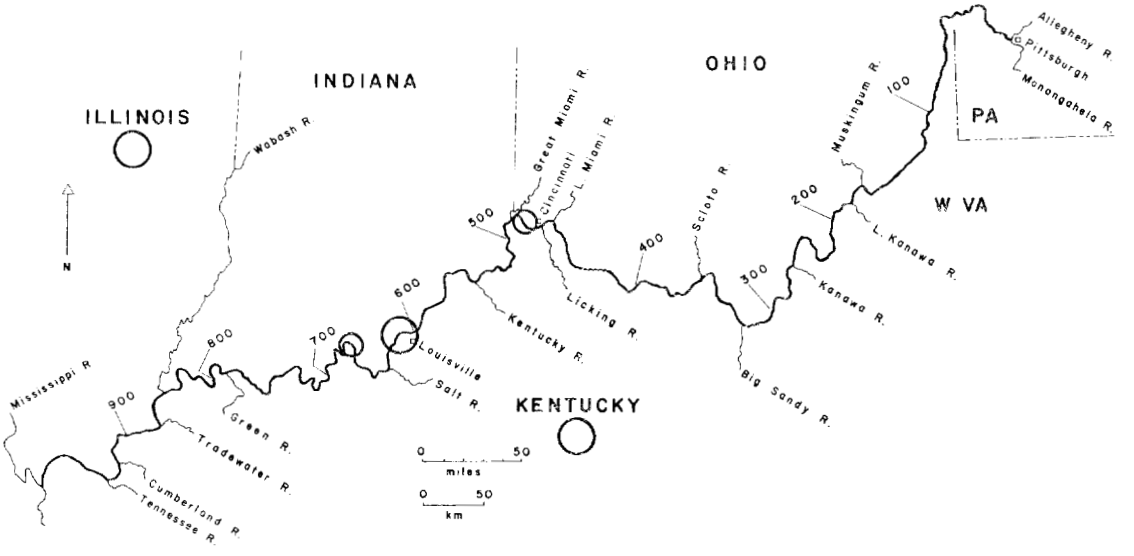

Figure 100. Distribution of *Lota lota* in the Ohio River.

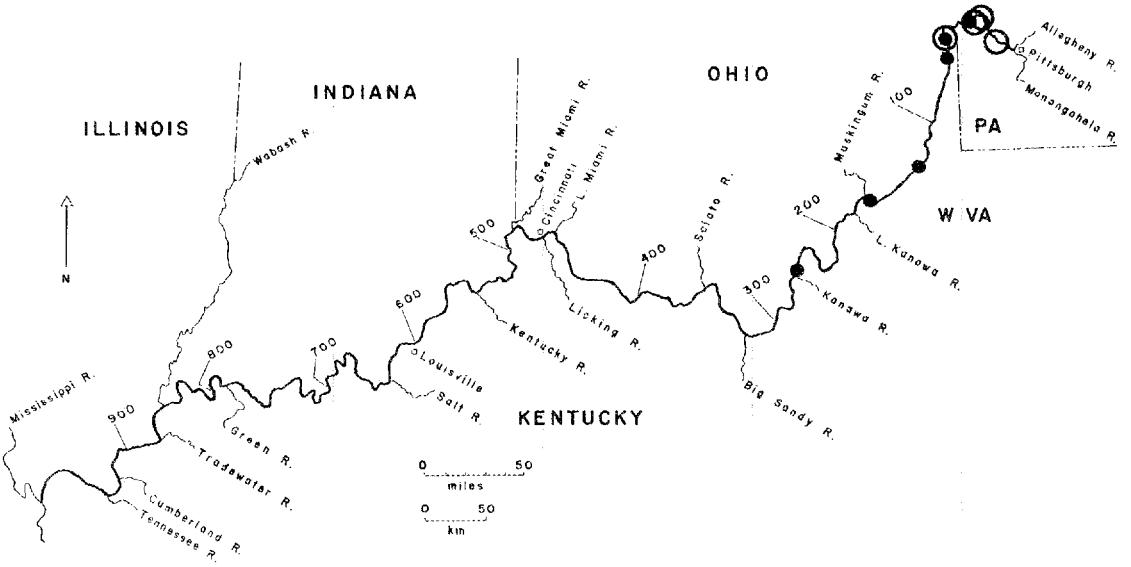

Figure 101. Distribution of *Fundulus diaphanus* in the Ohio River.

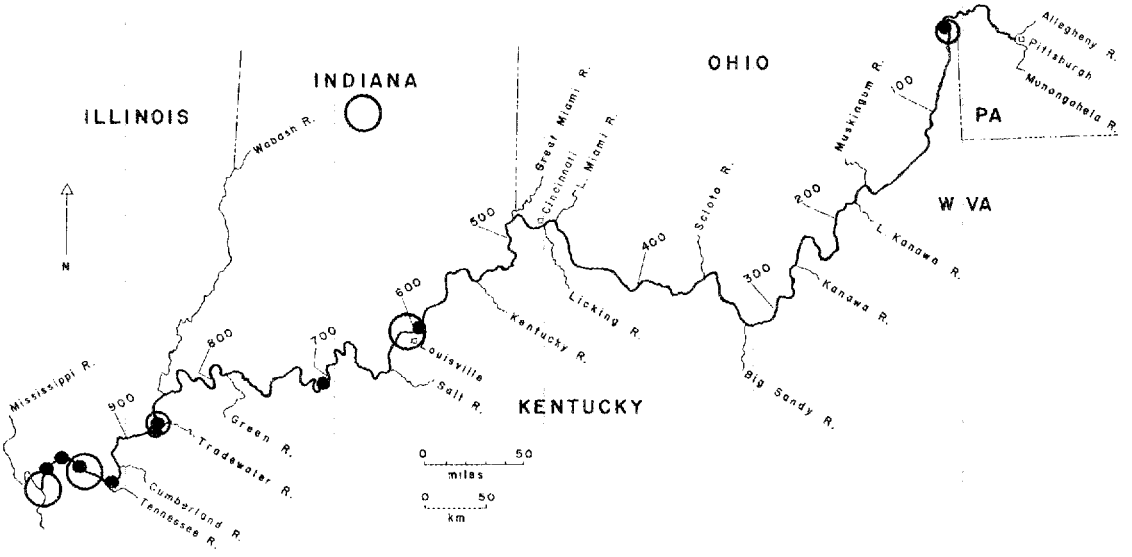

Figure 102. Distribution of *Fundulus notatus* in the Ohio River.

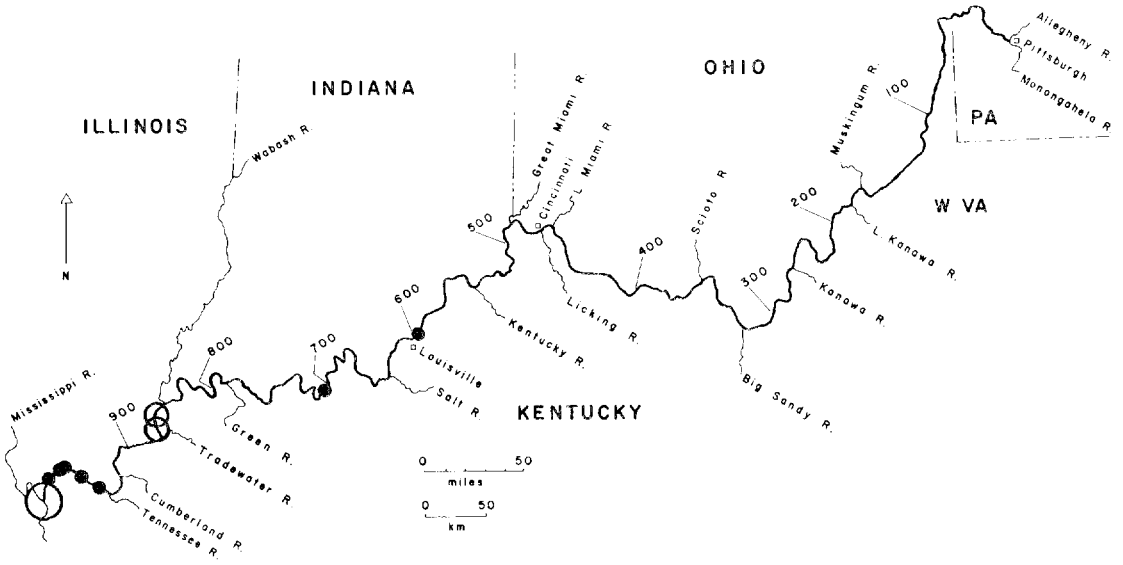

Figure 103. Distribution of *Gambusia affinis* in the Ohio River.

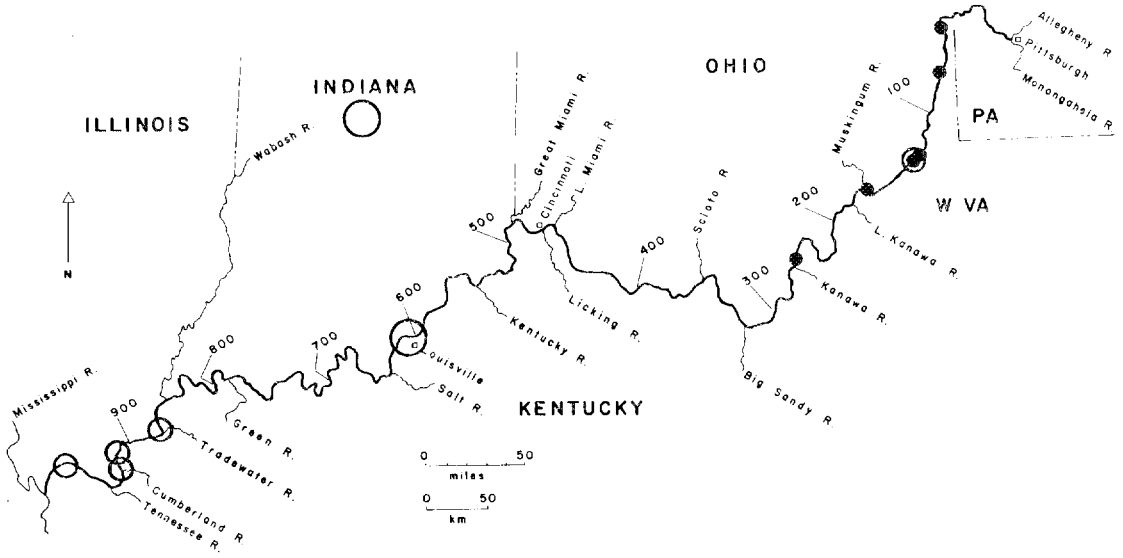

Figure 104. Distribution of *Labidesthes sicculus* in the Ohio River.

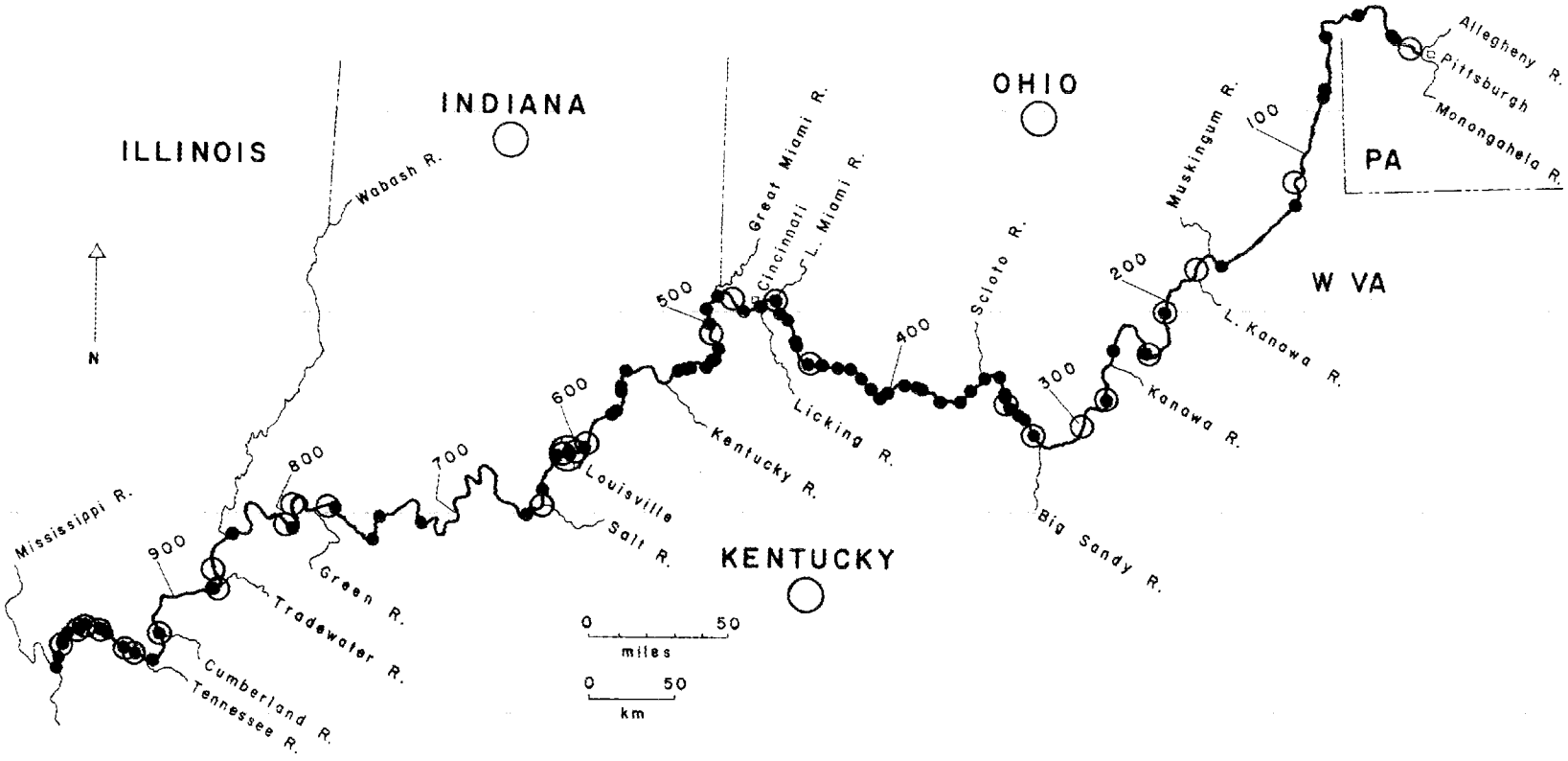

Figure 105. Distribution of *Morone chrysops* in the Ohio River.

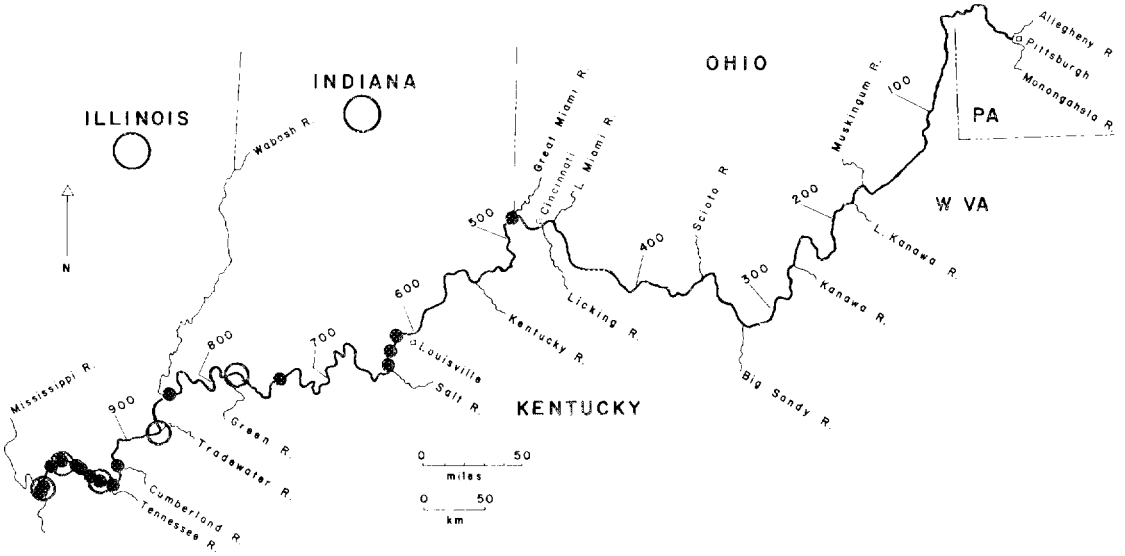

Figure 106. Distribution of *Morone mississippiensis* in the Ohio River.

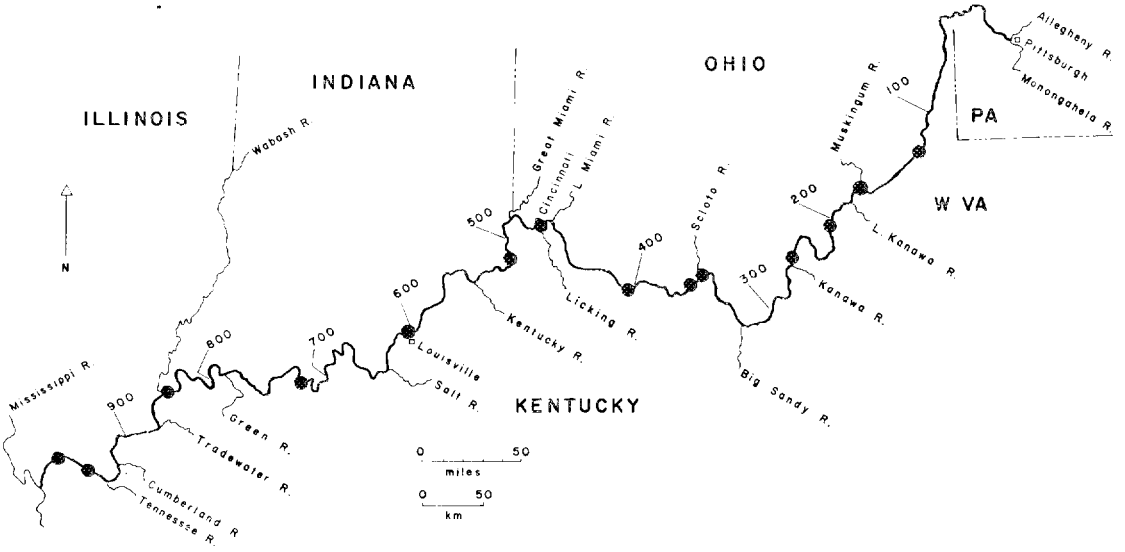

Figure 107. Distribution of *Morone saxatilis* in the Ohio River.

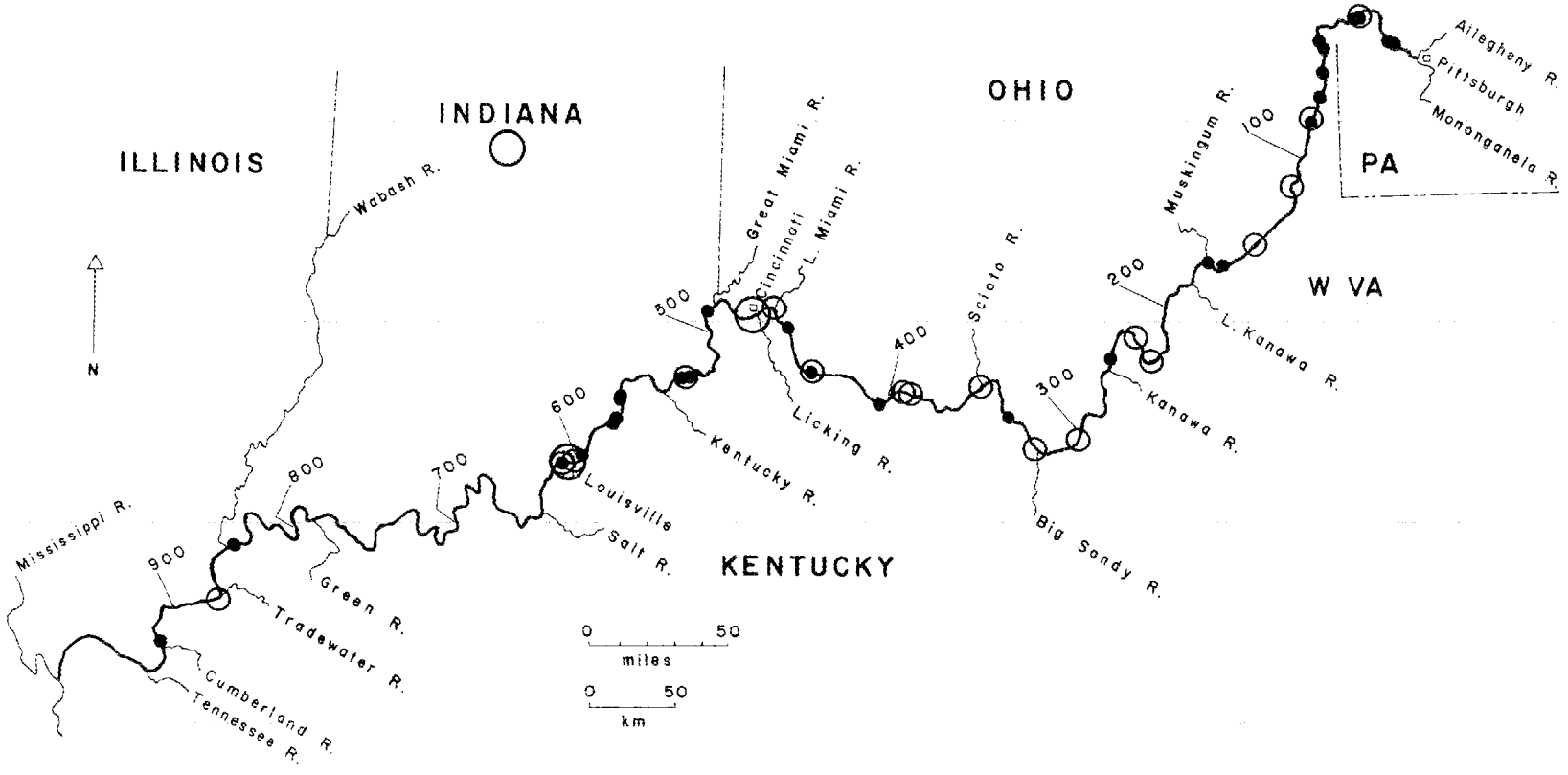

Figure 108. Distribution of *Ambloplites rupestris* in the Ohio River.

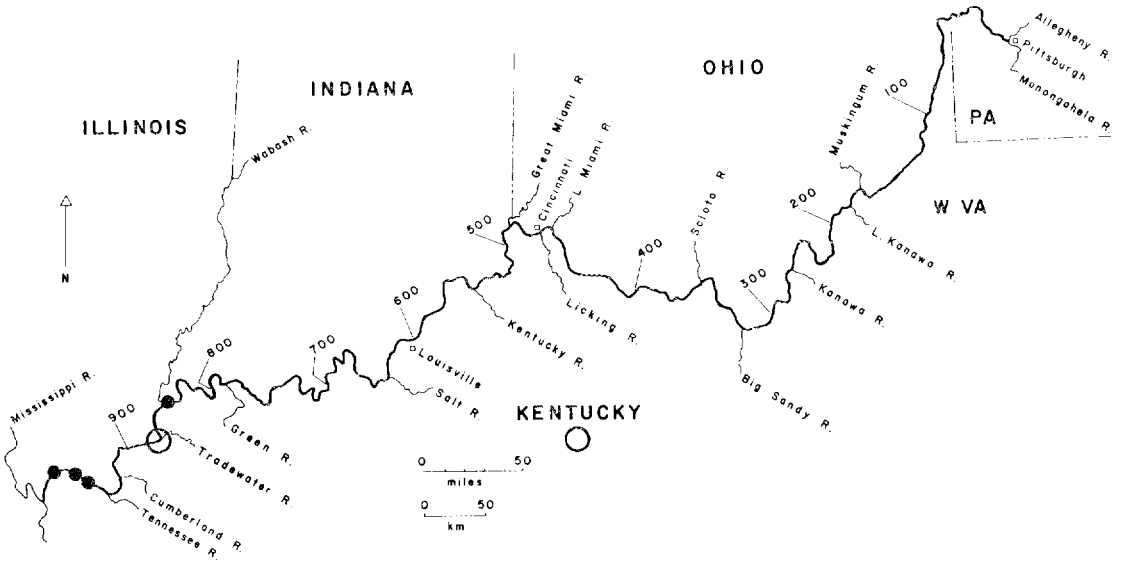

Figure 109. Distribution of *Centrarchus macropterus* in the Ohio River.

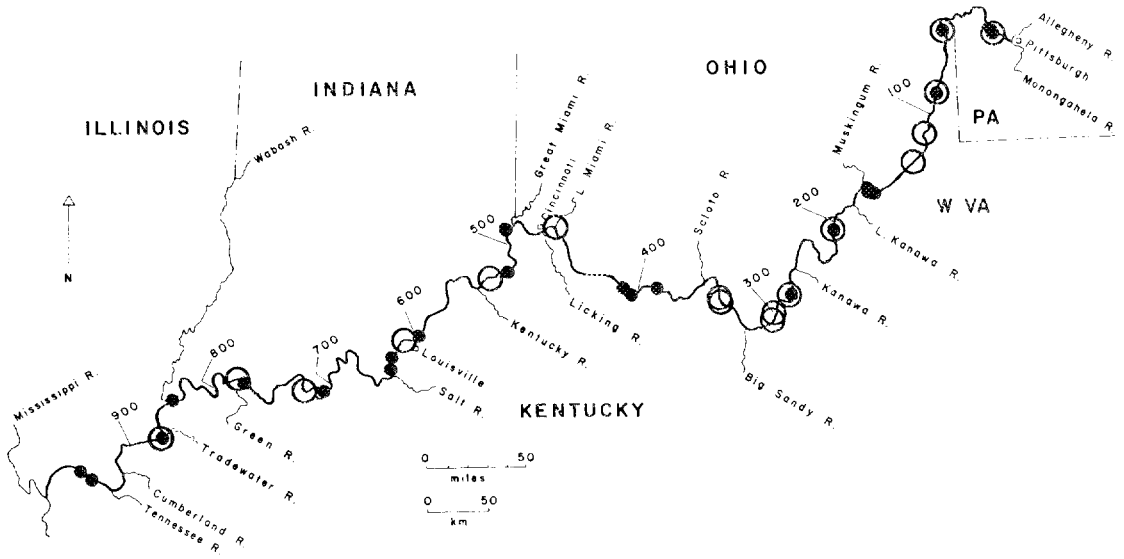

Figure 116. Distribution of *Lepomis microlophus* in the Ohio River.

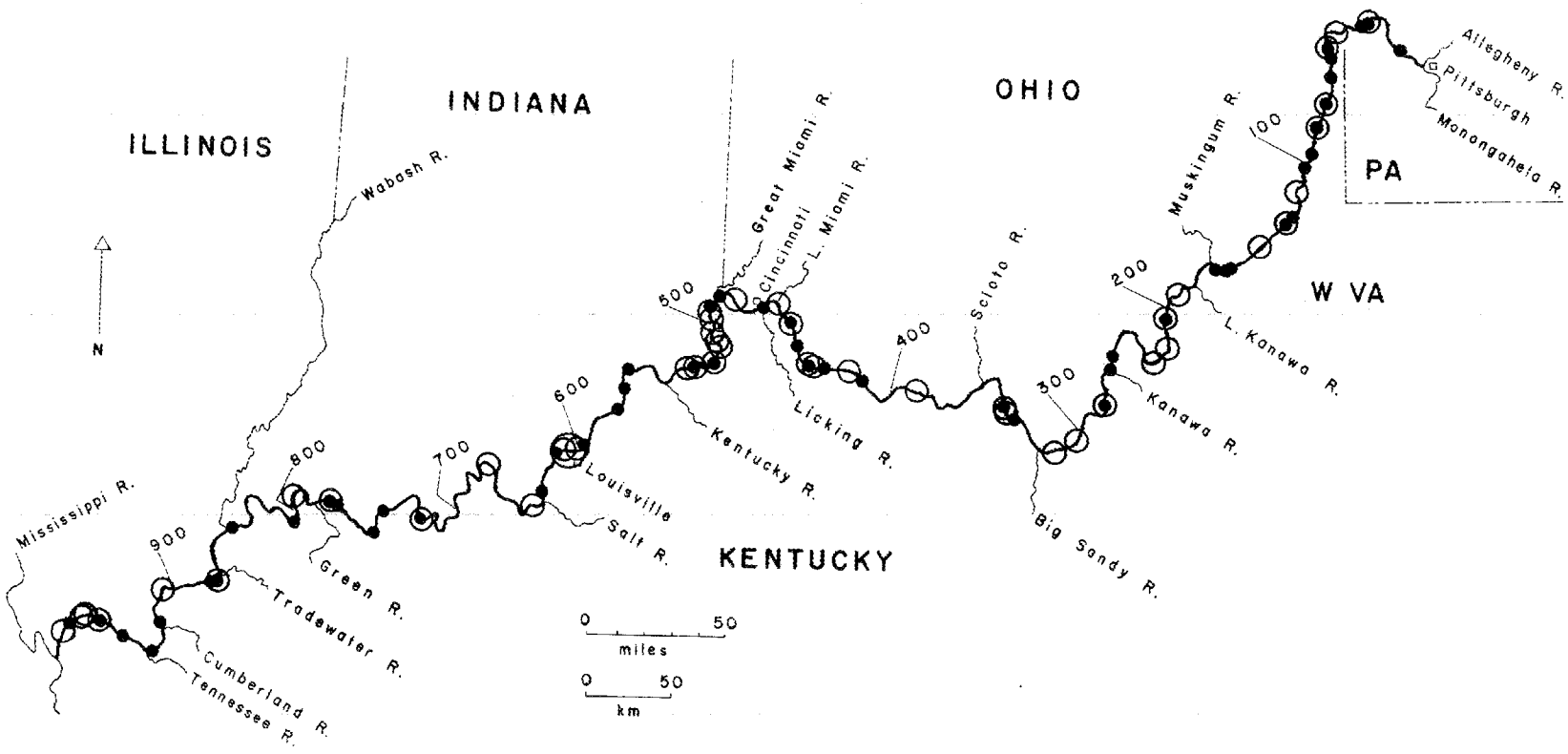

Figure 110. Distribution of *Lepomis cyanellus* in the Ohio River.

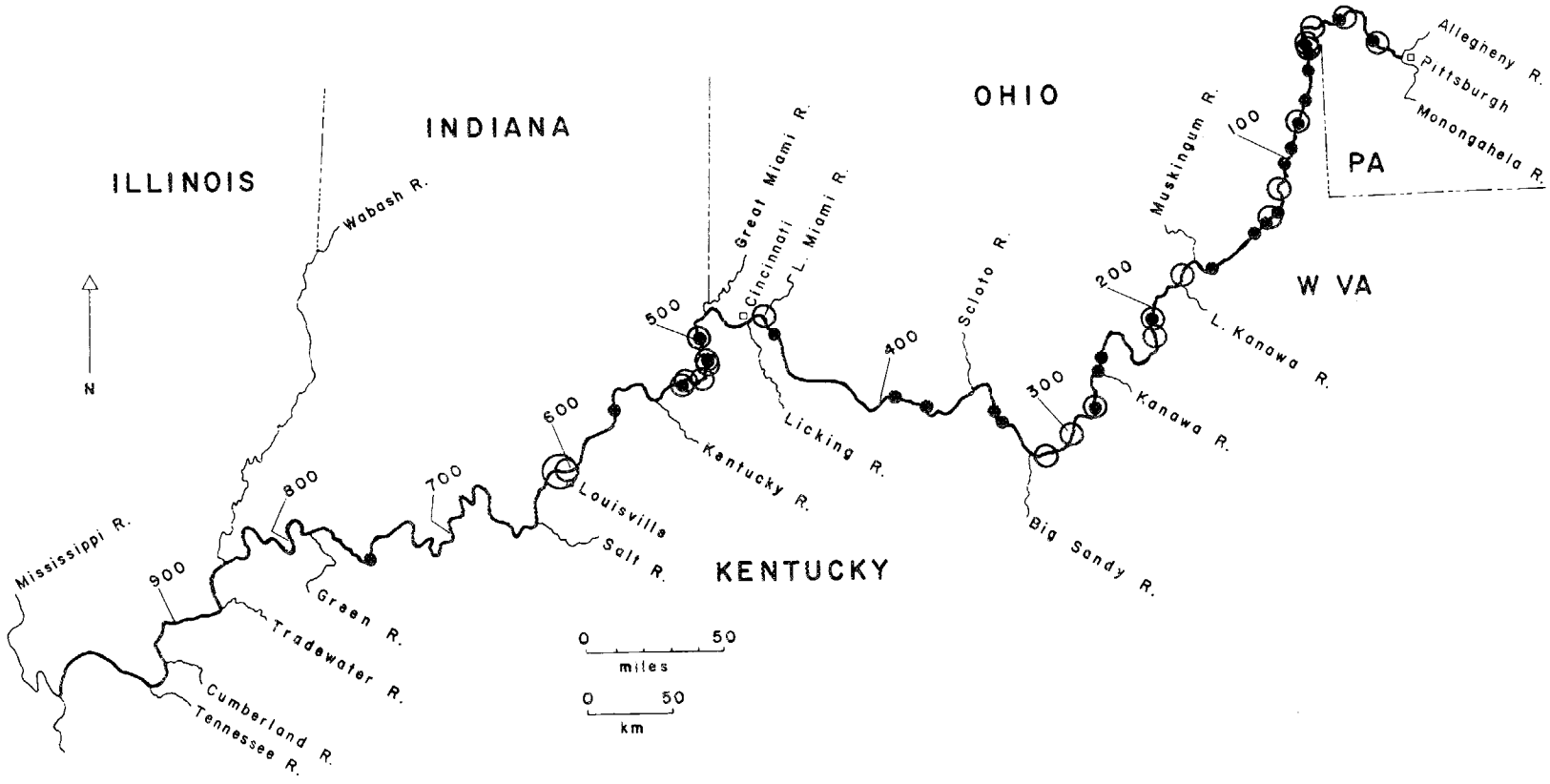

Figure 111. Distribution of *Lepomis gibbosus* in the Ohio River.

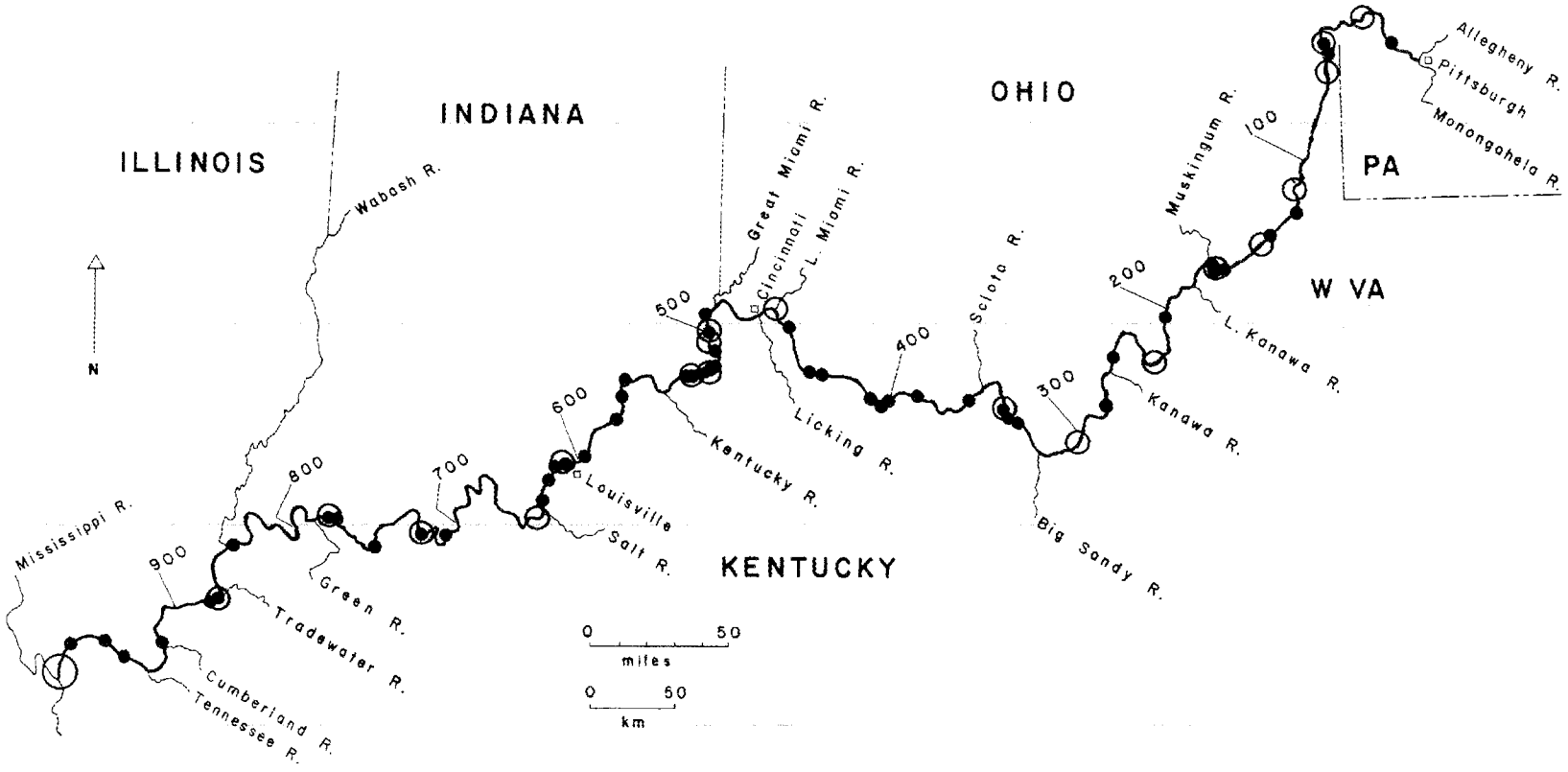

Figure 112. Distribution of *Lepomis gulosus* in the Ohio River.

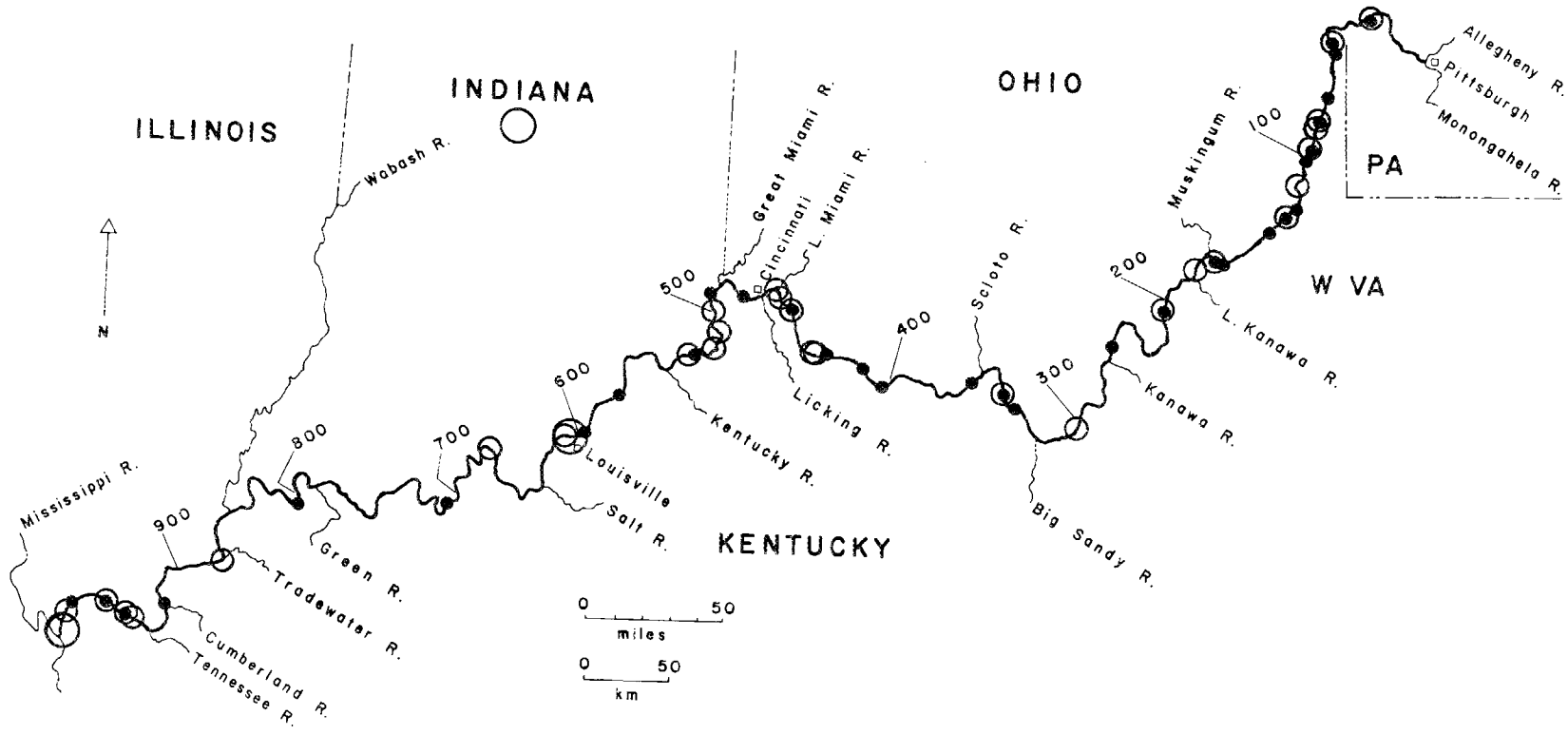

Figure 113. Distribution of *Lepomis humilis* in the Ohio River.

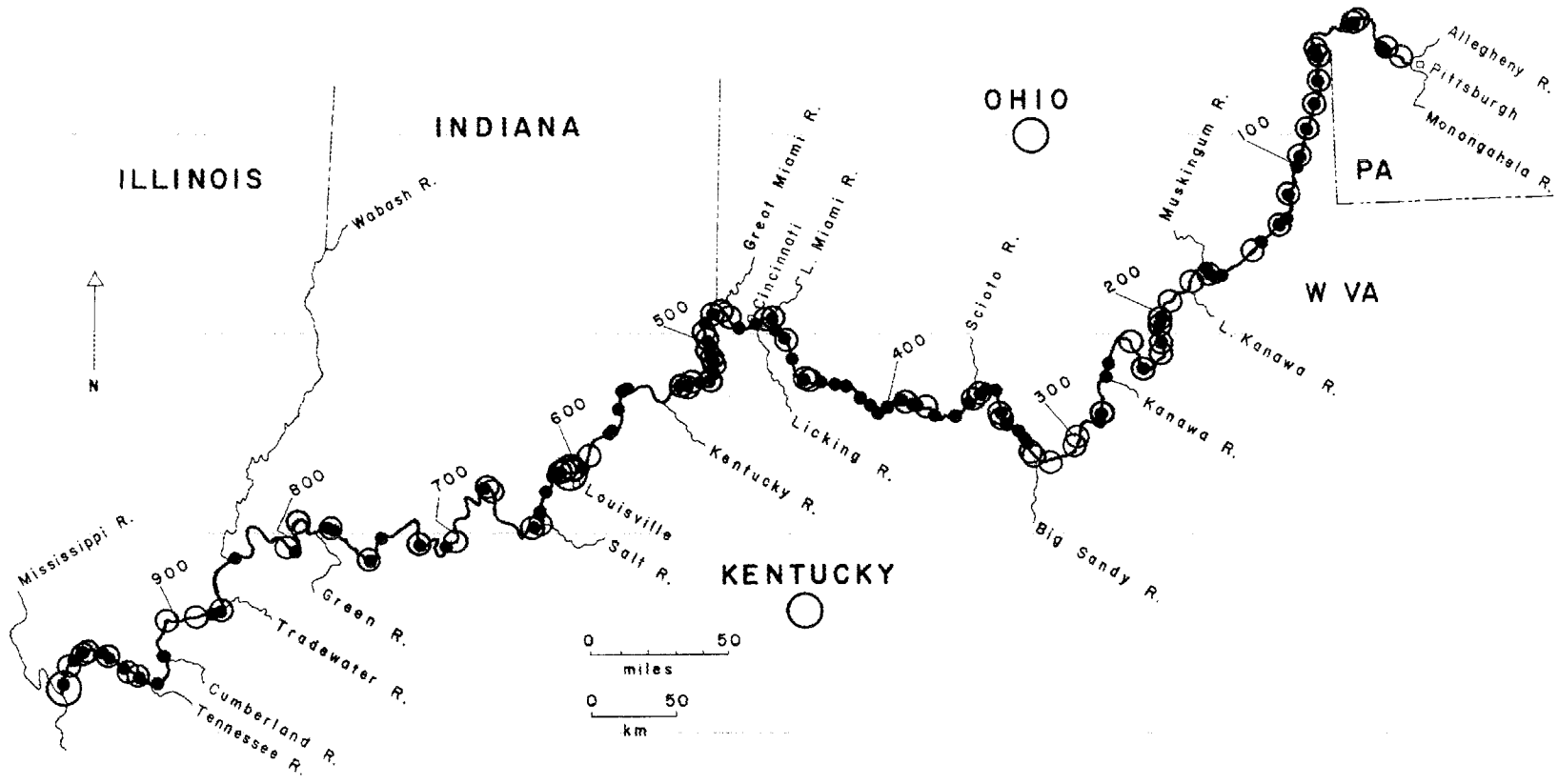

Figure 114. Distribution of *Lepomis macrochirus* in the Ohio River.

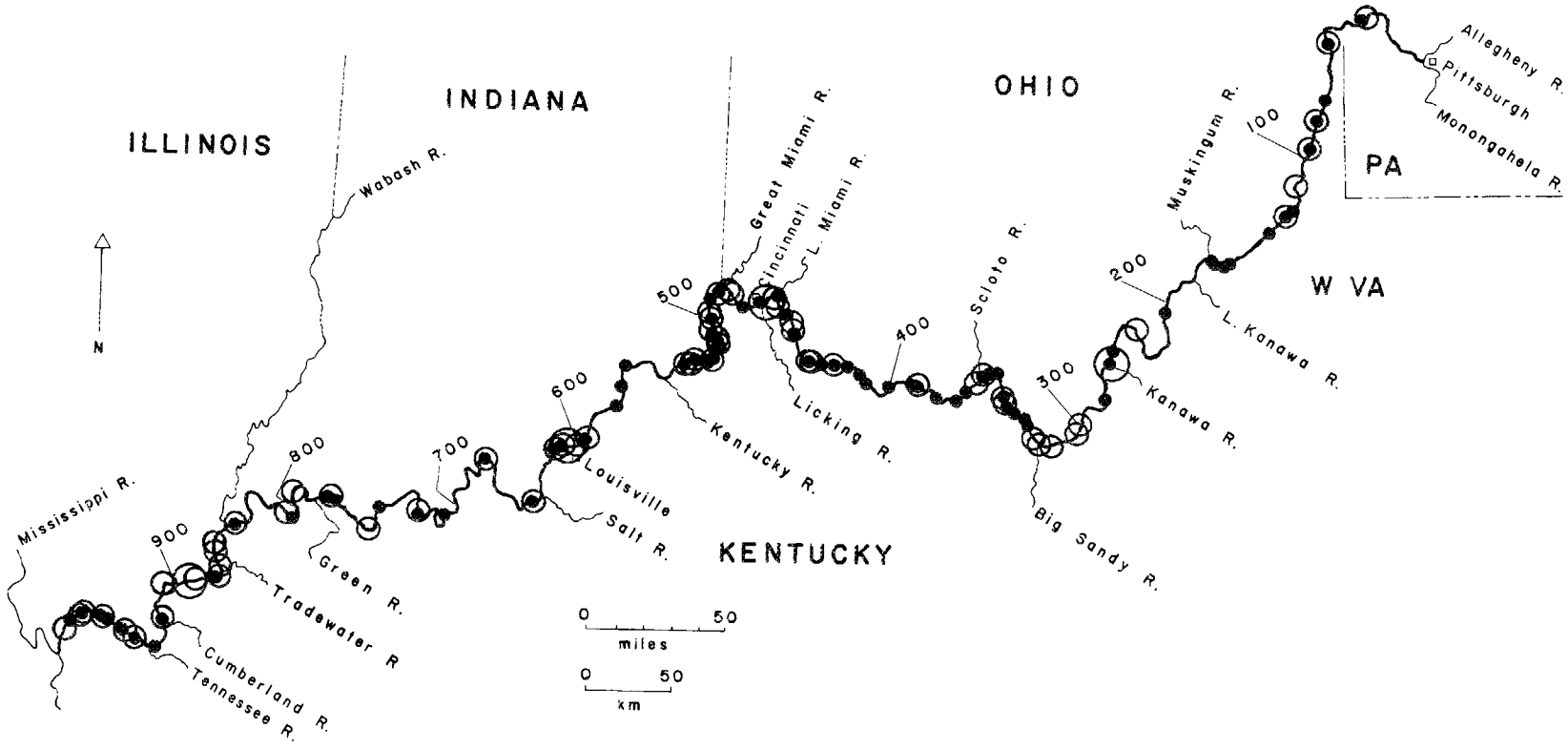

Figure 115. Distribution of *Lepomis megalotis* in the Ohio River.

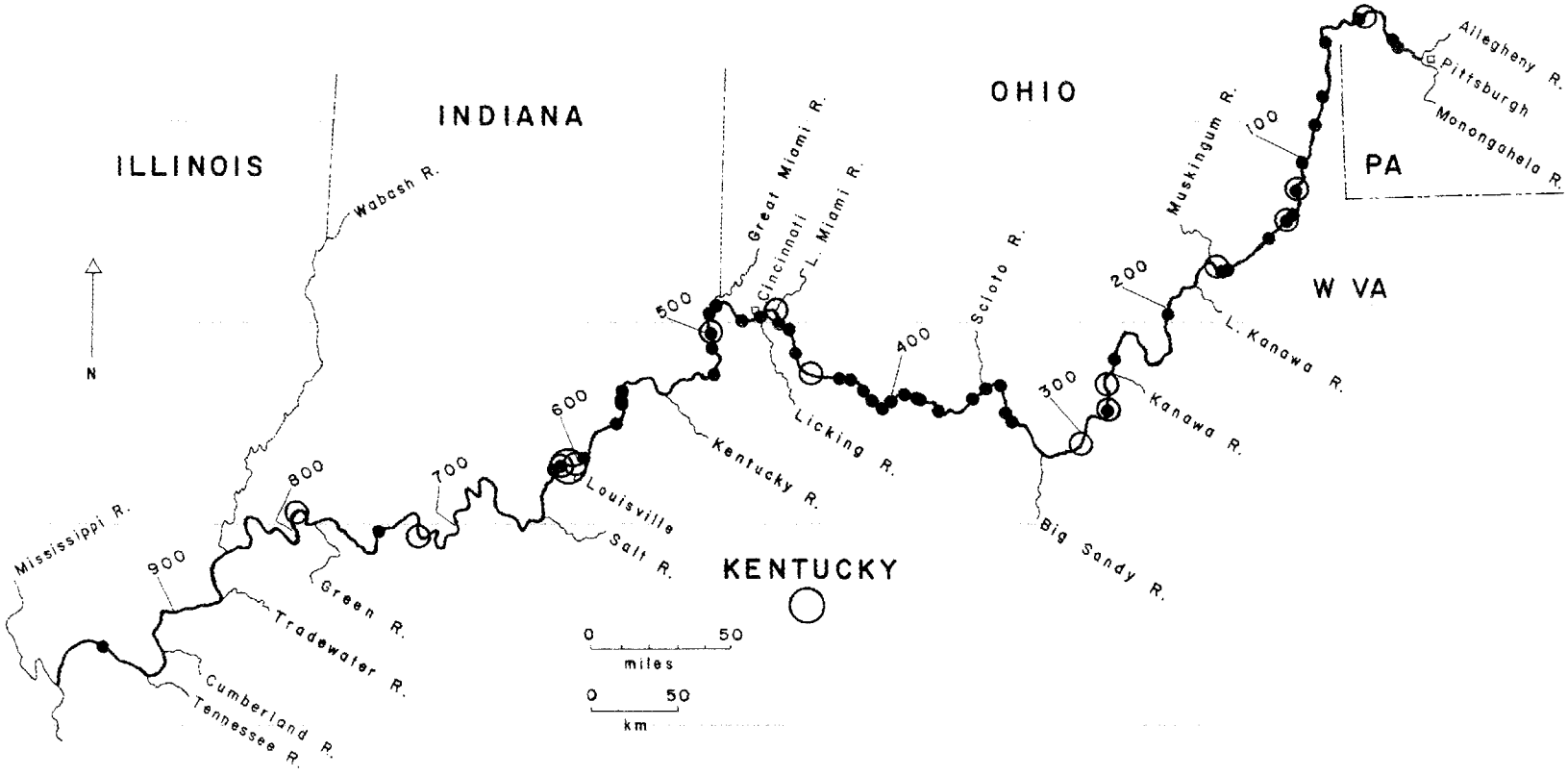

Figure 117. Distribution of *Micropterus dolomieui* in the Ohio River.

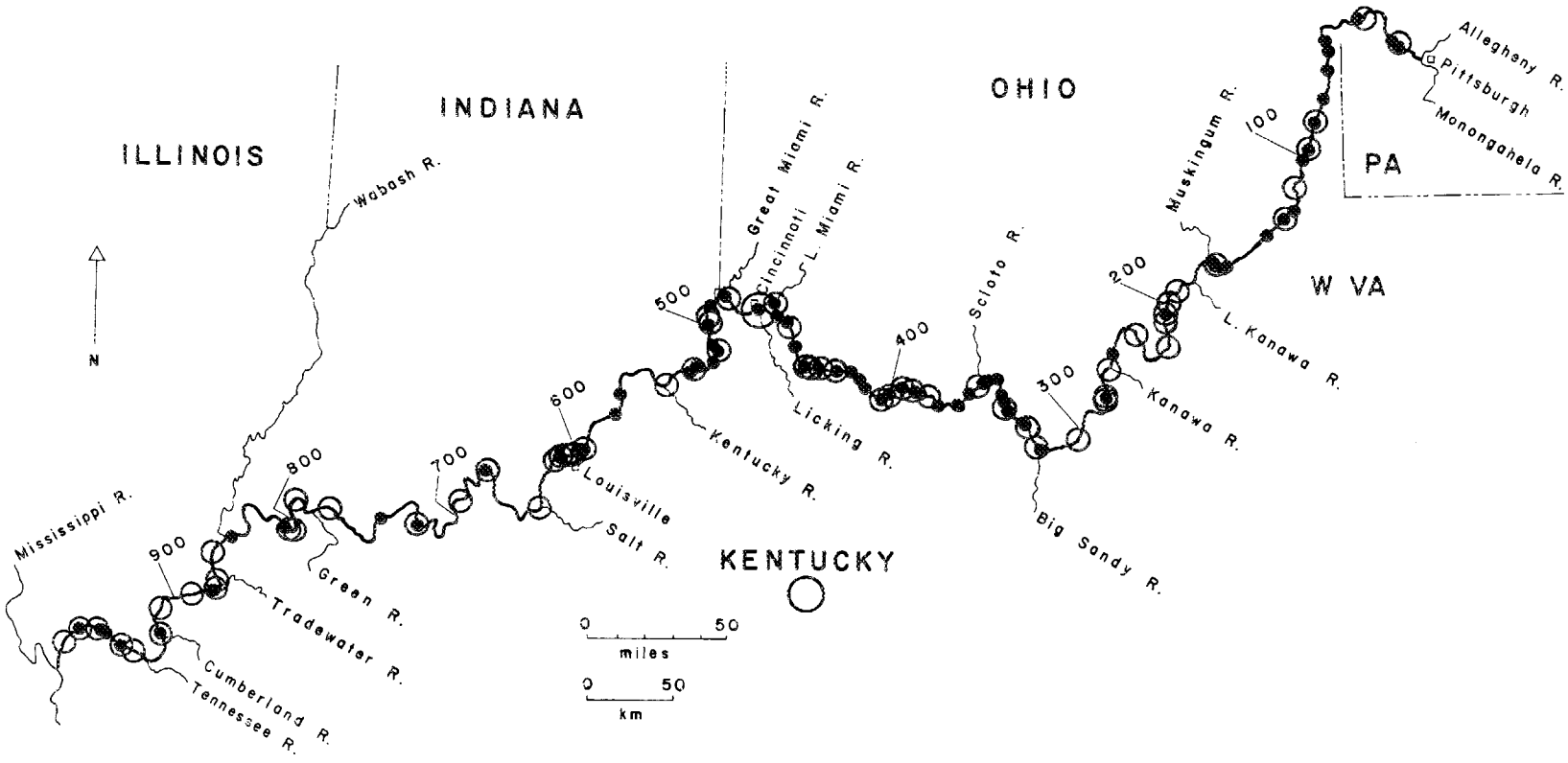

Figure 118. Distribution of *Micropterus punctulatus* in the Ohio River.

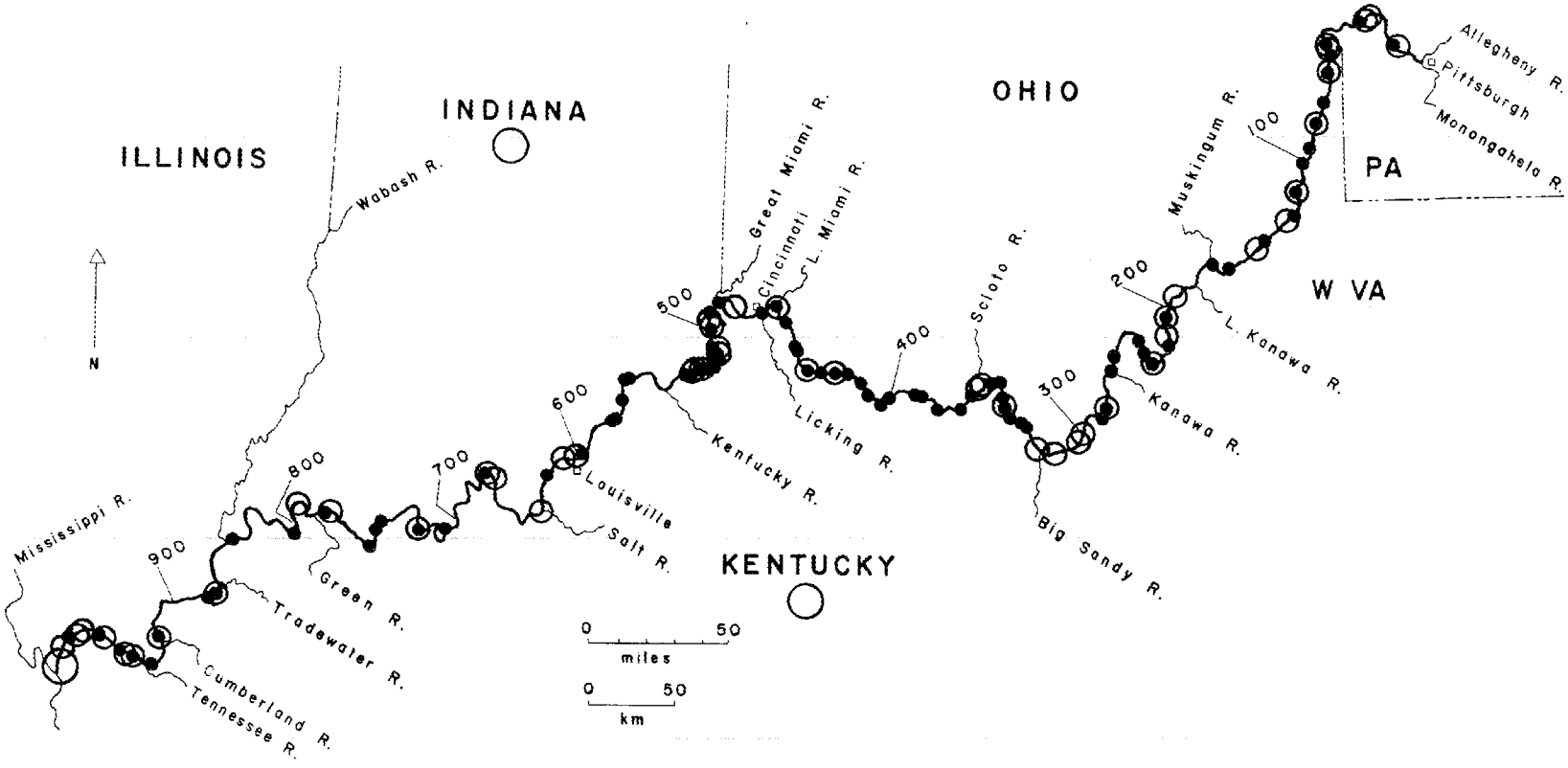

Figure 119. Distribution of *Micropterus salmoides* in the Ohio River.

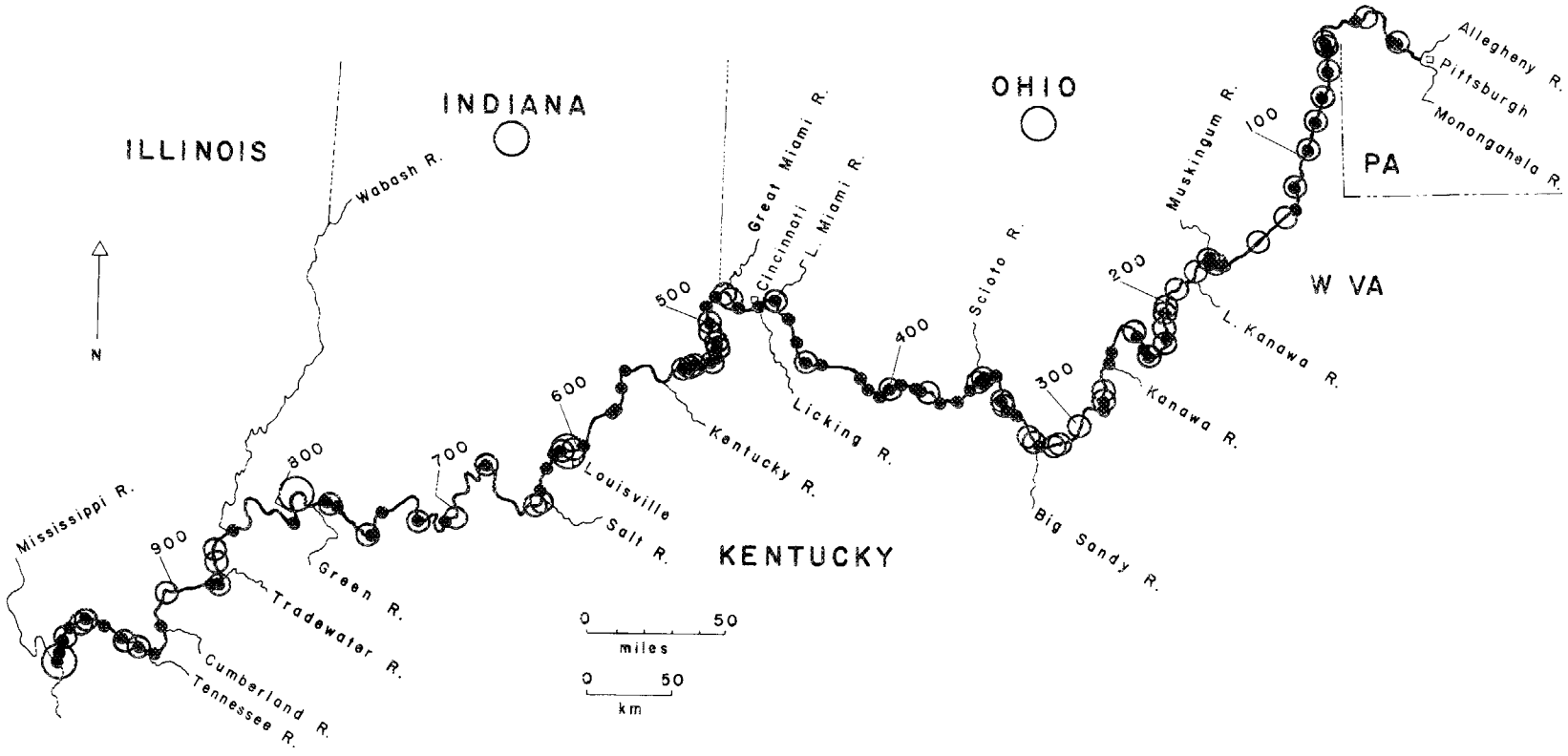

Figure 120. Distribution of *Pomoxis annularis* in the Ohio River.

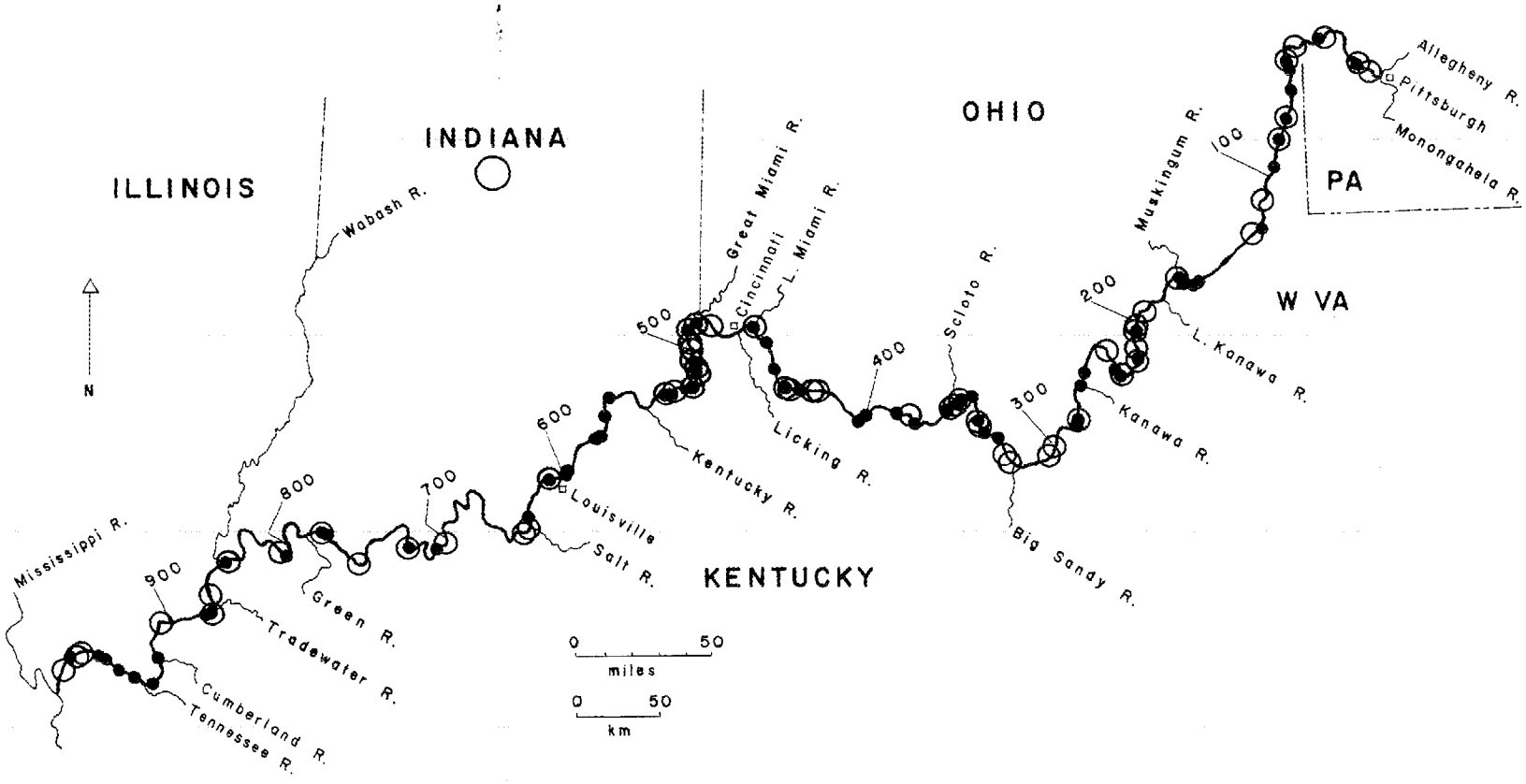

Figure 121. Distribution of *Pomoxis nigromaculatus* in the Ohio River.

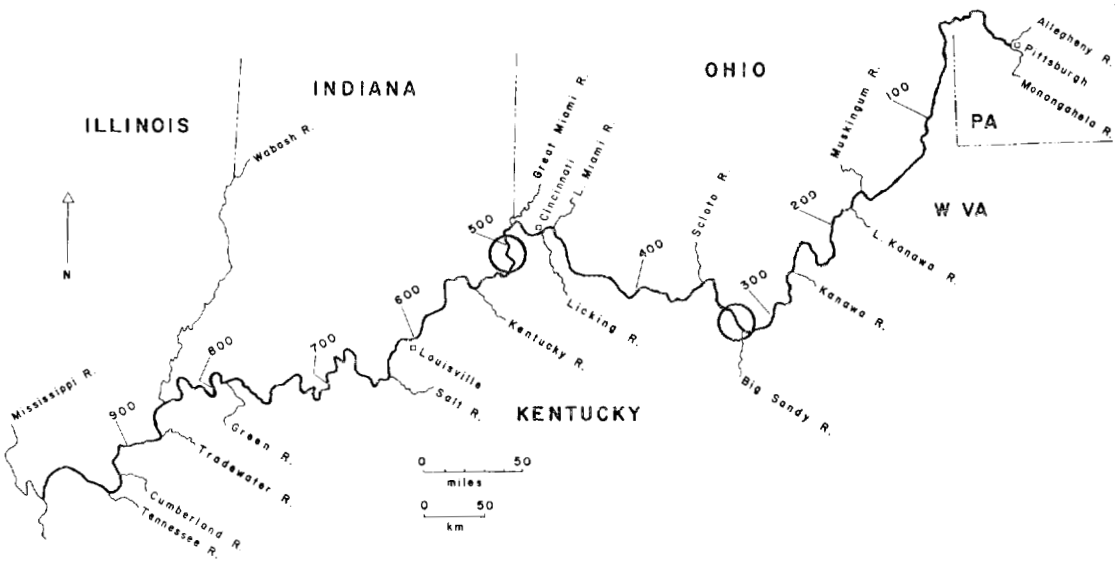

Figure 122. Distribution of *Ammocrypta asprella* in the Ohio River.

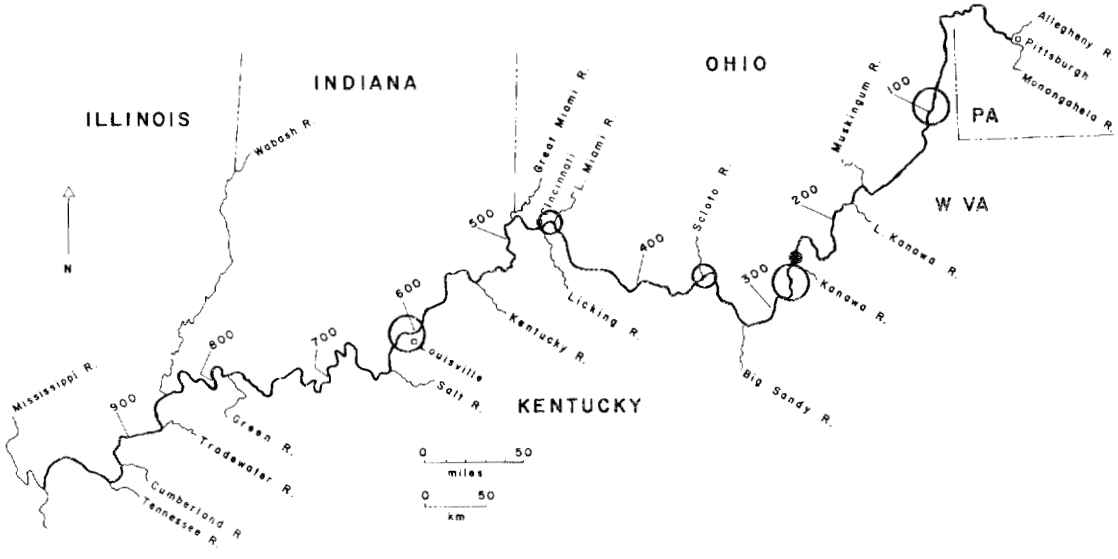

Figure 123. Distribution of *Ammocrypta pellucida* in the Ohio River.

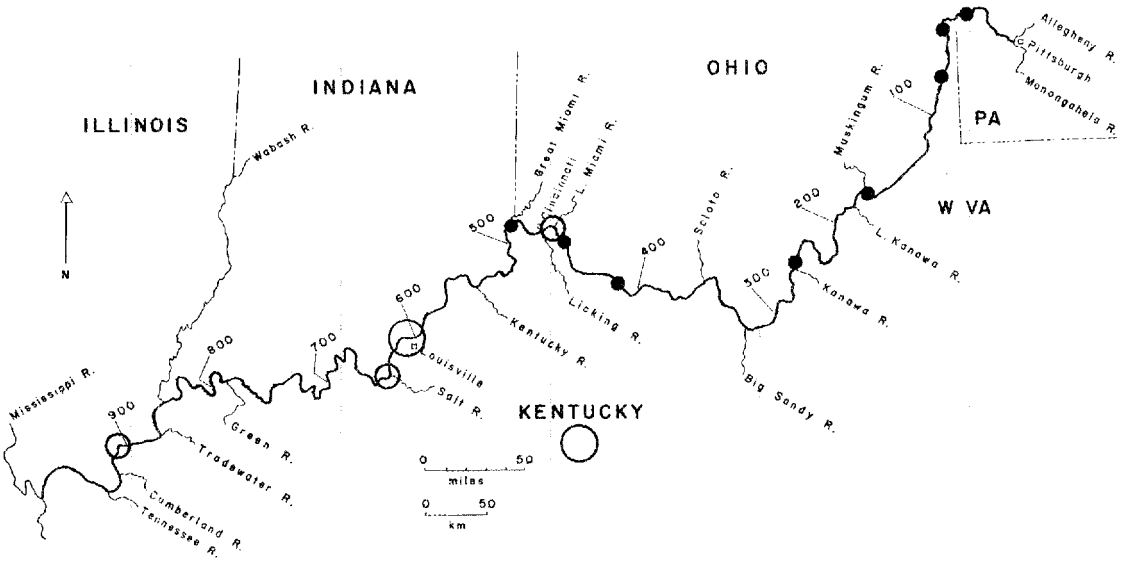

Figure 124. Distribution of *Etheostoma blennioides* in the Ohio River.

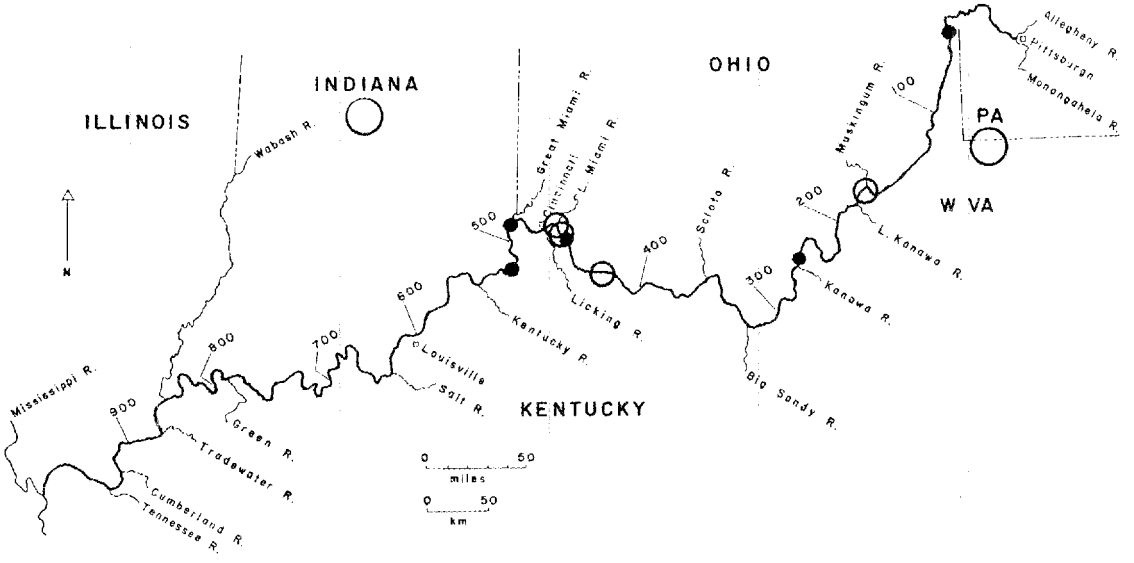

Figure 125. Distribution of *Etheostoma caeruleum* in the Ohio River.

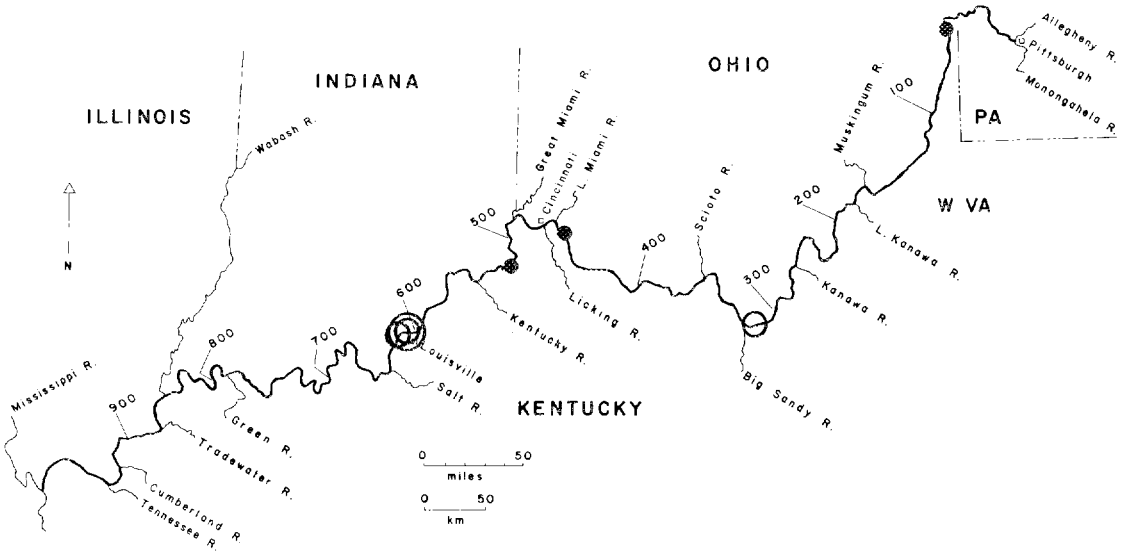

Figure 126. Distribution of *Etheostoma flabellare* in the Ohio River.

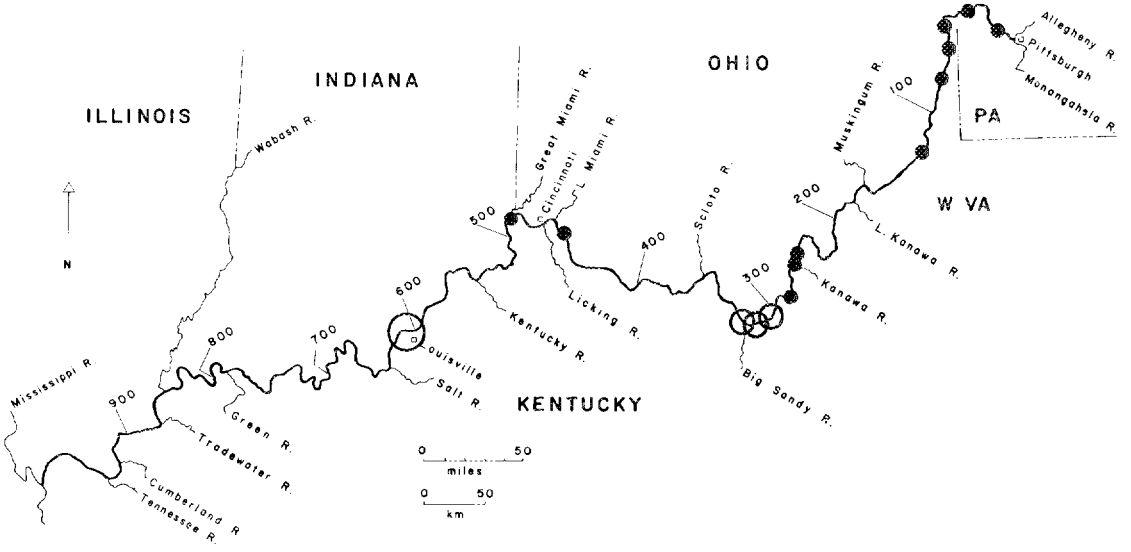

Figure 127. Distribution of *Etheostoma nigrum* in the Ohio River.

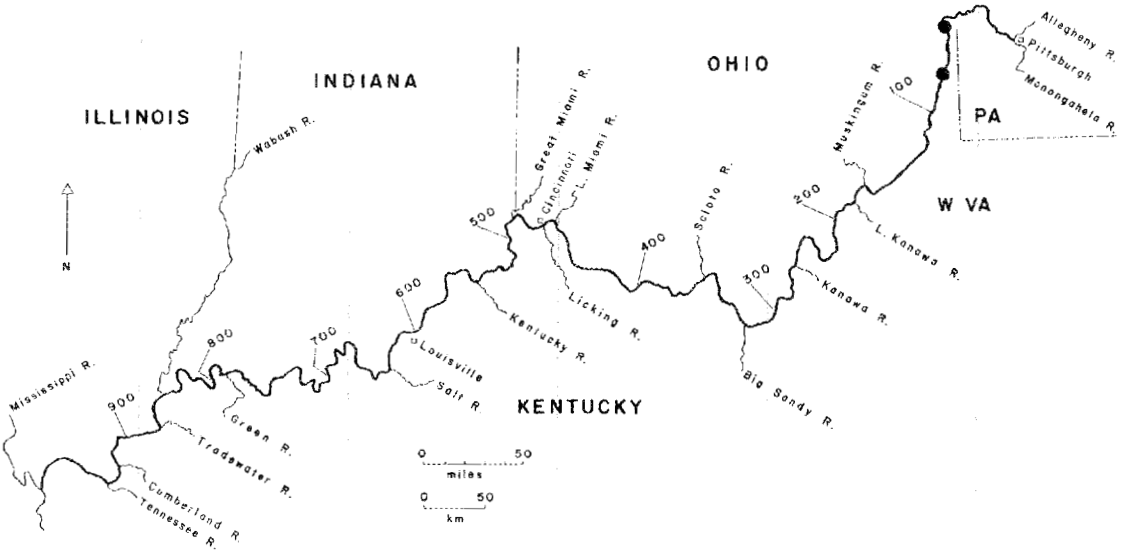

Figure 128. Distribution of *Etheostoma spectabile* in the Ohio River.

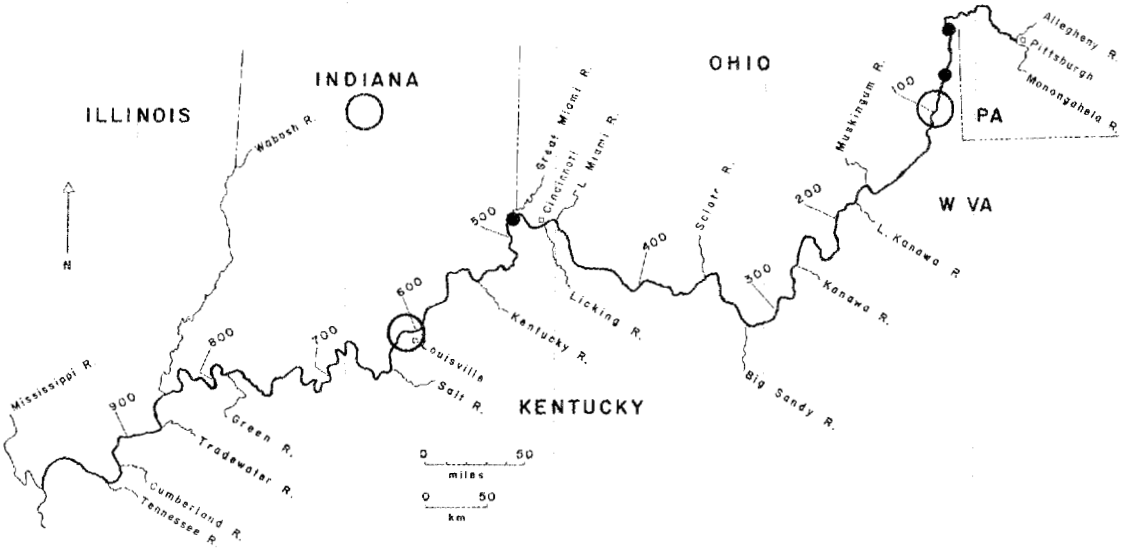

Figure 129. Distribution of *Etheostoma variatum* in the Ohio River.

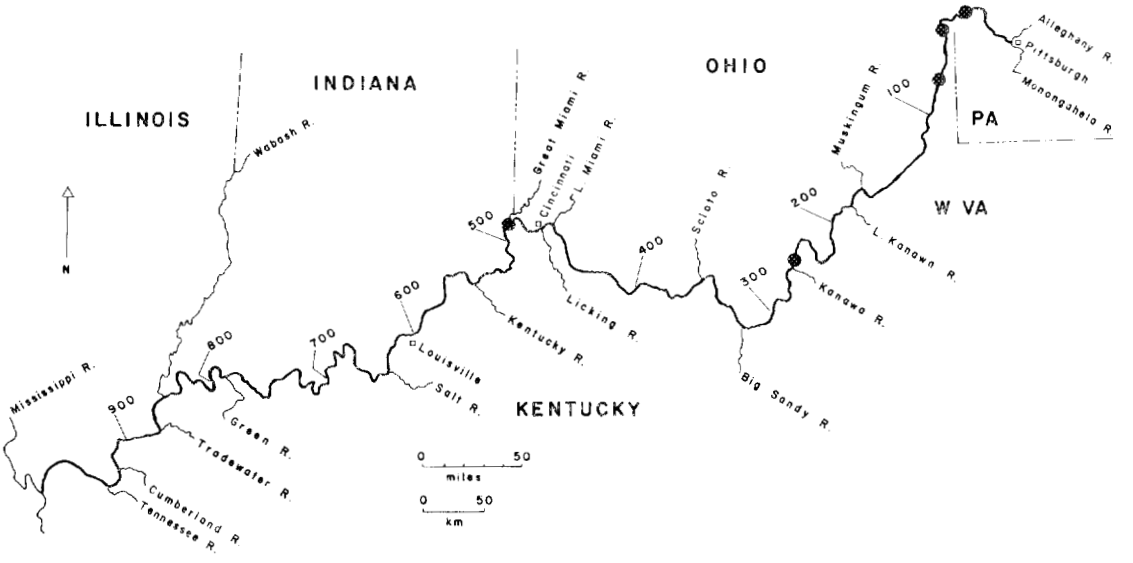

Figure 130. Distribution of *Etheostoma zonale* in the Ohio River.

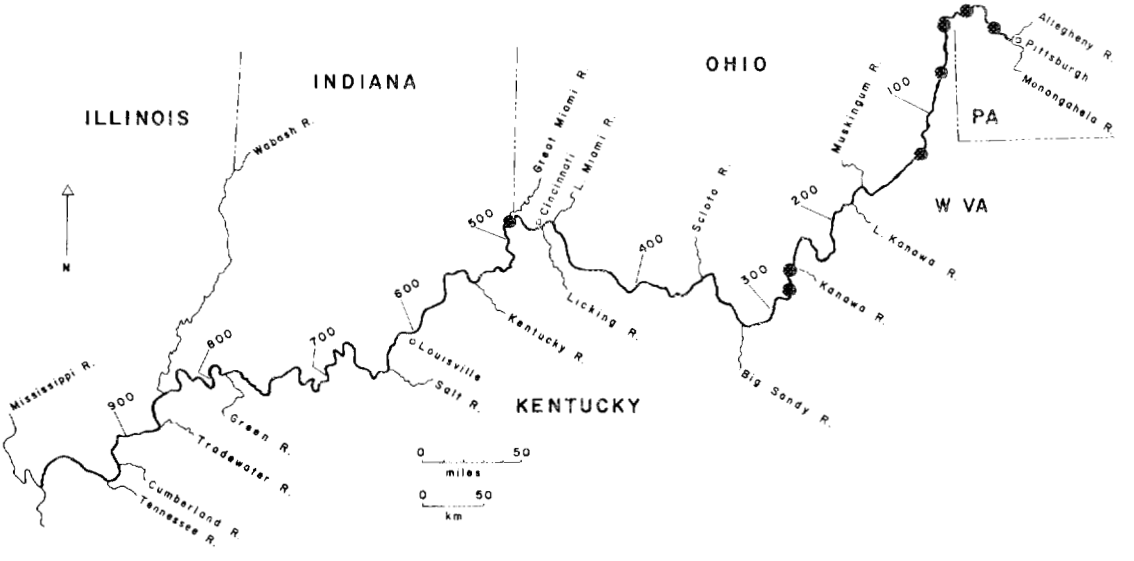

Figure 133. Distribution of *Percina copelandi* in the Ohio River.

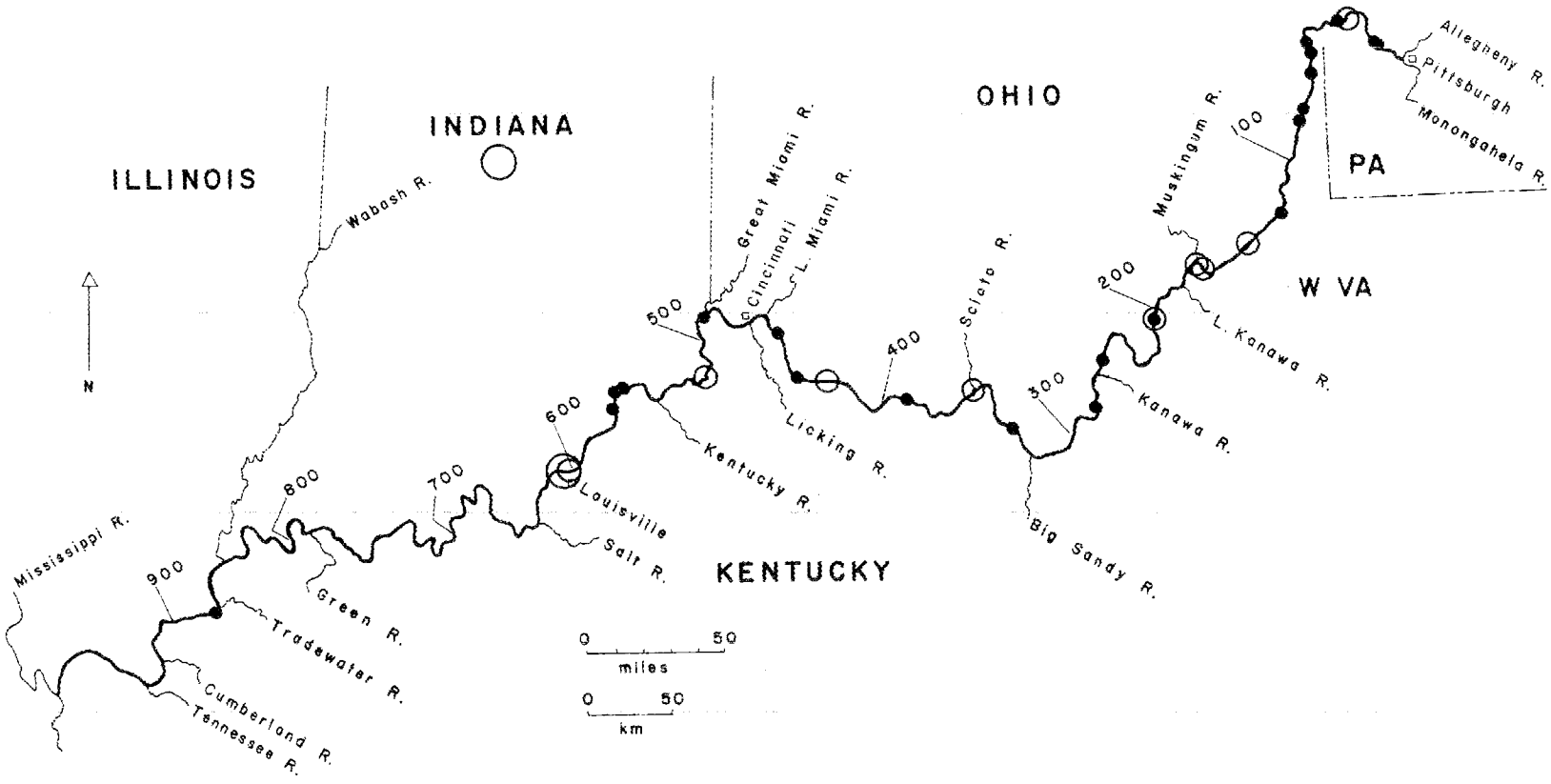

Figure 131. Distribution of *Perca flavescens* in the Ohio River.

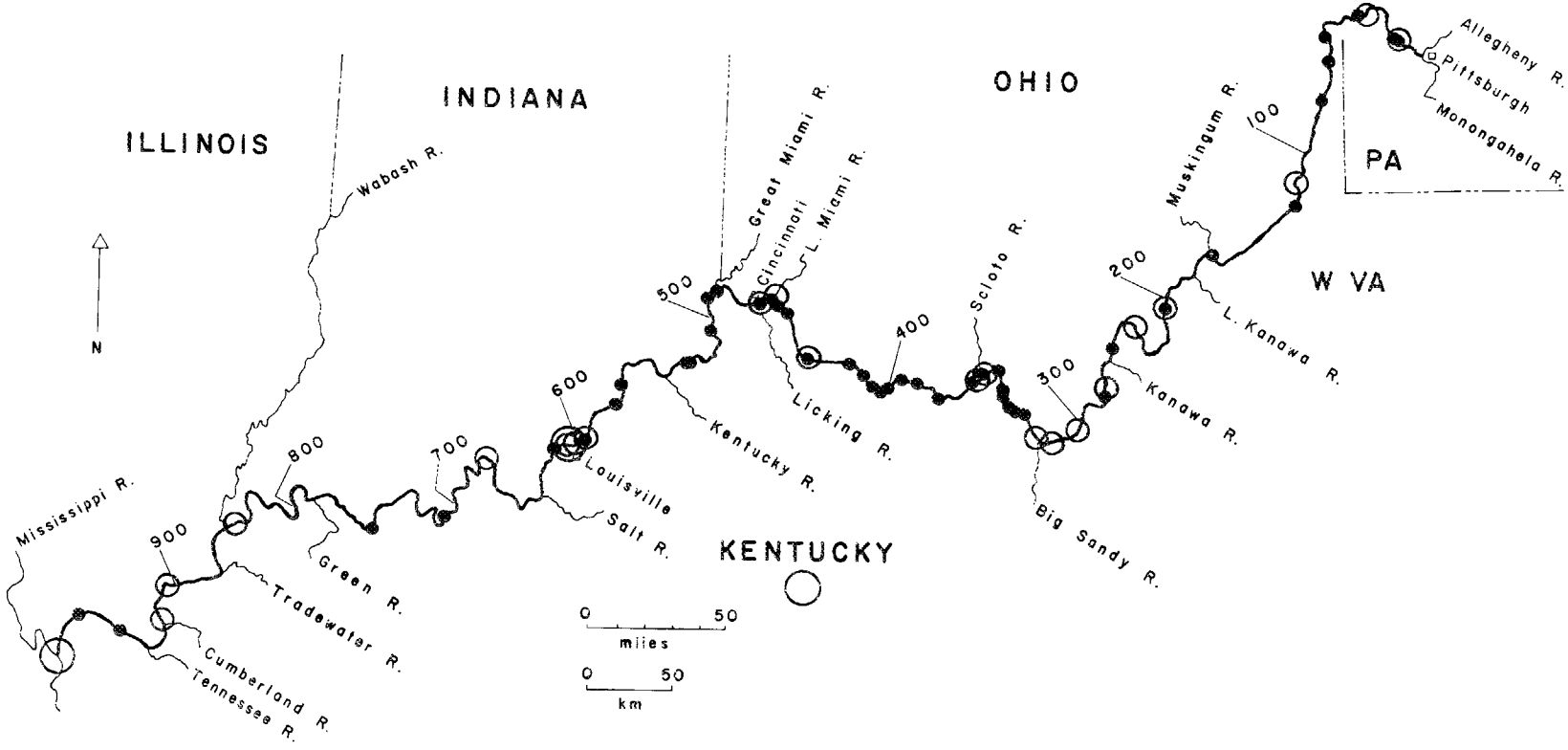

Figure 132. Distribution of *Percina caprodes* in the Ohio River.

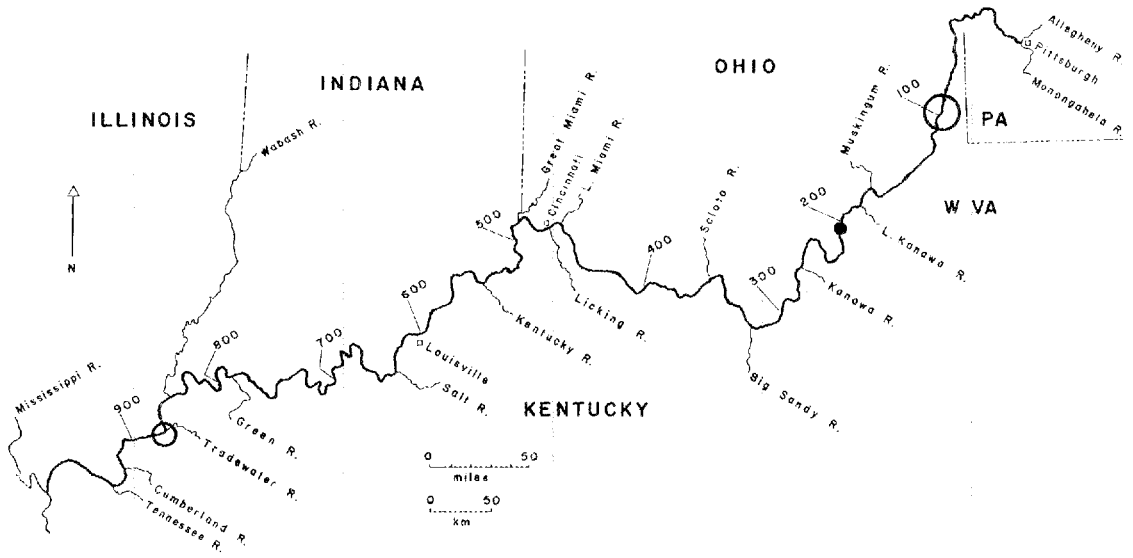

Figure 134. Distribution of *Percina maculata* in the Ohio River.

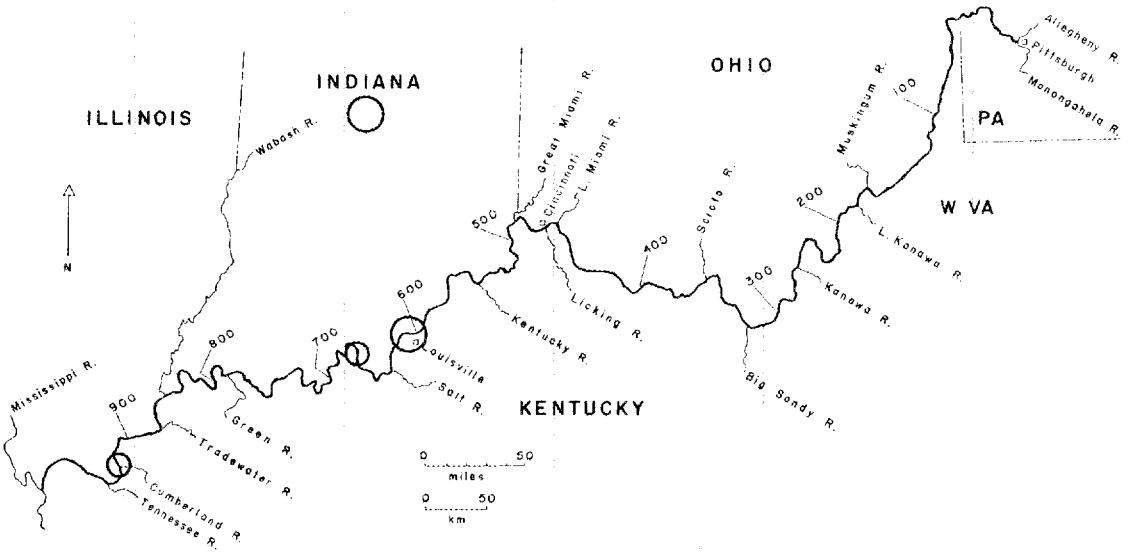

Figure 140. Distribution of *Cottus carolinae* in the Ohio River.

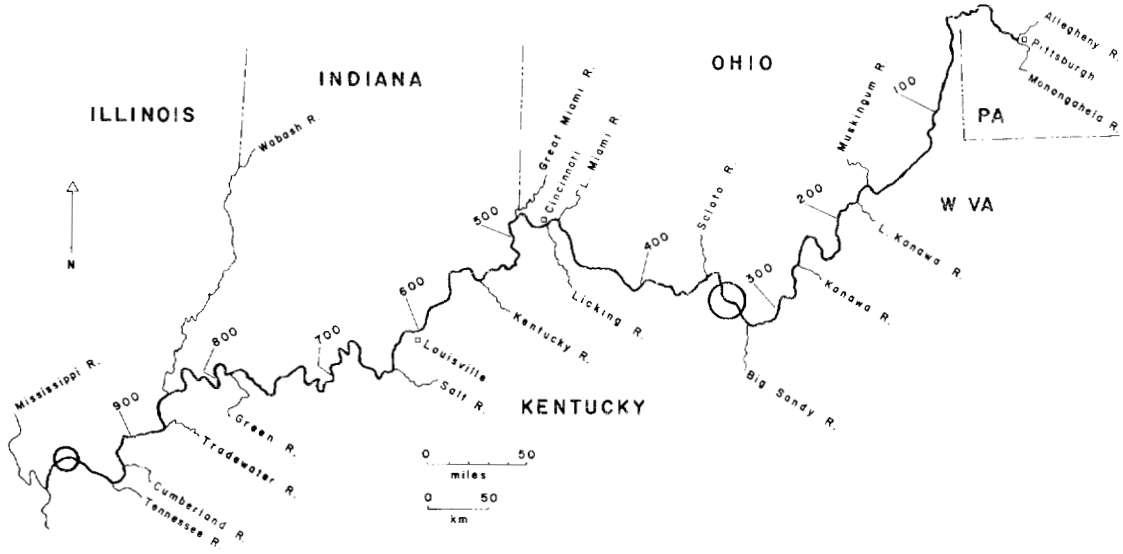

Figure 135. Distribution of *Percina sciera* in the Ohio River.

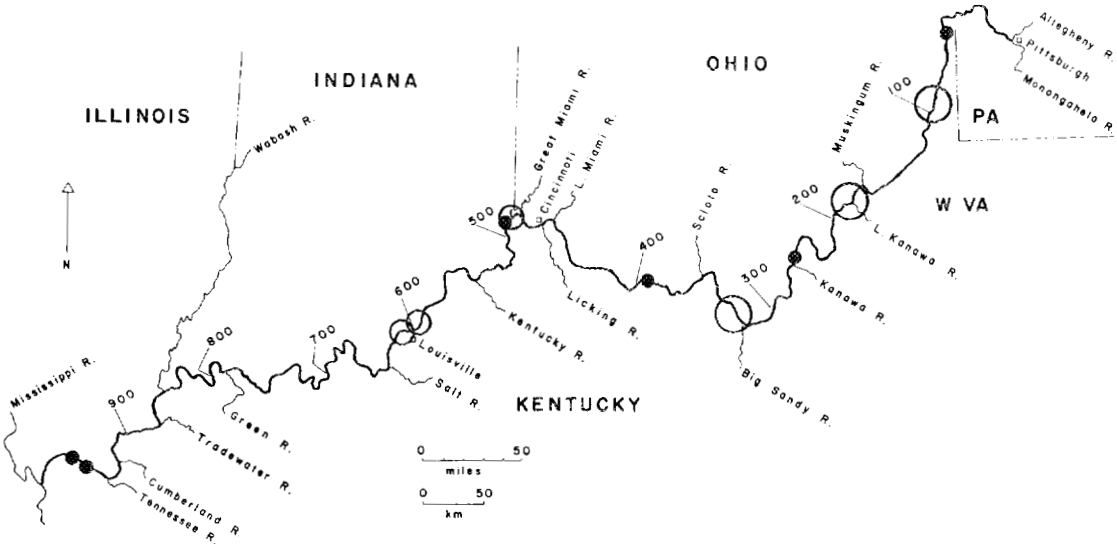

Figure 136. Distribution of *Percina shumardi* in the Ohio River.

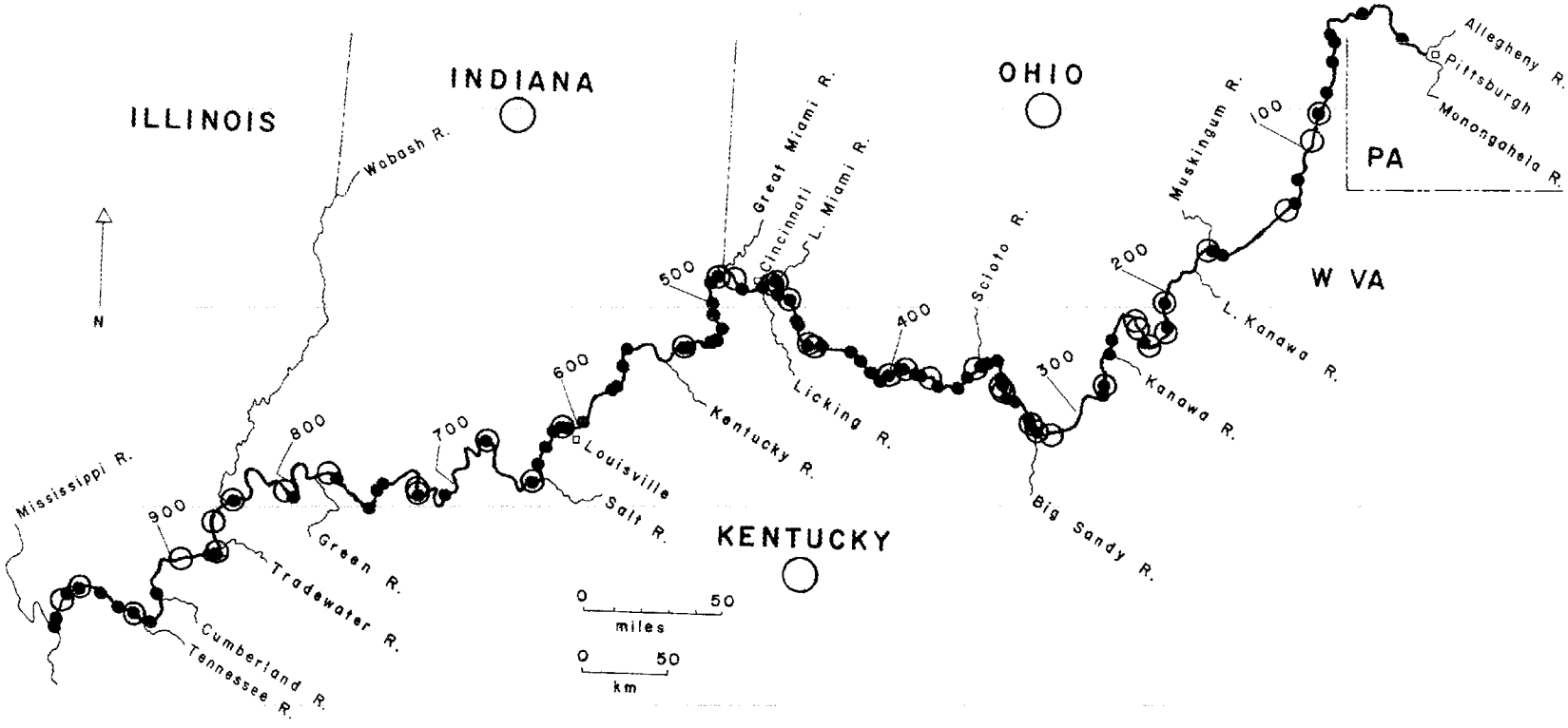

Figure 137. Distribution of *Stizostedion canadense* in the Ohio River.

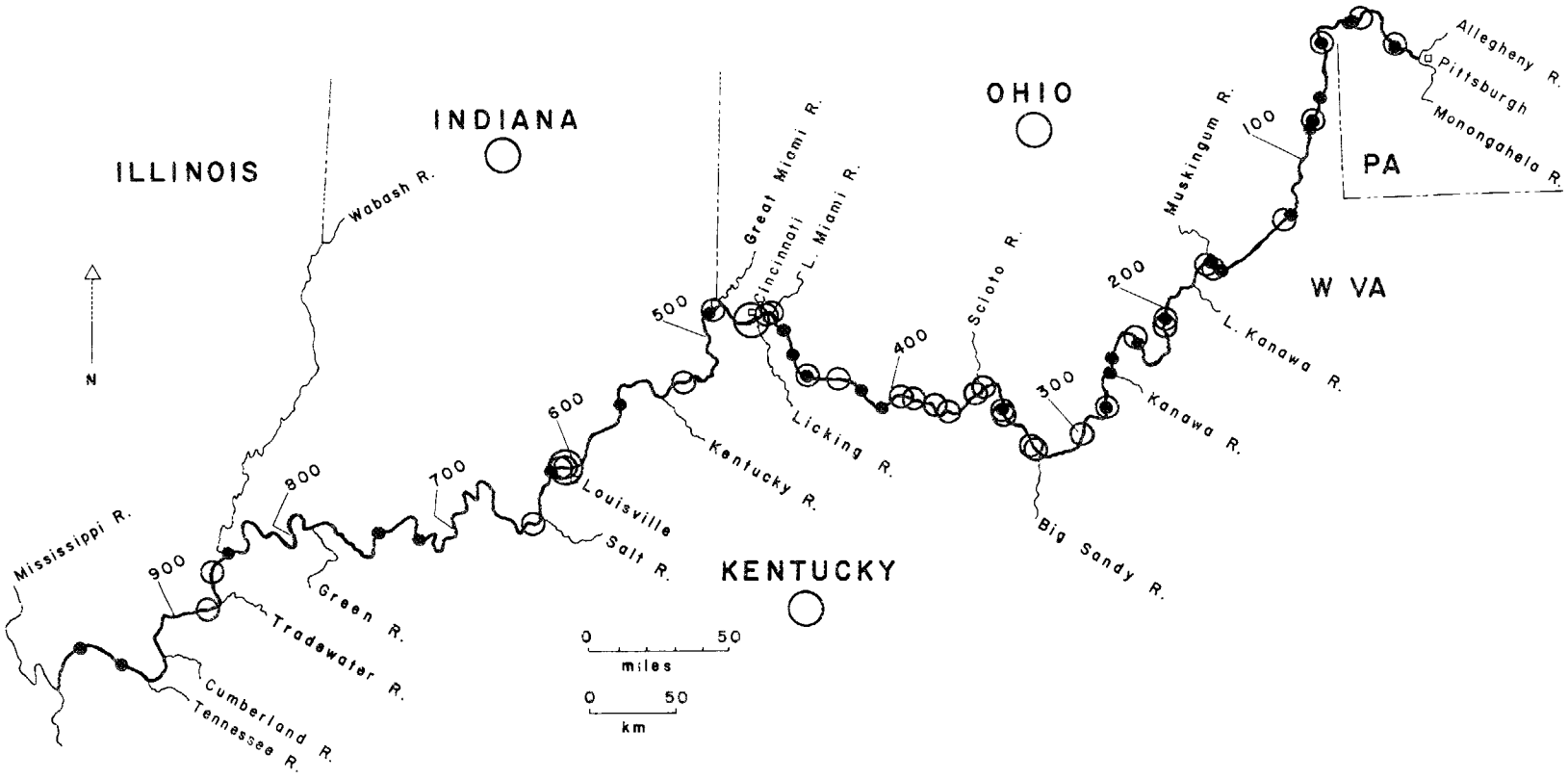

Figure 138. Distribution of *Stizostedion vitreum* in the Ohio River.

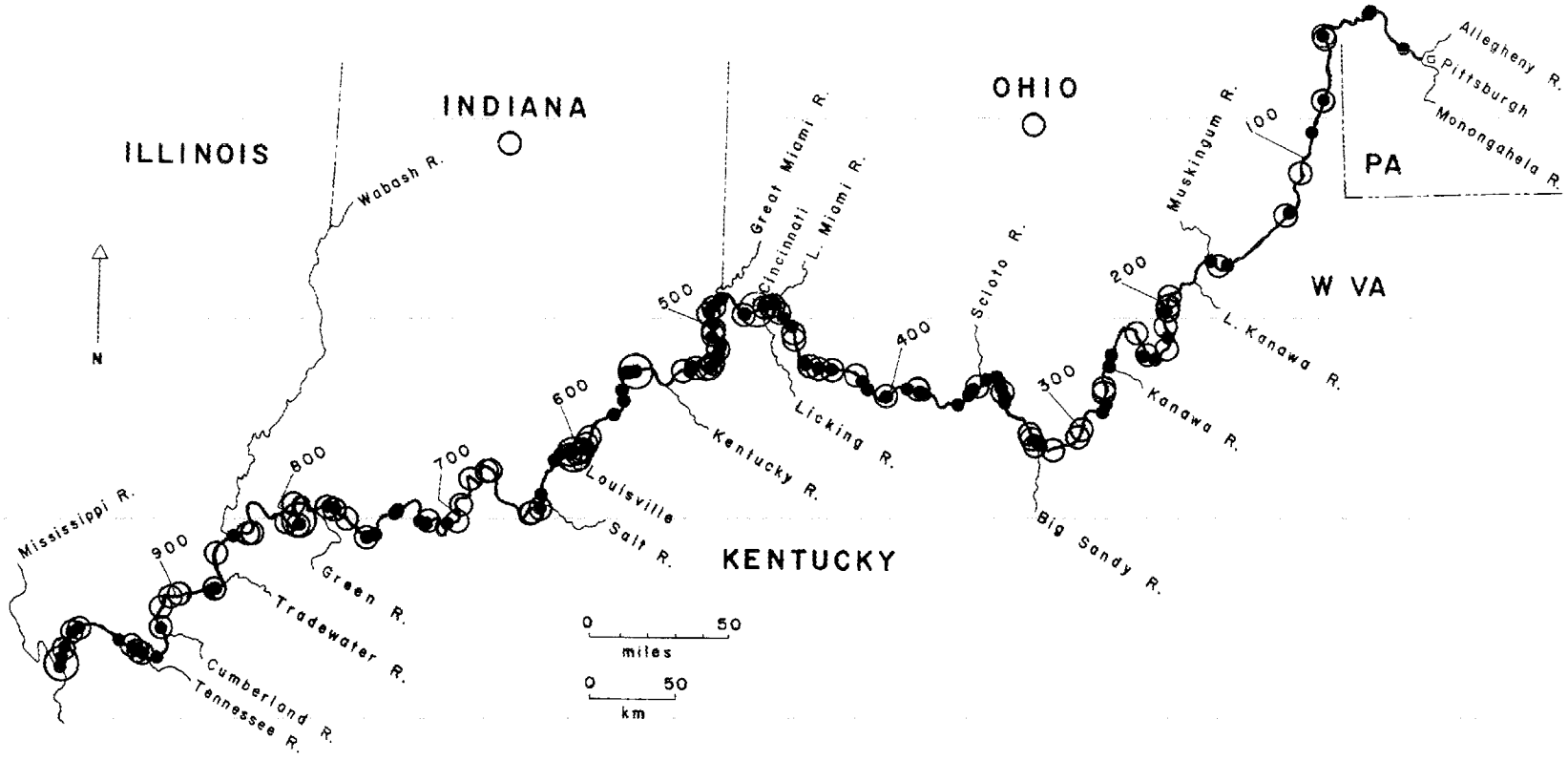

Figure 139. Distribution of *Aplodinotus grunniens* in the Ohio River.

CONCLUSIONS

Changes In The River Environment

1. The Ohio River has been converted from a free-flowing river with extreme annual variation in flow, depth, and width, to a river of relatively constant width and a minimum channel depth of nine feet by the installation of the current system of 20 navigation dams. The basin-wide system of flood-control reservoirs store flood waters and release them slowly during the dry seasons, resulting in much lower flood crests, and much higher flows in the late summer.

2. Land-use practices and construction of the navigation dams have together resulted in decreases in the area of rock, gravel, and coarse sand substrates in the river, and increases in silt, fine sand, and organic fines in the river. The navigation dams also inundated all of the rapids and riffles of the original river.

3. The number of islands in the river has declined from about 130 in 1818 to 110 today.

4. Approximately 80 permanent embayments have been created along the river by the navigation dams. Most of these embayments are found in the upper half of the river, where they provide the only extensive habitats for largemouth bass and the *Lepomis* sunfishes.

5. The mouths of most of the smaller tributaries to the Ohio have been converted to permanently flooded, steep-sided, and soft-bottomed canals near the mainstem.

6. The annual range of turbidities encountered by fishes in the river were probably not affected by human activities, but clearing of the land in the 1700's and 1800's did increase the mean annual turbidity

of the river up to 1960. After 1960 mean turbidity declined slightly as a result of better land-use practices and the release of clear waters from flood-control reservoirs throughout the basin.

7. The mean annual concentration of dissolved solids in the river also increased from original levels of perhaps 8-10 mg/l to maximum levels of about 24 mg/l at Joppa in 1966, and have since declined slightly to about 16 mg/l.

8. Dissolved oxygen concentrations in the river were often less than 4.0 ppm by the 1940's. The installation of primary and then secondary sewage treatment plants resulted in higher low-flow oxygen concentrations in the 1970's. However, oxygen concentrations of less than 5.0 ppm are still recorded below the metropolitan areas, particularly during very low flows, or following inevitable breakdowns in the sewage treatment facilities.

9. The mean temperature of the Ohio River probably increased slightly following the clearing of the watershed between 1800 and 1900, there are no confirming measurements available to us. Since the 1870's, when adequate measurement began, there appears to have been no long-term changes in the mean temperature of the Ohio River. Local increases in temperatures do occur where cooling waters from power plants are reintroduced to the river, and the effects of these increases are still not clear.

10. Acid mine drainage in the upper Ohio River Basin often depressed pH values to less than 4.0 in the 1940's and 50's, but pollution control measures have resulted in pH's of between 6.0 and 9.0 throughout the river since 1970.

11. Coliform bacteria concentrations in the river had reached extraordinarily high levels by the 1940's but were reduced precipitously by

the installation of primary sewage treatment facilities in the 1950's. The installation of secondary treatment facilities for most of the basin population in the 1960's and 70's did not further reduce coliform bacteria concentrations to any great extent, perhaps because of an increasing human population, and non-point sources of bacteria.

12. An increasing number of more-or-less exotic and difficult to measure elements and compounds are being reported from the river, and the flesh of fish therein, each year. Recent concerns have been expressed regarding heavy metals, PCB's pesticides, and phenolics. The presence of these toxic substances, together with taste and odor objections to food fishes from the river are retarding the recovery of both commercial and sport fisheries in the river.

13. The effects of pollution have historically been most severe in the upper 100 miles of the river. The most dramatic improvement in water quality has, therefore, been made in this area, and the most dramatic recoveries in the fish community have also been noted in this area since 1970. We attribute this recovery largely to the reclamations achieved under the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500).

Changes In The Fish Community

1. The lock chamber rotenone sampling program, conducted under the supervision of a basin-wide agency (ORSANCO) provides the most economic, reproducible, and reliable means of monitoring long-term changes in the fish community of the Ohio River. This program should be funded adequately and continued indefinitely.

2. The total number of fish species reported from the Ohio River by all authors up to 1983 was 154. The upper, middle, and lower thirds of

the river each provided 115-121 species, indicating a rather uniform distribution of species.

3. The diversity (Shannon-Weiner index) of fishes increased slightly from 1.26 in the upper third of the river to 1.51 in the lower third of the river. There were statistically significant increases in diversity values recorded in the upper 100 miles of the river between 1957 and 1980. Diversities in 1978-80 were significantly higher in the river as a whole than in the previous three time periods considered.

4. Eight native species which were reported before 1920 have not been reported since (least brook lamprey, Alabama shad, hornyhead chub, Ozark minnow, and the crystal, mud, gilt, and longhead darters). All of these fishes were apparently rare before 1920 and/or were riffle-rapid inhabiting forms.

5. Five additional species which were reported between 1920 and 1969 have not been found in the river since 1970 (lake sturgeon, burbot, southern redbelly dace, dusky darter, and banded sculpin).

6. Fourteen species of fish have been introduced to the Ohio River by man since 1870. Common carp, goldfish, white catfish, and banded killifish have established reproducing populations. Of the remaining ten introduced species (alewife, American shad, coho salmon, rainbow trout, brown trout, northern pike, grass carp, silver carp, mummichog, and striped bass) only the grass carp and, perhaps, the striped bass and northern pike seem likely to establish reproducing populations.

7. Useful data concerning the densities, even the relative densities, of Ohio River fishes simply does not exist before 1957. Nevertheless, by cautious interpretation of early works, we arrived at the following conclusions regarding significant long-term changes in the relative

abundances of Ohio River fishes.

a. The Alabama shad, lake sturgeon, and alligator gar represent three species which were occasional to common before 1900, and which are now absent, or nearly so, from the Ohio River.

b. Fishes which were apparently reduced greatly in abundance after 1900 were the lampreys, shovelnose sturgeon, paddlefish, muskellunge, and blue sucker. We also note in the Distributional Checklist that many of the smaller, riffle-inhabiting species (i.e., darters, madtoms, sculpins, and some minnows) were probably much more abundant before 1900.

c. Fishes which probably declined, albeit to a lesser extent, between 1900 and 1980 were the shortnose gar, mooneye, white sucker, redhorses, buffalofishes, and smallmouth and spotted basses.

d. Fishes which probably increased in abundance between 1900 and 1980 (other than the introduced common carp, goldfish, white catfish, and banded killifish) were the gizzard shad, threadfin shad, and river carpsucker.

8. Between 1957 and 1980 the ten most abundant fishes in the Ohio River, according to our analyses of the 243 lock-chamber poisonings made within this interval, were: emerald shiner, gizzard shad, freshwater drum, mimic shiner, channel catfish, common carp, bullheads, skipjack herring, white crappie, and threadfin shad.

9. The density of all fishes combined between 1957 and 1980 was 14,764/ha in the upper third of the river, and declined to 6,210 and 5,393/ha in the middle and lower thirds. However, these differences were not statistically significant at the .05 level according to t tests.

The extremely large densities in the upper river were due to large populations of emerald and mimic shiners.

10. Densities in the upper 100 miles of the river showed the greatest change during the 1957-80 period. Total densities in this section increased significantly (.05 level, t tests) from 3,532 to 11,071/ha during the period with the largest increase seen after 1977. We attribute this three-fold increase to improved water quality in this section resulting from the mandates of P.L. 92-500. Total densities declined between ORM 100 and 300 during 1957-80, primarily due to decreases in emerald and mimic shiner populations. Below ORM 300 total densities were relatively unchanged during this period.

11. Between 1957 and 1980 the ten fish which contributed the greatest overall biomass in the lock-chamber samples were: gizzard shad, common carp, freshwater drum, channel catfish, bigmouth and smallmouth buffalo, emerald shiner, paddlefish, flathead catfish, and bullheads (all three species combined).

12. Total biomasses of all fish combined were relatively low (about 100 kg/ha) in 1957-60, and increased significantly (.05 level, t tests) to about 450 kg/ha between 1967 and 1980. Biomasses were relatively constant between ORM 0 and 800, and then increased by a factor of 2 in the last 181 miles of the river. Most of this increase in biomass in the lower river was due to large catches of common carp and gizzard shad.

13. Above ORM 100 nearly all species of fish increased in density between 1957 and 1980, with the most dramatic increases seen after 1974.

14. Below ORM 100 the densities of emerald shiner, mimic shiner, silver chub, and several other minnows decreased while densities of common carp, white crappie, sauger, white bass, and freshwater drum increased.

15. The densities of paddlefish, longnose gar, and skipjack herring increased slightly between 1957 and 1980 in the lower third of the river.

16. Gizzard shad densities increased above ORM 600 during this period and decreased slightly below ORM 600.

16. Threadfin shad densities declined between 1957 and 1980 in the lower third of the river where they were most numerous.

18. Densities of bullheads (all species combined) and blue catfish declined in most 100-mile sections of the river between 1957 and 1980, and there was apparently a shift from black to brown bullheads in the upper third of the river.

19. Several fishes which have been reported in the Mississippi River near the mouth of the Ohio may eventually be found in the lower Ohio River. These species include the pallid sturgeon, western silvery minnow, plains minnow, sturgeon chub, flathead chub, and inland silverside.

Reproduction Of Fishes In The Ohio River

1. Of the 154 species of fish reported from the river we were able to assign 126 to one of Balon's reproductive guilds. Of these, 70% were non-guarders, 29% were guarders, and one was a live-bearer.

2. The three most abundant fishes in the river (emerald shiner, gizzard shad, and freshwater drum) are all pelagophils or litho-pelagophils. Apparently, producing pelagic or semi-pelagic eggs and/or larvae has been a successful strategy in the Ohio River. It may be worth repeating that the grass carp is also a pelagophil.

3. Non-guarding lithophils made up the largest guild (28 species) in the river, but included many species which have declined in abundance since the 1800's (i.e., shovelnose sturgeon, paddlefish, blue sucker, and redhorses). Evidence indicates that siltation and canalization have

smothered many gravel deposits with finer sediments and impaired the reproductive success of most non-guarding lithophils. Only one member of this guild (skipjack herring; 8th position) was found among the 10 most abundant fishes during 1957-80.

4. Fishes of the non-guarding phyto-lithophil guild produce eggs and larvae which are better suited to the finer sediments now found on the bottom of the river, and three members of this guild (threadfin shad, common carp, and mimic shiner) were among the 10 most abundant fishes in the river between 1957 and 1980.

5. Three members of the guarder guilds (channel catfish, bullheads, and white crappie) were among the 10 most abundant fishes in the river. Apparently the strategy of artifically cleaning the silt from a nesting site or cavity, and fanning the eggs placed therein, has also proven to be a successful strategy in the Ohio River.

6. Most fishes in the Ohio River spawn in the shore-debris zone of the river. The centrarchids (other than the crappies) spawn most successfully in embayments. Centrarchids may have difficulty in nesting successfully because of the physical disturbances associated with tow boat wakes.

7. Creek mouths and flooded creek channels near the mainstem are not important spawning areas for riverine fishes, although they may offer areas of refuge from pollution in the upper 100 miles of the river.

8. Larval fishes were present in the river between April and September of each year.

9. Densities of all larval fishes combined were greatest in May and June of each year.

10. Densities of all larval fishes combined increased substantially between each third of the river (from 9.6/100 m^3 in the upper reaches of

the river to 56.5/100 m^3 near Louisville, to 600/100 m^3 in the lower reaches of the river during the peak spawning period of April-July).

11. Cyprinid and percid larvae made up the most abundant taxa of larval fishes in the upper third of the river, while clupeids, cyprinids, and catostomids were most abundant in the lower two-thirds.

Extrapolation Of Trends In The Fish Community

1. The goals of P.L. 92-500 to eliminate pollutants have been approached with corresponding increases in fish populations. Although the most dramatic improvements have occurred in the upper 100 miles of the river where pollution was most severe, the modest improvements in the lower river, in the face of an ever-increasing human population in the watershed, indicate the value of pressing forward to the full realization of the goals stated in P.L. 92-500.

2. Increasing densities of fishes throughout the river will result in the continued development of both sport and commercial fisheries on the river. External factors which will increase the importance and value of the fisheries may be higher prices for all fishery products, increased travel costs, which may keep recreational fishermen in the metropolitan centers on the river closer to home, and improvements in the quality of fish flesh for human consumption.

3. The greatest potential for increases in the diversity, density, and biomass of fishes still exists in the uppermost 100 miles of the river, because relatively large expanses of gravel substrate still exist there and pollution-sensitive fishes will, hopefully, continue to increase in response to pollution abatement.

4. The documented return of many species to the upper reaches of the river should encourage us to undertake efforts to restore species

in the lower river which have been extirpated (i.e., lake sturgeon) or reduced to levels of great concern (i.e., alligator gar, shovelnose sturgeon, blue sucker, muskellunge, and paddlefish).

RECOMMENDATIONS

Primary Recommendations

1. There is a great need, and we cannot emphasize too much the importance of this recommendation, for an overall coordination of studies being conducted on the river. During the last decade there have been many laundry lists of fishes drawn up near the site of each new power plant or other proposed project. In some cases the few miles of river near 3 or 4 plants have been sampled routinely and diligently for seven or eight straight years. However, as Schindler (1978) has pointed out, many of these studies have no clear objective other than the need on the part of the project proposer, to meet a legislative requirement. The propagation of this form of "tokenism" or "mitigative assessments" (poor science) is not necessarily the result of a callow or indifferent applicant, it may also be the result of a failure to provide river-wide coordination of objectives by regulatory and management agencies.

Therefore, we recommend that regulatory and management agencies develop a set of realistic objectives concerning fishery resources in the Ohio River. It is convenient to divide these resources into three groups:

a) commercial fishes

b) sport fishes

c) native fishes not fitting into the above two categories.

We would anticipate that objectives concerning commercial species would center upon identifying concentrations of marketable fishes, improving

the palatability of fish flesh through water quality improvements, determining harvest levels, determining levels of toxic materials in fish flesh, developing and regulating gear, and developing uses for abundant species now under-utilized (i.e., gizzard shad).

Objectives concerning sport fishes would center upon identifying concentrations of the principal sport fishes (i.e., basses, sunfishes, crappies, catfishes, white bass, and sauger), improving catch rates, improving palatability, reducing toxic material in fish flesh, identifying factors limiting sport fish populations in the river and devising means of reducing their effects, and establishing populations of sport fishes not present or rare in the river (i.e., striped bass and muskellunge).

Objectives concerning native fishes which do not support fisheries would center upon determining temporal and spatial trends in abundance, identifying species in danger of extirpation and determining methods of restoring such populations, the reintroduction of extirpated species (i.e., lake sturgeon), and determining factors responsible for depressing given populations.

Two objectives which we feel sould be given high priorities are:

a) determining the effects of the new high-rise dams on upstream and downstream movement of declining species (i.e., sturgeons, paddlefish, blue sucker, mooneye, and redhorses).

b) determining the effects of tow boat wakes on reproduction of smallmouth, largemouth, and spotted basses and perhaps other nest-building fishes in the shore-debris zone.

Once a set of overall objectives have been agreed upon and prioritized, the regulatory and management agencies would be in a position to

identify data gaps, draft a river-wide study plan, coordinate the efforts of all investigators working on the river, and recommend individual studies which would maximize the amount and usefulness of information gathered, while reducing duplication, overlap, and meaningless compilations.

2. Because the annual lock chamber rotenone samples provide the most economic and reproducible means of monitoring fish populations in the Ohio River, it is imperative that the agencies involved in the program conduct it in a manner which will provide the maximum amount of information possible, and that the information be gathered by highly defined and standardized means to ensure comparable data from lock to lock and year to year. To this end we recommend the following:

a) That a validation of the lock chamber sampling method be undertaken. This validation procedure would compare results from a single lock with results from an intensive sampling and tagging effort in the open river near the lock.

b) That the cooperating agencies establish a definite sampling schedule specifying the lock to be sampled each year. At present the same locks are not sampled each year. Sampling should continue to be conducted in late summer or early fall when water levels are low. The exact sampling dates should probably be adjusted each year to conform to a specified set of water level and water temperature criteria.

c) That rotenone concentrations and efforts allotted for collecting fishes be standardized.

d) That collecting efforts be equally distributed among all sizes and species of fishes to ensure accurate and comparable data.

e) Provision should be made for the preservation of voucher specimens

of all fish species taken in each lock chamber sample on the Ohio River. The voucher specimens should be stored in a well-established and permanent collection. For reasons of economy and safety it might be best to distribute the voucher specimens amongst two or three such collections. Large collections now exist at Ohio State University, the University of Louisville, and the Illinois Natural History Survey.

f) That fishes which cannot be positively identified in the field be preserved and examined later in the laboratory. It would also be advisable to have representative specimens verified by recognized ichthyologists at the voucher deposition museums.

g) That a series of experiments be undertaken to determine if a more reliable means of collecting poisoned fish from the lock chambers can be devised. The use of lift nets on the bottom of the locks, stop nets pulled through the chamber, or benthic dredges may be of value. Even while maintaining a conscious effort to select fishes without bias, most people will be attracted to the large, unusual, or valuable specimen first.

h) That a detailed set of written instructions and data forms be provided to aid the collecting parties in achieving results with a minimum of error variance and a maximum amount of information.

3. The stated goals of P.L. 92-500 should continue to be pursued in order that the demonstrated program toward recovery of the fish community through enhanced water quality be maintained. A copy of all environmental impact assessments within the Ohio River Basin and all preliminary reports (microfiche if necessary) leading to such assessments should be filed with an existing, stable, library centrally located within the basin, as well as being made available through the National Technical Information

Service in Washington, D. C. Following the suggestions of Rosenberg et al. (1981) all documents must be attributed to the original author(s).

Secondary Recommendations

1. The results of the lock chamber poisonings made between 1957 and 1960 which resulted in the ORSANCO Aquatic-Life Resources report of 1962 are available, and should be incorporated into ORSANCO's computer-stored data base.

2. Tabular, raw data should be appended to all environmental reports submitted to regulatory agencies, and should be expressed in the original units of measure (i.e., number of fish shocked per unit of time or distance, area of seine haul, volume of water filtered, etc.). Agencies charged with either conducting or reviewing investigations of Ohio River fishes should specify units of measure to be used in routine collection of data.

3. Studies of reproductive success and larval fish distribution in the river are hampered by the inability to identify most specimens to species, given the current state of larval fish taxonomy and classification. Therefore, descriptive studies of larval sucker, cyprinids, and clupeids in particular should be encouraged.

4. All investigators should be encouraged to list fishes phylogenetically, follow the taxonomic usage established by Robbins et al. (1980), and standardize mesh sizes of all netting and means of quantifying each collection effort. It might even be possible for the Environmental Protection Agency to devise standard data forms for each collecting method.

5. All agencies which mandate studies of fishes on the Ohio River should follow the recommendations of the Association of Systematics

Collections (Lee et al. 1982) and demand as a condition of all contracts let that voucher specimens be properly collected and maintained.

6. Many collections of fishes have been made in the upper two-thirds of the Ohio River between 1970 and 1983, but relatively few collections have been made below ORM 635. We recommend that collecting efforts below mile 635 be encouraged by governmental agencies whenever possible, to complete our knowledge of the fishes in this, the least disturbed section of the river.

7. The lower 62 miles of the river remain unimpeded by high-lift dams (only two small wicket dams are present) and represent a refuge area for the shovelnose sturgeon, alligator gar, paddlefish, blue sucker, and other riverine species (Neff et al. 1981). A new high-rise dam is planned at Olmsted (ORM 964; U. S. Army Corps of Engineers 1979b and Woodyard, Per. Comm. 1983) and we recommend that if this dam is constructed, all possible consideration should be given to mitigating effects of the dam on fishes in the area, and that compensatory programs to actively offset any such deleterious effects be included in project plans.

8. The U. S. Army Corps of Engineers, in cooperation with other resource agencies, should seriously consider means by which the siltation of gravel and rubble substrates in the channel border and shore debris zone could be reduced for the reproductive benefit of the lithophil fishes. If structures and operation schedules can be devised to provide a year around 9' channel, it would seem that a means of keeping at least small areas of gravel clear could also be devised. The tailwater region below the dams would seem to be areas where such measures might be attempted. The need to keep the spectacular fossil beds at the Falls of the Ohio free of silt for observation purposes might provide an

initial justification and site for such experiments. Species of fish which would benefit from these measures would include the shovelnose sturgeon, paddlefish, blue sucker, redhorses, darters, walleye, and sauger.

9. Public participation in defining the long-term objectives of fishery investigation and management practices on the river should be increased, and the public should be encouraged to observe river conditions and fishes and report their observations freely to designated state and federal officials.

10. The Fish and Wildlife Agencies of the states bordering the river should, with the cooperation of the U. S. Fish and Wildlife Service, consider seriously a program to reintroduce the lake sturgeon to the Ohio River. This large, magnificent, and valuable fish, a native of the river, is far more deserving of the attentions of our fish propagationists than the striped bass and northern pike (both of which were stocked in the river in the 1970's). Recent advances in the artificial culture of white sturgeon in California [Aquaculture 8(2):4-5] should be easily transferred to the culture of lake sturgeon. It should be possible to obtain lake sturgeon brood stock from the states of Minnesota and Wisconsin. We believe personnel of the Kentucky Department of Fish and Wildlife Resources at the Minor Clark Fish Hatchery, having demonstrated great success in rearing such difficult species as muskellunge and striped bass, are eminently qualified to spawn and rear young sturgeon. Potential release sites would include the Markland, McAlpine, and Cannelton pools, and the lower Ohio River below Smithland Dam.

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* = Publications from which larval fish densities were extracted.

+ = Publications which, although they yielded distribution data on fishes in the Ohio River, are not cited in the text.

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