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VOLUME 17

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ENVIRONMENTAL STATUS OF THE LAKE MICHIGAN REGION

VOLUME 17. INLAND FISHES OF THE LAKE MICHIGAN DRAINAGE BASIN

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Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
Price: Printed Copy $10.00; Microfiche $2.25

ANL/ES-40 Volume 17

ENVIRONMENTAL STATUS OF THE LAKE MICHIGAN REGION

Volume 17. Inland Fishes of the Lake Michigan Drainage Basin

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ANL/ES-40 Vol. 17
Environmental Control Technology
and Earth Sciences (UC-11)

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

ENVIRONMENTAL STATUS OF THE LAKE MICHIGAN REGION

Volume 17. Inland Fishes of the Lake Michigan Drainage Basin

by

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Division of Environmental Impact Studies

September 1976

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PREFACE

Assessments of the environmental impacts of individual nuclear power plants sited on the shores of Lake Michigan have led to increased recognition of the need for regional considerations of the environmental impacts of various human activities, and a compendium of information on the environmental status of the region for use in assessing such impacts. In response to these needs, a report series describing the status of Lake Michigan and its watershed is in preparation. This series is entitled "Environmental Status of the Lake Michigan Region"; this report is part of that series.

The report series provides a reasonably comprehensive descriptive review and analysis of natural features and characteristics, as well as past, present, and proposed natural processes and human activities that influence the environmental conditions of Lake Michigan, its watershed, and certain adjacent metropolitan areas. This series will constitute a regional reference document useful both to scientific investigators and to other persons involved in environmental protection, resource planning, and management. In these regards, the "Environmental Status of the Lake Michigan Region" will serve in part as an adjunct to reports of broader scope, such as the Great Lakes Basin Commission's Framework Study.

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ENVIRONMENTAL STATUS OF THE LAKE MICHIGAN REGION

VOL. 17. INLAND FISHES OF THE LAKE MICHIGAN DRAINAGE BASIN

by

George C. Becker

Abstract

This report catalogs the fishes that inhabit the inland waters of the Lake Michigan Drainage Basin. For each species identified, data are presented on its distribution, habitat and spawning requirements, limiting factors, aesthetic attributes, value, and status. A section of Additional References includes selected citations regarding thermal and chemical effects on fishes.

INTRODUCTION

The goal of this study is to bring together information on the distribution of inland fishes in the Lake Michigan Drainage Basin.

Historically and commercially, the Basin is one of the most important in the United States. In recent years Lake Michigan has become one of the "hottest" sport fishing spots in the world. Largely reliant upon an introduced salmonid fishery, the Lake and its tributary streams have attracted anglers from all over the country.

Inland fishing, especially in Wisconsin and Michigan streams and lakes, is well known and well patronized. It may seem strange, therefore, that no single compendium is available treating distributional data and specific requirements of individual species of fish. Much of this information lies scattered in the literature, in files of state and federal agencies, on shelves of museums, and in notes and records awaiting publication. This effort brings some important items together, and it is hoped that it will be a foundation for further studies of inland fishes in the Lake Michigan watershed.

DESCRIPTION OF THE STUDY REGION

Lake Michigan, the world's sixth largest lake in both area and volume, is the only one of the Laurentian Great Lakes that lies entirely within the boundaries of the United States (Wells and McLain, 1973). It has a surface

area of 57,800 km^2 (22,300 mi^2) in a drainage basin which, including the Lake, covers 175,800 km^2 (67,900 mi^2) (Mortimer, 1975).

Wells and McLain (1973) summarized the study region as follows:

> *"Much of the shore along the southern two-thirds of Lake Michigan is characterized by a smooth, unbroken shoreline, backed by gently rolling terrain; extensive dunes border the eastern and southern shores. The northern end of the lake has an irregular shoreline and in most places is bordered by hills. The southern part of the watershed is a mixture of farmland and urbanized areas, the central portion is primarily farmland, and the northern section is mostly forested. The largest city along the shoreline, Chicago, Illinois, is not considered to be in the watershed, because its drainage has been into the Mississippi River since the completion of the Chicago sanitary canal in 1900."*

Long (1974) noted conifer-hardwoods in the north, deciduous forest in the south, some prairie in the south, and areas greatly altered by man. Smith (1975b--letter) wrote: *"The Great Lakes drainage ... so far as Illinois is concerned ... is virtually all either urbanized or industralized ..."*

Michigan constitutes the major surface area in the Lake Michigan Drainage Basin (Fig. 1), followed by Wisconsin, Indiana, and Illinois. The streams in Lake Michigan's western watershed, with the exception of the Fox and Menominee, are small and generally discharge less than 28.3 cubic meters per second (cms) [1000 cubic feet per second (cfs)] (Table 1). The eastern watershed of Lake Michigan is more extensive, and six streams record average discharges of more than 28.3 cms (1000 cfs) (Todd, 1970).

The Basin has numerous inland lakes created by glacial action. The largest, Lake Winnebago, Wisconsin, is 45.2 km (28 mi) long, 16.9 km (10.5 mi) wide, and covers 557 km^2 (215 mi^2). Its maximum depth is only 6.4 m (21 ft). In Wisconsin, the deepest lake, Green Lake (Green Lake County), covers 29.5 km^2 (11.4 mi^2) and has a maximum depth of 70.1 m (229 ft) (Wis. Dep. Nat. Resour., 1974). In Michigan, Torch Lake (Antrim County) has a purported depth of 90.8 m (298 ft).

The natural drainage of Basin waters is eastward through the Straits of Mackinac into Lake Huron; the average discharge rate is 1,444 cms (51,000 cfs) (Mortimer, 1975). This water eventually flows through the St. Lawrence system into the North Atlantic Ocean. Another 91 cms (3200 cfs) presently is being diverted from the Basin through the Chicago Sanitary and Ship Canal. These waters flush the partially treated wastes from Chicago into the Illinois River, thus connecting the Great Lakes with the Mississippi watershed; this connection may serve as a potential passageway for fish between these major watersheds.

The glacial history of the Great Lakes shows a close affinity with the Mississippi watershed. Early in the series of glacial advances and retreats, the southern tip of Lake Michigan, known as Lake Chicago, drained into the Illinois River, and Middle Lake Maumee of the Erie basin was drained by the Wabash River (Fig. 2). Later, during the main Algonquin stage (Fig. 3), Lake Michigan waters drained eastward into New York harbor via the Mohawk and

Fig. 1. Map of Lake Michigan Drainage Basin. Modified from White (1976--unpublished).

Table 1. Flow of Selected Streams

River and Station	Drainage Area		Average Discharge	
	km^2	(mi^2)	cms	(cfs)
Michigan				
Escanaba, Cornell	2,253	(870)	26.94	(952)
Manistique, Manistique	2,849	(1,100)	37.78	(1,335)
Manistee, Sherman	2,331	(900)	30.56	(1,080)
Pere Marquette, Scottville	1,836	(709)	17.60	(622)
Muskegon, Newaygo	6,087	(2,350)	51.90	(1,834)
Grand, Grand Rapids	12,691	(4,900)	96.87	(3,423)
Kalamazoo, Fennville	4,144	(1,600)	38.48	(1,360)
St. Joseph, Niles	9,378	(3,620)	89.91	(3,177)
Wisconsin				
Menominee, McAllister (Wis.)	10,412	(4,020)	95.99	(3,392)
Oconto, Gillett	1,756	(678)	16.19	(572)
Fox, Wrightstown	15,929	(6,150)	119.26	(4,214)
Kewaunee, Kewaunee	334	(129)	2.01	(71)
Sheboygan, Sheboygan	1,119	(432)	6.34	(224)
Milwaukee, Milwaukee	1,777	(686)	10.81	(382)
Menominee, Wauwatosa	319	(123)	2.09	(74)
Root, Racine	484	(187)	3.88	(137)
Indiana				
St. Joseph, Elkhart	8,648	(3,339)	94.81	(3,350)

References: Michigan and Indiana, Todd (1970); Wisconsin, U. S. Geological Survey (1974).

Hudson rivers and southwestward through the Illinois River into the Mississippi system (Martin, 1932; Hough, 1958). During the postglacial Nipissing stage, when the Lake Michigan level was 184.4 m (605 ft) above sea level [compared to the present 176.8 m (580 ft)], the Illinois River outlet was still functional in the Great Lakes.

Such persistent and large waterway connections between the forming Great Lakes and the Mississippi drainage basin undoubtedly accounted for many Mississippi basin fish species found in the Great Lakes. The old paddlefish records extracted from historical writings (Hubbs and Lagler, 1958) illustrate a species so low in numbers at the time of the early explorers that it was already near extirpation. The three species of buffaloes were rare and were encountered only in the southern part of the Basin where they were widely disjunct in distribution. Some records are very old (Hubbs and Lagler, 1958). The buffaloes are examples of early fish migrants from the Mississippi basin when large water connectives existed to the forming Great Lakes.

Within the last 150 years in the Great Lakes region, there were still connectives, at least intermittent ones, to the Mississippi. In Wisconsin, Greene (1935) called attention to (*i*) the low divide between the Fox and

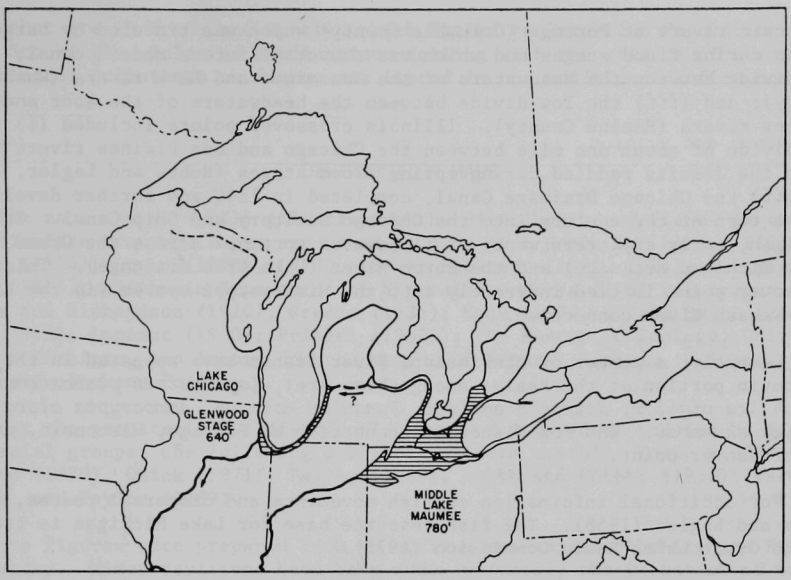

Fig. 2. Lake Chicago and Middle Lake Maumee. Slightly modified from Hough (1958) (with permission, see credits).

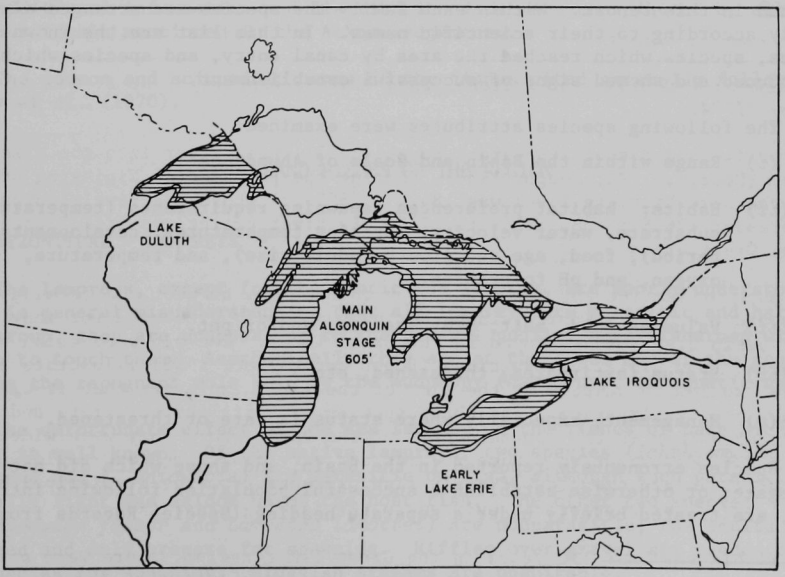

Fig. 3. Main Algonquin Stage. Slightly modified from Hough (1958) (with permission, see credits).

Wisconsin rivers at Portage (Columbia County) which was traveled by barges and canoes during flood stages and which was converted into a modern canal; (*ii*) the low divide between the headwaters of the Menominee and Bark rivers (Washington County); and (*iii*) the low divide between the headwaters of the Root and Des Plaines rivers (Racine County). Illinois crossover points included (*i*) the low divide of about one mile between the Chicago and Des Plaines rivers over which the Jesuits paddled during spring flood stages (Hubbs and Lagler, 1958), and (*ii*) the Chicago Drainage Canal, completed in 1840 and further developed at the turn of the century into the Chicago Sanitary and Ship Canal. In Michigan, early explorers wrote of floodwater portages across the Grand River (Lake Michigan drainage) and the Huron River (Lake Erie drainage). This crossover point is tied indirectly into the Mississippi system via the Lake Erie-Wabash River connective.

Recently, a number of Mississippi River fishes have appeared in the Wisconsin portion of the Basin; among these are: *Lepisosteus platostomus*, *Pimephales vigilax*, *Notropis emiliae*, *Fundulus notatus*, *Ammocrypta clara*, and *Percina shumardi*. The Fox-Wisconsin connective at Portage, Wisconsin, may be the crossover point.

For additional information on fish movements and dispersal routes, see Hubbs and Lagler (1958). The fish resource base for Lake Michigan is treated by the Great Lakes Basin Commission (1975).

SPECIES SELECTION AND TREATMENT

One-hundred thirty-eight species of fishes found within the Basin are treated in this report. Within each family the species are arranged alphabetically according to their scientific names. In this list are the known native fishes, species which reached the area by canal entry, and species which were introduced and showed signs of successful establishment.

The following species attributes were examined:

(*i*) Range within the Basin and Scale of Abundance*.

(*ii*) Habits: habitat preferences, spawning requirements (temperature, substrate, water velocity, hatching temperatures, developmental period), food, age and growth (adult size), and temperature, oxygen, and pH tolerances.

(*iii*) Value as food, bait, prey species, and/or pet.

(*iv*) Status (extirpated, threatened, etc.)

(*v*) Management, expecially where status is rare or threatened.

Species erroneously reported in the Basin, and those which did not survive, propagate, or otherwise establish a successful population following introduction, are treated briefly under a separate heading (Species Records from the

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**See the Glossary of Abbreviations and Terminology.*

Basin that are in Error and Species which Failed to Establish Populations after Stocking). Selected publications dealing with the effects of thermal and chemical pollutants on fishes are listed in the Additional References section.

DISTRIBUTION MAPS

The maps (Figs. 4-111) illustrating the distribution of fishes in the Lake Michigan Drainage Basin are based on data from Hubbs and Lagler (1958); Taylor (1954); Braun (1973a, 1973b, 1974); Peterson (1971, 1974); Gerking (1945, 1955); Wisconsin Department of Natural Resources (1961 to present); Forbes and Richardson (1920); Greene (1935); Koch (1972, 1974); Smith (1965, 1971, 1973); Lopinot (1970); Priegel (1967b); the Museum of Zoology, University of Michigan, Ann Arbor; and the Museum of Natural History, University of Wisconsin--Stevens Point.

For the preparation of distribution maps of individual species or fishes of special groups, the following publications were useful: Koelz (1931), Jenkins (1970), Quick (1971), Bailey (1959), Hubbs and Cooper (1935), Parsons (1973), and Taylor (1969).

The figures were prepared from an outline map supplied by Argonne National Laboratory. Minor revisions have been made, primarily the retention of only the outline of the cities so as to make spot locations more visible. Figure 1 serves as a reference for clear depiction of drainage features that may be obscured in figures illustrating species distribution.

Additional information and distribution data were contributed by agencies and individuals mentioned in the Acknowledgements.

The common and scientific names of the fishes cited generally follow Bailey *et al.* (1970).

INLAND FISHES OF THE REGION

PETROMYZONTIDAE - LAMPREYS

The lampreys, except for the exotic sea lamprey, are poorly understood. There is general misunderstanding that all lampreys are parasitic and harmful. As a group, they are unappealing to the general public; some fishermen will refuse to touch them. Aesthetically they are at the lower end of the scale, sharing the repugnant role held by the mudpuppy (*Necturus*), an aquatic amphibian.

The unfortunate effect of the sea lamprey on the fishes of Lake Michigan proper is well known. Of the native lampreys, two species (*Ichthyomyzon castaneus* and *I. unicuspis*) are parasitic on fish, although such parasitism is generally light and seldom harms the host fish. The other two species (*Ichthyomyzon fossor* and *Lampetra lamottei*) are nonparasitic; the adults do not feed and only prepare for spawning. Riffles over gravel are needed by all species for spawning. Sluggish streams are unsuitable.

The ammocetes (larval forms) of the native lampreys filter-feed and so compete with other fish species, all of which are also filter feeders early in growth. All life stages of lamprey are eaten by game fishes, supplying them with a source of protein food. Some fishermen use lamprey ammocetes and adults as bait for trout, largemouth bass, and walleyes.

In Europe, adult sea lampreys are the gourmet's delight and a ready market exists for them. In recent years cured and smoked lamprey have been marketed in Ontario. Elaborate recipes call for grilling, frying, marinating, and steaming, along with wines and special sauces. Lampreys have been salted and canned (Vladykov, 1949). More education of the public is required to reestablish on this continent the former popularity of lampreys as a wholesome and palatable dish.

Ichthyomyzon castaneus Girard. CHESTNUT LAMPREY

Range: There are numerous records of the chestnut lamprey (Fig. 4) from lower Michigan and a few from the Indiana waters of the Lake Michigan watershed; there also are a few records from the Wolf and Fox rivers in Wisconsin (see Starrett, Harth, and Smith, 1960).

Habits: The chestnut lamprey is parasitic on fishes and is generally found in larger rivers. Spawning occurs in the spring when the mature adults ascend small streams; spawning has been observed in mid-April in central Wisconsin. After hatching, the ammocetes bury themselves in a peaty mud, frequently covered with organic debris and within inches of the stream's edge. The time spent in the ammocete stage is a year or more. Metamorphosis into an adult begins in the fall, during which time the eyes and sucking disc develop. For some 15 months it is a parasite on fishes, growing to 177-355 mm (7-14 in.).

Ichthyomyzon fossor Richard and Cummins. NORTHERN BROOK LAMPREY

Range: In Wisconsin, the northern brook lamprey (Fig. 5) is the common non-parasitic lamprey of the Lake Michigan Drainage Basin. There are disjunct populations throughout Michigan. None have been reported in the Lake Michigan watershed of Indiana or Illinois.

Habits: Transformed individuals, 102-152 mm (4-6 in.) long, appear in late summer to fall and migrate upstream to spawn, generally in April and May. Riffles over gravel are needed for spawning. Sluggish streams are unsuitable. Hankinson (1932) stated that he found them nesting openly and that their behavior was indistinguishable from that of *Lampetra lamottei*. Vladykov (1949) reported that spawning reached its peak at water temperatures of 13.3-15.6°C (56°-60°F). The adults have a short life span, generally less than six months, during which time they do not feed.

Ichthyomyzon unicuspis Hubbs and Trautman. SILVER LAMPREY

Range: The silver lamprey (Fig. 6) is probably present in more waters than indicated by record; records from inland waters in the Lake Michigan Basin are

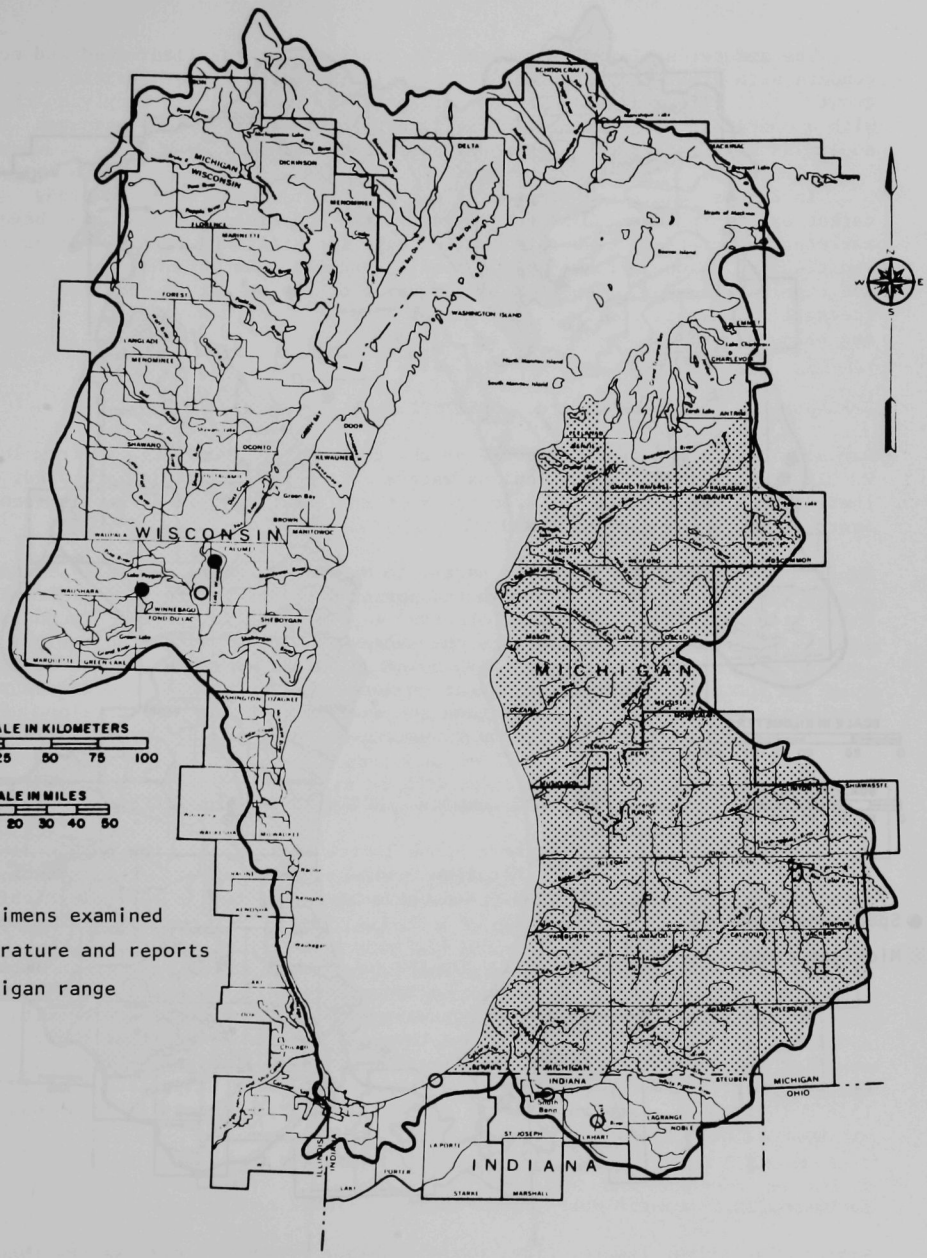

Fig. 4. Distribution of the Chestnut Lamprey (*Ichthyomyzon castaneus*).

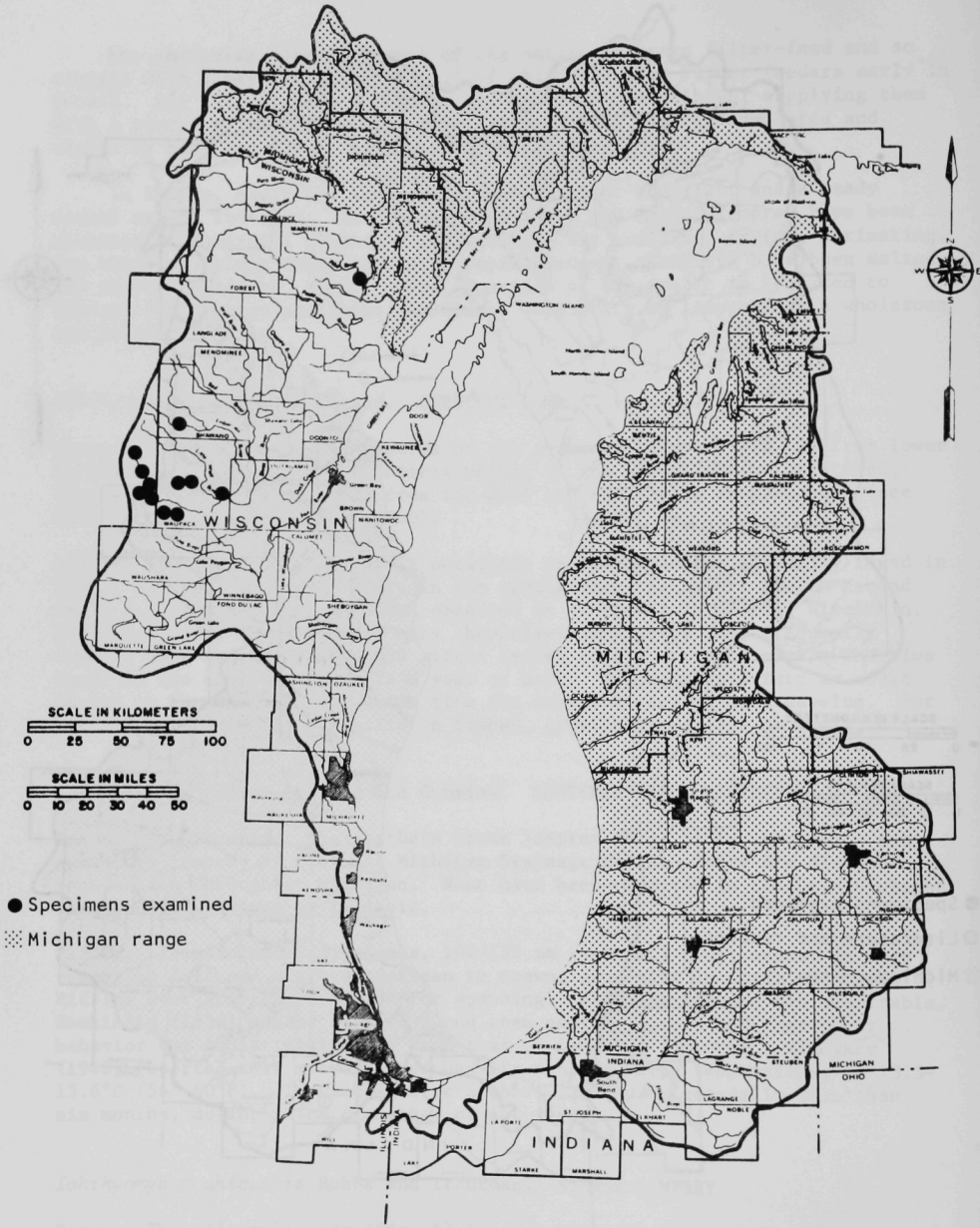

Fig. 5. Distribution of the Northern Brook Lamprey (*Ichthyomyzon fossor*).

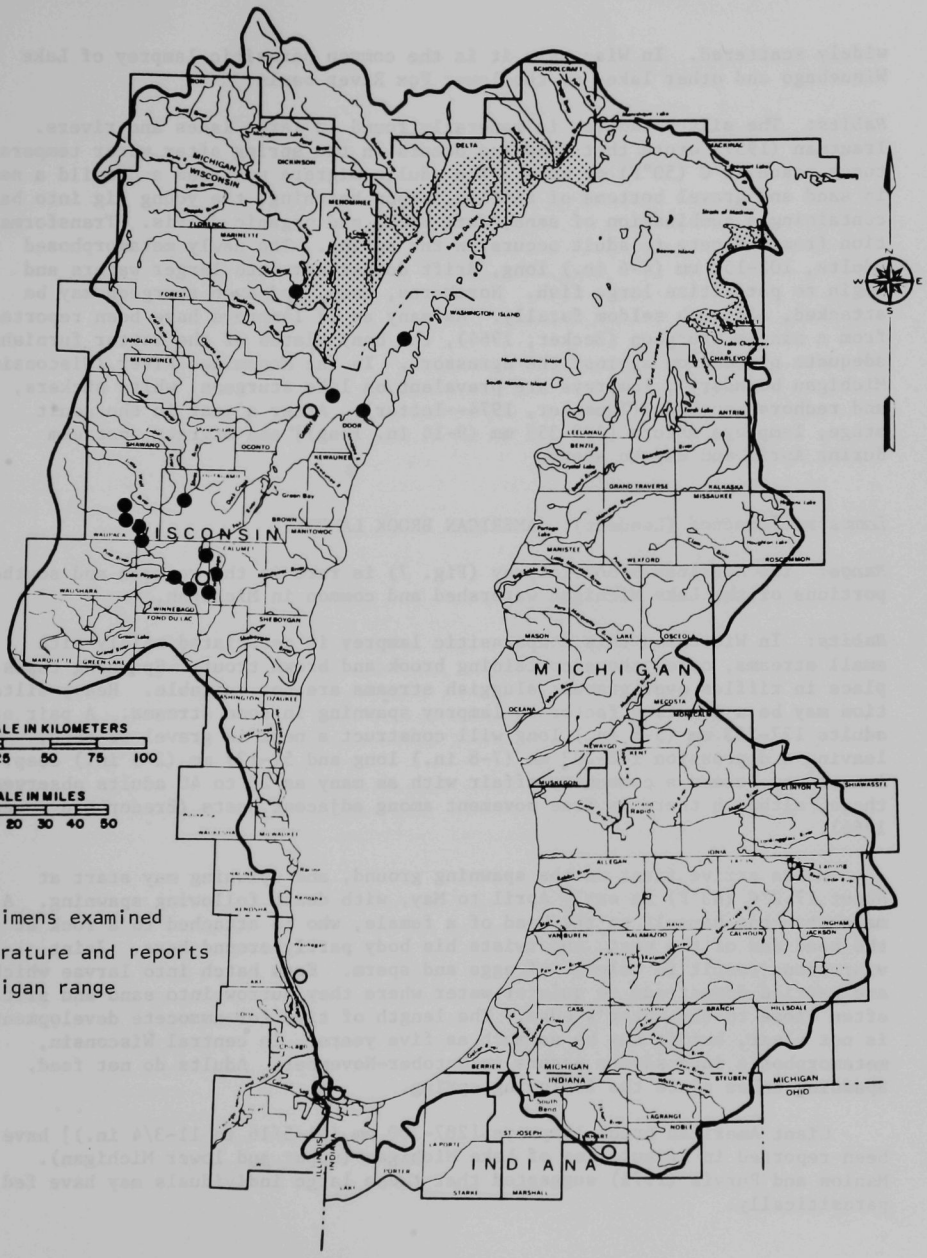

Fig. 6. Distribution of the Silver Lamprey (*Ichthyomyzon unicuspis*).

widely scattered. In Wisconsin it is the common parasitic lamprey of Lake Winnebago and other lakes of the lower Fox River basin.

Habits: The silver lamprey is generally found in large lakes and rivers. Trautman (1957) wrote that spawning occurs in the spring after water temperatures reach 10°C (50°F) or more. The adults migrate upstream and build a nest in sand and gravel bottoms of riffles. Upon hatching, the young dig into bars containing a combination of sand, dark muck, and organic debris. Transformation from ammocete to adult occurs in the spring. The newly metamorphosed adults, 102-152 mm (4-6 in.) long, drift downstream into larger waters and begin to parasitize large fish. Northerns, carp, and even sturgeon may be attacked, although seldom fatally. As many as 17 lampreys have been reported from a single sturgeon (Becker, 1964), the bony plates of the latter furnishing adequate protection against the agressors. In the Menominee River (Wisconsin-Michigan boundary), lampreys are prevalent on lake sturgeon, white suckers, and redhorse suckers (Thuemler, 1974--letter). After a year in the adult stage, lampreys mature [228-355 mm (9-14 in. long)] and migrate upstream during April and May to spawn.

Lampetra lamottei (Lesueur). AMERICAN BROOK LAMPREY

Range: The American brook lamprey (Fig. 7) is rare in the western and southern portions of the Lake Michigan watershed and common in Michigan.

Habits: In Wisconsin this nonparasitic lamprey is associated mainly with small streams, often those containing brook and brown trout. Spawning takes place in riffles over gravel; sluggish streams are not suitable. Heavy siltation may be a limiting factor in lamprey spawning in some streams. A pair of adults 127-203 mm (5-8 in.) long will construct a nest in gravel or sand, leaving a depression 178-203 mm (7-8 in.) long and 51-127 mm (2-5 in.) deep. A nest may become a community affair with as many as 25 to 40 adults observed there, although there is free movement among adjacent nests (Breder and Rosen, 1966).

Males arrive first on the spawning ground, and spawning may start at about 17.2°C (63°F) in early April to May, with death following spawning. A male attaches himself to the head of a female, who is attached to a rock at the head end of the nest, and twists his body partly around hers. Joint vibrations result in release of eggs and sperm. Eggs hatch into larvae which are carried downstream to quieter water where they burrow into sand and silt, often close to the water's edge. The length of time for ammocete development is not clear, but it may be as much as five years. In central Wisconsin, metamorphosis into adults occurs in October-November. Adults do not feed. Spawning takes place the following spring.

Giant American brook lampreys [287-300 mm (11-5/16 to 11-3/4 in.)] have been reported in tributaries of Lake Michigan (upper and lower Michigan). Manion and Purvis (1971) suggested that these large individuals may have fed parasitically.

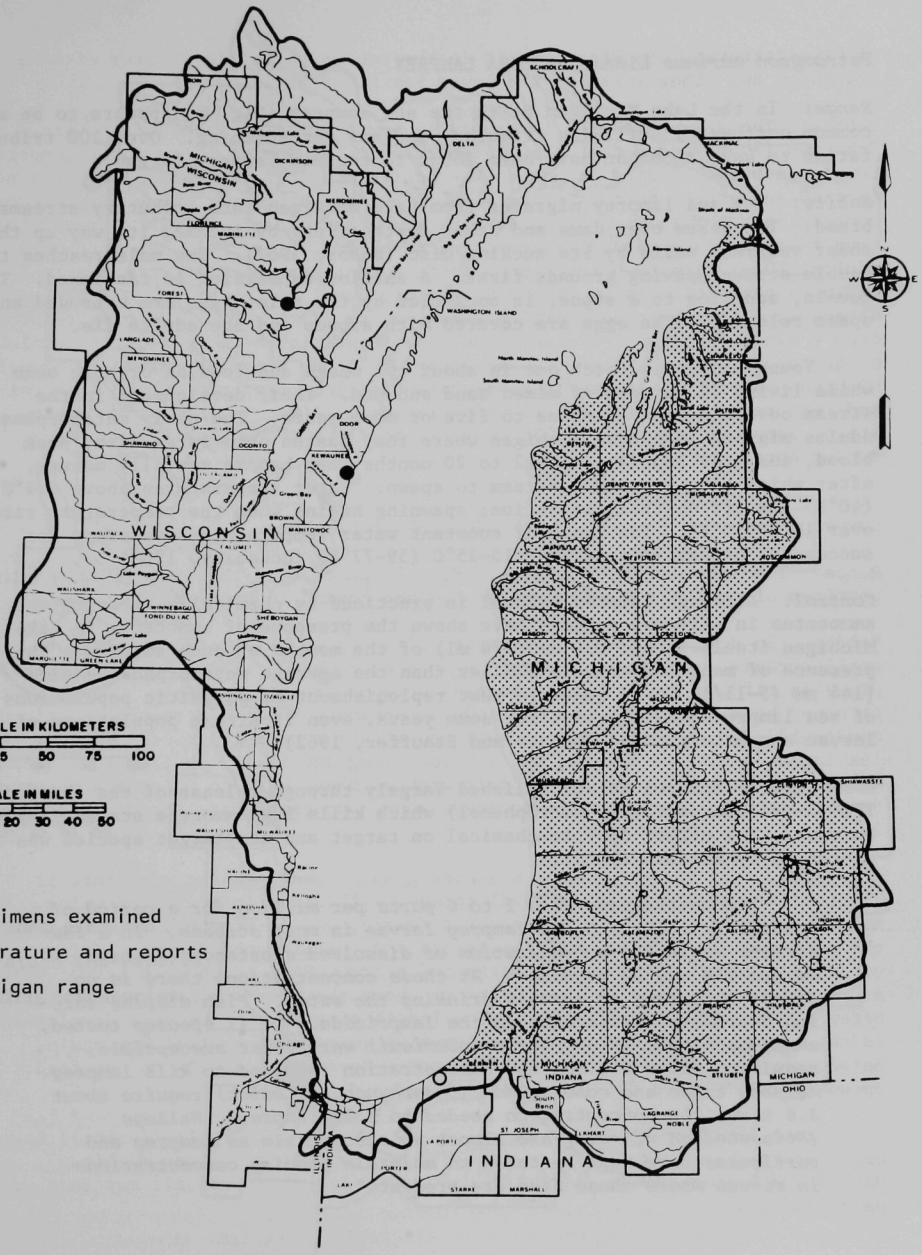

Fig. 7. Distribution of the American Brook Lamprey (*Lampetra lamottei*).

Petromyzon marinus Linnaeus. SEA LAMPREY

Range: In the Lake Michigan Basin the sea lamprey (Fig. 8) appears to be more common northward, utilizing tributary streams for spawning. Over 100 tributaries to Lake Michigan have been found to contain lamprey larvae.

Habits: The sea lamprey migrates from Lake Michigan into tributary streams to breed. It passes over dams and other obstructions by inching its way up the sheer vertical walls by its sucking disc (Hubbs, 1963). The male reaches the pebble-strewn spawing grounds first. A shallow depression is fashioned. The female, adhering to a stone, is encircled by the male; eggs are extruded and sperm released. The eggs are covered with stones and the adults die.

Young ammocetes hatch out in about two weeks and feed on organic ooze while living in burrows of mixed sand and mud. Their development in the stream covers a span of three to five or more years. The newly metamorphosed adults migrate into Lake Michigan where they fasten onto large fish, suck blood, and grow rapidly. In 12 to 20 months they become sexually mature, after which they migrate upstream to spawn. Water temperatures above 4.4°C (40°F) set off upstream migration; spawning begins when the temperature rises over 10°C (50°F). The range of constant water temperatures necessary for successful hatching is narrow, 15-25°C (59-77°F) (McCauley, 1963).

Control: Although lamprey control is practiced by chemically treating the ammocetes in streams, surveys have shown the presence of ammocetes in Lake Michigan itself within 0.4 km (1/4 mi) of the mouths of such streams. The presence of many individuals smaller than the average metamorphosing size [144 mm (5-11/16 in.)] suggests that replenishment of parasitic populations of sea lampreys will persist for some years, even if stream populations of larvae are exterminated (Wagner and Stauffer, 1962).

Lamprey control is accomplished largely through release of the chemical TFM (3-trifluoromethyl-4-nitrophenol) which kills the ammocete stages in their burrows. The effect of this chemical on target and non-target species was discussed by Baldwin (1968):

> *"Concentrations from 1 to 6 parts per million for a period of 8 hours is lethal to sea lamprey larvae in most streams. In a few streams where the concentration of dissolved substances is high, 14 ppm TFM may be required. At these concentrations there is no danger to humans or animals drinking the water. Fish display varying degrees of resistance to the lampricide. Of 11 species tested, smallmouth bass (Micropterus dolomieui) were least susceptible, requiring about 8 times the concentration required to kill lamprey. Rainbow trout and coho salmon (Oncorhynchus kisutch) require about 3.6 times the concentration needed to kill lamprey. Walleye (Stizostedion vitreum) are almost as susceptible as lamprey and particular care must be taken to maintain precise concentrations in rivers where these fish are present."*

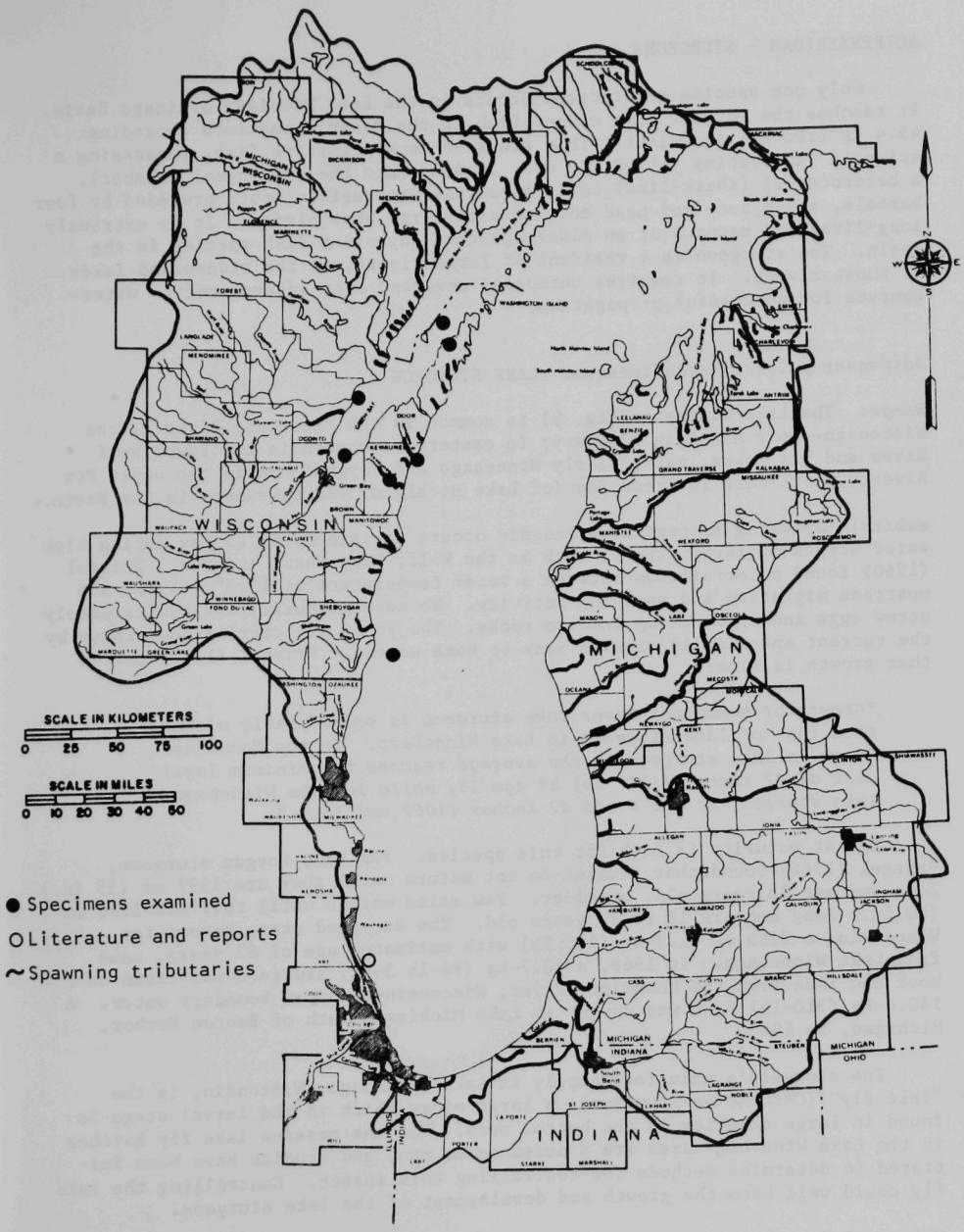

Fig. 8. Distribution of the Sea Lamprey (*Petromyzon marinus*).

ACIPENSERIDAE - STURGEONS

Only one species of sturgeon occurs in the Lake Michigan Drainage Basin. It reaches the largest size of any fish in the Basin, sometimes exceeding 45.4 kg (100 lb) in weight. This sturgeon is a primitive fish, possessing a spiracle (an opening behind the eye, leading into the pharyngeal chamber), a heterocercal (shark-like) tail, a ventral protrusible mouth preceded by four barbels, and a body and head covered with large bony plates. It is extremely long-lived and matures at an older age than any other fish species in the Basin. The sturgeon is a resident of large rivers and the widespread lakes of those rivers. It requires unimpeded movement over interconnected watercourses for successful propagation.

Acipenser fulvescens Rafinesque. LAKE STURGEON

Range: The lake sturgeon (Fig. 9) is common in the Menominee River at the Wisconsin-upper Michigan boundary; in eastern Wisconsin in the lower Wolf River and its lakes, particularly Winnebago and Poygan; and in the upper Fox River. It is rare in Green Bay (of Lake Michigan) and elsewhere in the Basin.

Habits: Spawning in central Wisconsin occurs in late April to May during high water stages on large rivers, such as the Wolf, Embarrass, and Fox. Priegel (1960) found a correlation between a water temperature of 12.8°C (55°F) and upstream migration and spawning activity. No nest is built; the adults simply strew eggs and sperm among inshore rocks. The young are carried downstream by the current and finally migrate back to home waters. Priegel (1973) stated that growth is slow:

> *"Growth of Menominee River lake sturgeon is considerably slower than that of lake sturgeon in Lake Winnebago. In the Menominee River, a lake sturgeon on the average reaches the minimum legal size of 42 inches [1067 mm] at age 15, while in Lake Winnebago lake sturgeon at age 8 are 42 inches [1067 mm] long."*

Age at maturity is high for this species. For Lake Poygan sturgeon, Priegel (1964) found that females do not mature until they are 1397 mm (55 in.) long and are 25 years old, or older. Few males mature until they are 1270 mm (50 in.) long and are 18 to 22 years old. The accepted state record for Wisconsin, a fish of 81.7 kg (180 lb) with estimated age of 82 years, came from Lake Winnebago. In 1968, a 42.7-kg (94-lb 3-oz) sturgeon was taken on hook and line from the Menominee River, Wisconsin-Michigan boundary water. A 140.6-kg (310-lb) fish was caught in Lake Michigan south of Benton Harbor, Michigan, in 1943.

The sturgeon's main food supply in Lake Winnebago, Wisconsin, is the "lake fly" (*Chironomus plumosus*), a large midge which in the larval stage is found in large quantity in the bottom muds. But the massive lake fly hatches in the Lake Winnebago area are a nuisance to man, and studies have been initiated to determine methods for controlling this insect. Controlling the lake fly could well harm the growth and development of the lake sturgeon.

Value: Today the sturgeon is a prized fish. In Wisconsin, where spearing of sturgeon is still allowed, its capture is much in the same category as bagging

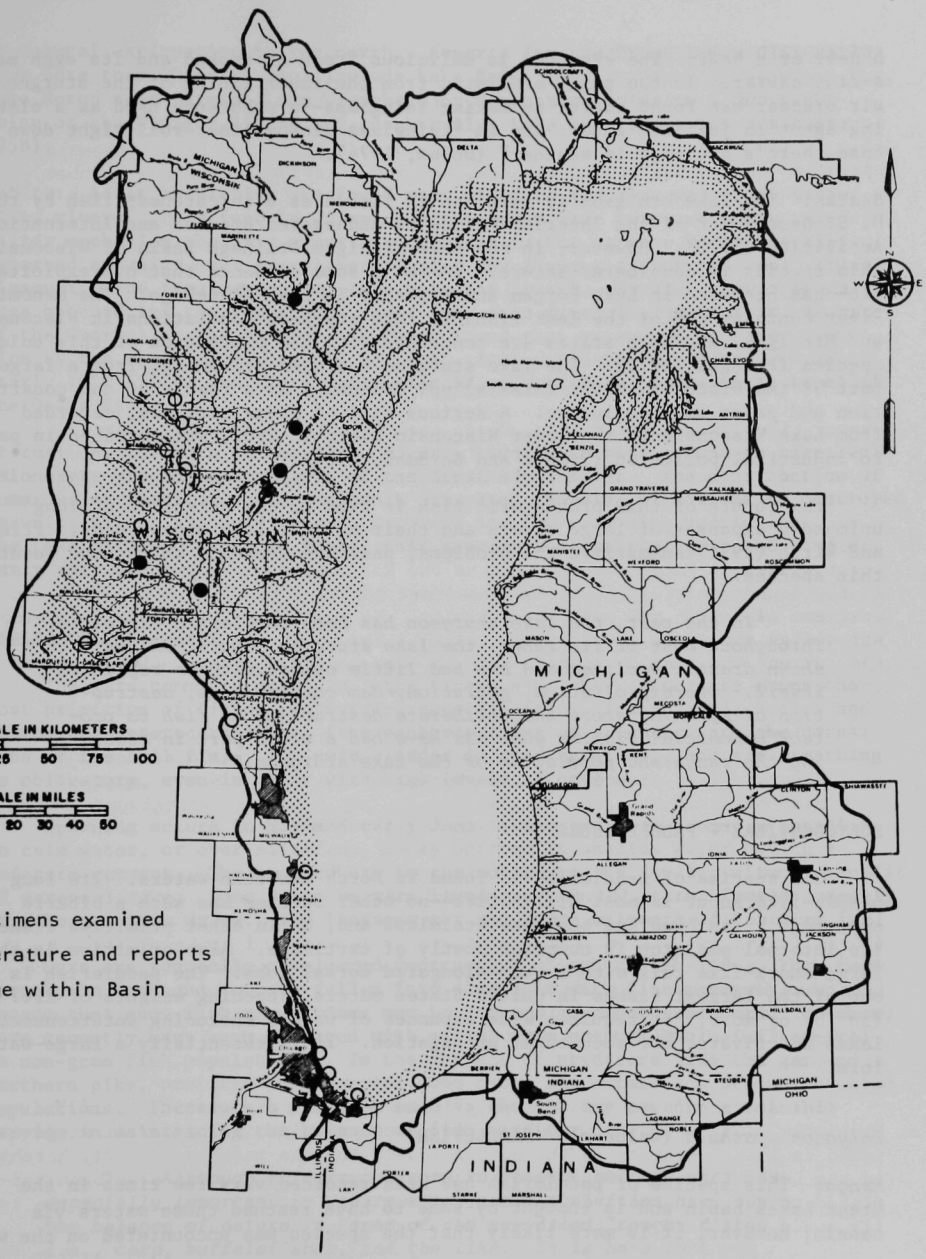

Fig. 9. Distribution of the Lake Sturgeon (*Acipenser fulvescens*).

a deer or a bear. The sturgeon is delicious fresh or smoked and its eggs make a fine caviar. In the past, a gelatin from the inner lining of the sturgeon's air bladder was found useful in making isinglass--a substance used as a clarifying agent in jellies, glues, and in "isinglass windows that roll right down in case there's a change in weather" (Downs, 1974).

Status: The lake sturgeon is rare and is listed as a threatened* fish by the U. S. Department of the Interior Office of Endangered Species and International Activities (1973). However, in the Lake Michigan Drainage Basin of Wisconsin this species is considered secure. There is some evidence that overexploitation has occurred in Lake Poygan and probably in Lake Winnebago. The Menominee River contains one of the last fishable lake sturgeon populations in Wisconsin and Michigan, and both states are concerned with the protection of this unique species (Priegel, 1973). The lake sturgeon has been eliminated from a large part of the Wisconsin River (Mississippi drainage) as a result of dam construction and paper mill pollution. A serious kill of large sturgeon, recorded from Lake Wisconsin in the lower Wisconsin River in 1967, was ascribed in part to industrial pollution (Stautz and Gerdman, 1967).

The future of this prehistoric fish is tied to the retention of long unimpeded expanses of large rivers and their natural lake widespreads. Priegel and Wirth (1971) summarized the problems, past and present, which have beset this species:

> *"In the past, the lake sturgeon has been recklessly exploited. Throughout most of its range, the lake sturgeon population has shown drastic declines and has had little opportunity to replenish itself. Overexploitation, pollution, dam construction, destruction of spawning areas and deliberate destruction of fish to protect commercial fishing gear all have had a major part in reducing the range and population of the lake sturgeon."*

POLYODONTIDAE - PADDLEFISHES

One species of paddlefish is found in North American waters. Its long paddle-like snout is most distinctive--no other species has such a bizarre appendage. Its head and body are scaleless and, as in other primitive fishes, its internal skeleton is composed mostly of cartilage. Also primitive is the large shark-like tail with a much-elongated dorsal lobe. The paddlefish is one of the largest fishes in United States waters, reaching weights of 22.7 kg (50 lb) or more. It requires wide expanses of water, including interconnecting lakes and rivers, for successful propagation. It is essentially a large-water form.

Polyodon spathula (Walbaum). PADDLEFISH

Range: This species of paddlefish has been recorded very few times in the Great Lakes basin and is thought by some to have reached these waters via canals; however, it is more likely that the species was encountered on the way

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**Species or subspecies of fishes that are so few in numbers or so threatened by present circumstances, as to be in danger of extinction.*

to natural extirpation in the north. Reports for the Great Lakes (all dating from more than 50 years ago) include Lake Erie, Spanish River on Georgian Bay, Lake Huron near Sarnia, Lake Winnebago or Green Bay (prior to 1700), Lake Helen on the Nipigon River, and, doubtfully, Lake Ontario (Hubbs and Lagler, 1958).

Habits: Adult paddlefish are found most often in the open waters of large, silty rivers. They feed by swimming with mouths wide open, extracting by filter mechanism the many plankton organisms in the water. Purkett (1961) reported spawning over gravel bars during the flood stage of the Osage River, Missouri. The females engaged in a spawning "rush". Within a few days the eggs hatched and the young were swept into deep water (headwaters of the Lake of the Ozarks) by the current. Purkett found that extensive upstream migration by the spawning adults did not take place until the water had warmed to nearly 10°C (50°F) and there was a rise of several feet in the water level of the Osage River.

Status: At the turn of the 20th century, paddlefish were common in Lake Pepin (Minnesota-Wisconsin boundary) of the Mississippi River. The construction of numerous navigation dams undoubtedly disrupted spawning migrations or destroyed spawning sites. Today Wisconsin protects its few remaining paddlefish. In the Lake Michigan Drainage Basin, this species was extirpated at the time of early settlement.

LEPISOSTEIDAE - GARS

The gars commonly occur in large rivers and lakes. They are among the most primitive of fishes, possessing ganoidal (rhomboidal-shaped) scales and abbreviate-heterocercal tail (the backbone turns up slightly into the dorsal lobe of the tail fin). The swim bladder is used as a lung, and air-breathing is obligatory, even in water with high levels of oxygen.

Spawning occurs in May and early June. Eggs are strewn over vegetation in calm water, or over silt-free, rocky bottoms in shallow water having a moderate current. The eggs adhere to the substrate and develop without benefit of parental care. Some longnose gars live more than 20 years; females usually live longer than males. The longnose gar may reach a length of 1.5 m (5 ft).

Gars are generally considered destructive of other fish life. They feed largely on fish and so have fallen into disrepute with fish managers, who reason that game fish populations may be reduced by these predators. However, gars recently have been credited with acting as a natural biological control on non-game fish populations. In the absence of predators like the gar and northern pike, prolific fish species soon crowd the waters and produce stunted populations. Therefore a predator such as the gar may perform a valuable service in maintaining the balance of fish species:

> *"... Although this is contrary to general belief, gars are especially important in waters where man's activities have upset the balance of nature in favor of the so-called "rough" fishes, i.e., carp, buffalofishes, and the like. It is here that gar populations often reach their greatest numbers and importance.*

In all of these environments, the gar exerts a profound controlling influence on the tendency of both rough and game species to overpopulate." (Branson, 1966).

The gar is generally unaffected by antimycin formulations of 15 parts per billion (ppb), which is the level used in fish-kill programs.

In addition to its possible value in the biological control of other fish species, the gar is eaten to a limited extent. The flesh is white and has a rather fine grain. However, the eggs are a bright dark green and are purported to be among the most poisonous and deadly of fish products. According to Eddy and Surber (1947),

"In Louisiana a limited number of the skins are marketed annually; they are used by the jewelry and novelty trade for covering picture frames and boxes of various kinds. The horny cuticle of these skins is very hard and may be polished smooth and even, retaining an ivory-like finish. Before the days of the steel plow the skin of the gar was often used to cover plowshares, and it is even now used for this purpose in some sections of the rice-growing area of the United States."

Lepisosteus oculatus (Winchell). SPOTTED GAR

Range: The spotted gar (Fig. 10) occurs in Indiana and the southern third of lower Michigan. Its extension into Michigan represents the northernmost range for this species.

Habits: The spotted gar is almost wholly confined to clear, weedy glacial lakes. Trautman (1957) found that it decreased in abundance or disappeared with the decrease or disappearance of aquatic vegetation. He reported weights of 0.5-2.3 kg (1-5 lb), the largest specimens being 1118 mm (44 in.) long and weighing 2.7 kg (6 lb).

Lepisosteus osseus (Linnaeus). LONGNOSE GAR

Range: The longnose gar (Fig. 11) is generally found in large rivers and lakes and is increasingly rare northward.

Habits: The longnose gar is usually found near the surface in open rivers and lakes; northward it is found most commonly in weedy glacial lakes (Hubbs and Lagler, 1958). In Indiana, the optimum temperature range was 33-35°C (91.4-95.0°F) (Gammon, 1973).

Value: This species is a predator at the top of the food chain and thus is a biological control on game and non-game fish populations. The flesh is edible and can be baked with the skin intact, but the roe are highly poisonous. Under no circumstances should the eggs be eaten as caviar.

The longnose gar is a highly colorful and attractive fish during its first and second year of life (longer if kept in an aquarium). As an aquarium pet, it is a fascinating feeder: it stalks the minnow or other fish given as

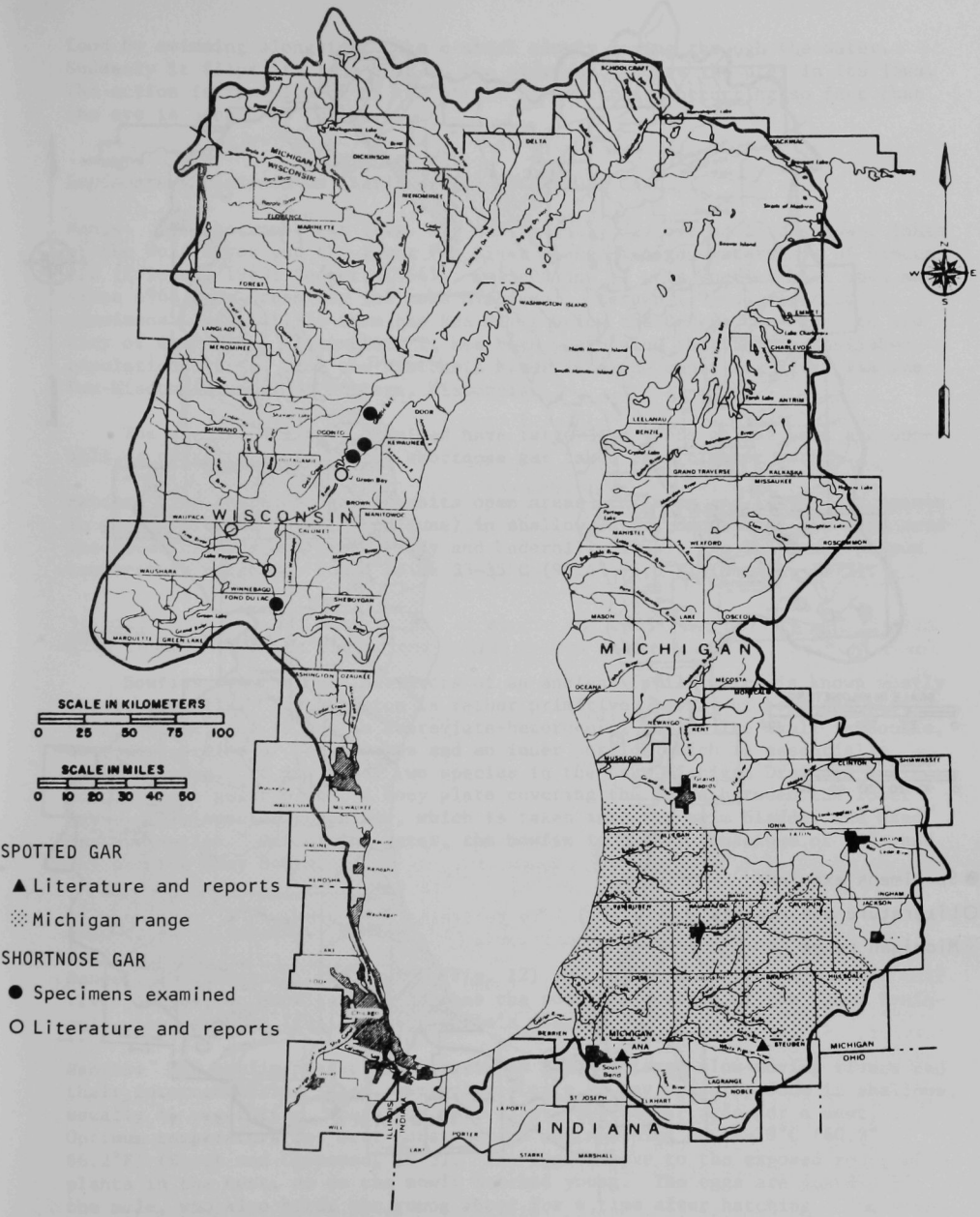

Fig. 10. Distribution of the Spotted Gar (*Lepisosteus occulatus*) and Shortnose Gar (*Lepisosteus platostomus*).

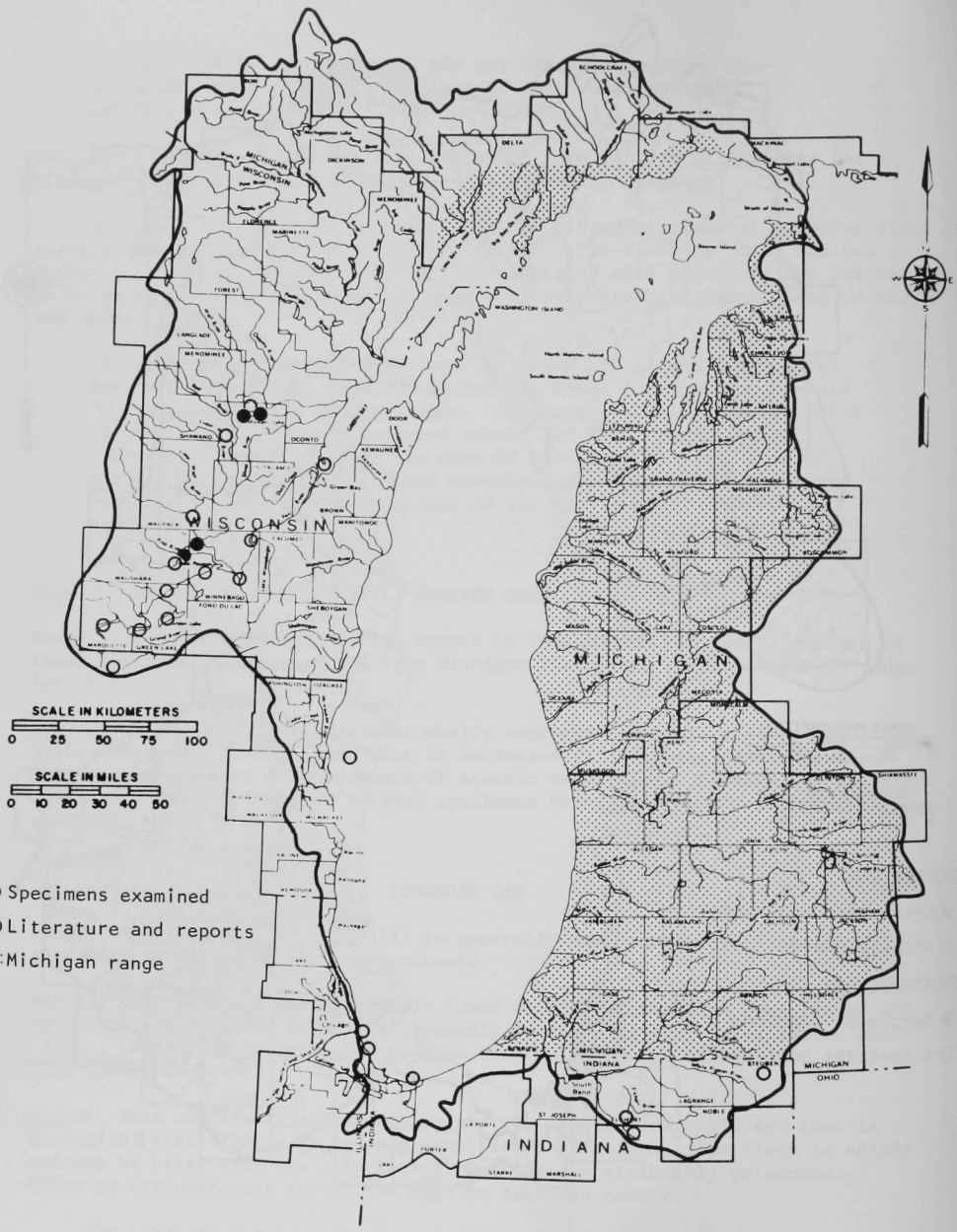

Fig. 11. Distribution of the Longnose Gar (*Lepisosteus osseus*).

food by swimming alongside, like a stick slowly moving through the water. Suddenly it flips its long beak to the side and catches the prey in its jaws. The action is reminiscent of the strike of a rattler, occurring so fast that the eye is unable to follow.

Lepisosteus platostomus (Rafinesque). SHORTNOSE GAR

Range: The shortnose gar (Fig. 10) was recently discovered in the lower lakes of the Wolf River and the lower Fox River (Lake Michigan watershed) of Wisconsin (Priegel, 1963; Becker, 1964). Collections of this species have been made since 1968 from Green Bay (of Lake Michigan). Kernen (1974a) reported 17 specimens taken in 1974 from the Fox River below the DePere dam close to the city of Green Bay, Wisconsin. It has been postulated that this established population crossed from the Wisconsin River into the upper Fox River via the Fox-Wisconsin canal at Portage, Wisconsin.

The specimens I have examined have large dark spots on the back and upper bill, a characteristic of the shortnose gar taken from clearer waters.

Habits: The shortnose gar inhabits open areas of rivers and lakes. It spawns in grassy sloughs (usually in June) in shallow water, depositing the eggs amid the aquatic weeds and grass (Eddy and Underhill, 1974). In Indiana, optimum temperature range was found to be 33-35°C (91.4°-95.0°F) (Gammon, 1973).

AMIIDAE - BOWFINS

Bowfins are the only survivors of an ancient family which is known mostly through fossils. Its skeleton is rather primitive, partly of bone and partly of cartilage, and it has an abbreviate-heteroceral tail. The skull is double, an outer portion of bony plates and an inner portion which is essentially cartilaginous. It is one of two species in the Lake Michigan Drainage Basin possessing a gular plate, a bony plate covering the space between the lower jaws. This species gulps air, which is taken into the swim bladder and used in respiration. Out of the water, the bowfin is highly tenacious of life and may survive many hours.

Amia calva (Linnaeus). BOWFIN

Range: In Wisconsin, the bowfin (Fig. 12) is common in the Fox and lower Wolf river basins; in Michigan, it reaches the southern portion of the Upper Peninsula, the northern limit of the bowfin's range.

Habits: The bowfin prefers the vegetated bays of large slow-moving rivers and their interconnecting lakes. Spawning occurs in May or early June in shallows, usually in vegetation, where the male clears a circular area for a nest. Optimum temperature for nest construction and spawning is 16-19°C (60.8°-66.2°F) (Scott and Crossman, 1973). The eggs adhere to the exposed roots of plants in the nest, as do the newly hatched young. The eggs are guarded by the male, who also herds the young about for a time after hatching. The young hatch in eight to ten days. They have an adhesive organ on the tip of the snout by which they remain attached to vegetation for seven to nine days. The

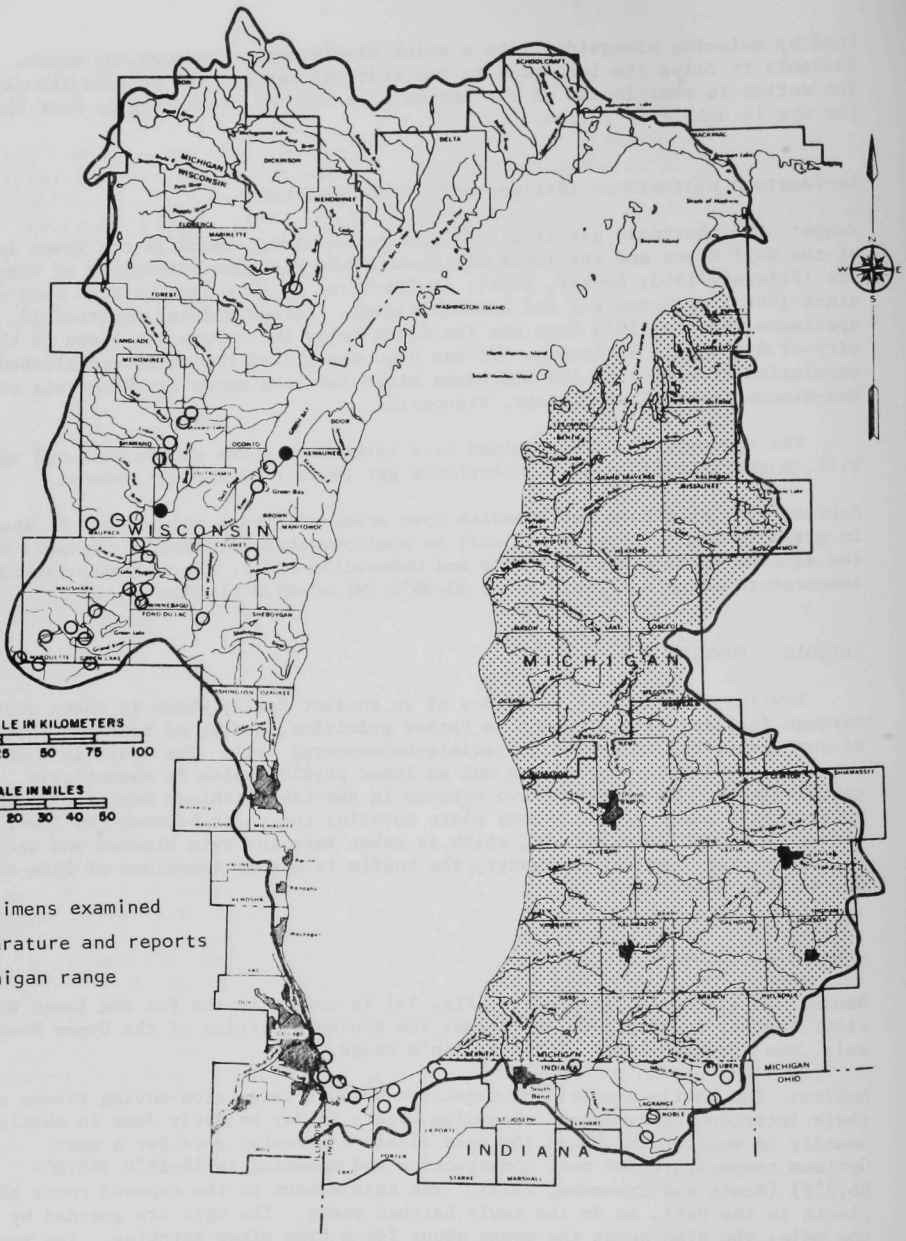

Fig. 12. Distribution of the Bowfin (*Amia calva*).

young are 127-229 mm (5-9 in.) in length by October. Adults will attain over 761 mm (30 in.) in length and 4.5 kg (10 lb) in weight. Its food is largely other fishes, crayfishes, and frogs.

Value: Since the bowfin is at the top of the food chain and eats mostly fish and crayfish, its value in the natural ecosystem may be in keeping other fish populations in check. Although taken in commercial fisheries, its value at two cents per pound hardly justifies the effort. This fish is occasionally eaten, but the flesh is soft and undersirable, though it is reported to be tasteful when properly cured and smoked (Eddy and Surber, 1947).

Males and immature females posses a black spot (ocellus) on the upper base of the tail; in mature males this is ringed by orange-yellow. The paired fins turn a deep green in breeding adults. The bowfin swims slowly, by undulating the long dorsal fin. Its movements are deliberate and it makes an interesting aquarium fish.

ANGUILLIDAE - FRESHWATER EELS

The single freshwater eel found in North American waters gains access via rivers draining into the Gulf of Mexico and the Atlantic Ocean. It lacks paired pelvic fins; the much elongated dorsal fin is continuous with the tail and a much elongated anal fin. The opercular slit is small. The skin appears to be scaleless; in reality, many minute scales are embedded in the skin.

Anguilla rostrata (Lesueur). AMERICAN EEL

Range: The American eel (Fig. 13) is rare in the Lake Michigan Basin. It has been reported in Green Bay (of Lake Michigan), the lower Fox River in Wisconsin, and in Indiana waters of Lake Michigan. The Kalamazoo County (Michigan) record is an old introduction (before 1900) in a land-locked lake.

Habits: This species must return to the sea for spawning. Eels in fresh water are females that must return to the Sargasso Sea of the Atlantic Ocean where, after spawning, they die. The breeding season starts in late winter or early spring and extends into summer. Spawning occurs in deep water, and nothing is known of the mating activity (Breder and Rosen, 1966). Young eels, after passing through larval stages, ascend the rivers--often thousands of miles--and live for several years in quiet, pool-like reaches where they mature (Eddy and Surber, 1947).

According to Hubbs and Lagler (1958), eels are reported to be the most voracious of all carnivorous fishes. They are principally nocturnal feeders and, in addition to being netted by commercial fishermen, are occasionally taken by minnow on hook and line. They may reach a length of 1.8 m (6 ft) and weigh over 4.5 kg (10 lb). They travel readily over short stretches of land and have been reported to make forays into swamps and wet meadows to catch frogs and other small animals (Eddy and Surber, 1947).

Value: According to Harlan and Speaker (1956), the flesh of the eel, while very rich, is delicious. It can be pan-fried, smoked, or pickled in vinegar and spices. It is considered a delicacy and when available commands a high

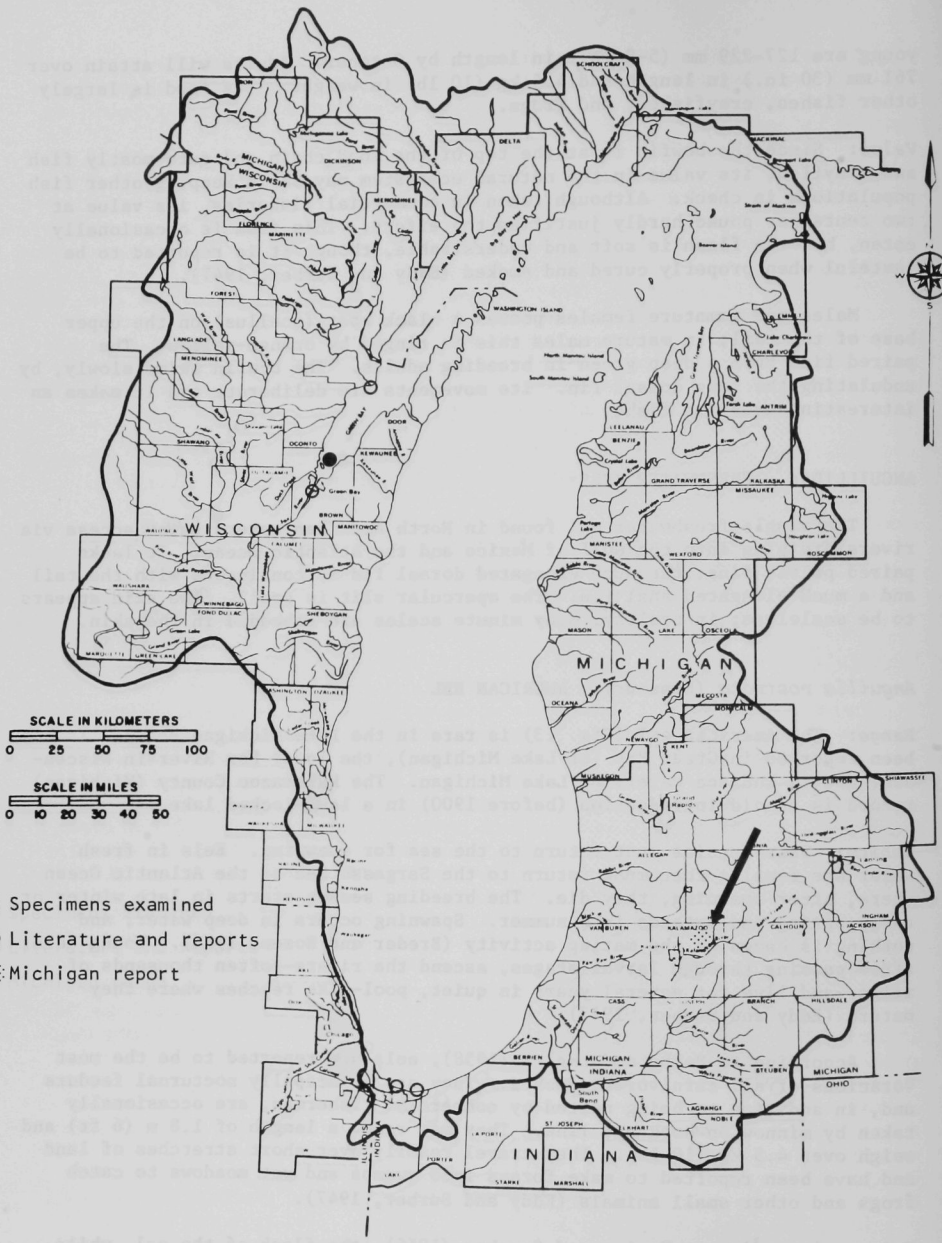

Fig. 13. Distribution of the American Eel (*Anguilla rostrata*).

price on the markets. Most of the eels sold commercially in the United States are caught on the east coast. In former years their skins had considerable value. They were used for many things, including the manufacture of fine buggy whips and book bindings (Eddy and Surber, 1947).

Status: This fish is so rare in the Lake Michigan Basin that a catch usually makes newspaper headlines. A capture off Peshtigo Point of Green Bay, Wisconsin, in mid-1975 was written up in the Marinette Eagle-Star with the caption: "Fisherman Nets Strange Creature". In Wisconsin, the American eel has watch* status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

CLUPEIDAE - HERRINGS

Herring are characterized by a row of modified scales or scutes along the entire edge of the belly, leading to the name "sawbelly". The body is more or less slender, the sides thin, and the meat bony. Hence, as a food fish, these species leave much to be desired. Herring are spring spawners and the anadromous species, such as the alewife, crowd into the streams in spectacular runs. The eggs are deposited at random, and no care is given to them or to the newly hatched young.

Alosa pseudoharengus (Wilson). ALEWIFE

Range: By 1954, the alewife (Fig. 14) had spread through all of the upper Great Lakes [including depths to 54.9 m (30 fathoms)] (Hubbs and Lagler, 1958) and now is abundant. In Wisconsin, it has been observed "running" into Kangaroo Lake (Door County) and up the Pigeon River system in Sheboygan and Manitowoc counties, apparently establishing a permanent population in Pigeon Lake (Kernen, 1974b--letter). It has been reported in the East Twin River (Manitowoc County), the Sheboygan River (Sheboygan County), and the Milwaukee River (Milwaukee County). In Michigan, spawning has been observed in the Kalamazoo River (Allegan County) and the Grand River at Grand Haven (Edsall, 1964).

Habits: Spawning occurs from March to July in the shallows of Lake Michigan and in tributary streams when water temperatures are 12.8-15.5°C (55-60°F) (Threinen, 1958). Hatching occurs in six days at 15.5°C (60°F) or in three days at 22.2°C (72°F) (Mansueti and Hardy, 1967). Peak feeding temperature is 12.2°C (54°F), and the species is active at 8.9-22.2°C (48-72°F). By late fall alewives move to the central depths of the Lake, where they feed off the bottom. They complete the yearly cycle when they migrate shoreward again in mid-March and April (Downs, 1974). They feed mainly on zooplankton. Adults average 152 mm (6 in.) in length and occasionally attain 215 mm (8-1/2 in.) (Threinen, 1958). It has been estimated that alewives comprise over 80% of the total fish biomass in Lake Michigan (S. H. Smith, 1968).

**Species or subspecies that may or may not be holding their own at the present time. They will be under special observation to identify conditions that could cause further decline or factors that could help to insure their survival in the state.*

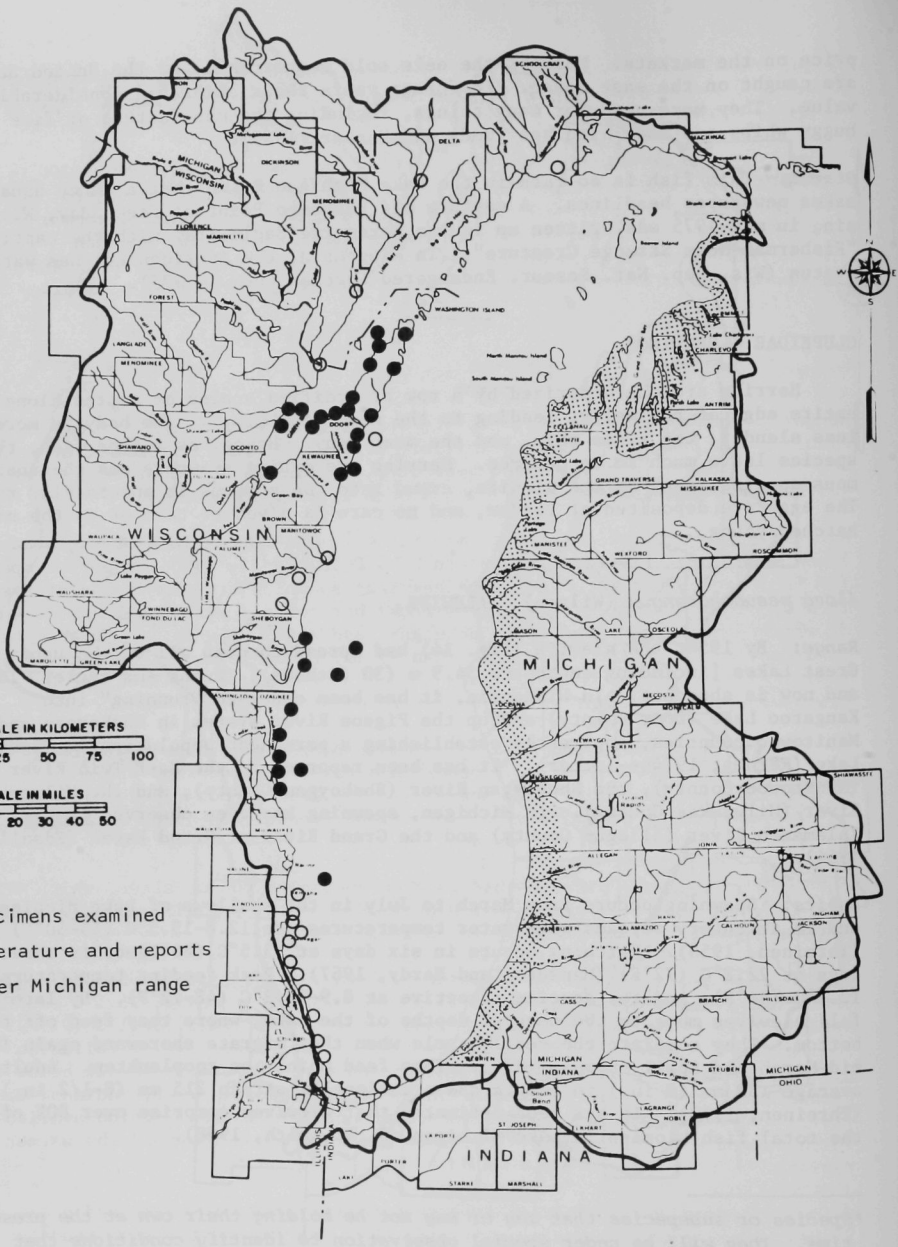

Fig. 14. Distribution of the Alewife (*Alosa pseudoharengus*).

Value: The alewife has become the bread-and-butter fish in Lake Michigan, especially attractive to the large plantings of salmon and trout. According to Downs (1974),

> *"Biologists estimate that coho salmon are now consuming 80 to 100 million pounds of alewives each year, but this still amounts to less than 5% of the alewives in Lake Michigan. Meanwhile, commercial harvesting and processing operations in Green Bay are converting tons of this small, bony fish to meal and fertilizer. And entrepreneurs are developing ways to process alewives as a sardine-like delicacy."*

Dorosoma cepedianum Lesueur. GIZZARD SHAD

Range: The gizzard shad (Fig. 15) is believed to be a recent arrival in Lake Michigan via the Chicago Canal (Miller, 1957). It was first taken in 1953 west of Muskegon, Michigan, and near Gary, Indiana, and appeared in Green Bay (of Lake Michigan) about 1964. Its status is rare to uncommon.

Habits: Spawning may occur from mid-March to mid-August in sloughs, ponds, lakes, and large rivers. In western Lake Erie, Bodola (1966) reported spawning from early June into July with heaviest spawning at water temperatures of 19.5°C (67°F) or more over a sandy, rocky bar covered with 0.6-1.2 m (2-4 ft) of water. Most spawning occurs at night, and after spawning the fish return to deeper water. In the Lake Michigan Basin, probable river spawning is indicated by capture of the gizzard shad from the lower Fox River at DePere, Wisconsin, and the lower Kalamazoo River, Michigan. Miller (1960) observed:

> *"A group of males and females swimming near the surface begin to roll and tumble about each other in a mass, the eggs and sperm being ejected during this activity. The sticky eggs slowly sink to the bottom or drift with the current, readily becoming attached to any object they may contact."*

Fully developed gizzard shad feed on phytoplankton or algae, which they extract from the water with their elongated, closely set gill rakers. Adults reach more than 381 mm (15 in.) in length.

Clark (1969) summarized temperature data for the gizzard shad as follows: preferred field temperature, 22.8-23.9°C (73-75°F); spawning, 26.1°C (79°F); satisfactory growth, 33.9°C (93°F); and upper lethal limit, 36.1°C (97°F). The latter three data were recommendations of the Federal Water Pollution Control Administration (FWPCA). Clark noted that temperatures well below lethal limit can be in the stress range. In the Wabash River, Indiana, Gammon (1973) found that gizzard shad selected the coolest thermal region available, which ranged from 22.2 to 28.9°C (72-84°F), and tended to avoid the warmer regions.

Value: Young gizzard shad are important forage fishes for game and predacious fishes. During the second year of life they grow beyond the size readily acceptable to carnivorous fishes, and the adult population may become extremely abundant. Bodola (1966) reported that in Lake Erie their value as a forage fish is outweighed by the nuisance created when heavy mortality occurs and by

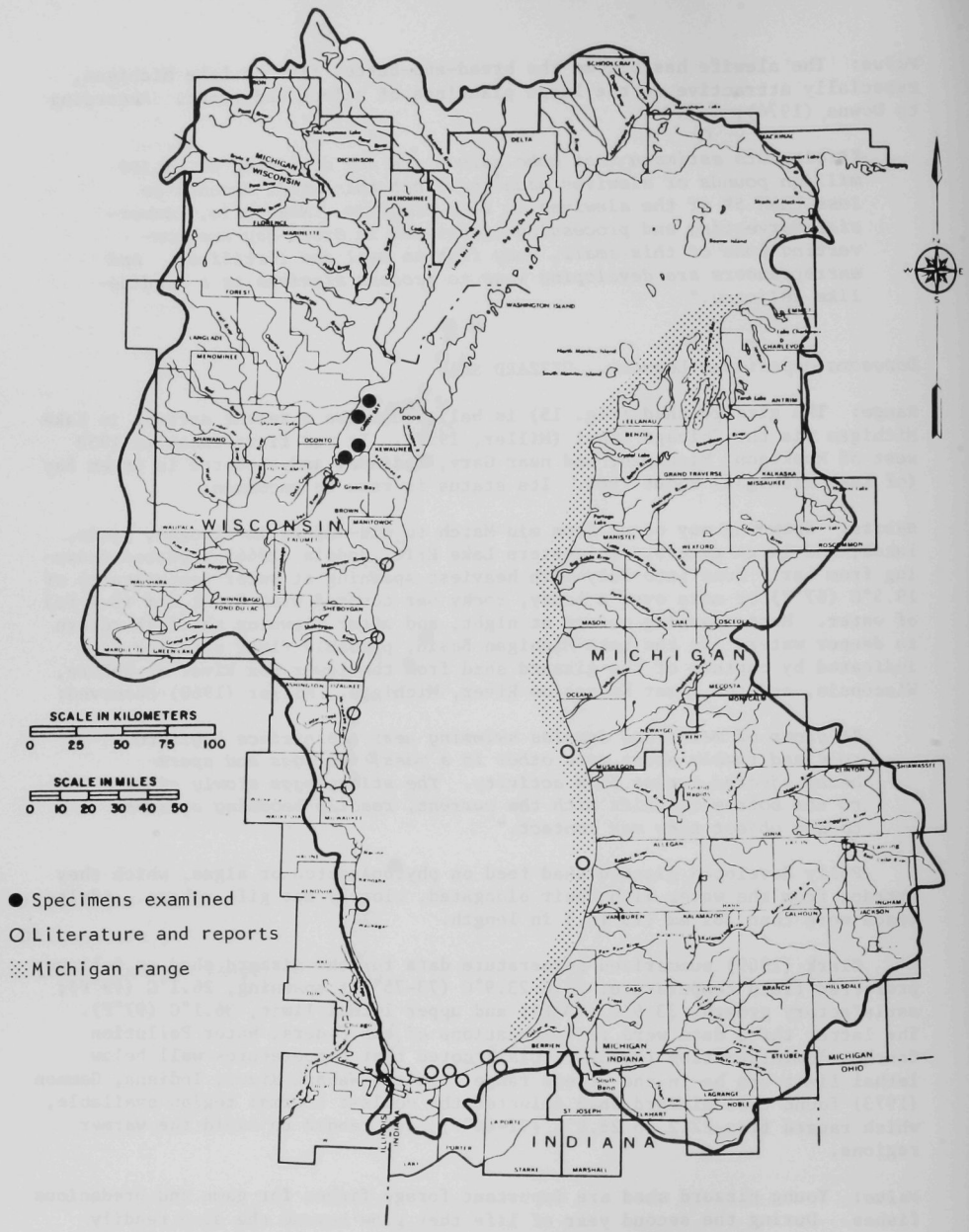

Fig. 15. Distribution of the Gizzard Shad (*Dorosoma cepedianum*).

the inconvenience caused to fishermen in whose nets they become entangled. This species has been used as fertilizer and as food for cattle and hogs. It is a poor bait fish since the young are fragile and die quickly. According to Scott and Crossman (1973), the flesh is soft and generally considered to be unappetizing and bony, making it undesirable for human consumption.

HIODONTIDAE - MOONEYES

The mooneyes are represented by two species within a single genus, *Hiodon*, and of these only one species is found in the Lake Michigan Drainage Basin. The mooneyes are moderate-sized, deep-bodied, laterally compressed, silvery fishes resembling herrings. Teeth are well developed on the jaws and other bones lining the mouth, and on the tongue. No oviducts are present in the female; the eggs are discharged through the body cavity, and leave the body cavity through a pore near the vent.

Hiodon tergisus Lesueur. MOONEYE

Range: Lake Michigan records of the mooneye (Fig. 16) are uncommon. Inland, the most numerous populations appear in the Wolf and lower Fox rivers of Wisconsin.

Habits: The biology of this species is not well known. Trautman (1957) said that it migrates up rivers in spring to spawn, lives in shallow water, and prefers clear water. With the increase in turbidity in waters of the Basin, this species appears to be decreasing in numbers. Over its range the mooneye is found only in the largest lakes and rivers; hence its true range may be more correctly represented by a few lines which follow waterways known to support this species rather than by a shaded area on the map. In Indiana, Gammon (1973) found an optimum temperature range of 27.5-29.0°C (81.5-84.2°F). Its maximum known size is 445 mm (17-1/2 in.) in length and 964 g (2 lb 7 oz) in weight.

Value: The literature reports that the mooneye is of some value as forage for game fishes but has little value as a food fish. Occasionally it is smoked and marketed as a smoked shiner. Scott and Crossman (1973) reported that in times of shortages of goldeye (*H. alosoides*, a related species in the Mississippi and Hudson Bay watersheds), the mooneye is often smoked and sold as the more valuable species. The authors also reported that *"it will take a variety of artificial flies and lures and will provide good fun on light tackle."*

SALMONIDAE - TROUTS AND SALMONS

Many important game and food fishes are found in this family. All salmonids are cold-water fishes and in the Basin they are found in Lake Michigan, deep inland lakes, and suitable tributary streams. The salmonids are characterized by the presence of a rayless adipose fin and the other fins with soft rays. Fin spines are absent. In many species, juveniles have vertical bars known as parr marks. The gonadal products are shed into the body cavity; ducts for conveying the gametes to the outside are absent.

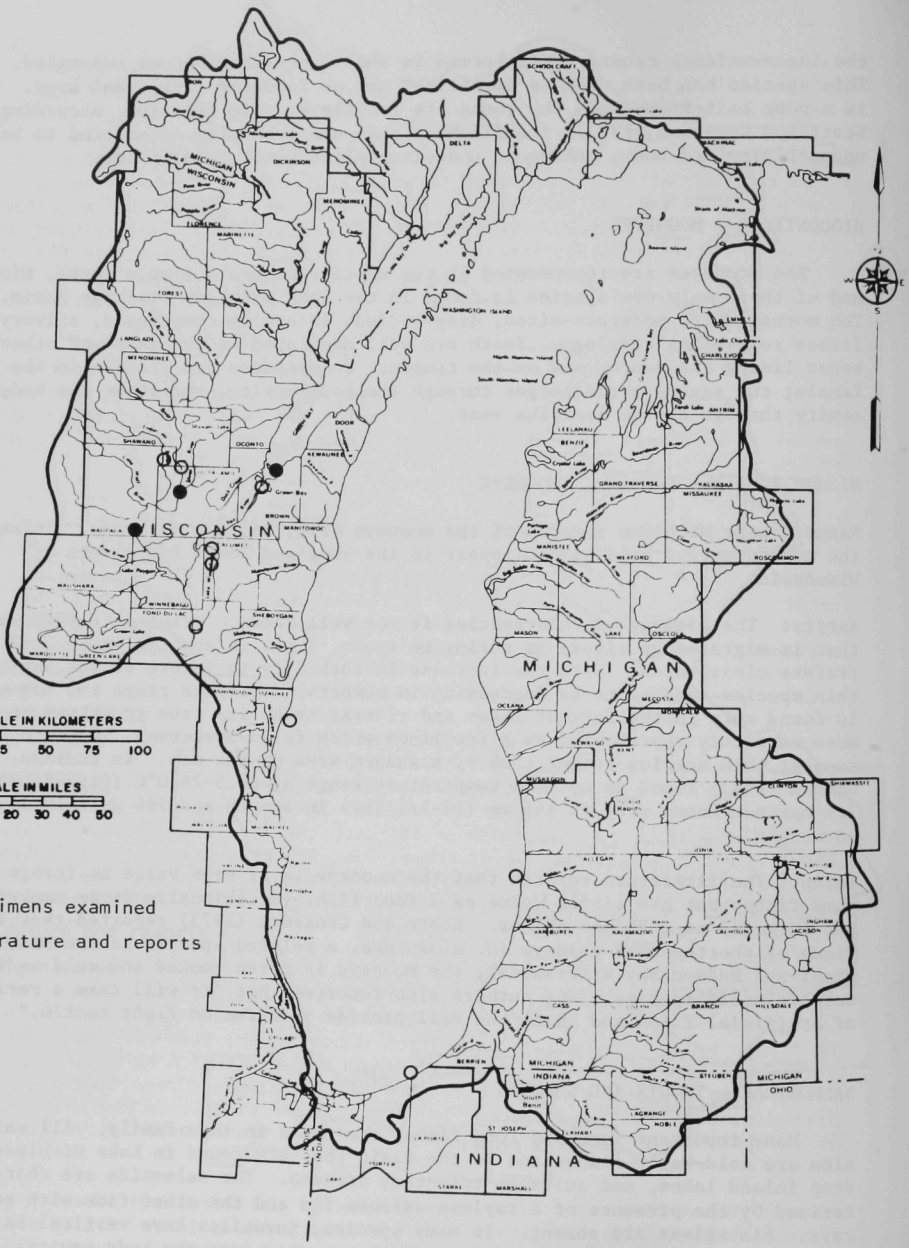

Fig. 16. Distribution of the Mooneye (*Hiodon tergisus*).

Over the years many exotic species have been brought into the Basin. Early successes led to the establishment of the brown and rainbow trout. In recent years salmon were introduced to utilize the abundant alewives. The success of this venture was greater than expected. The present salmon fishery of Lake Michigan is tied to the stream tributaries of the Lake. At the turn of the century, attempts were made to stock salmon directly into the Lake, but these plantings failed. With the initiation of the Michigan plan to allow young salmon to imprint in tributary streams, a successful sport fishery has developed. After growing, fattening, and maturing in the Lake, the fish return to the shore areas and tributary streams in which they had imprinted. In Wisconsin, the return has been 3.2 kg (7 lb) of fish caught for every pound of fish stocked.

Native salmonids have not fared well in recent years. Lake trout were eliminated by the sea lamprey. The chub species of Lake Michigan were drastically curtailed, first by commercial fishing and then by the attacks of the lamprey. Today only one species of chub remains in any numbers and it, too, appears to be in trouble.

Coregonus artedii Lesueur. CISCO OR LAKE HERRING

Range: The cisco (Fig. 17) is naturally present in Lake Michigan and a number of inland lakes, and has been introduced in others. Taylor (1954) said, *"Only a few of the inland lakes of the area [upper Michigan] are known to support populations of this species."*

Habits: The cisco is rarely found at temperatures above 16.7-17.8°C (62-64°F) (Hile, 1936) or at oxygen concentrations below 3 or 4 parts per million (ppm) at the deeper limit of their distribution. Spawning in inland lakes occurs from mid-November to mid-December. John (1956) stated that the cisco arrives at spawning grounds when the temperature drops to 5-6.1°C (41-43°F). Spawning activities rise rapidly to a maximum when the temperature falls below 4°C (39.2°F) in water more than 1.8 m (6 ft) deep, and just before the formation of ice in water 0.9-1.8 m (3-6 ft) deep. The slightly viscous eggs fasten to rocks, vegetation, or debris on the bottom. No nest is built. The developmental period is long, with the fry emerging in late April or early May. The cisco is essentially a plankton feeder (primarily copepods and cladocerans) but large adults take mollusks, insect larvae, crustaceans, and small fish.

Value: As a food fish, the cisco is held in high esteem. It is used fresh in a wide variety of ways, but it is most desirable smoked. The inland forms in the larger lakes are small, ranging from three to four fish per pound, but individuals in some waters may attain weights of 0.9 to 1.4 kg (2-3 lb). A 2.1-kg (4-lb 10-oz) fish was caught from Big Green Lake (Green Lake County), Wisconsin, in 1969. This species is eaten by lake trout. In the inland lakes, man sportfishes for cisco by jigging with colored beads, especially in winter through the ice.

Status: Eutrophication is a serious problem in almost all the lakes of the southern Lake Michigan watershed. With eutrophication, lakes rapidly become undesirable habitats to the cisco, forcing the fish into the narrow, warmer thermocline as the oxygen in the cooler hypolimnion is used up. This may quickly be followed by extirpation. Since this species is intolerant of

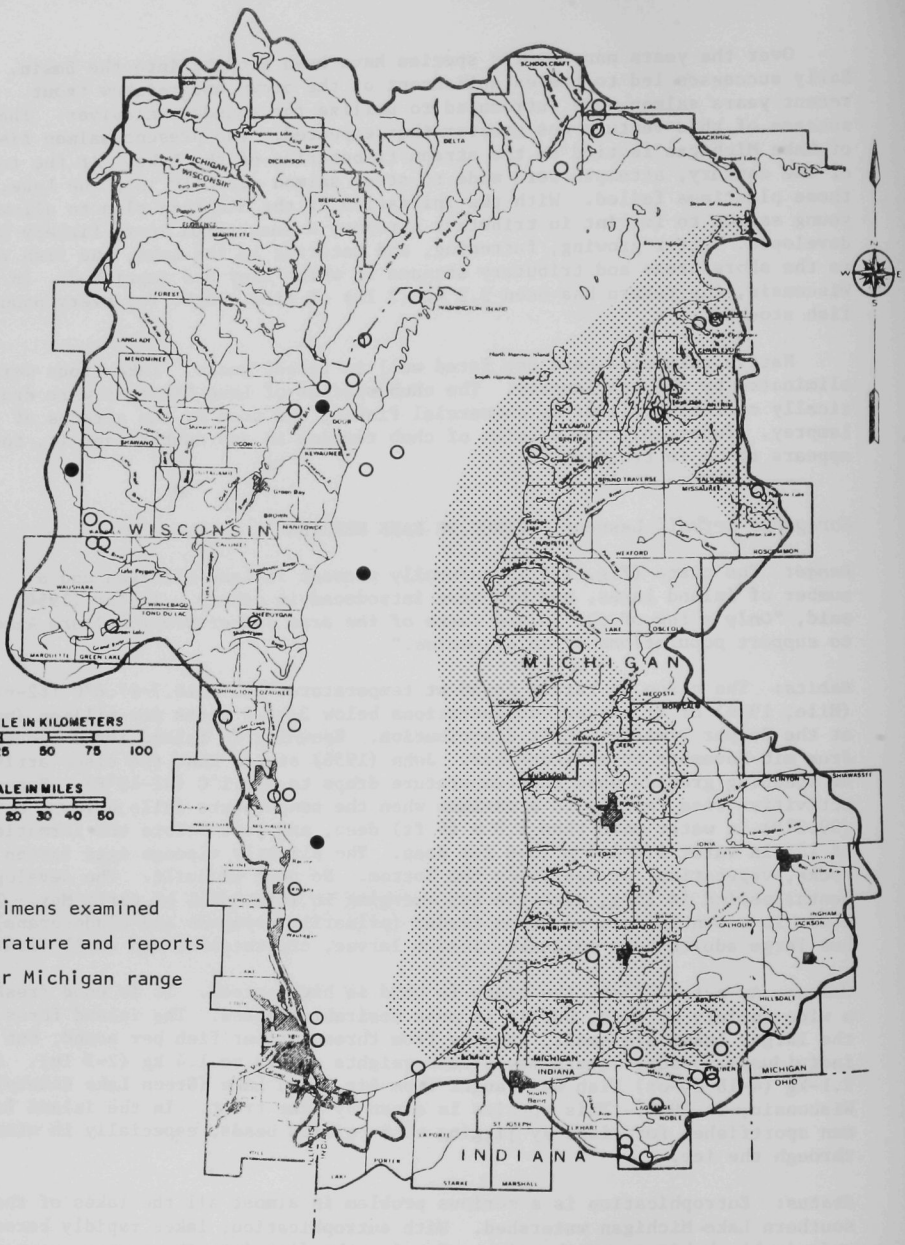

Fig. 17. Distribution of the Cisco or Lake Herring (*Coregonus artedii*).

temperatures much above 15.6°C (60°F), cultural eutrophication which would force the fish into the epilimnion (which for most inland lakes in the Basin is well above the temperature tolerance level) should be avoided. Perhaps the greatest enemies are agricultural fertilizers, sewage wastes (which drain from cottages and communities within a lake basin) high in BOD, and thermal pollution from industry. In southern Wisconsin, a number of lakes which formerly held healthy populations of this species no longer do. Wisconsin accords this species watch status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

Coregonus clupeaformis (Mitchill). LAKE WHITEFISH

Range: The lake whitefish (Fig. 18) is common in the shore waters of Lake Michigan; in upper Michigan it has been reported in Chicagoan Lake (Iron County) and Gulliver Lake (Schoolcraft County) by Hubbs and Lagler (1958). The same authors reported it from Torch Lake (Antrim County) in southern Michigan. In Wisconsin, this species has been reported in Lake Lucerne (Forest County) and Keyes Lake (Florence County) (Johnson and Becker, 1970).

Habits: This species typically frequents shallow to moderate depths. Spawning usually occurs in November and December at depths of less than 7.6 m (25 ft) over a sand or stone bottom. Lake whitefish spawning is random and no nest is constructed; spawning occurs at water temperatures of 4.5-10°C (40-50°F). Optimum temperature for development of eggs is close to 0.6°C (33°F), while mortalities increase with higher temperatures until eggs incubated at 10°C (50°F) suffer 99% mortality (Scott and Crossman, 1973). The newly hatched larvae form aggregations along steep shorelines, remaining in shallow inshore waters until early summer, when they move into deeper water. In inland waters, lake whitefish seldom reach more than 1.4-2.3 kg (3-5 lb), but in the Great Lakes they often grow to weigh 9.1 kg (20 lb), living about 10 years, with a few living almost 30 years. A 10.9-kg (24-lb) fish was found dead in Torch Lake (Antrim County), Michigan, in 1948.

Value: The lake whitefish has been the most valuable food fish in the Great Lakes. Downs (1974) noted:

> *"Long the patrician of the Great Lakes, the whitefish has always been a prime commerical target, prized for the delectable quality of its meat. In 1836, a scientist in field wrote, 'We can say from personal experience that a diet of whitefish alone, with no other food, can be eaten for days without losing its appeal.'"*

Management: This species was formerly artificially propagated on a large scale in the region, but this activity is now greatly curtailed since it has never been shown that the millions of fry planted at considerable expense have increased or even maintained the supply (Hubbs and Lagler, 1958). Its continuation in the few inland lakes where it is still found is contingent upon controlling eutrophication.

Coregonus hoyi (Gill). BLOATER

Range: The bloater (Fig. 19) has been reported in Lake Charlevoix (Emmet County), Michigan, and is probable in Lake Macatawa (Ottawa County). It is the most common chub remaining in Lake Michigan.

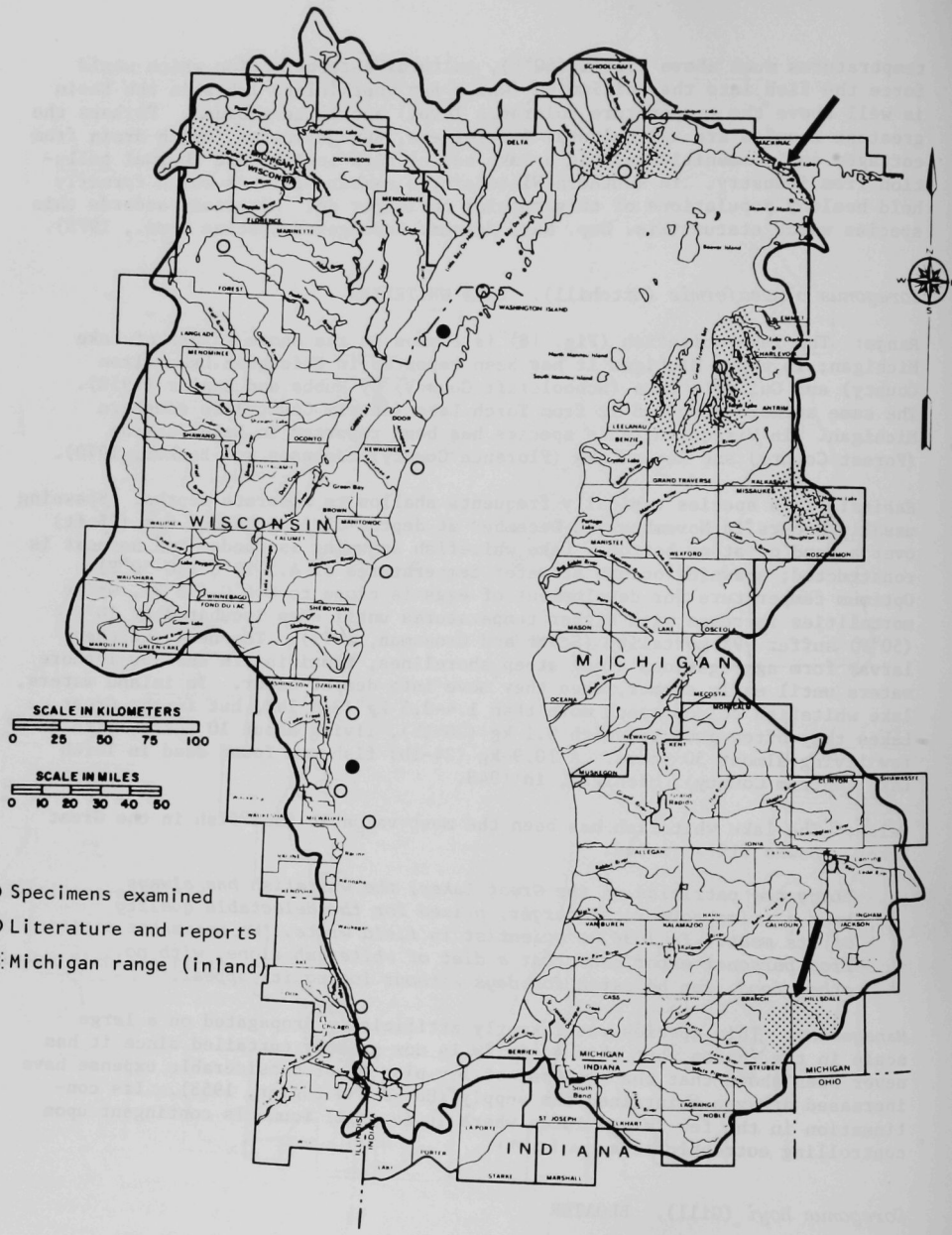

Fig. 18. Distribution of the Lake Whitefish (*Coregonus clupeaformis*).

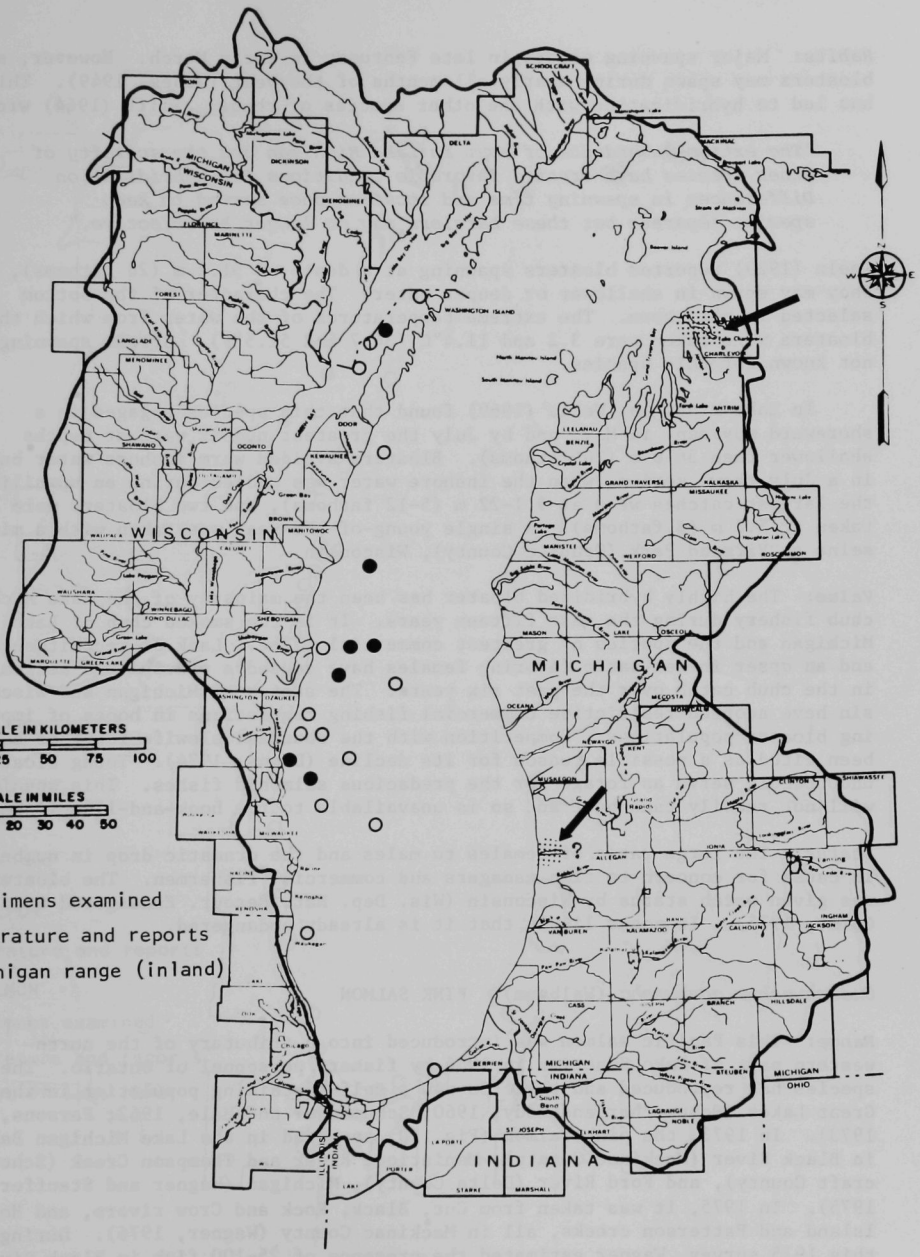

Fig. 19. Distribution of the Bloater (*Coregonus hoyi*).

Habits: Major spawning occurs in late February to early March. However, some bloaters may spawn during nearly all months of the year (Jobes, 1949). This has led to hybridization with the other species of chubs. Smith (1964) wrote:

> *"The extreme abundance of hoyi in Lake Michigan and the scarcity of other species have created favorable conditions for hybridization. Differences in spawning time and location once served to keep species separate but these barriers may no longer be effective."*

Koelz (1929) reported bloaters spawning at a depth of 51.2 m (28 fathoms), but they may spawn in shallower or deeper water. The character of the bottom selected is not known. The extreme temperatures of the water from which the bloaters were taken were 3.2 and 11.4°C (34.7 and 52.5°F). Stream spawning is not known for this species.

In Lake Michigan, Wells (1969) found that this species engaged in a shoreward movement in May, and by July the greatest number were at depths shallower than 36.6 m (20 fathoms). Bloaters avoided warm inshore water but in a July trawl series, when the inshore water was cooled during an upwelling, the largest catches were at 9.1-22 m (5-12 fathoms), and two bloaters were taken at 5.5 m (3 fathoms). A single young-of-the-year was taken with a minnow seine at Virmond Park (Ozaukee County), Wisconsin.

Value: The highly hybridized bloater has been the mainstay of the Lake Michigan chub fishery during the past fifteen years. It is the smoked chub of Lake Michigan and the species of greatest commercial value. Lack of recruitment and an upset in sex ratio favoring females have caused a precipitous decrease in the chub catch over the past six years. The states of Michigan and Wisconsin have adopted restrictive commercial fishing regulations in hopes of improving bloater populations. Competition with the abundant alewife for food has been cited as a possible reason for its decline (Downs, 1974). Young bloaters undoubtedly serve as forage for the predacious salmonid fishes. This species will not readily take bait and so is unavailable to the hook-and-line fisherman.

Status: The large ratio of females to males and the dramatic drop in numbers is cause for concern to fish managers and commercial fishermen. The bloater was given watch status by Wisconsin (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975). It seems likely that it is already endangered.

Oncorhynchus gorbuscha (Walbaum). PINK SALMON

Range: This Pacific salmon was introduced into a tributary of the northwestern part of Lake Superior in 1956 by fishery personnel of Ontario. The species has reproduced and there is now a self-sustaining population in the Great Lakes (Schumacher and Eddy, 1960; Schumacher and Hale, 1962; Parsons, 1973). In 1973, the pink salmon (Fig. 20) appeared in the Lake Michigan Basin in Black River (Mackinac County), Manistique River and Thompson Creek (Schoolcraft County), and Ford River (Delta County), Michigan (Wagner and Stauffer, 1975). In 1975, it was taken from Cut, Black, Rock and Crow rivers, and Hog Island and Patterson creeks, all in Mackinac County (Wagner, 1976). During this 1975 survey, Wagner estimated the presence of 25-100 fish in Black River, Crow River, and Patterson Creek, and less than 25 fish in each of the other streams.

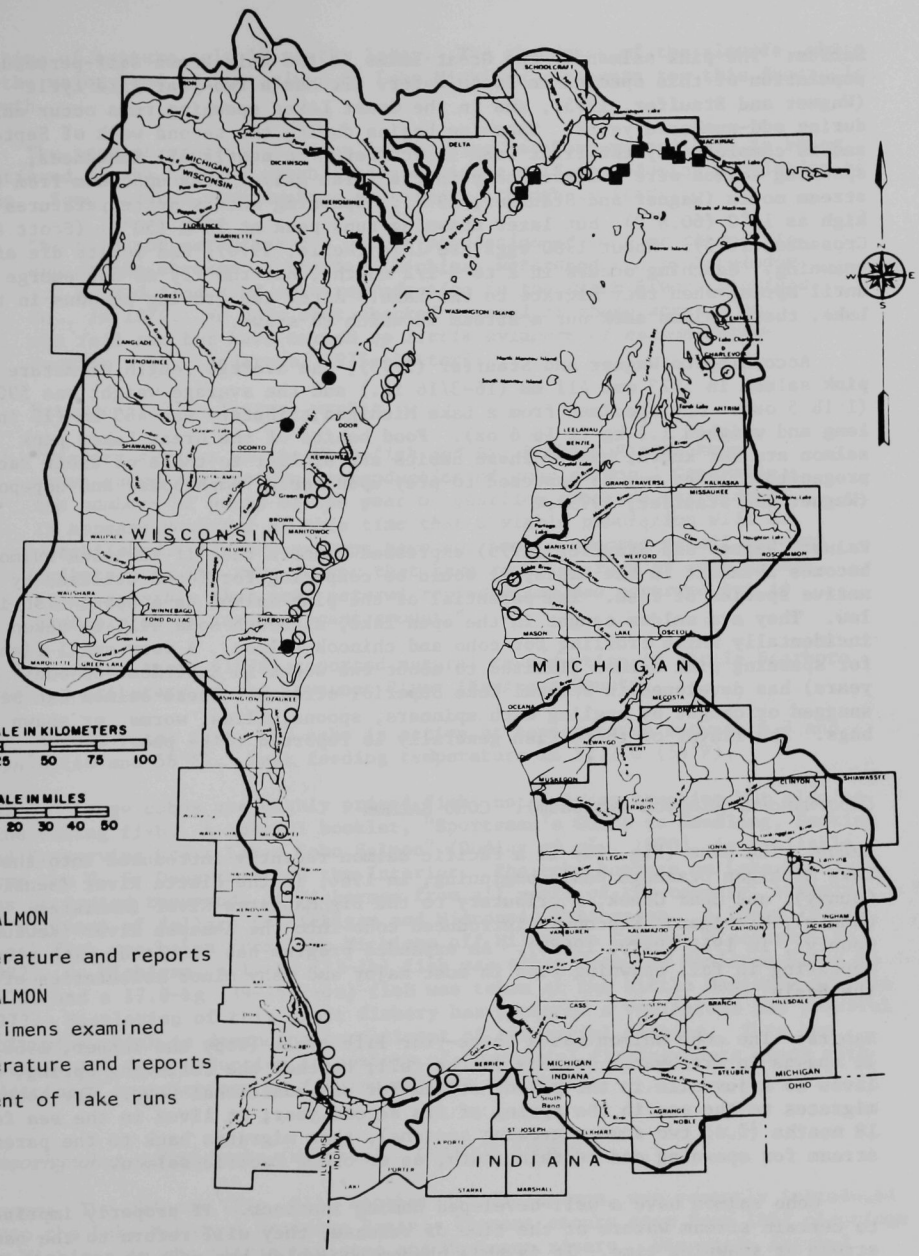

Fig. 20. Distribution of the Pink Salmon (*Oncorhynchus gorbuscha*) and Coho Salmon (*Oncorhynchus kisutch*).

Habits: The pink salmon of the Great Lakes is the only known self-perpetuating population of this species in fresh water. It has a two-year life cycle (Wagner and Stauffer, 1975), and in the Great Lakes spawning runs occur only during odd-numbered years. Spawning begins during the second week of September and is completed by the first week in October. In nearly all instances, spawning salmon were observed only in the first gravel area upstream from the stream mouth (Wagner and Stauffer, 1975). Spawning occurs at temperatures as high as 16°C (60.8°F), but later spawning runs peak at 10°C (50°F) (Scott and Crossman, 1973). About 1900 eggs are laid (Helle, 1970), and adults die after spawning. Hatching occurs in 2 to 3-1/2 months, but the fry do not emerge until spring when they migrate to the Lake. After two growing seasons in the Lake, these salmon seek out a stream in which to spawn.

According to Wagner and Stauffer (1975), the average length of mature pink salmon in 1973 was 411 mm (16-3/16 in.) and the average weight was 590 g (1 lb 5 oz). One specimen from a Lake Michigan tributary was 483 mm (19 in.) long and weighed 1.1 kg (2 lb 6 oz). Food habits of the Great Lakes pink salmon are not known, but if these habits are similar to those of their Pacific progenitors, they may be expected to prey upon *Mysis*, amphipods, and copepods (Wagner and Stauffer, 1975).

Value: Wagner and Stauffer (1975) expressed concern that if the pink salmon becomes abundant in the Basin, it would be competing for foods utilized by native species of fish. The potential of the pink salmon as a sport fish is low. They are seldom caught in the open lake, although some will be taken incidentally while trolling for coho and chinook salmon. A very small fishery for spawning pink salmon (limited to about two weeks in September of odd years) has developed in several Lake Superior streams. These salmon can be snagged or caught by angling with spinners, spoons, flies, worms, or spawn bags. The flavor of these fish generally is reported to be poor.

Oncorhynchus kisutch (Walbaum). COHO SALMON

Range: The coho (Fig. 20) is a Pacific salmon recently introduced into the Lake Michigan Drainage Basin beginning, in 1966, in the Platte River (Benzie County), and Bear Creek, a tributary to the Big Manistee River (Manistee County), Michigan. Wisconsin introduced coho into the Ahnapee River (Kewaunee County), in 1968 (Daly, 1968b). An expanded program has resulted, with coho appearing in fall spawning runs in most major and many minor tributaries of the Basin.

Habits: The coho salmon has a three-year life cycle (Tody and Tanner, 1966). It spawns in freshwater streams in the fall, hatches the following spring, and lives as a juvenile in the parent stream for one additional year. The coho migrates to the sea in the spring of its second year; it lives in the sea for 18 months (*i.e.* two summer growing seasons), then migrates back to the parent stream for spawning and certain death, as do other Pacific salmon.

Coho salmon have a well-developed homing instinct. If properly imprinted to certain stream waters at the time of release, they will return to the same stream at spawning time. It is this phenomenon which has made the present salmon-stocking program a success, returning the fish to "home" waters after growth from a mere 28 g (1 oz) at the time of release to 4.5-9.7 kg (10-20 lb)

at time of capture only 18 months later. The abundance of the alewife, which is the major food of the salmon in Lake Michigan, accounts for this fantastic growth.

The present program of annually stocking hatchery-raised fish is being continued in the hope of establishing a viable self-reproducing population of coho. Some natural reproduction is evident, though limited:

> *"We have not established a viable population of coho or chinook in any of the streams in the Lake Michigan watershed--to my knowledge. ... We did find some coho reproduction in the Black River, Mackinac Co., in 1970. We have spot checked several of these streams on the fall run but have turned up little evidence of salmon reproduction ..."* (Anderson, 1975--letter).

Peterson (1975--letter) wrote:

> *"Fishery surveys on the Whitefish and Big Fishdam Rivers have shown successful natural reproduction of coho salmon. Generally, the numbers of young of the year or yearling coho are quite small. It appears doubtful at this time that a viable population will be established. Fishery surveys have not been conducted on all streams tributary to the Bays de Noc that have received runs of coho salmon. It is possible that some natural reproduction has occurred but is probably of an insignificant amount."*

In Wisconsin, Avery (1974) reported natural reproduction in Little Scarboro Creek, a tributary of the Kewaunee River (Kewaunee County).

A cold-water fish, the coho is active at temperatures between 6.7 and 14.4°C (44 and 58°F). Peak feeding temperature is 12.2°C (54°F).

Value: Large cohos are highly prized fish, not only as trophies but also as fine eating fish. A special booklet, "Sportsman's Guide to Handling, Smoking and Preserving Great Lakes Coho Salmon" (Dudley *et al.*, 1970), is available from the U. S. Department of the Interior. The coho bonanza on Lake Michigan has attracted thousands of fishermen from all parts of the country, bringing in millions of dollars to Michigan and Wisconsin businesses. A 10-kg (22-lb 2-oz) fish was taken from Lake Michigan off Milwaukee County, Wisconsin, in 1972. In Michigan, a 15-kg (33-lb) fish was taken from the Manistee River in 1970, and a 17.8-kg (39-lb 2-oz) fish was taken at the Little Manistee weir in 1973. Escalation of this sport fishery has produced a vociferous and powerful following which is demanding curtailment of commercial fishing. This has already led to a reduction in numbers of commercial fishing boats along with additional restrictions in fishing methods and take.

Oncorhynchus tshawytscha (Walbaum). CHINOOK SALMON

Range: The chinook (Fig. 21), another Pacific salmon, was recently introduced into the Lake Michigan Drainage Basin. Present stocks stem from 1967 plantings by Michigan in the Little Manistee and Muskegon rivers. Wisconsin stocked Strawberry Creek (Sturgeon Bay Ship Canal) in 1969, and Sheboygan, Manitowoc, Kewaunee, and Algoma streams in 1971.

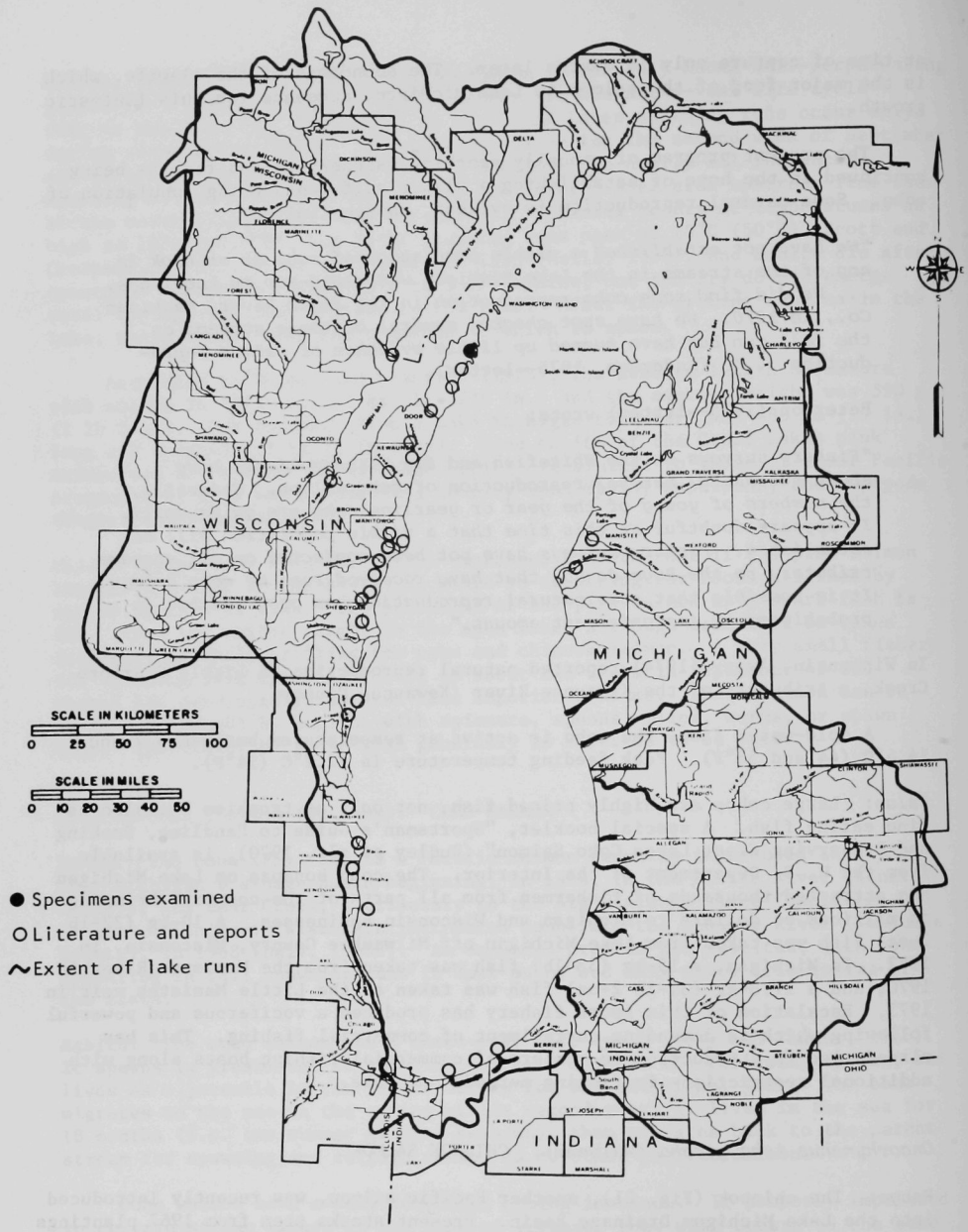

Fig. 21. Distribution of the Chinook Salmon (*Oncorhynchus tshawytscha*).

Habits: The chinook normally has a four-year life span and dies after spawning. According to Scott and Crossman (1973), chinook tend to spawn in deeper water and on larger gravel than the other Pacific salmon. Spawning time varies, depending on the extent upstream of the migration. Generally it occurs in early fall. The female digs a nest or redd,* which can be as large as 3.7 m (12 ft) long and 0.4 m (1 ft) deep.

> *"Each female is attended by a larger, dominant male and often several smaller males. At spawning the female and the dominant male swim into the nest, the two fish approximate, their mouths gape, they vibrate, and eggs and sperm are released."* (Scott and Crossman, 1973).

After spawning, the female digs at the head of the redd and covers the eggs with gravel. She may then repeat the entire process with another redd.

The same spring after hatching, the chinook reaches the smolt stage and migrates into the Lake. Growth is rapid and in its fourth year it may be about 1.0 m (40 in.) long and weigh 10.4 kg (23 lb) (Daly, 1971). An 18.3-kg (40-lb 4-oz) chinook was taken from the Menominee River, upper Michigan-Wisconsin boundary, in 1973, and in 1975, a 20-kg (44-lb 2-oz) fish was taken from the St. Joseph River (Berrien County), Michigan.

Value: In Lake Michigan, the chinook is truly king. Currently it reaches the largest size of any fish in the Lake and is considered a prime food fish. Because of its large size and high quality, this species has always commanded the highest market price. It assists in curtailing alewife numbers and possibly will prevent an alewife explosion such as occurred in 1966.

Management: The chinook offers one big advantage over the coho in that it should provide year-round angling, weather and regulations permitting (Borgeson and Tody, 1967). Since the young have migrated out of the streams into the Lake by late spring, warm summer stream temperatures have no influence on the fall chinook. In fact, the chinook sustains itself quite nicely in some California streams that go completely dry in the summer.

To date, the chinook stocked in the Lake Michigan Basin have shown little sign of natural reproduction. Continuation of a strong stocking program is justified as long as forage fish stock hold up. Imprinting the stocked fish to streams brings the adults back to home waters where the bulk of such fish can be caught. The distance adults migrate up lower Michigan streams is considerable. In most streams, even in Wisconsin, this may be a mile or more, or until the first dam is reached.

Salmo gairdneri Richardson. RAINBOW TROUT

Range: The rainbow trout (Fig. 22) is an introduced species, common and self-reproducing in many fast-water streams of the Lake Michigan Basin. The rainbow was introduced into the Great Lakes from the West Coast. Spring-run and, to a

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**A nest may be a depression in sand or gravel, or vegetation shaped or used in its existing state for the deposition of eggs; redd is a term applied specifically to the nests made in gravel, generally by salmon and trout.*

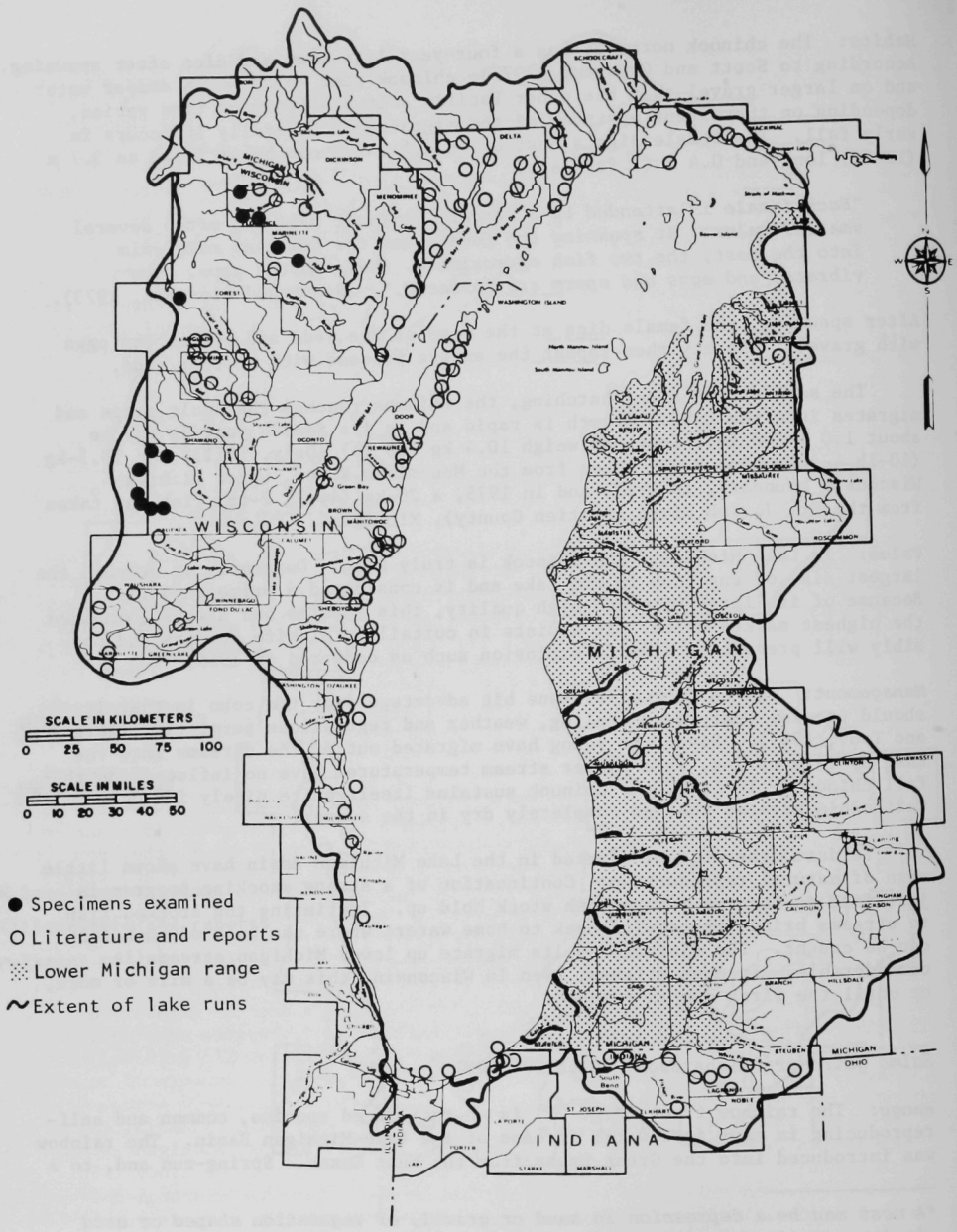

Fig. 22. Distribution of the Rainbow Trout (*Salmo gairdneri*).

lesser extent, fall-run populations have been established in Lake Michigan and offer outstanding fishing as they migrate into tributary streams. Tributary waters in Michigan appear to be more suitable to this species than those in Wisconsin.

Habits: Rainbow trout prefer fast, white-water sections of cool streams; however, they adapt readily to clean, cold inland lakes and have done well in Lake Michigan, where they have an apparent preference for shoal water 4.6-10.7 m (15-35 ft) deep (Daly, 1968a).

Spawning generally occurs from January through March. Fall-spawning rainbows are also known in Lake Michigan. Limited spawning and redd building by Lake Michigan rainbow trout have been observed by Daly (1968a) in Stoney Creek and Whitefish Bay Creek (Door County) and in Little Scarboro Creek (Kewaunee County). Little Scarboro Creek has produced successful hatches of lake-run rainbows (Avery, 1974). Yearling and fingerling rainbows were collected from Stoney Creek, yearling trout from the Little Scarboro, and fingerling trout from Whitefish Bay Creek. Although the fall spawning run is minor compared to the spring run, evidence was obtained that fall-spawning fish will also drop their eggs in the lake if stream conditions are unsuitable (Daly, 1968b).

The female alone engages in the construction of the redd, which is similar to that of the brook trout and may take as long as two days to excavate. Often two males engage in the spawning act with a single female; after deposition of 800-plus eggs, the female covers them with gravel. Additional redds are dug by the female upstream of the first and the above process is repeated. The rainbow may spawn three or four times during its lifetime.

The incubation period varies with water temperature, averaging about 80 days at 4.4°C (40°F) and 19 days at 15.6°C (60°F) (Embody, 1934). Of all the Basin trout, the rainbow is the most tolerant of a wide range of temperature, from about 0.0 to 28.3°C (32-83°F). These fish are usually near the surface when water temperatures are below 21.1°C (70°F), but move downward when the upper layers exceed this, tending to concentrate at levels between 15.6 and 21.1°C (60 and 70°F). Although they prefer well-oxygenated water, they can survive at very low oxygen levels, especially at lower temperatures and after longer periods of acclimation. For example, mean lethal oxygen concentrations ranged from 1.05 ppm at 11.1°C (52°F) to 1.51 ppm at 20°C (68°F) for wild New York rainbow averaging 97 mm (3-3/4 in.) (Burdick *et al.*, 1954). Rainbows do well in water of varying pH, ranging from at least 5.8 to 9.5.

Value: There is no trout of comparable size that surpasses the rainbow in fighting qualities. In Lake Michigan, the abundance of alewives as a source of food has provided an extremely fast-growing rainbow [from 113 g (4 oz) to 7.3 kg (16 lb) in five years] and has resulted in impressive numbers of rainbow trout in the 4.5- to 8.6-kg (10- to 19-lb) class. An 11-kg (24-lb 4-oz) rainbow was taken from Lake Michigan off Sheboygan, Wisconsin, in 1973, and a 12-kg (26-lb 8-oz) fish was taken in 1975 off Berrien County, Michigan. The incidence of lamprey-scarring on rainbows has dropped materially since 1962. Almost every year since the sea lamprey has been brought under control and the lake stocked with rainbow trout, record rainbows topple the previous year's record. Lake Michigan rainbows are truly trophy fish!

The rainbow is a fine eating fish--baked, fried, or smoked. However, many consider it the least delectable of the trout species.

Salmo trutta (Linnaeus). BROWN TROUT

Range: The brown trout (Fig. 23), a European species, is well established in the Lake Michigan Basin but only sporadically distributed in the Upper Peninsula of Michigan (Taylor, 1954). It is common in Lake Michigan, where it was recently introduced.

Habits: The spawning period in Wisconsin occurs mainly during October and November, depending partly on water temperatures. The female excavates a saucer-shaped redd in the gravel bottom of the stream. In the absence of gravel, spawning has occurred in areas of sand or hard clay particles. Hatching varies from 40 to 70 days, depending on water temperatures. At 10.6°C (51°F) the young will hatch in 40-52 days. Unlike the salmon, the brown trout does not die after spawning, and an individual typically spawns more than once (Brynildson *et al.*, 1963).

Wisconsin first released brown trout into Lake Michigan in 1966 (Daly, 1968b). In 1968, over 150,000 brown trout were stocked. One year after release, these fish had typically increased in size from 203 mm (8 in.) to a length of 445 mm (17-1/2 in.) and a weight of 1.6 kg (3 lb 8 oz). Five additional months of Lake feeding produced fish averaging 546 mm (21-1/2 in.) and 2.5 kg (5 lb 8 oz). After one year in the Lake, brown trout had ranged as far as 322.8 km (200 mi) south to Waukegan, Illinois, and across the Lake to Muskegon, Michigan. The majority of returns were recovered less than 24.2 km (15 mi) from their point of release. There was a minor spawning run in 1967. Brown trout did not enter streams in 1968, largely due to low water flow. Most trout spawned in the Lake along rocky and rubble-filled areas; fish were so heavily concentrated in these areas that aggressive action and fighting occurred among the males. Of the Basin trout, this is the longest-lived, reaching the age of eight years or more in some instances.

Saprolegnia has caused heavy mortalities in lake-run brown trout. Of 162 fish examined in one spawning location, 124 or 76% were infected with this fungus. Daly (1968b) reported that the fungus invaded the lesions and scrapes produced by aggressive actions of the males, and that the females developed fungus on the head and tail regions as a result of redd-building activities.

The following temperatures were reported by Clark (1969): preferred temperature range in the laboratory generally for younger fish, 11.7-17.8°C (53°-64°F); and recommendations by the FWPCA for satisfactory growth, 20°C (68°F); for spawning, 12.2°C (54°F); and the upper lethal limit, 25.6°C (78°F) (the stress range may be well below this limit). The minimum dissolved oxygen tolerated at 20°C (68°F) is approximately 5 ppm (Brynildson *et al.*, 1963). At lower temperatures, lower oxygen concentrations can be tolerated.

Value: The brown trout is highly esteemed as a food fish. It is superior in eating qualities to the rainbow trout. Of all the trout, the brown is the most difficult to catch. The larger browns are especially wary of the fisherman's hook but continue their fish-eating ways, consuming brook trout and other species for their own sustenance.

The habitat requirements of the brown trout are not as restricted as those of the native brook trout. With deteriorating habitat and warming water temperatures, the brook trout may disappear or be seriously reduced in number;

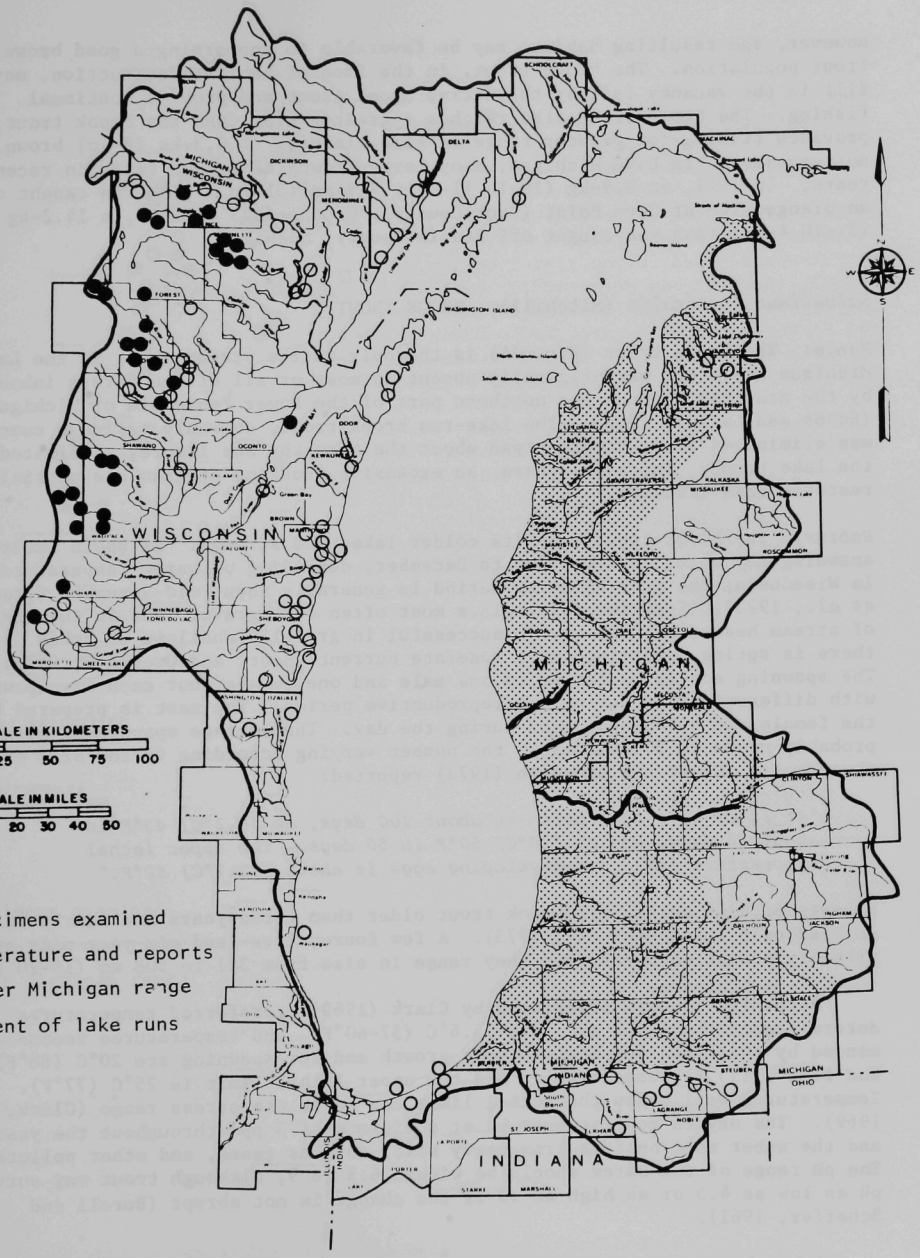

Fig. 23. Distribution of the Brown Trout (*Salmo trutta*).

however, the resulting habitat may be favorable to supporting a good brown trout population. The brown trout, in the face of habitat destruction, may fill in the vacancy left by the native brook trout and provide continual fishing. The brown trout also reaches a greater size than the brook trout and provides fishing for greater range in size classes. A 2.3-kg (5-lb) brown is not uncommon. In Lake Michigan, many large browns have been taken in recent years. In 1971, an 8.9-kg (19-lb 11-oz), 787-mm (31-in.) fish was caught on an orange Cleo at Cave Point (Door County), Wisconsin. In 1975, a 14.2-kg (31-lb 4-oz) fish was caught off Benzie County, Michigan.

Salvelinus fontinalis (Mitchill). BROOK TROUT

Range: The brook trout (Fig. 24) is the only native stream trout in the Lake Michigan Basin but was originally absent in most or all of the waters inhabited by the grayling through the northern part of the Lower Peninsula of Michigan (Hubbs and Lagler, 1958). The lake-run brook trout, commonly called a coaster, was eliminated from Lake Michigan about the time the sea lamprey eliminated the lake trout. In recent years, an extensive stocking program has partially restored this fishery.

Habits: The brook trout inhabits colder lakes and streams. At Basin latitude, spawning may occur from October to December, depending on water temperatures. In Wisconsin, the peak spawning period is generally about mid-November (Brasch *et al.*, 1973). Spawning takes place most often over gravel beds in the shallows of stream headwaters but may be successful in gravelly shallows of lakes if there is spring upwelling and a moderate current (Scott and Crossman, 1973). The spawning act is performed by one male and one female, but each may spawn with different mates during the reproductive period. The nest is prepared by the female and spawning occurs during the day. The average spawning female probably produces 300-400 eggs, the number varying according to the size of the female. Scott and Crossman (1973) reported:

> *"At [5°C] 41°F eggs hatch in about 100 days, at [6.1°C] 43°F in about 75 days, and at [10°C] 50°F in 50 days. The upper lethal temperature limit for developing eggs is about [11.7°C] 52°F."*

Because of high mortality, brook trout older than three years are fairly rare in Wisconsin (Brasch *et al.*, 1973). A few four-, five- and six-year-olds are probably caught each season. They range in size from 381 to 508 mm (15-20 in.).

According to data summarized by Clark (1969): preferred temperatures determined in the field are 13.9-15.6°C (57-60°F), and temperatures recommended by the FWPCA for satisfactory growth and for spawning are 20°C (68°F) and 12.8°C (55°F) respectively, and the upper lethal limit is 25°C (77°F). Temperatures well below the lethal limit can be in the stress range (Clark, 1969). The oxygen content must be at a minimum of 5 ppm throughout the year and the water must be free from heavy silt, noxious gases, and other pollutants. The pH range of the water should be within 6.5 to 9, although trout may survive pH as low as 4.5 or as high as 10 if the change is not abrupt (Borell and Scheffer, 1961).

A brook trout population in Lake Michigan and tributary streams was established by the Wisconsin Department of Natural Resources in 1967 with the release

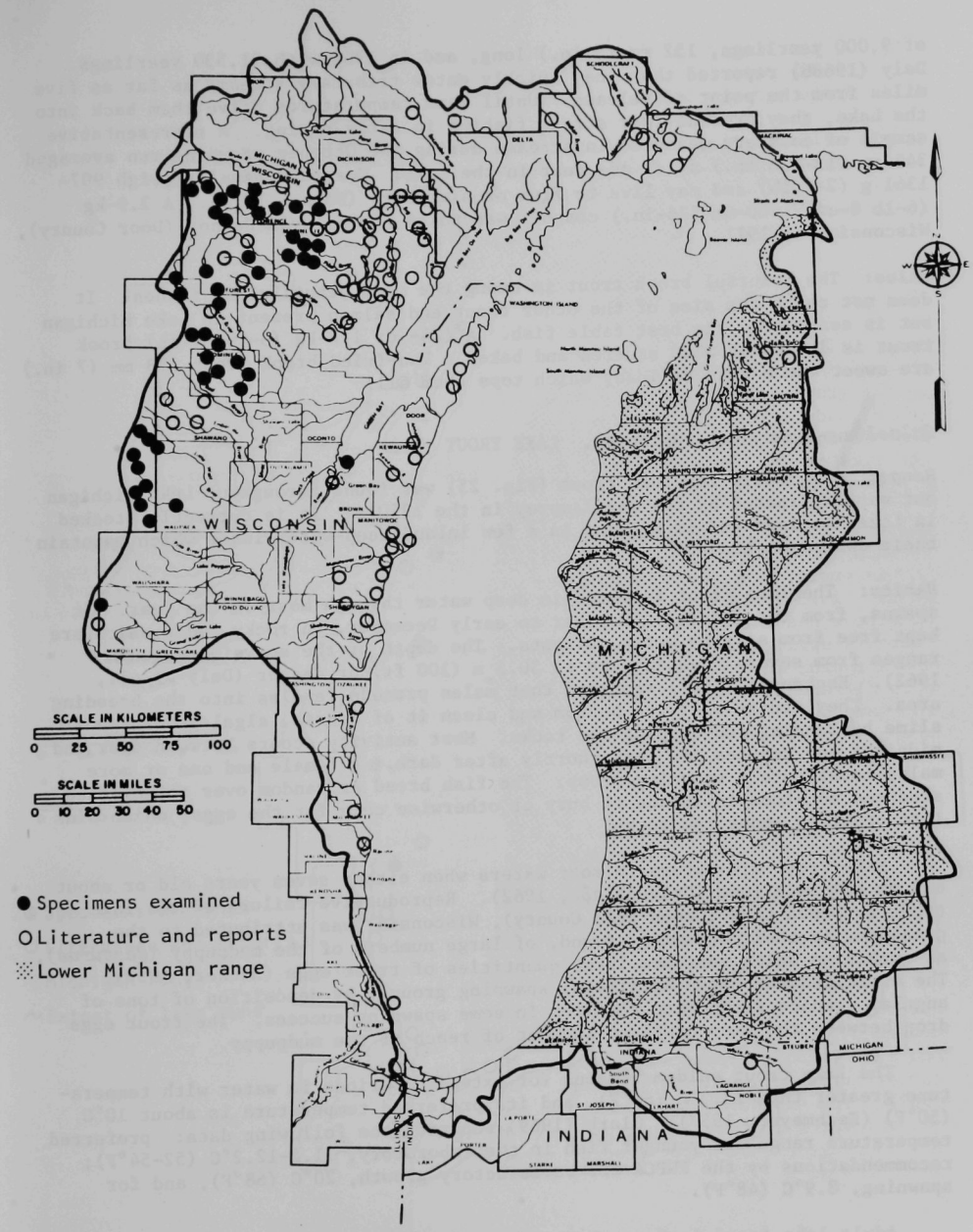

Fig. 24. Distribution of the Brook Trout (*Salvelinus fontinalis*).

of 9,000 yearlings, 152 mm (6 in.) long, and in 1968 with 21,530 yearlings. Daly (1968b) reported that they quickly enter tributary streams as far as five miles from the point of release. Until warm temperatures drive them back into the Lake, they provide fair stream fishing in early spring. A representative sample of coasters measured in streams during the October spawning run averaged 345 mm (13-5/8 in.) after one year in the Lake. Coasters usually weigh 907-1361 g (2-3 lb) and may live to five or six years (Downs, 1974). A 2.9-kg (6-lb 8-oz), 660-mm (26-in.) coaster was taken at Bailey's Harbor (Door County), Wisconsin, in 1971.

Value: The colorful brook trout is among the most beautiful of fishes. It does not reach the size of the other trout and salmon present in Lake Michigan but is considered the best table fish. A 1.4- or 1.8-kg (3- or 4-lb) brook trout is delicious when stuffed and baked. Pan-fried brook trout 178 mm (7 in.) are sweet and a fish delicacy which tops them all!

Salvelinus namaycush (Walbaum). LAKE TROUT

Range: Originally the lake trout (Fig. 25) was found throughout Lake Michigan but was extirpated by the sea lamprey in the 1950's. It is currently stocked in Lake Michigan and is present in a few inland deep-water lakes which maintain their own populations.

Habits: The lake trout is found in deep water through most of the year. It spawns, from the middle of October to early December, on rocky reefs which are kept free from silt by water currents. The depth of the spawning grounds ranges from several centimeters to 30.5 m (100 ft) or deeper (Daly *et al.*, 1962). Eschmeyer (1957) reported that males precede females into the breeding area. They cruise over the bottom and clean it of debris, algal growth, and slime by fanning and rubbing the rocks. Most activity occurs between dusk and midnight and reaches its peak shortly after dark. A female and one or more males constitute a spawning group. The fish breed at random over the cleaned area and no attempt is made to bury or otherwise care for the eggs, which sink into crevices among the rocks.

Lake trout are mature in most waters when either seven years old or about 610 mm (24 in.) long (Daly *et al.*, 1962). Reproductive failure of the lake trout in Green Lake (Green Lake County), Wisconsin, was attributed to the presence, in their spawning ground, of large numbers of the mudpuppy (*Necturus*), an amphibian which consumes large quantities of trout eggs (Hacker, 1957). The establishment of an artificial spawning ground, by deposition of tons of angular granite rocks, has resulted in some spawning success. The trout eggs drop between the deep crevices and out of reach of the mudpuppy.

The lake trout seldom remains for extended periods in water with temperature greater than 18.3°C (65°F), and its preferred temperature is about 10°C (50°F) (Eschmeyer, 1957). Clark (1969) reported the following data: preferred temperature range for younger fish in the laboratory, 11.1-12.2°C (52-54°F); recommendations by the FWPCA for satisfactory growth, 20°C (68°F), and for spawning, 8.9°C (48°F).

Adult lake trout in Green Lake, Wisconsin, feed on the cisco (91.7%), sunfish, and lake emerald shiner. In Lake Michigan, stocked lake trout utilize the alewife as early as nine months after release. A 16-kg (35-lb 4-oz) lake

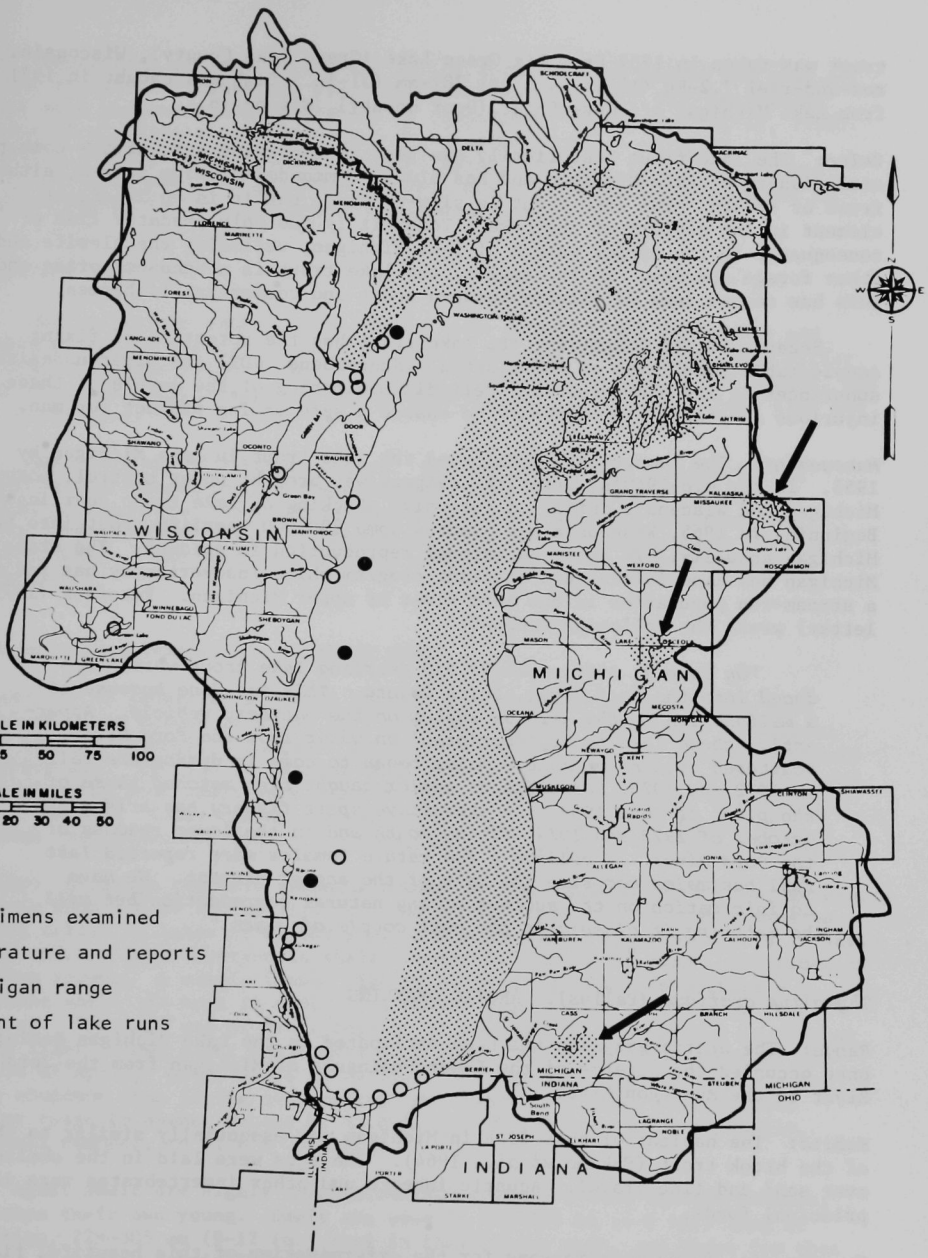

Fig. 25. Distribution of the Lake Trout (*Salvelinus namaycush*).

trout was taken in 1957 from Big Green Lake (Green Lake County), Wisconsin. A rod-and-reel 7.2-kg (15-lb 14.5 oz) 787-mm (31-in.) fish was caught in 1971 from Lake Michigan off Cave Point (Door County), Wisconsin.

Value: The lake trout historically has been an important part of the commercial fishery of Lake Michigan and has always commanded premium prices, either fresh or smoked. The lake trout is slow-growing, but it is an important element in the ecology of the Lake. Today it is the only predator fish of consequence in the deeper waters of Lake Michigan, utilizing the alewife and other forage species. To the angler, the lake trout is a handsome prize and this has caused some difficulty between sport and commercial fishermen.

Because of its longevity, the lake trout has the potential of fixing considerable quantities of chlorinated hydrocarbons (DDT) and other undesirable substances in its body tissues. Periodic monitoring of the levels of these injurious substances is necessary to ensure a safe eating product for man.

Management: The lamprey had extirpated the lake trout in Lake Michigan by 1955. In the mid-1960's, after the lamprey was brought under control, both Michigan and Wisconsin initiated intensive stocking of lake trout yearlings. Beginning in 1965, Wisconsin has planted some 900,000 yearling trout into Lake Michigan annually. To date, no natural reproduction is evident. The state of Michigan has also initiated a stocking program which inadvertently has led to a stream-run population in the Ford River of upper Michigan. Peterson (1975--letter) wrote the following account:

> *"On June 9, 1969, some 99,530 yearling lake trout were introduced into the Ford River, Delta County. This was done because of a malfunction in the aerator system on the hatchery vehicle. Apparently, these lake trout 'imprinted' on water from the Ford River. Scattered returns of mature males began to come in during the fall of 1972 and 1973. Finclips of angler caught fish matched those of the plant of June 1969. An attractive sport fishery has arisen in October of 1973 and 1974 off the mouth and in the lower reaches of the Ford River. I believe a few mature females were reported last fall but males comprise the bulk of the angler harvest. We have no information on the success of any natural reproduction but will be watching it closely in the next couple of years."*

Thymallus arcticus (Pallas). ARCTIC GRAYLING

Range: The arctic grayling has been extirpated in the Lake Michigan Basin; it once occupied the streams of the Lower Peninsula of Michigan from the Jordan River to the Muskegon River.

Habits: The habitat of this fish in Michigan was essentially similar to that of the brook trout (Fukano *et al.*, 1964). The eggs were laid in the shallows over sand and fine gravel. Aquatic insects and other invertebrates were its principal foods.

Management: Three main reasons for the extermination of this beautiful fish in Michigan have been advanced. Some have said that it was eliminated by anglers and lumbermen using illegal methods of capture. Others have claimed

that the running of logs during the spring spawning time gouged the eggs out of the gravel or crushed the fry. Still others have held that introduced trout were responsible as predators or competitors (Hubbs and Lagler, 1958). Fukano *et al.* (1964) concluded that there seems to be no prospect that a grayling fishery can be restored in the Basin, and that if such a fishery could be developed, the grayling probably would offer little enticement to anglers except for the promise of an unusual catch.

OSMERIDAE - SMELTS

The smelts are small marine fishes, some of which are anadromous and ascend rivers to spawn. Closely related to the salmonid fishes, they differ in that they have larger scales, stronger teeth in jaws and on the tongue, and they lack the axillary process at the base of the pelvic fin. These fish are all predacious.

Smelt are an introduced species. All the smelt eggs stocked by the Michigan State Board of Fish Commissioners were obtained from the U. S. Bureau of Fisheries. The Bureau operated a smelt hatchery at Green Lake, Maine, which carried a native freshwater race of the rainbow smelt (Fukano *et al.*, 1964). The smelt in the Lake Michigan Basin are undoubtedly from this source.

Osmerus mordax (Mitchill). RAINBOW SMELT

Range: It is generally accepted that rainbow smelt (Fig. 26) in the Lake Michigan Basin spread from the 1912 stocking of 16,400,000 smelt in Crystal Lake (Benzie County), Michigan. By 1928 it was found in the Wisconsin waters of Green Bay. By 1930 it reached Manitowoc and extended south to Racine, and the following year smelt were reported from Kenosha, Wisconsin, and Michigan City, Indiana. Today during spawning, the smelt is found in almost all streams from Milwaukee County northward and in both upper and lower Michigan.

Habits: Although the main spawning ground of the smelt is in streams, generally no more than 0.8 to 1.6 km (1/2 to 1 mi) above the mouth, it also spawns on gravel deltas in lakes or in any pool with a current. Spawning occurs in early April and has been observed in shallow water in streams at night, sometimes in massive groups. A single female with up to five males may constitute a spawning unit. No nest is made. The sticky eggs adhere to whatever they contact. The main run of smelt returns to the lake in the morning as soon as it is light. Most older smelt move into very shallow spawning areas by the middle of April. Adult smelt in northern Lake Michigan, where they are far more abundant than in the southeastern portion of the Lake, extend their summer range to deeper waters of 45.8-64 m (150-210 ft) and occasionally, in small numbers, to 91.4 m (300 ft).

Adult smelt are highly carnivorous and consume perch, emerald shiners, and even their own young. Smelt are usually 152-229 mm (6-9 in.) long at maturity, 229-305 mm (9-12 in.) long in their third year, and those few that happen to live to their fourth year may be up to 381 mm (15 in.) long (Eddy and Underhill, 1974). Optimum temperatures are from 6.1 to 13.9°C (43-57°F). This is referred to as the active range for this species.

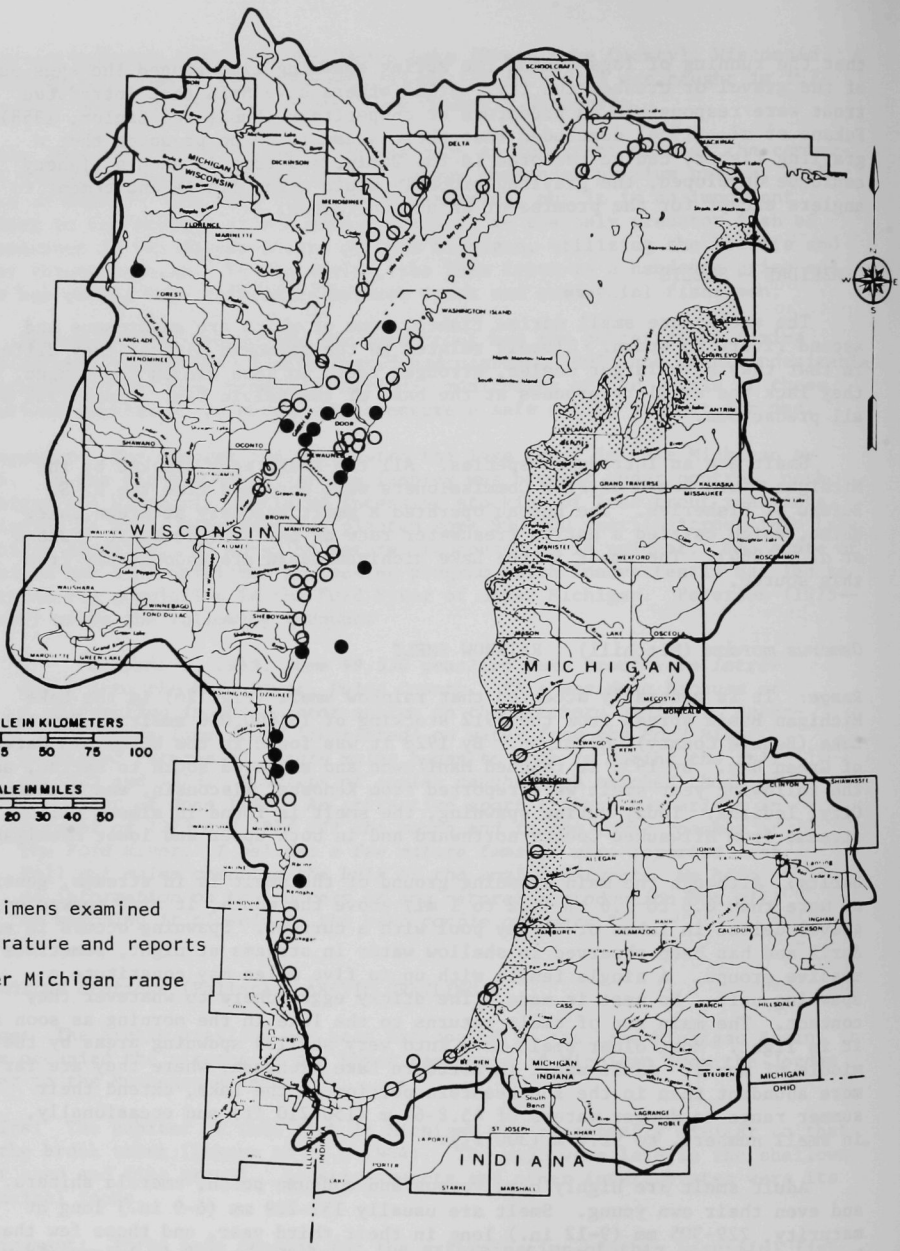

Fig. 26. Distribution of the Rainbow Smelt (*Osmerus mordax*).

Value: As a table fish, fried smelt rank with the best. In the Great Lakes, smelt are sought for their meat as well as for the sport of dipping, which reaches festive proportions. On the Oconto River, Wisconsin, during the 1930's, as many as 20,000 people would line up, elbow to elbow, vying with one another for these silvery fish. A "smestling" match was held in a ring covered with two tons of smelt upon which the wrestlers fought to a dubious victory. The event got newsreel coverage from all of the news services of the day. The smelt explosion has now come to an end and along with it the number of smelt dippers has decreased.

Young smelt are foraged heavily by walleyes, northerns, and other predators; however, the position and value of smelt in the ecosystem are not clearly understood by fishery biologists. Lake Lucerne (Forest County), Wisconsin, has a strong but stunted population of smelt which is important forage to large game fish. It is surmised that the population was introduced via the minnow bucket.

UMBRIDAE - MUDMINNOWS

The mudminnow family includes three genera and four species in North America, but only one species occurs in the Lake Michigan Drainage Basin. It is a small, oval to laterally compressed fish with rounded caudal fin (all fins are soft-rayed), short snout, and a somewhat flattened head. Adults are dark brown above and laterally, with the underside paler. There is a prominent, vertical black bar at the base of the tail.

Umbra limi (Kirtland). CENTRAL MUDMINNOW

Range: The central mudminnow (Fig. 27) is common throughout most of the Lake Michigan Basin.

Habits: This species typically is found in spring-fed pools with soft bottoms, and often is common in very stagnant waters (Hubbs and Lagler, 1958). Mudminnows spawn in the early spring when water temperatures are 12.8-15.6°C (55°-60°F); the eggs are laid on vegetation in streams or ponds. No nest building has been reported. This relative to the pike family is tenacious of life under adverse conditions, including oxygen deficiency. It may be the only species to survive a winterkill. When disturbed, it is reported to dive into bottom muds to a depth of 102-229 mm (4-9 in.). Animals form the main diet, with insects, mollusks, and entomostracans among the preferred items.

Value: The mudminnow is sold as a bait minnow because of its tenacity to life, even on the hook. Although eaten by game fishes, it is not a preferred bait. It seldom exceeds 102 mm (4 in.) in length and is not used as a food by man. To the aquarist, this species is attractive and interesting.

ESOCIDAE - PIKES

This family includes the true pikes or pickerels, all of which are members of the genus *Esox*. The body is elongated and the heads are much depressed anteriorly, to which the name "duck-billed" is often applied. The jaws are

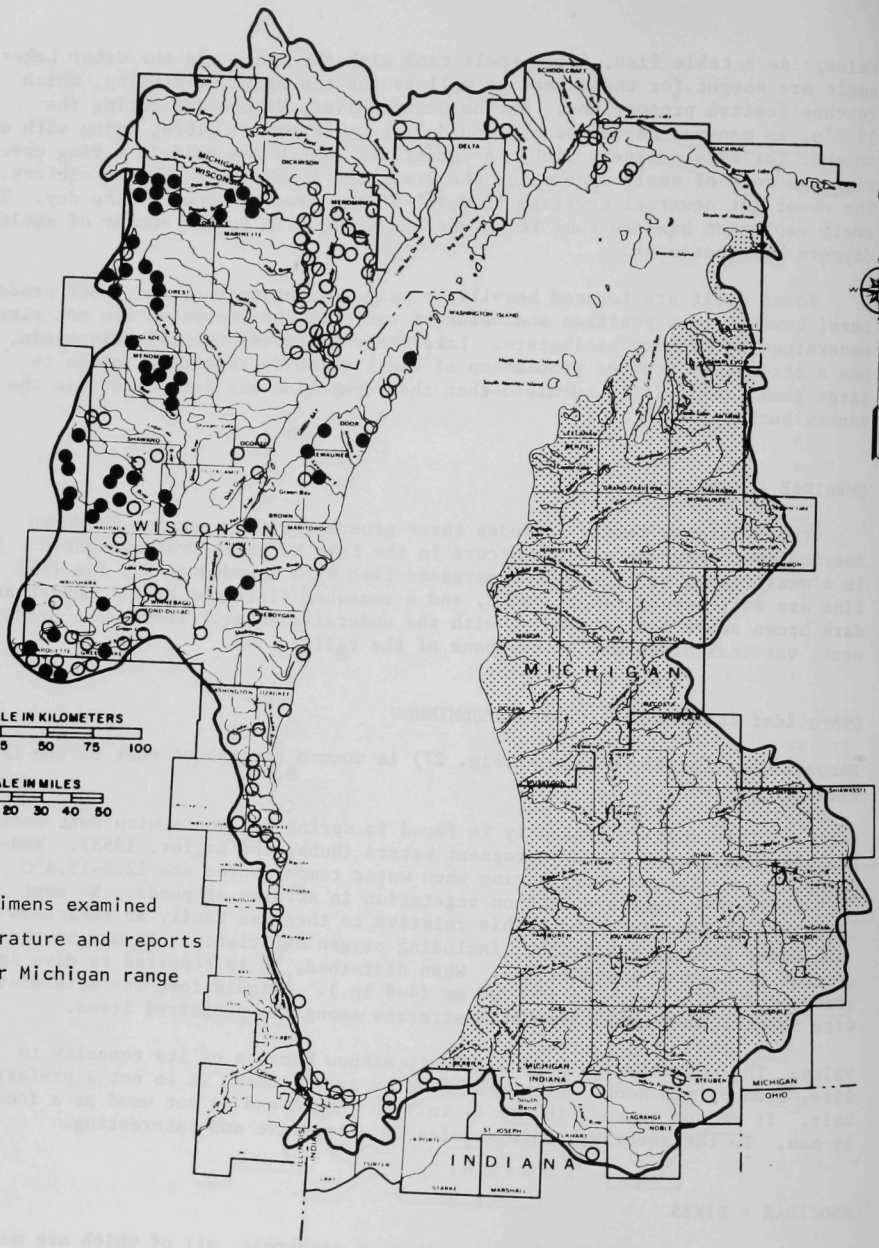

Fig. 27. Distribution of the Central Mudminnow (*Umbra limi*).

well armed with large canine-type teeth. There is a single soft-rayed fin far back on the body. Three species are found in the Basin, two of which, the northern pike and the muskellunge, are frequent fishing targets.

Esox americanus vermiculatus Lesueur. GRASS PICKEREL

Range: The grass pickerel (Fig. 28) occurs in the lower half of the Lake Michigan Drainage Basin, where it is common. In the Basin, it is at the northern limit of its range.

Habit: This species is usually found in quiet, weedy waters over a mud bottom. Spawning of the grass pickerel occurs mainly in the spring immediately after the ice goes out. The fish congregate in sloughs at temperatures of 4.4-11.7°C (40-53°F). No nest is built. The eggs are broadcast and abandoned; they settle and adhere to vegetation, hatching in 11-15 days at water temperatures of 7.8-8.9°C (46-48°F). A 157-mm (6-3/16 in.) female in Michigan had an estimated total egg count of 15,700, of which 800 were ready for spawning and the remainder were in two different recruitment stages (Scott and Crossman, 1973). There is evidence that a secondary spawning may occur in the fall. Scott and Crossman (1973) postulated that changing water temperature (upward in spring, downward in fall), not just the increase in temperature, is the stimulus to spawning. Significant differences between the early post-hatching stages of the grass pickerel and the northern pike are discussed by Kleinert and Mraz (1966).

Young pickerel eat zooplankton. Mature fish may be only 102 mm (4 in.) in length (McCarraher, 1960). In grass pickerel over 102 mm (4 in.), the diet is almost completely fish and crayfish, with occasional fly nymphs (Scott and Crossman, 1973). Trautman (1957) recorded maximum size in the United States as 381 mm (15 in.) in length and 397 g (14 oz) in weight. Scott and Crossman (1973) reported its lower tolerance level to oxygen concentration as 0.3-0.4 ppm in Michigan. The range of pH in Canadian habitats is 6.26-8.32.

Value: The fisherman's interest in this species is small because the overall size of the fish is insufficient for the pan. It will take baited hooks and can provide enjoyable sport on very light tackle. The impact of pickerel on populations of other fishes, particularly northern pike, may be detrimental, and Kleinert and Mraz (1966) suggested that management efforts should be directed at preventing the spread of the species. The grass pickerel is easily maintained in aquaria and makes a handsome aquarium fish, but it usually requires live fishes or crayfishes as food (Scott and Crossman, 1973).

Esox lucius Linnaeus. NORTHERN PIKE

Range: The northern pike (Fig. 29) is common and is present throughout the Lake Michigan Drainage Basin (including all counties of the Upper Peninsula of Michigan). A mutant form of the northern pike, called the "silver pike" or "silver muskellunge", has been reported from two lakes in Marinette County, Wisconsin (Thuemler, 1975--personal communication).

Habits: This species inhabits cool to moderately warm, generally weedy, lakes, ponds, and sluggish rivers (Hubbs and Lagler, 1958). It is an early

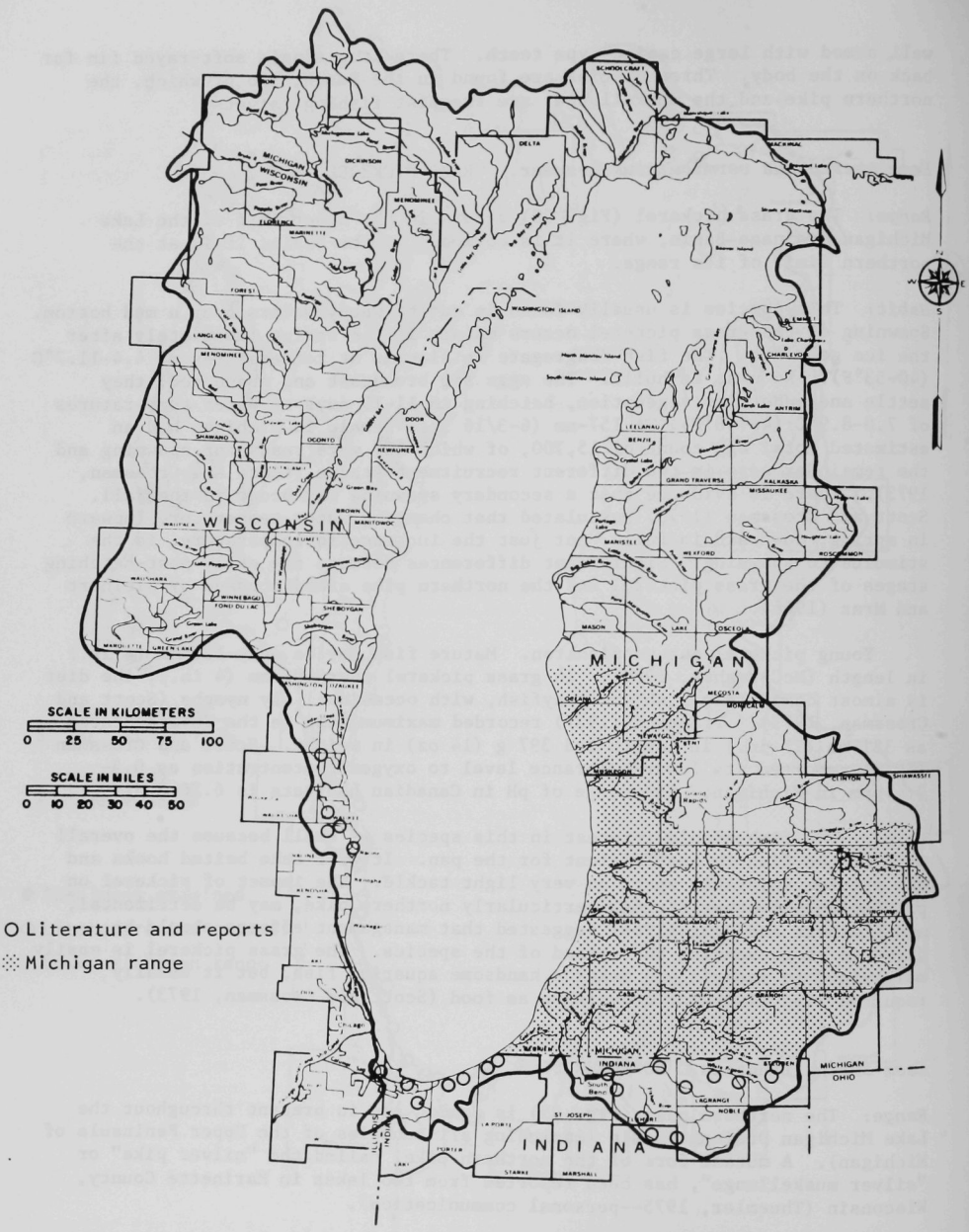

Fig. 28. Distribution of the Grass Pickerel (*Esox americanus vermiculatus*).

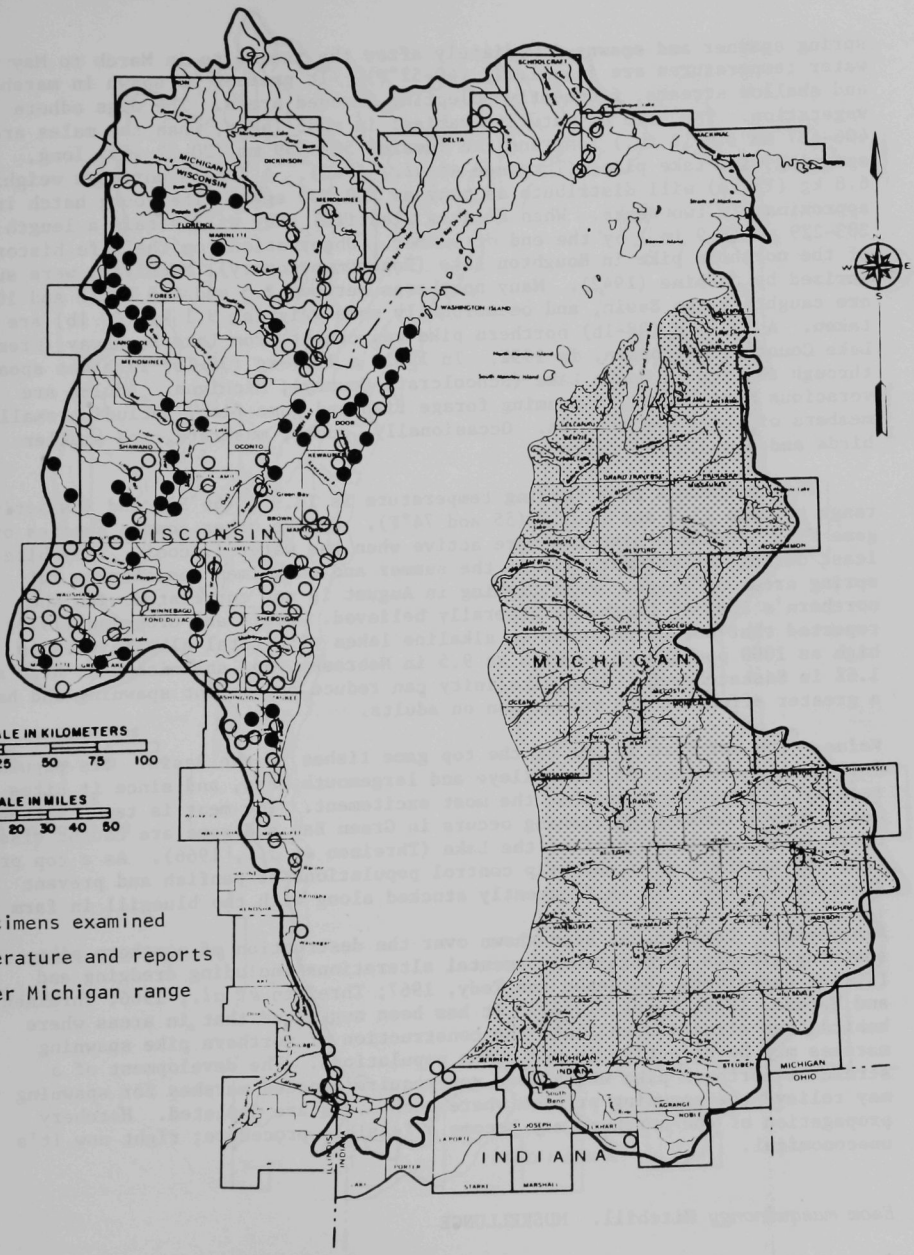

Fig. 29. Distribution of the Northern Pike (*Esox lucius*).

spring spawner and spawns immediately after the ice melts in March to May when water temperatures are 4.4-11.1°C (40-52°F). It prefers to spawn in marshes and shallow streams, frequently selecting flooded areas. The eggs adhere to vegetation. The size at maturity varies; in most lakes, when the males are 406-457 mm (16-18 in.) long and the females 508-559 mm (20-22 in.) long, spawning will take place (Threinen *et al.*, 1966). A female northern weighing 6.8 kg (15 lb) will distribute as many as 100,000 eggs. The young hatch in approximately two weeks. When food is plentiful they will attain a length of 203-229 mm (8-9 in.) by the end of summer. Observations on the life history of the northern pike in Houghton Lake (Roscommon County), Michigan, were summarized by Carbine (1942). Many northerns between 2.3 and 4.5 kg (5 and 10 lb) are caught in the Basin, and occasionally some weighing 9.1 kg (20 lb) are taken. A 17.2-kg (38-lb) northern pike was caught from Lake Puckaway (Green Lake County), Wisconsin, in 1952. In 1961, a 17.7-kg (39-lb) fish was speared through the ice in Dodge Lake (Schoolcraft County), Michigan. Adults are voracious meat-eaters, consuming forage fish and game fish, including smaller members of their own species. Occasionally, ducks, muskrats, and smaller birds and mammals are eaten.

The northern's peak feeding temperature is 18.9°C (66°F), and its active range between 12.8 and 23.3°C (55 and 74°F). Unlike other common species of game fish, northern pike are more active when the water is cool. They bite least during the warmest part of the summer and sometimes concentrate in spring areas or seeps. Poor fishing in August is not correlated with the northern's loss of teeth, as generally believed. Scott and Crossman (1973) reported that northerns occur in alkaline lakes with total alkalinities as high as 1000 ppm and pH as high as 9.5 in Nebraska, and salinities as high as 1.6% in Saskatchewan. High alkalinity can reduce or prevent spawning and has a greater effect on the young than on adults.

Value: The northern is one of the top game fishes in the Basin. Its popularity follows closely that of the walleye and largemouth bass, and since it bites readily it probably furnishes the most excitement. The meat is tasty although quite bony. Commercial fishing occurs in Green Bay and some are caught elsewhere in the northern part of the Lake (Threinen *et al.*, 1966). As a top predator, the northern pike may help control populations of panfish and prevent stunting in them. It is frequently stocked along with the bluegill in farm ponds.

Management: Concern has been shown over the destruction of northern pike spawning grounds through environmental alterations including dredging and filling operations (Borgeson and Tody, 1967; Threinen *et al.*, 1966; Threinen and Herman, 1958; Fagot, 1973). It has been suggested that in areas where habitat has already been lost, the construction of northern pike spawning marshes may be effective in restoring populations. The development of a strain of northern pike which does not require flooded marshes for spawning may relieve the spawning problem where such areas are depleted. Hatchery propagation of the northern may become a feasible procedure; right now it's uneconomical.

Esox masquinongy Mitchill. MUSKELLUNGE

Range: The muskellunge (Fig. 30) is uncommon to rare in the northern half of the Lake Michigan Basin; many records are the result of intensive stocking.

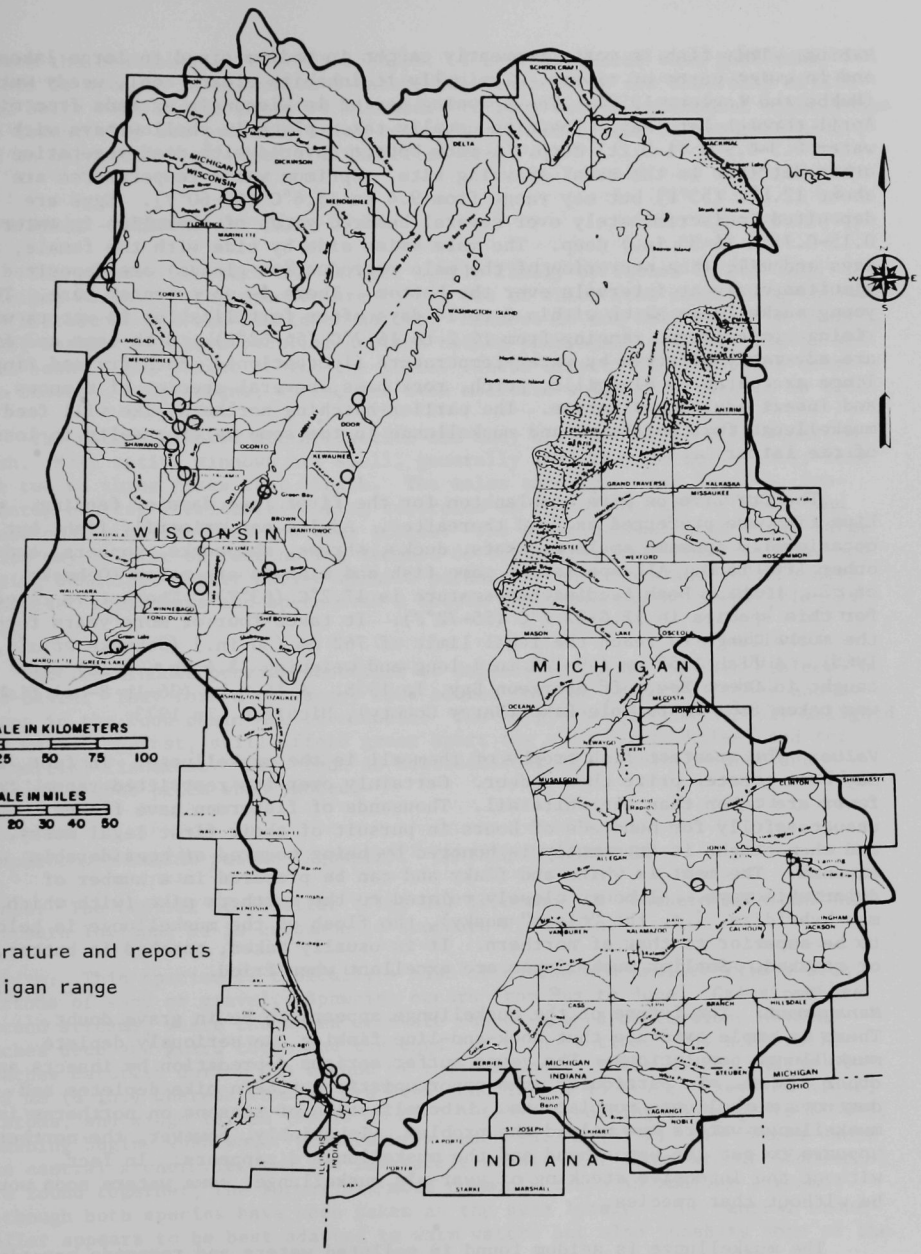

Fig. 30. Distribution of the Muskellunge (*Esox masquinongy*).

Habits: This fish is most frequently caught in medium-sized to large lakes and in quiet parts of rivers. Typically it inhabits clear, cool, weedy waters (Hubbs and Lagler, 1958). The spawning period in Wisconsin extends from mid-April through late May. Spawning usually takes place in shallow bays with water 0.3-0.9 m (1-3 ft) deep. A muck bottom covered with dead vegetation and other detritus is the usual spawning site. Optimum water temperatures are about 12.8°C (55°F) but may range from 9.4 to 15.6°C (49-60°F). Eggs are deposited indiscriminately over several hundred yards of shoreline in water 0.15-0.76 m (6-30 in.) deep. The male swims side by side with the female, and eggs and milt (the secretion of the male reproductive glands) are deposited simultaneously at intervals over the bottom. There is no parental care. The young muskellunge hatch within 8 to 14 days after fertilization in waters with rising temperatures ranging from 12.2 to 16.7°C (54-62°F). Both eggs and fry are adversely affected by water-temperature fluctuations. Both fry and fingerlings are eaten by bluegills, perch, rock bass, several species of minnows, and insect adults and larvae. The earlier-hatching northern pike will feed on muskellunge fry; northerns and muskellunge in the same water results in loss of the latter.

The fry live on live zooplankton for the first four days of feeding. Live fish are preferred as food thereafter. Adults eat primarily fish, but occasionally consume small muskrats, ducks, shrews, chipmunks, gophers, and other live food. All species of game fish and minnows are eaten (Oehmcke *et al.*, 1965). Peak feeding temperature is 17.2°C (63°F). The active range for this species is 12.8-22.2°C (55-72°F). It takes four or more years for the muskellunge to reach the legal limit of 762 mm (30 in.) (Oehmcke *et al.*, 1965). A fish 1257 mm (49-1/2 in.) long and weighing 13.6 kg (30 lb) was caught in Green Bay, off Sturgeon Bay, in 1938. A 16.6-kg (36-lb 8-oz) fish was taken from Thornapple Lake (Barry County), Michigan, in 1973.

Value: The greatest fish trophy of them all is the muskellunge. In fact, it may be a greater prize than a deer. Certainly over its restricted range, far fewer are taken than the whitetail. Thousands of fishermen have fished unsuccessfully for hundreds of hours in pursuit of their first legal musky, and when caught it frequently is honored by being mounted at considerable expense. The meat is white and flaky and can be prepared in a number of delectable ways. Although closely related to the northern pike (with which it may hybridize, *i.e.* the "tiger" musky), the flesh of the muskellunge is held to be superior to that of northern. It is usually baked, poached in butter, or steaked. Smaller muskellunge are excellent when fried.

Management: The future of the muskellunge appears to be in grave doubt. There is ample evidence that hook-and-line fishing can seriously deplete muskellunge populations. The young suffer serious depredation by insects and other fishes. In particular, the opportunistic northern pike depletes and destroys muskellunge populations. Liberalization of seasons on northerns in muskellunge waters has helped the problem. Invariably, however, the northern appears to get the upper hand and the muskellunge disappears. In fact, without the intensive stocking of year-old muskellunge, some waters soon would be without that species.

The muskellunge is seldom found in polluted waters and responds negatively where there is excessive human development on lakeshores. It prefers cooler water than the northern pike. Drastic measures may have to be adopted to

ensure the continuation of this species. I have suggested that good musky waters be open to fishermen on a catch-and-return basis and that only artificial baits with single hooks be allowed. In many waters undersized muskellunge are taken; they are probably being removed from the system before they have had an opportunity to breed for the first time.

CYPRINIDAE - MINNOWS AND CARPS

The minnows comprise the largest single family of fishes in the Lake Michigan Basin. Forty species are known, two of which (the carp and goldfish) are introduced and the remainder native. Minnows do not have teeth in their jaws; rather they have peculiar devices called pharyngeal or throat teeth set well back in the throat behind the gills. These effectively crush and tear the insects, crustaceans, worms, and even mollusks which they take in as food.

The native minnows are attractive and many have become popular aquarium fish. Most native minnows are small, generally less than 76 mm (3 in.); some are two to three times that length. The males tend to be the largest, frequently bearing formidable-looking tubercles on the snout, top of head, and occasionally on the fins and body scales. The spawning habits of these large males may consist of fascinating defense of territory, nest construction, and mating behavior. Other native minnows parasitize the nests and still others broadcast their eggs and sperm over a bottom which has had no preparation at all.

Native minnows provide thousands of dollars in income to bait dealers in the Basin. They form a necessary food source for the predator fishes and as steps in the food chain are invaluable. The carp, though considerably maligned and warred against, still afford great sport for avid "carpophiles" and for commercial fishermen. Carp rank as delicacies among certain people, and command a good price when smoked.

Campostoma anomalum pullum (Agassiz). CENTRAL STONEROLLER

Range: The central stoneroller (Fig. 31) is common in southern Michigan and northern Indiana; it is uncommon in southern Wisconsin.

Habits: This species is typically a fish of creeks and smaller rivers with bottoms of sand or gravel. Spawning occurs from May to June. Great numbers ascend streams, where the males excavate funnel-shaped depressions several inches deep and guard these and the eggs for a short time. The stoneroller reaches maturity during its second or third summer. Males attain a size of 152 mm (6 in.) whereas females are less than 127 mm (5 in.). They eat algae, diatoms, and midge larvae (Dobie *et al.*, 1948). According to Langlois (1941), spawning begins when water temperatures reach 18.3°C (65°F). In waters where the central stoneroller and the largescale stoneroller (*Campostoma oligolepis*) are found together, the former are more commonly taken in smaller streams, although both species have been taken at the same locale. The central stoneroller appears to be best adapted to warm waters but also inhabits some of the borderline trout waters.

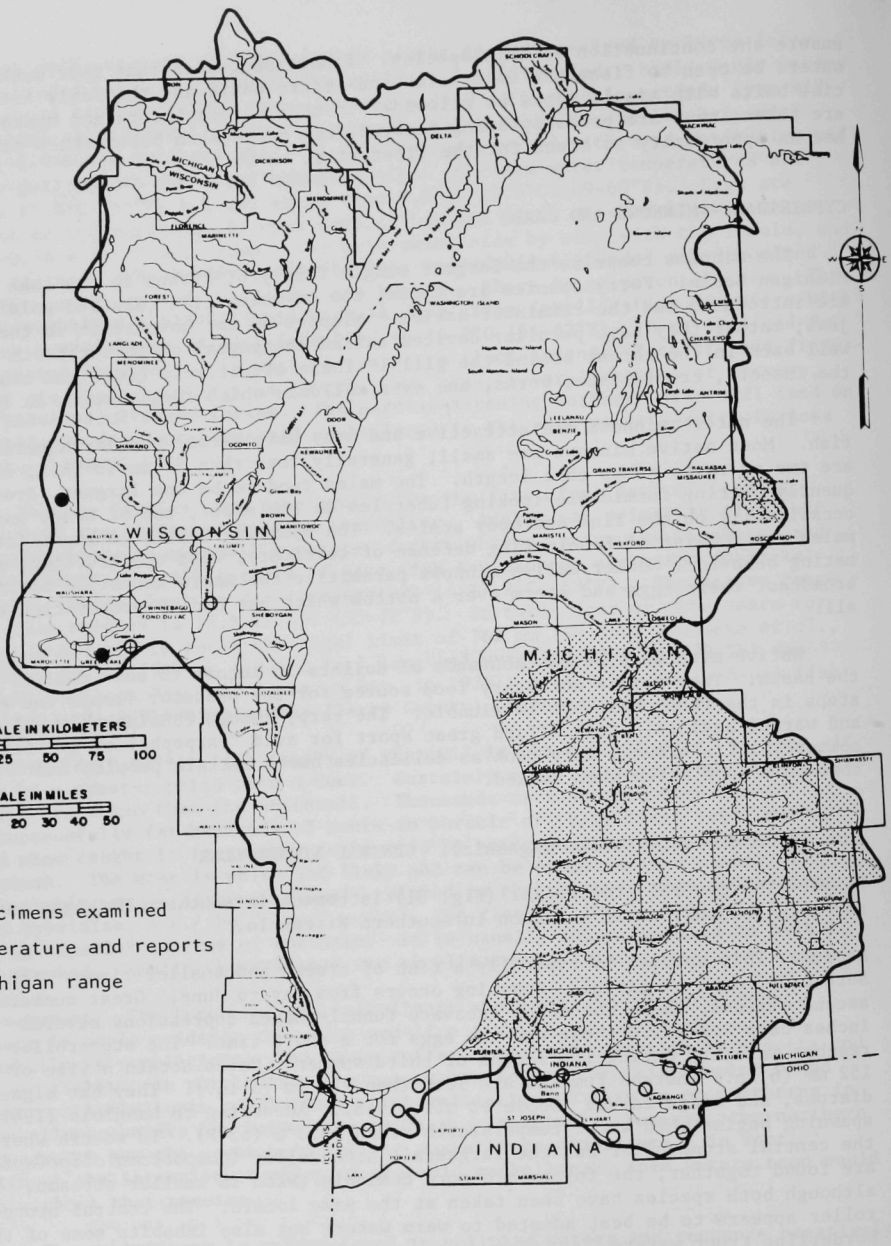

Fig. 31. Distribution of the Central Stoneroller (*Campostoma anomalum pullum*).

Value: Although commonly found in bait dealers' tanks in the Lake Michigan Basin, this minnow is not considered a prime bait minnow nor does it have a reputation for being hardy. Although it is not a table fish in this area, Lennon and Parker (1960) reported that it is prized as a food fish in Tennessee and the Smoky Mountains. These authors found that the spawning stoneroller limits reproduction of rainbow trout (*Salmo gairdneri*) by destroying trout redds.

Campostoma oligolepis Hubbs and Greene. LARGESCALE STONEROLLER

Range: The largescale stoneroller (Fig. 32) has been reported in Wisconsin in the Wolf River and upper Fox River basins, and the tributaries of Lake Michigan from Kewaunee to Kenosha counties.

Habits: This stoneroller is found in central Wisconsin in medium- to large-sized streams and occasionally in large rivers. Little is known about its breeding habits. Preferred food is algal material plucked from stones. Diatoms and midge larvae are taken in large measure.

Status: The largescale stoneroller was recognized as a distinct form by Hubbs and Greene (1935) and given subspecific status (*Campostoma anomalum oligolepis*). Pflieger (1971) noted that this form was reproductively isolated from *Campostoma anomalum*, and he considered it a full species.

Carassius auratus (Linnaeus). GOLDFISH

Range: In the Lake Michigan Basin, goldfish (Fig. 33) records are indicated from the Milwaukee and Chicago areas. Woods (1970) stated that large goldfish could still be seen in the weed beds of the various yacht harbors at Chicago. Smith (1975a--letter) commented:

> *"Meek and Hildebrand (1910) reported both Carassius carassius (Crucian carp) and C. auratus from the Chicago lagoons. I believe the former soon disappeared, but the goldfish and goldfish-carp hybrid are still common in the Chicago area."*

Hubbs and Cooper (1936) stated that in the Lower Peninsula of Michigan *C. auratus* was rare in sluggish waters, lakes, and rivers.

Habits: The following account comes from Dobie *et al.* (1956):

> *"Goldfish normally start spawning when the water reaches [15.6°C] 60°F, and continue to spawn throughout the summer if the temperature remains above 60°F and the fish are not overcrowded. The favorite spawning time is right after sunrise on sunny days. The female lays the eggs on grass, roots, leaves, or similar objects. The eggs are adhesive and stick to any object they touch. The male fertilizes the eggs immediately. ... The eggs hatch in 6 to 7 days in water of 60°F. A female goldfish may lay 2,000 to 4,000 eggs at one time and may spawn several times during the season. ... Goldfish feed largely on plankton, but will take insects and very small fish."*

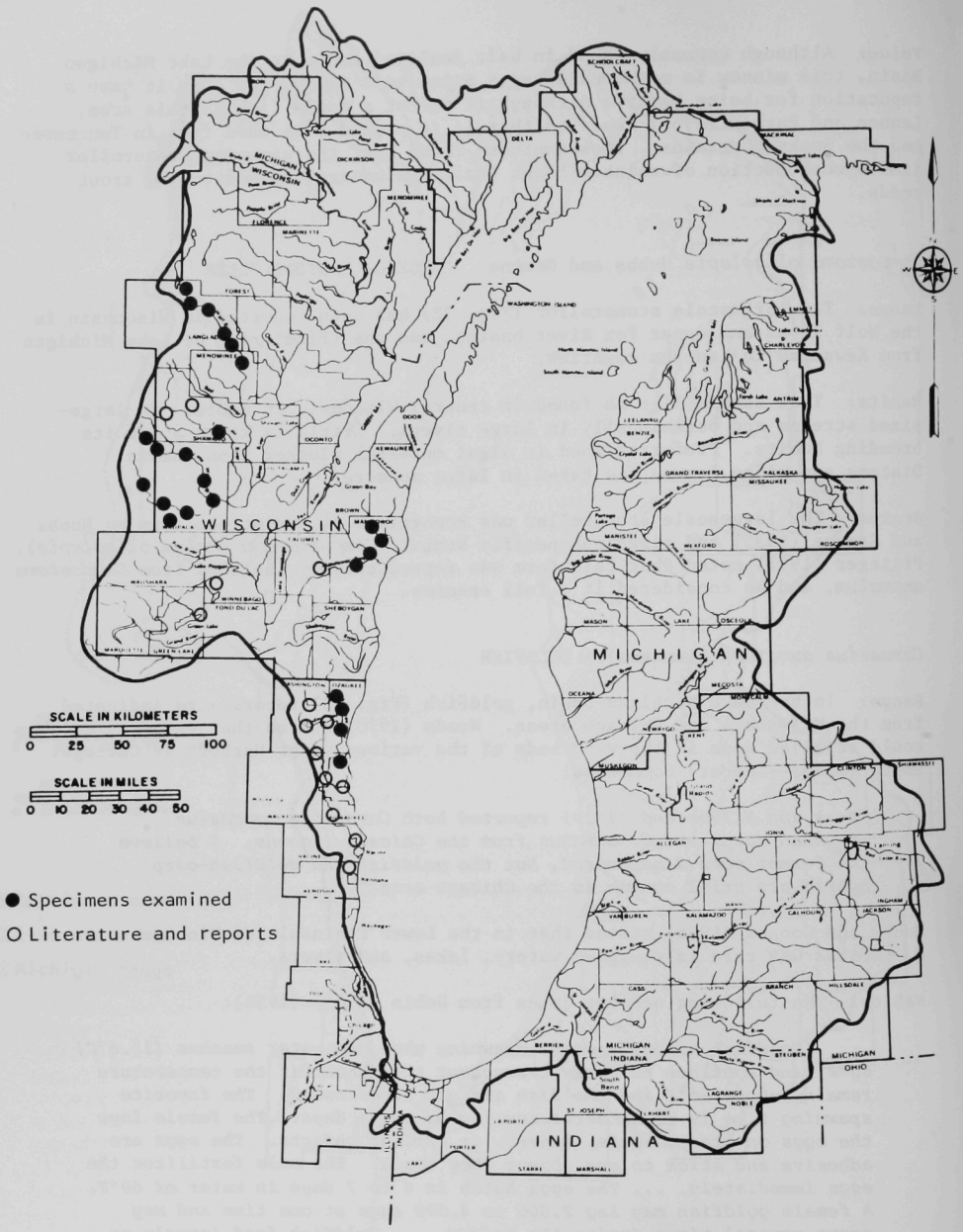

Fig. 32. Distribution of the Largescale Stoneroller (*Campostoma oligolepis*).

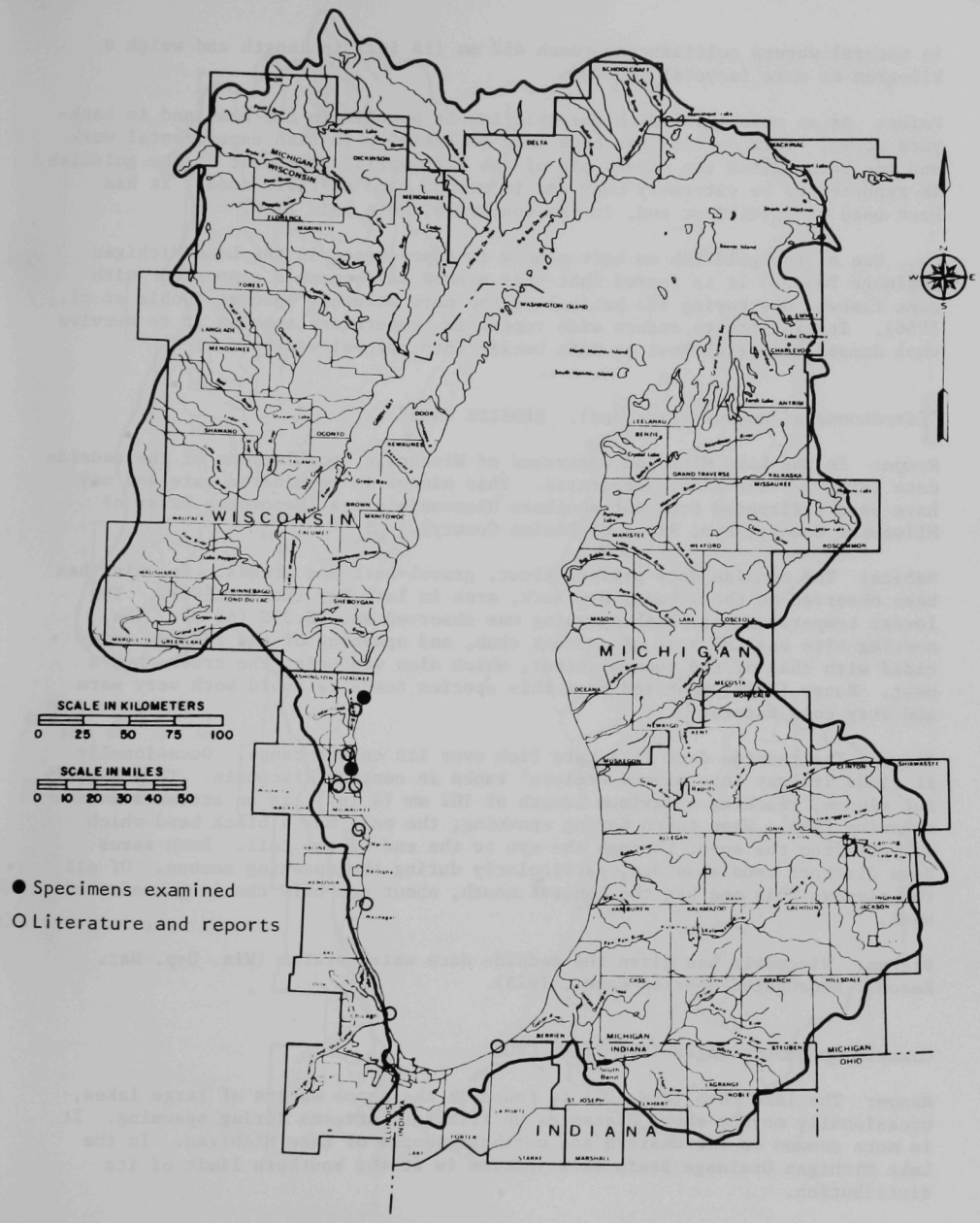

Fig. 33. Distribution of the Goldfish (*Carassius auratus*).

In natural waters goldfish may reach 457 mm (18 in.) in length and weigh a kilogram or more (several pounds).

Value: As an ornamental fish the goldfish is popular in the home and in backyard pools. This species has been used extensively in fish experimental work and has been called the guinea pig of the fish world. The meat of the goldfish is reported to be extremely bony and is seldom used as table food. It has been used as fertilizer and, in the southeast, as a bait fish.

Use of the goldfish as bait minnow is discouraged in the Lake Michigan Drainage Basin. It is feared that this minnow may become a competitor with game fishes, destroying the habitat of the more valuable species (Dobie *et al.*, 1956). Its ability to endure wide ranges in temperature enables it to survive when dumped from fish bowl or bait bucket into natural waters.

Clinostomus elongatus (Kirtland). REDSIDE DACE

Range: In the Lake Michigan watershed of Wisconsin, populations of the redside dace (Fig. 34) are widely separated. This minnow is considered rare and may have been extirpated from the southern Wisconsin sites (Menomonee River of Milwaukee County; Root River of Racine County).

Habits: The redside dace prefers clear, gravel-bottomed creeks. Spawning has been observed in the Ithaca, New York, area in late May (Raney, 1969). The lowest temperature at which spawning was observed was 18.3°C (65°F). The nesting site was the nest of a creek chub, and spawning of the redside coincided with that of the common shiner, which also was using the creek chub's nest. Raney (1969) reported that this species tends to avoid both very warm and very cold waters.

Value: The redside dace is a rare fish over its entire range. Occasionally it finds its way into minnow dealers' tanks in central Wisconsin. This beautiful minnow, reaching a maximum length of 102 mm (4 in.), is an attractive aquarium fish. When taken during spawning, the male has a black band which extends from the snout through the eye to the end of the tail. Both sexes have distinct reddish sides, particularly during the spawning season. Of all the minnows this one has the longest mouth, about one half the length of the head.

Status: Wisconsin has given the redside dace watch status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

Couesius plumbeus (Agassiz). LAKE CHUB

Range: The lake chub (Fig. 35) is found in the shore waters of large lakes, occasionally moving short distances up tributary streams during spawning. It is more common on the western and northern shores of Lake Michigan. In the Lake Michigan Drainage Basin this species is at the southern limit of its distribution.

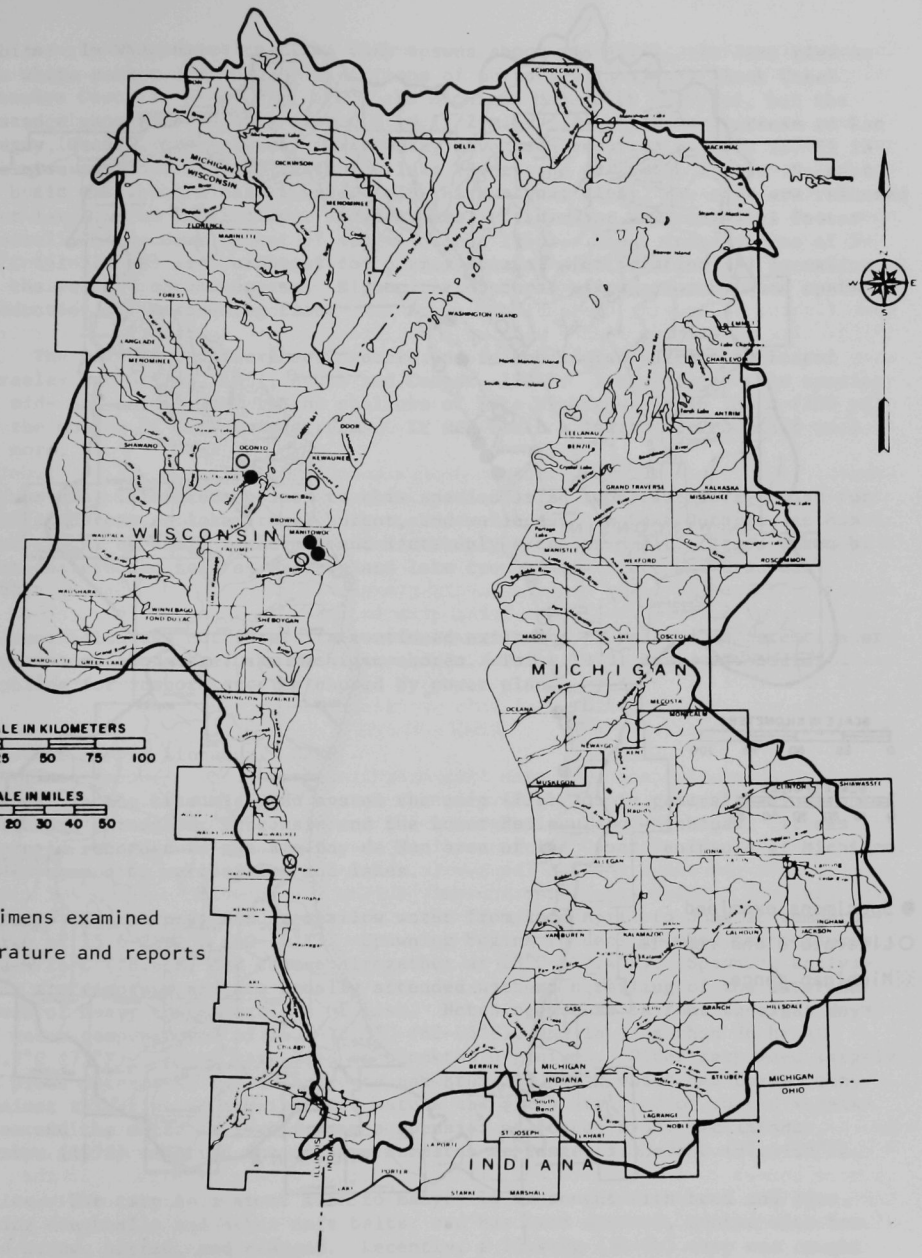

Fig. 34. Distribution of the Redside Dace (*Clinostomus elongatus*).

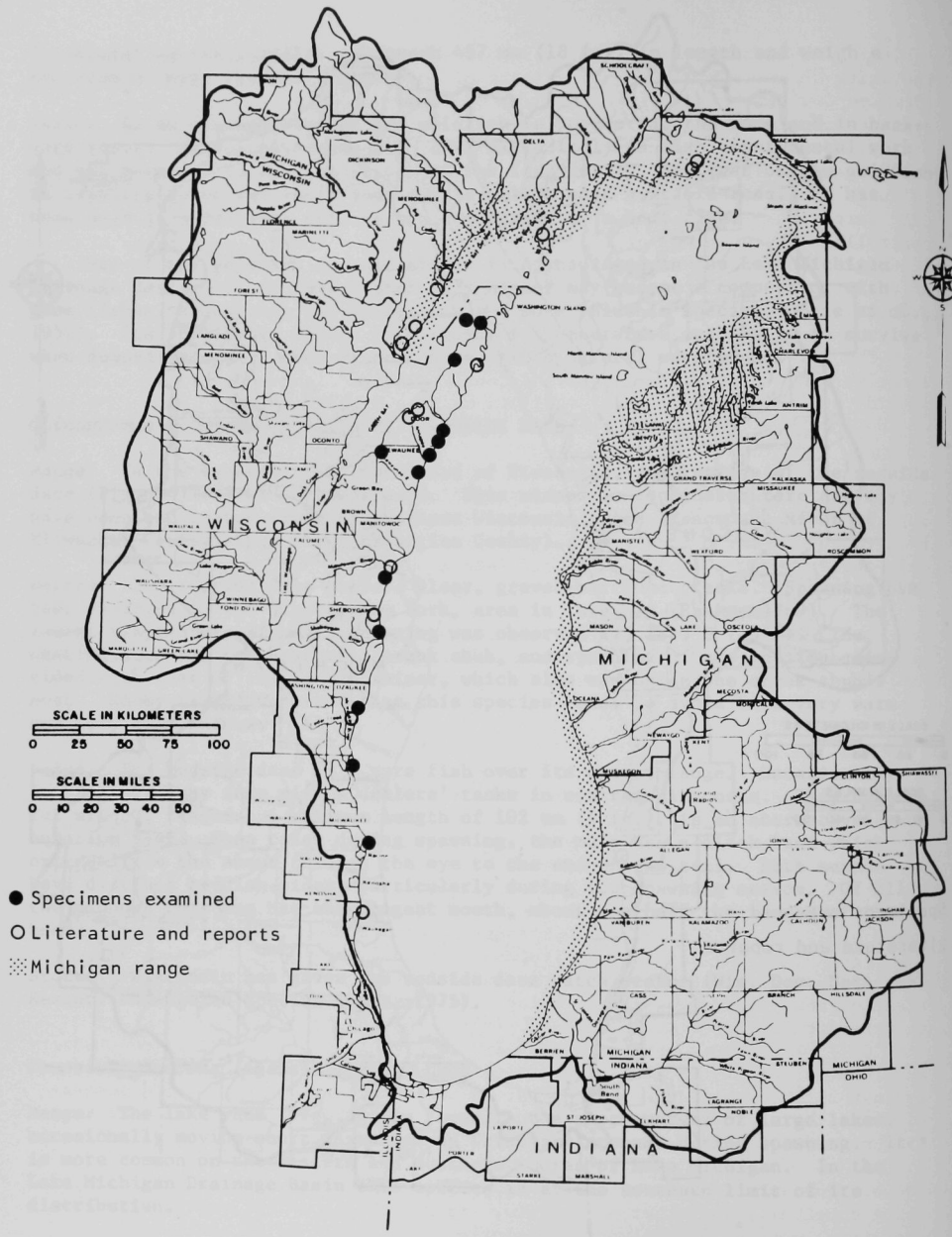

Fig. 35. Distribution of the Lake Chub (*Couesius plumbeus*).

Habits: In Wisconsin, the lake chub spawns about mid-April, the same time as the white sucker and smelt. Migrations of up to 1.6 km (1 mi) [Sauk Creek (Ozaukee County), Wisconsin] from Lake Michigan have been reported, but the distance generally is less than 0.8 km (1/2 mi). In a tributary stream to Lac Saugay, Quebec, temperatures at spawning have been reported as 14°C (57°F) in the stream and 19°C (66.2°F) in the lake (Scott and Crossman, 1973). No nest is built nor are the eggs guarded. In the Montreal River, the eggs are released over large rocks in shallows. Temperature is the major environmental factor controlling the development of sperm (Ahsan, 1966). Lower temperatures of 5-12°C (41-53.6°F) are essential for normal gonadal proliferation and formation of the primary spermatocytes. Higher temperatures hasten or terminate sperm production in prespawning fish.

The lake chub prefers cool waters and is considered a trout indicator (Greeley and Greene, 1931; Hubbs and Cooper, 1936). I have found this species in mid- and late-summer in the shallows of Lake Michigan within 183 m (200 yd) of the mouths of tributary streams. It may reach a length of 203 mm (8 in.) or more.

Value: The literature points to this species as an important forage fish for such predators as lake trout, burbot, and walleyes. In Lake Ontario, it has been caught by smelt fishermen and mistakenly eaten as smelt. It is taken by bait dealers and sold as walleye and lake trout bait (Scott and Crossman, 1973).

Status: Although not rare, its continued existence is related to retention of cool waters along the Lake Michigan shores. Tait (1973) reviewed special problems for inshore species caused by power plants.

Cyprinus carpio Linnaeus. CARP

Range: In the Lake Michigan system the carp (Fig. 36) is generally distributed northward throughout Wisconsin and the Lower Peninsula of Michigan. It was recently recorded in the Big Bay de Noc area of the Upper Peninsula of Michigan. It is common in warm rivers and lakes.

Habits: The carp spawns in shallow water from late April to June at temperatures of 15.6-21.1°C (60-70°F). Spawning begins to decline when temperatures reach 26°C (78.8°F) and ceases altogether at 28°C (82.4°F). Spawning activities are vigorous and are usually attended with much roiling of the water in areas of heavy concentrations of fish. Hatching occurs in four to eight days at water temperatures of 16.7-18.3°C (62-65°F), and in less than 96 hr at 21.7°C (71°F). Young carp feed on plankton organisms. Older carp feed largely on plant materials, including roots and stems, a habit which has turned many against this fish. Carp-infested waters are often stripped of rooted vegetation and the water is turbid from suspension of bottom muds. In Indiana, Gammon (1973) reported the optimum temperature range as 33-36°C (91.4-95°F).

Value: The carp is a sport fish to many. It is sought with hook and line, using doughballs and other soft baits, and has been speared, hunted with bow and arrow, netted, and snagged. Recently, a 15.4-kg (34-lb) carp was caught from the Milwaukee River (Milwaukee County), Wisconsin. A 27.9-kg (61-lb 8-oz) fish was taken from Big Wolf Lake (Jackson County), Michigan, in 1974.

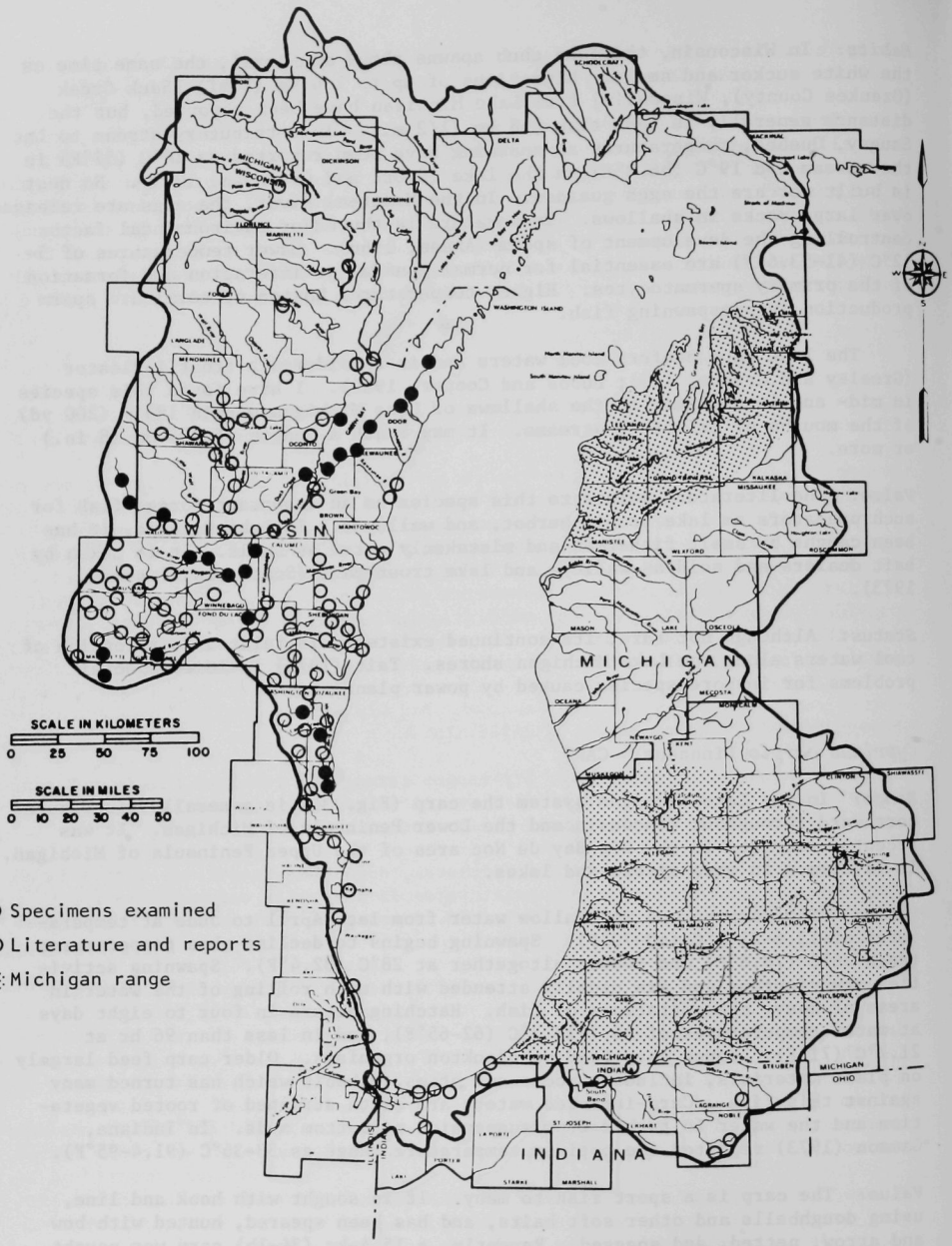

Fig. 36. Distribution of the Carp (*Cyprinus carpio*).

In many waters of the southern part of Lake Michigan, the carp is first in numbers and fish biomass.

Young carp are probably consumed by such game fishes as northern pike, muskellunge, and largemouth bass, although it is not known to what extent. Commercially, more and more carp are taken in fishermen's nets, and a substantial part of the catch from Green Bay and Lake Winnebago, Wisconsin, is of this species. Prices to the commercial fisherman for fresh fish in the round are only 5 to 10¢ per pound, but the consumer pays close to $1 per pound for carp fillets and smoked chunks. Smoked carp is becoming increasingly popular and carp meat products, where sold, are finding a growing market.

Ericymba buccata Cope. SILVERJAW MINNOW

Range: Records of the silverjaw minnow (Fig. 37) lie entirely within the Indiana tributaries to Lake Michigan. This species is considered common here.

Habits: The silverjaw inhabits the sandy stretches of small, clear, permanent-flowing streams. It seems to be the ecological counterpart of the plains-inhabiting *Notropis dorsalis* (bigmouth shiner) in the clearer and more stable streams in the eastern and southern parts of the Mississippi Valley (Pflieger, 1971). Trautman (1957) noted that it has a surprisingly high tolerance to turbidity and to domestic and industrial pollutants, especially mine wastes, provided these do not cover the sand. In Indiana, two major spawnings occur from the end of April to at least the end of July (Wallace, 1973). The silverjaw is a small minnow, and occasionally reaches a length of 102 mm (4 in.).

Hybognathus hankinsoni Hubbs. BRASSY MINNOW

Range: The brassy minnow (Fig. 37) ranges throughout the Lake Michigan Basin except along the southern edge. Its status is common. In the Basin, this species is near the southern edge of its range.

Habits: The brassy minnow occurs in creeks, bog lakes, and occasionally in big rivers. Spawning occurs in quiet water in the early spring (Eddy and Underhill, 1974). In Wyoming, Copes (1975) observed spawning in the last week of May at water temperatures from 15.6 to 26.7°C (60-80°F) in and over vegetation. The slightly adhesive eggs cling to vegetation. Dobie *et al.* (1956) stated that adhesive eggs probably are scattered over bottom sand, mud, or debris early in the spring when water temperatures reach 10-12.8°C (50-55°F). Growth is slow and maturity probably is reached at the age of two years with a length of 64 to 76 mm (2-1/2 to 3 in.). The brassy minnow feeds on phytoplankton, zooplankton, and some aquatic insects. The largest individuals approximate 102 mm (4 in.). In field studies (Copes, 1975), it survived a maximum water temperature of 28.9°C (84°F), minimum temperatures near 0°C (32°F) for prolonged periods, and daily variations in water temperature of as much as 17.8°C (32°F).

Value: This species is considered to be a valuable bait and forage minnow in many parts of the United States and is sold as walleye, crappie, and perch bait. It is readily subject to predation by other fishes.

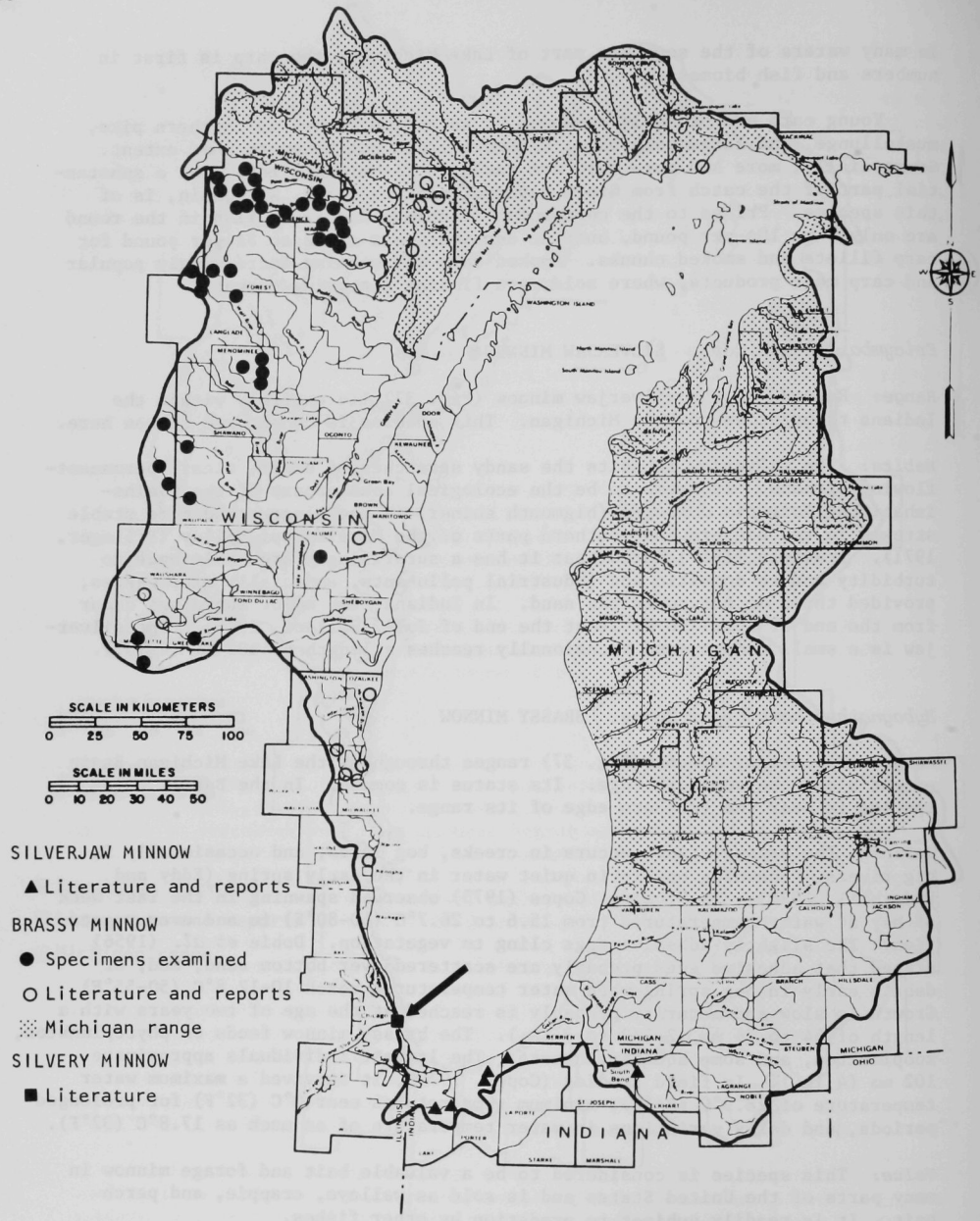

Fig. 37. Distribution of the Silverjaw Minnow (*Ericymba buccata*), Brassy Minnow (*Hybognathus hankinsoni*), and Silvery Minnow (*Hybognathus nuchalis*).

Hybognathus nuchalis Agassiz. SILVERY MINNOW

Range: Hubbs and Lagler (1958) noted that the silvery minnow (Fig. 37) generally avoided the Great Lakes basin but was once reported from the Detroit River and once from the mouth of the Chicago River (Forbes and Richardson, 1920) at the head of the Chicago Drainage Canal. However, Hubbs and Lagler were unable to verify these reports and believed that they may have been based on *H. hankinsoni*. Smith (1975a--letter) concurred that the Chicago record is probably in error, but he pointed out that this species was once common in northeastern Illinois and although it no longer occurs there, the possibility exists that it may have at one time.

Habits: The silvery minnow occurs in large silty rivers, pools, backwaters, and oxbows. The spawning habits were described by Raney (1939) from Cayuga Lake in New York State. Spawning occurred in late April and early May at temperatures of 13-20.5°C (55.4-68.9°F). Nonadhesive eggs were laid on the bottom ooze in water about 0.3 m (1 ft) deep among emergent grasses and reeds. This minnow will reach a length of 127 mm (5 in.).

Value: The silvery minnow is considered a good bait minnow in parts of the United States. Scott and Crossman (1973) reported that in Maryland it is esteemed by many when deep-fried in oil. It is doubtful that this species now exists in the Lake Michigan Drainage Basin. Even before extirpation, its numbers must have been exceedingly low.

Hybopsis amblops (Rafinesque). BIGEYE CHUB

Range: The bigeye chub (Fig. 38) was reported only once, from Trail Creek (La Porte County), Michigan, by Eigenmann and Beeson (1894). The lack of recent records suggests extirpation of this species from the Lake Michigan Basin although it is commonly reported from the Lake Erie watershed of southeastern lower Michigan.

Habits: Trautman (1957) reported that spawning occurs between late April and early June. The preferred habit is moderate- or small-sized streams in which the gradients are moderate and where there is much clean sand and fine gravel. The same author found that siltation resulted in population decrease. Adults are 51 to 89 mm (2 to 3-1/2 in.) long.

Status: This species appears to be decreasing in abundance over its entire range.

Nocomis biguttatus (Kirtland). HORNYHEAD CHUB

Range: The hornyhead chub (Fig. 38) is present throughout the Lake Michigan Basin, except the northernmost sectors of lower Michigan and the Upper Peninsula of Michigan. It is common throughout its range.

Habits: This chub occurs in clean, gravelly creeks of medium size, and occasionally in gravelly shallows of large rivers and oligotrophic lakes. Spawning occurs late in May and early in June on gravelly riffles in 0.3-0.6 m (1-2 ft) at temperatures of 18.3°C (65°F) or warmer. Mating activities and the transport

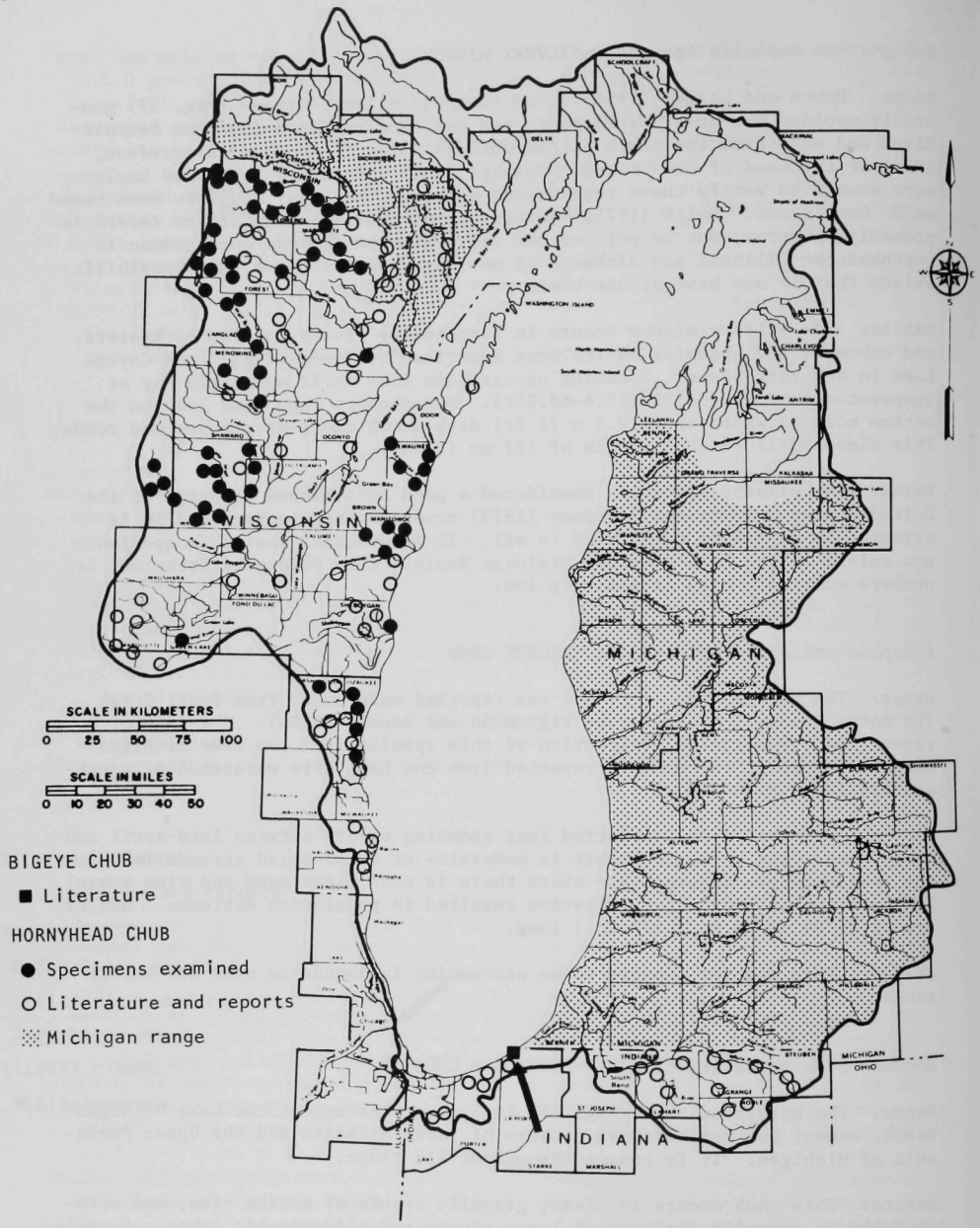

Fig. 38. Distribution of the Bigeye Chub (*Hybopsis amblops*) and Hornyhead Chub (*Nocomis biguttatus*).

of stones into the nest by males are alternated so that the pebbles and eggs are mixed in the nest. The nest pile is large, often covering about 0.3 m^2 (3 ft^2) of bottom, with a cavity 51-152 mm (2-6 in.) deep (Dobie *et al.*, 1956). The nest increases in size with successive spawnings. The hornyhead is a large minnow, and males often reach lengths of 152 mm (6 in.) and over.

Value: The hornyhead is an excellent bait fish for northern pike because of its large size and hardiness on the hook. Hubbs and Cooper (1935) reported that the piles of gravel made by male hornyheads are used as spawning sites by several other species of stream fishes: the blacknose dace, common shiner, striped shiner, rosyface shiner, southern redbelly dace, central stoneroller, and blackside darter. Young hornyheads undoubtedly are preyed upon by other fish. I have eaten this species and know of others who eat them regularly. They are easily taken on worms and dry flies and provide action when other fishing is slow.

Nocomis micropogon (Cope). RIVER CHUB

Range: The river chub (Fig. 39) is common in the southern two-thirds of lower Michigan. Its presence in northern Indiana is inferred from numerous records in the St. Joseph River basin of southern Michigan.

Habits: Its breeding habits are similar to that of the hornyhead chub. From mid-April to the end of May, spawning occurs in gravelly streams over a nest of stones built by the male. Spawning occurs at temperatures ranging from 10-25°C (50-77°F) (Reighard, 1943). A channel or depression is first excavated, all sand and fine gravel is removed, and then the depression is filled with newly gathered stones. Each spawning act takes place in a shallow trough constructed for this purpose by the male, and the trough is immediately filled in with small stones and pebbles on completion of the spawning act (Scott and Crossman, 1973). Males are larger than females, reaching a length of over 203 mm (8 in.).

Value: The river chub undoubtedly is used as bait and eaten by man.

Notemigonus crysoleucas (Mitchill). GOLDEN SHINER

Range: The golden shiner (Fig. 40) is common to abundant throughout the Lake Michigan Basin.

Habits: This species prefers lakes but is also common in the quiet sections of some of the larger rivers, frequenting weedy bays and shoals (Dobie *et al.*, 1956). The spawning season extends from the time the water reaches 20°C (68°F) through the rest of the summer. Spawning has been observed in Michigan from June to August with some evidence that it begins in May in some areas (Hubbs and Cooper, 1936). The eggs, which are adhesive and stick to plants, are commonly scattered over filamentous algae and less frequently over rooted aquatic plants. The golden shiner is omnivorous and reaches a maximum length of 254 mm (10 in.); in the northern part of its range, most individuals are less than half that size.

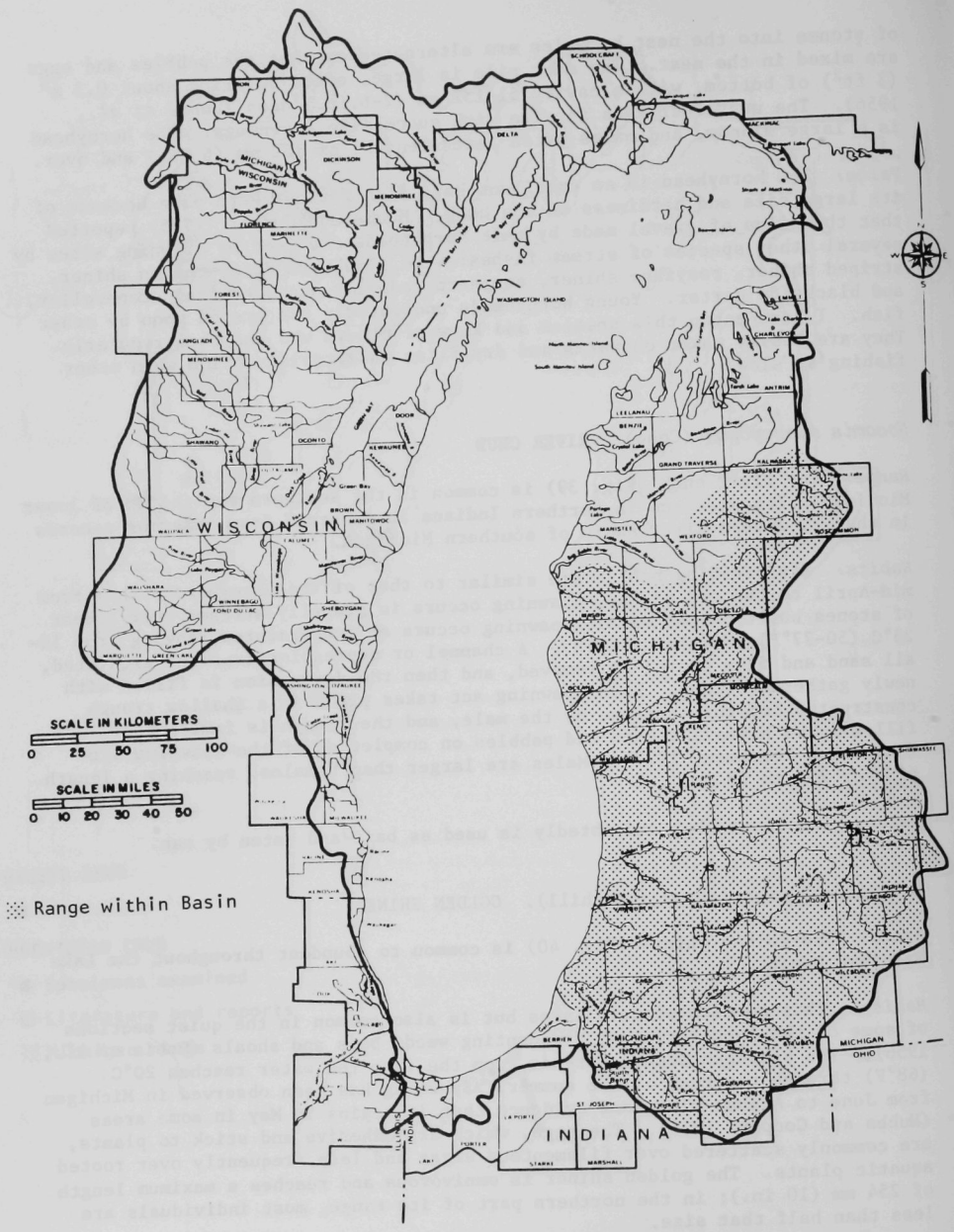

Fig. 39. Distribution of the River Chub (*Nocomis micropogon*).

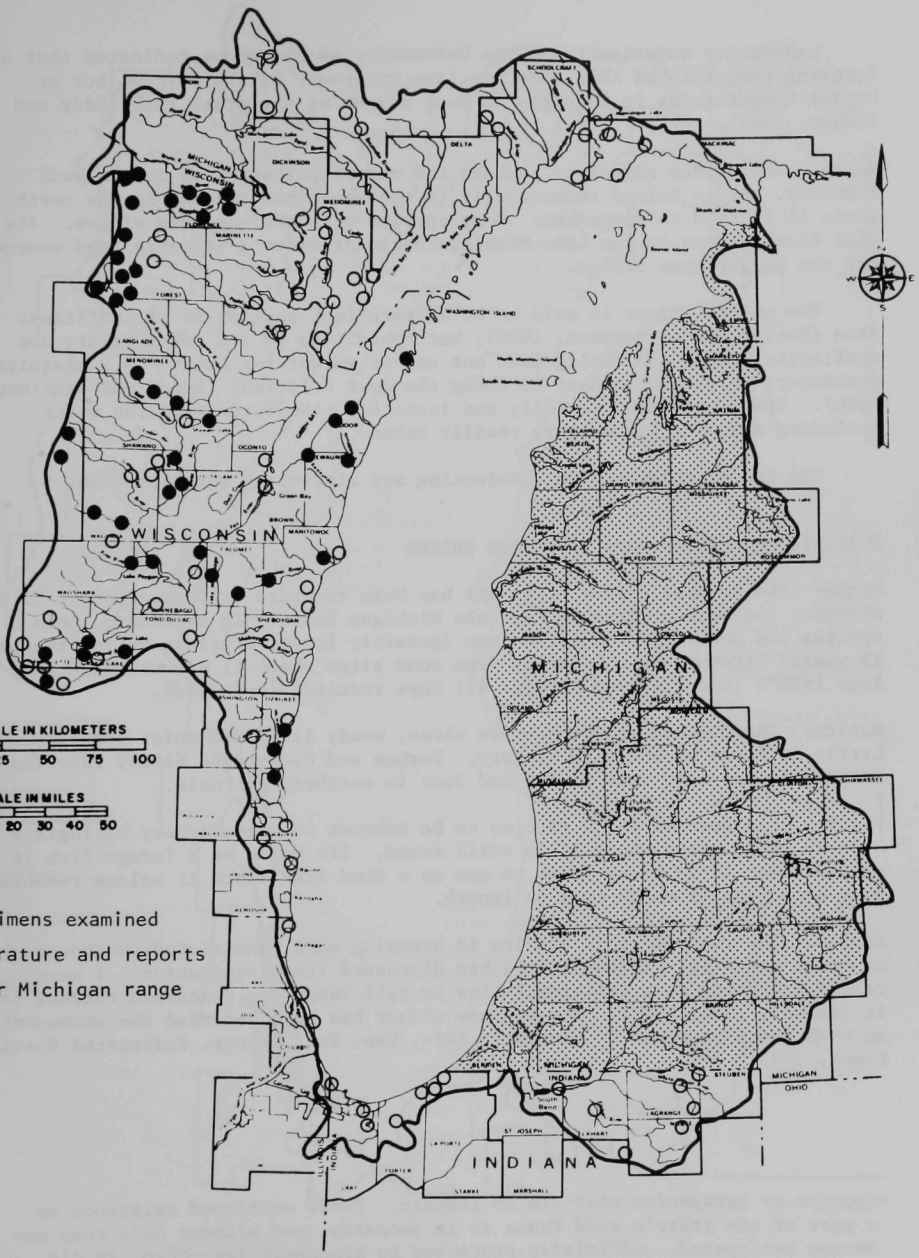

Fig. 40. Distribution of the Golden Shiner (*Notemigonus crysoleucas*).

Laboratory experiments at the University of Minnesota indicated that at freezing temperatures this fish can live with very little oxygen, but at higher temperatures it requires as much oxygen as any other fish (Eddy and Surber, 1947).

Value: The golden shiner is perhaps the most important fish in the bait industry. It is raised commercially in the south and trucked to the north where it is sold to fishermen. Game species bite well on this minnow. Its wide distribution in the Lake Michigan Basin provides a valuable food source for the larger game fishes.

The golden shiner is said to be an excellent panfish if of sufficient size (Forbes and Richardson, 1920), but reports as to its palatability are conflicting and man normally does not use it except for bait. As a mosquito destroyer, this species must be among the most efficient (Adams and Hankinson, 1926). Its mouth opens dorsally and insects on the surface of the water, including mosquito larvae, are readily taken.

The golden shiner is an interesting and attractive aquarium fish.

Notropis anogenus Forbes. PUGNOSE SHINER

Range: The pugnose shiner (Fig. 41) has been recorded at approximately 25 disjunct collection sites in the Lake Michigan Basin. In Wisconsin, this species has been taken only from two (possibly three) stations during the past 15 years; attempts to collect it from some sites where it was taken in the late 1920's (open circles in Fig. 41) have resulted in failure.

Habits: The pugnose shiner prefers clear, weedy lakes and quiet streams. Little is known of its life history. Forbes and Richardson (1920) reported females filled with eggs in May and June in northern Illinois.

Value: This species is so rare as to be unknown to most fishery biologists even in those areas where it is still found. Its value as a forage fish is unknown, and it is of no value to man as a food fish since it seldom reaches much more than 51 mm (2 in.) in length.

Status: The range of this species is becoming more constricted as the result of human activity. Bailey (1959) has discussed its distribution. I have called attention to a decrease in its overall range and discussed reasons for it (Becker, 1961, 1971). The pugnose shiner has been accorded the status of an endangered* species by Wisconsin (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

**Species or subspecies that are in trouble. Their continued existence as a part of the state's wild fauna is in jeopardy, and without help they may become extirpated. Officially protected by Wisconsin law--Chap. 29.415, Wis. Stats.*

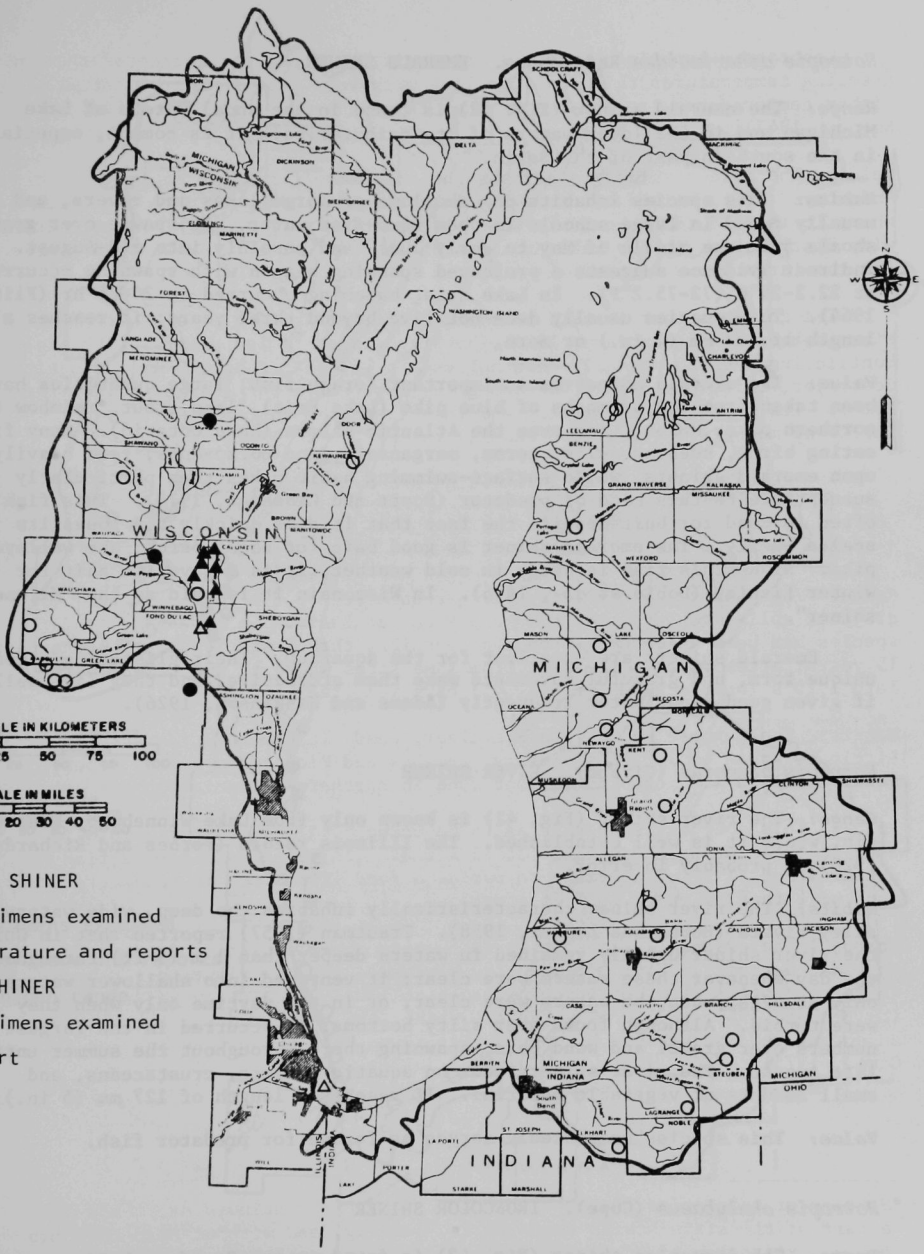

Fig. 41. Distribution of the Pugnose Shiner (*Notropis anogenus*) and River Shiner (*Notropis blennius*).

Notropis atherinoides Rafinesque. EMERALD SHINER

Range: The emerald shiner (Fig. 42) is found in the shoal waters of Lake Michigan and in the lower waters of its tributaries. It is common, especially in the southern part of the Basin.

Habits: This species inhabits the shallows of large lakes and rivers, and is usually found in large schools in open weed-free water. It spawns over gravel shoals from the middle of May to early June, and possibly into mid-August. Indirect evidence suggests a prolonged spawning season with spawning occurring at 22.2-24°C (72-75.2°F). In Lake Erie, hatching occurred in 24-26 hr (Flittner, 1964). This species usually does not live beyond three years; it reaches a length of 102 mm (4 in.) or more.

Value: The emerald shiner is an important forage fish; large quantities have been taken from the stomachs of blue pike (Lake Erie), lake trout, rainbow trout, northern pike, burbot, and even the Atlantic salmon (Lake Ontario). Many fish-eating birds, such as gulls, terns, mergansers, and cormorants, feed heavily upon emerald shiners, whose surface-swimming habit makes them particularly susceptible to this kind of predator (Scott and Crossman, 1973). This fish often is used for bait despite the fact that it dies quickly and loses its scales easily. The emerald shiner is good bait for bass, perch, and walleye pike. Since this fish is hardy in cold weather, it is a favorite bait for winter fishing (Dobie *et al.*, 1956). In Wisconsin it is sold as the "Milwaukee shiner".

Emerald shiners are excellent for the aquarium. Their glistening sides, unique form, and graceful movements make them attractive, and they live well if given good clear water frequently (Adams and Hankinson, 1926).

Notropis blennius (Girard). RIVER SHINER

Range: The river shiner (Fig. 41) is known only from Lake Winnebago, Wisconsin, where it is well established. The Illinois record (Forbes and Richardson, 1920) is probably in error.

Habits: The river shiner characteristically inhabits the deep, wide waters of silty rivers (Hubbs and Lagler, 1958). Trautman (1957) reported that in Ohio the river shiner usually remained in waters deeper than 1 m (3 ft) throughout the day whenever these waters were clear; it ventured into shallower waters only at night when the waters were clear, or in the daytime only when they were turbid. Although found over silty bottoms, it occurred in the largest numbers over gravel and sand bars, spawning there throughout the summer until late August. The river shiner feeds on aquatic insects, crustaceans, and small amounts of vegetable material. It reaches a length of 127 mm (5 in.).

Value: This species undoubtedly serves as forage for predator fish.

Notropis chalybaeus (Cope). IRONCOLOR SHINER

Range: The ironcolor shiner (Fig. 43) is found in the St. Joseph River system of Michigan and Indiana. In Wisconsin, it has been reported from the Fox River (Columbia County), and Blake Creek (Waupaca County) (Johnson and Becker, 1970).

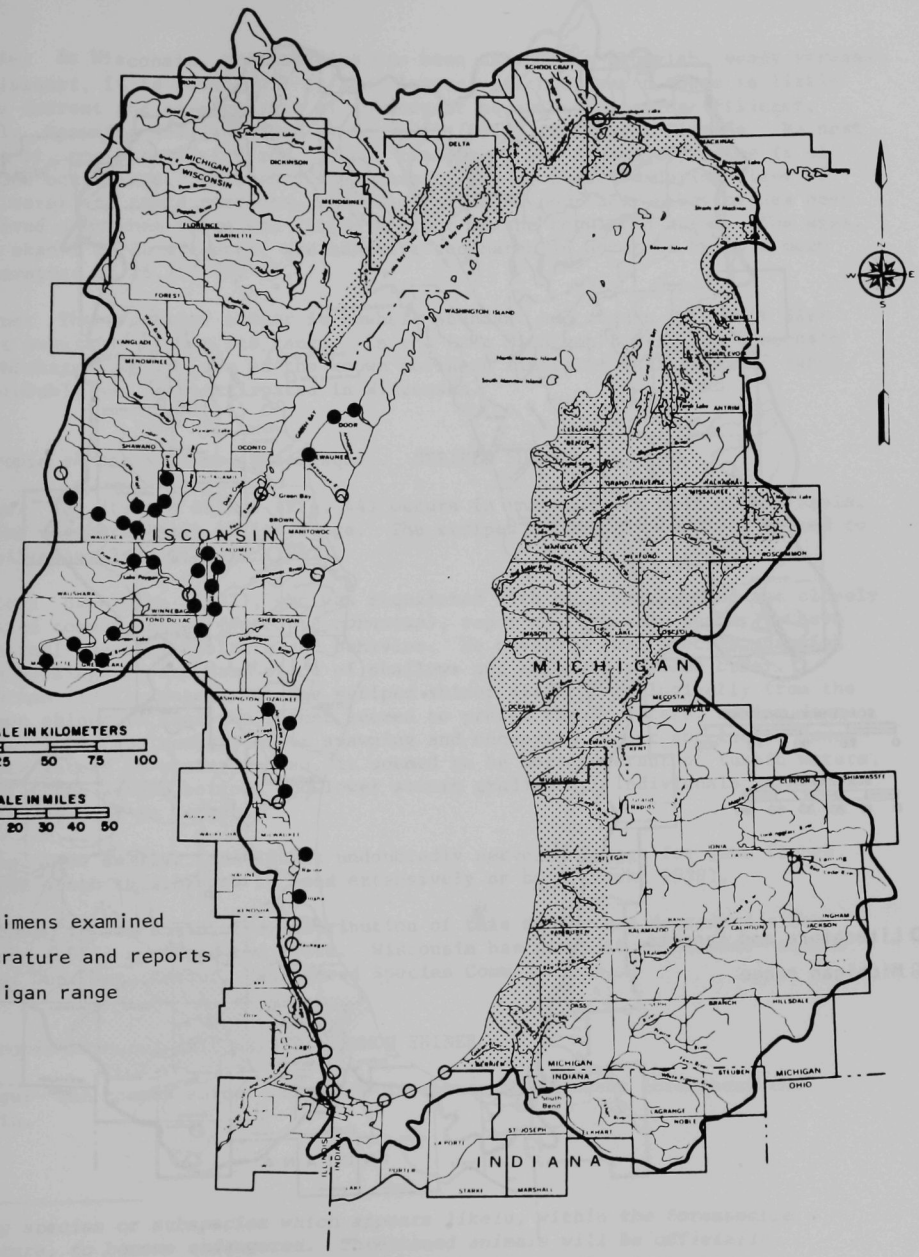

Fig. 42. Distribution of the Emerald Shiner (*Notropis atherinoides*).

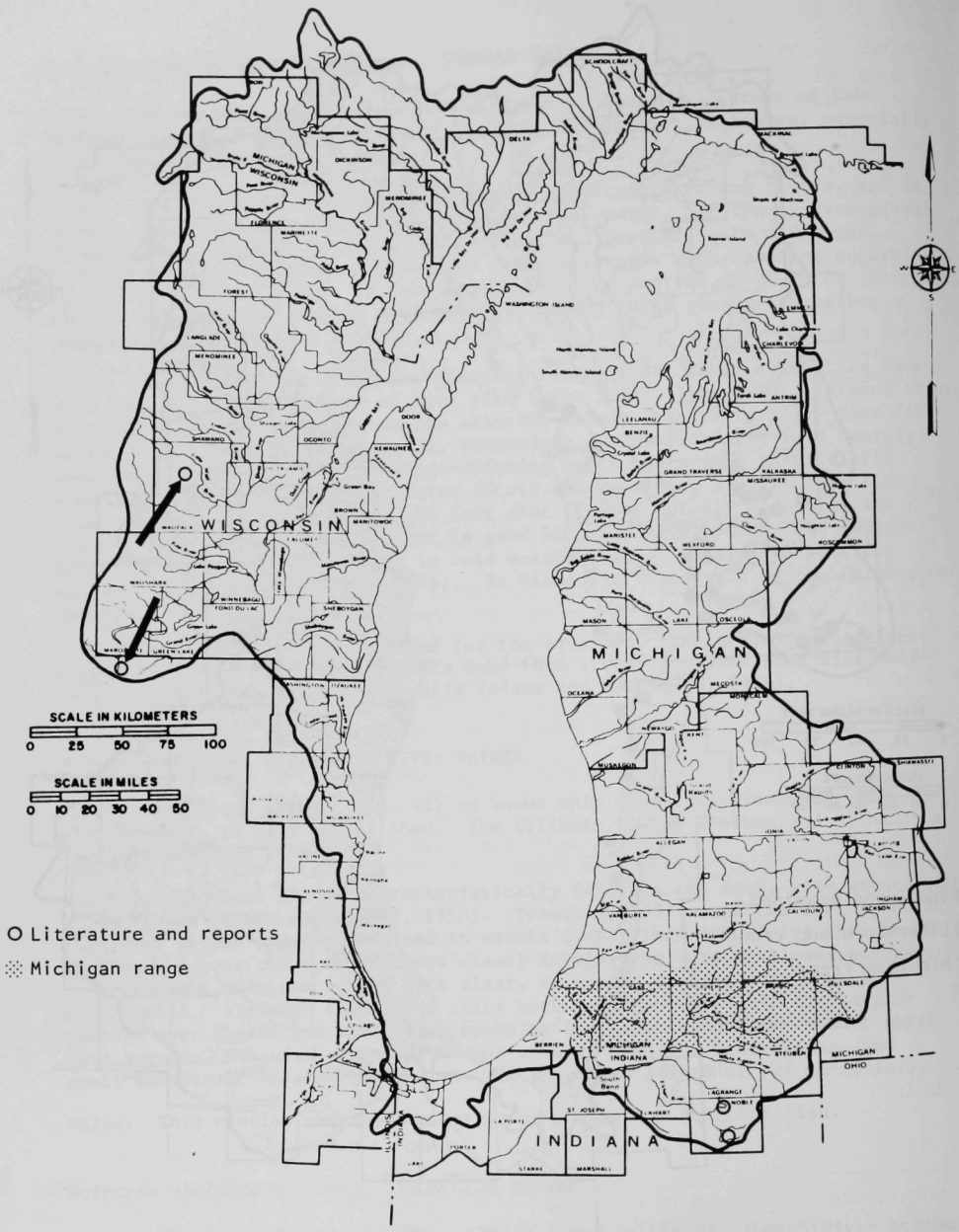

Fig. 43. Distribution of the Ironcolor Shiner (*Notropis chalybaeus*).

Habits: In Wisconsin, this species has been taken from sluggish, weedy streams. In Missouri, it is found only in the clearest ditches, where there is little or no current and an abundance of submergent aquatic vegetation (Pflieger, 1971). Spawning was described by Marshall (1947) in central Florida. No nest is built, nor bottom cleared. Sexual chasing of the females by males is of regular occurrence. Whereas sexual chasing may be observed during times of high water and rapid currents, the culmination of courtship behavior has been observed only when there was little current in the populated areas. The eggs, less than 1 mm in diameter, are adhesive and hatch in about 54 hr at a mean temperature of 16.7°C (62°F).

Status: The ironcolor shiner is nowhere abundant and occurs in widely disjunct populations over its range. In the Lake Michigan Basin, the Wisconsin and Michigan records are at the known northern limits of this species' range. It probably has been extirpated in Wisconsin.

Notropis chrysocephalus (Rafinesque). STRIPED SHINER

Range: The striped shiner (Fig. 44) occurs in the southern half of the Basin, at the northern limit of its range. The striped shiner was recently raised to specific level by Gilbert (1961).

Habits: Hankinson (1932), who was acquainted with this species and the closely related common shiner (*Notropis cornutus*), reported that they appear to have identical spawning habitats and behavior. He observed both species spawning with holdings on the same piece of shallows and adjacent to each other. Trautman (1957) stated that the striped shiner differed ecologically from the common shiner in that the former seemed to prefer warmer waters, moving downstream in larger numbers after spawning and occupying deeper and larger downstream waters in winter. Also, it seemed to be more tolerant of turbid waters, silt on the stream bottom, and lower stream gradients. Individuals may reach 229 mm (9 in.) in length.

Value: The smaller individuals undoubtedly serve as forage for game fishes. In the south this minnow is used extensively as bait (Cook, 1959).

Status: In Wisconsin, the distribution of this minnow has decreased since Greene (1935) surveyed the state. Wisconsin has given it threatened* status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

Notropis cornutus (Mitchill). COMMON SHINER

Range: The common shiner (Fig. 45) is common to abundant throughout the Basin.

**Any species or subspecies which appears likely, within the foreseeable future, to become endangered. Threatened animals will be officially designated, upon passage of pending legislation in the state, and afforded varying degrees of protection as necessary.*

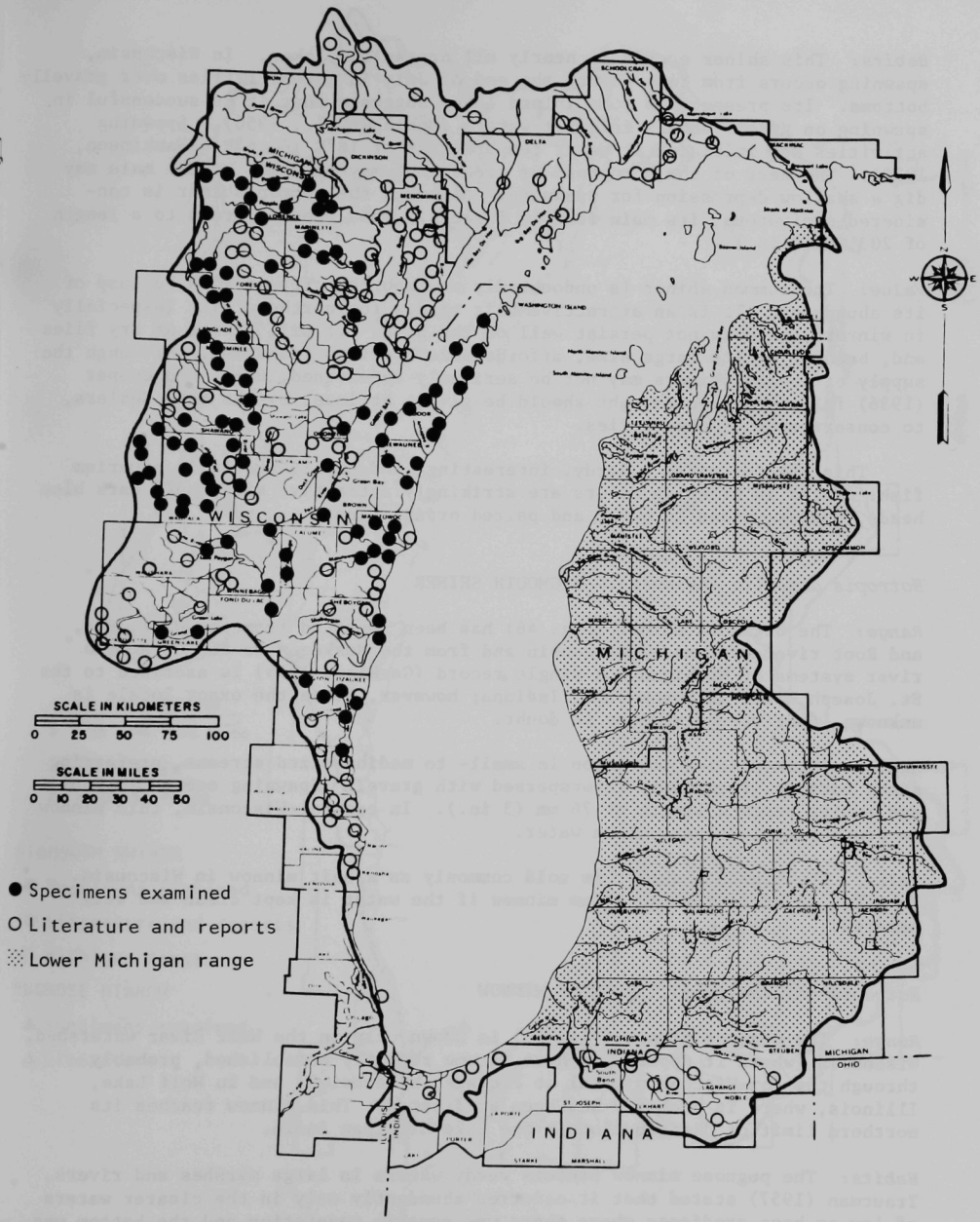

Fig. 45. Distribution of the Common Shiner (*Notropis cornutus*).

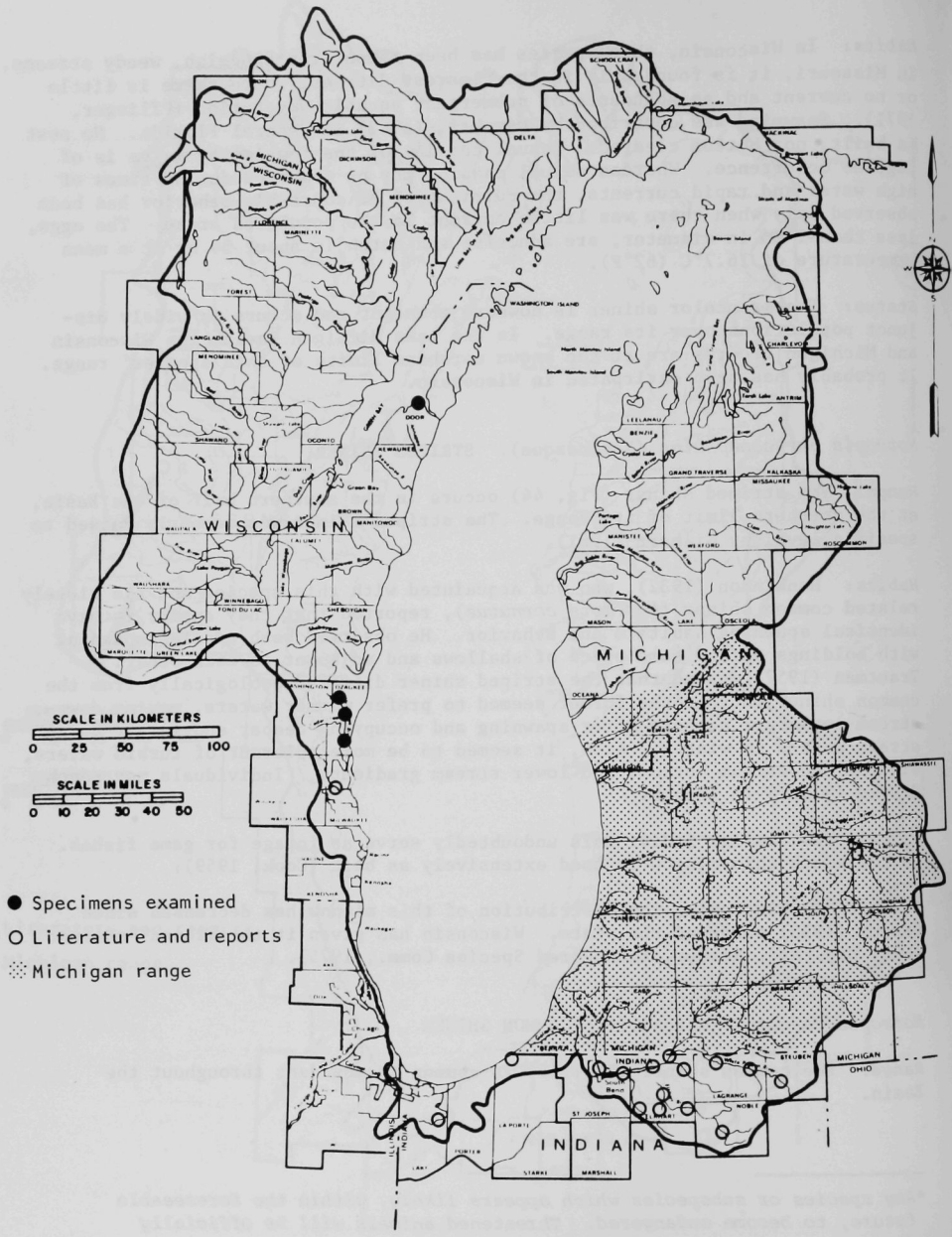

Fig. 44. Distribution of the Striped Shiner (*Notropis chrysocephalus*).

Habits: This shiner occurs in nearly all creeks and lakes. In Wisconsin, spawning occurs from late May to the end of July in stream riffles over gravelly bottoms. Its presence in some inland lakes suggests that it is successful in spawning on gravel shoals in quiet waters (Dobie *et al.*, 1956). Spawning activities are initiated at water temperatures of 18°C (64.4°F) (Hankinson, 1932). The nest of the hornyhead or creek chub may be used, or the male may dig a shallow depression for spawning. Although the common shiner is considered omnivorous, its main food is insects. This species grows to a length of 203 mm (8 in.).

Value: The common shiner is undoubtedly an important forage fish because of its abundance. It is an attractive bait minnow for northern pike (especially in winter) but does not persist well on the hook. It will strike at dry flies and, because of its large size, affords some sport to fishermen. Although the supply of common shiners may not be seriously threatened, Hubbs and Cooper (1936) felt that some thought should be given, at least by the bait dealers, to conservation of the species.

This species makes a hardy, interesting, and easily available aquarium fish. Males in breeding colors are strikingly attractive with their dark blue heads, bodies washed in pink, and paired orange fins.

Notropis dorsalis (Agassiz). BIGMOUTH SHINER

Range: The bigmouth shiner (Fig. 46) has been reported from the Wolf, Fox, and Root river systems of Wisconsin and from the Muskegon to the Kalamazoo river systems of Michigan. A single record (Gerking, 1955) is ascribed to the St. Joseph River at South Bend, Indiana; however, since the exact locale is unknown, that record remains in doubt.

Habits: This species is common in small- to medium-sized streams, preferring sandy bottoms, frequently interspersed with gravel. Spawning occurs in June and adults reach a length of 76 mm (3 in.). In central Wisconsin, this minnow is found only in clear, clean water.

Value: The bigmouth shiner is sold commonly as a bait minnow in Wisconsin. It makes an attractive aquarium minnow if the water is kept clean and well aerated.

Notropis emiliae (Hay). PUGNOSE MINNOW

Range: The pugnose minnow (Fig. 46) is known only in the Wolf River watershed, Wisconsin (where it appears to have become recently established, probably through the Fox-Wisconsin canal at Portage, Wisconsin), and in Wolf Lake, Illinois, where it probably has been extirpated. This minnow reaches its northern limit of distribution in the Lake Michigan Basin.

Habits: The pugnose minnow prefers weedy waters in large marshes and rivers. Trautman (1957) stated that it occurred abundantly only in the clearer waters of low or base gradients where there was aquatic vegetation and the bottom was sand or organic debris. In Illinois, tuberculate males and gravid females were taken in mid-June (Forbes and Richardson, 1920). Collections from southern

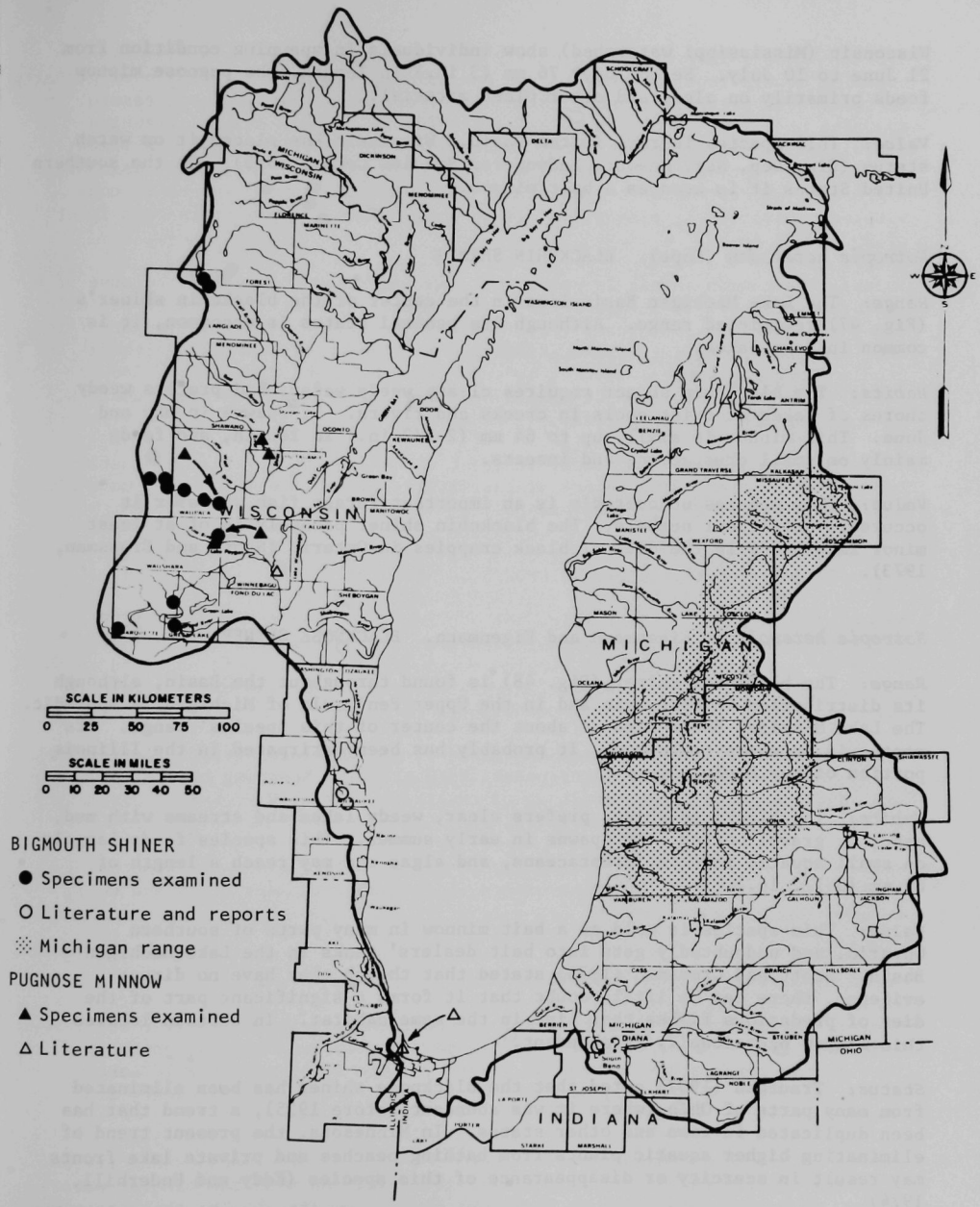

Fig. 46. Distribution of the Bigmouth Shiner (*Notropis dorsalis*) and Pugnose Minnow (*Notropis emiliae*).

Wisconsin (Mississippi watershed) show individuals in spawning condition from 21 June to 10 July. Seldom over 76 mm (3 in.) in length, the pugnose minnow feeds primarily on algae and other plant material.

Value: This species is rare in the Basin. Wisconsin has placed it on watch status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975). In the southern United States it is used as a bait minnow.

Notropis heterodon (Cope). BLACKCHIN SHINER

Range: The Lake Michigan Basin lies in the center of the blackchin shiner's (Fig. 47) restricted range. Although its general status is uncommon, it is common in some lakes.

Habits: The blackchin shiner requires clear, weedy water, and prefers weedy shores of lakes or quiet pools in creeks and rivers. It spawns in May and June. This minnow is small, up to 64 mm (2-1/2 in.) in length, and feeds mainly on small crustaceans and insects.

Value: This species undoubtedly is an important forage fish wherever it occurs in sufficient numbers. The blackchin shiner probably is of at least minor importance in the diet of black crappies in Ontario (Scott and Crossman, 1973).

Notropis heterolepis Eigenmann and Eigenmann. BLACKNOSE SHINER

Range: The blacknose shiner (Fig. 48) is found throughout the Basin, although its distribution in Wisconsin and in the Upper Peninsula of Michigan is sporadic. The Lake Michigan Basin lies at about the center of this species' range. Its status is uncommon to common. It probably has been extirpated in the Illinois portion of the Basin.

Habits: The blacknose shiner prefers clear, weedy lakes and streams with mud, sand, or gravel bottom. It spawns in early summer. This species feeds largely on small aquatic insects, crustaceans, and algae and may reach a length of 89 mm (3-1/2 in.).

Value: This species is sold as a bait minnow in many parts of southern Ontario, and undoubtedly gets into bait dealers' tanks in the Lake Michigan Basin. Scott and Crossman (1973) stated that though they have no direct evidence, there can be little doubt that it forms a significant part of the diet of predacious fishes that live in the same habitat. In certain locales this minnow occasionally is abundant.

Status: Trautman (1957) noted that the blacknose shiner has been eliminated from many parts of Ohio (where it was abundant before 1935), a trend that has been duplicated in Iowa and other states. In Minnesota, the present trend of eliminating higher aquatic plants from bathing beaches and private lake fronts may result in scarcity or disappearance of this species (Eddy and Underhill, 1974).

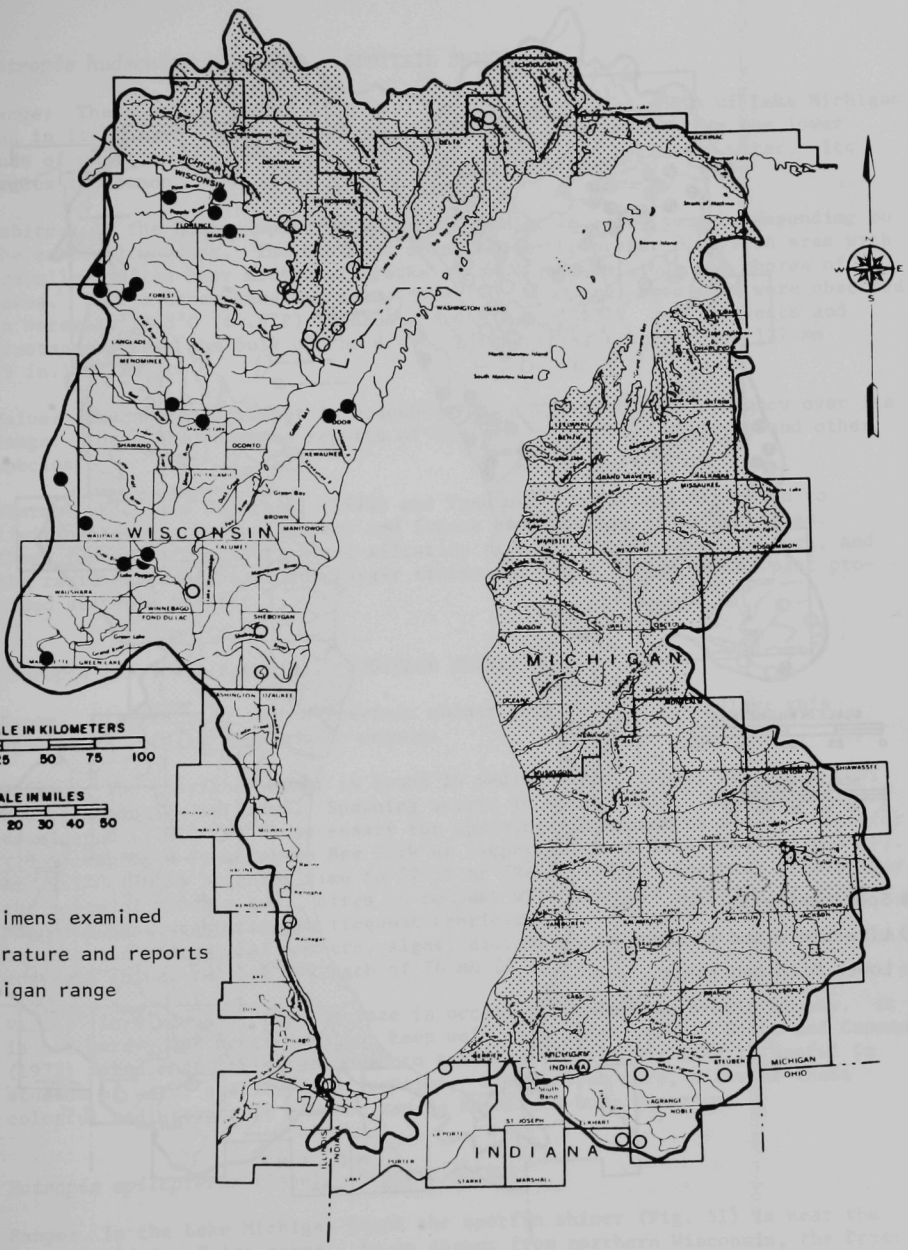

Fig. 47. Distribution of the Blackchin Shiner (*Notropis heterodon*).

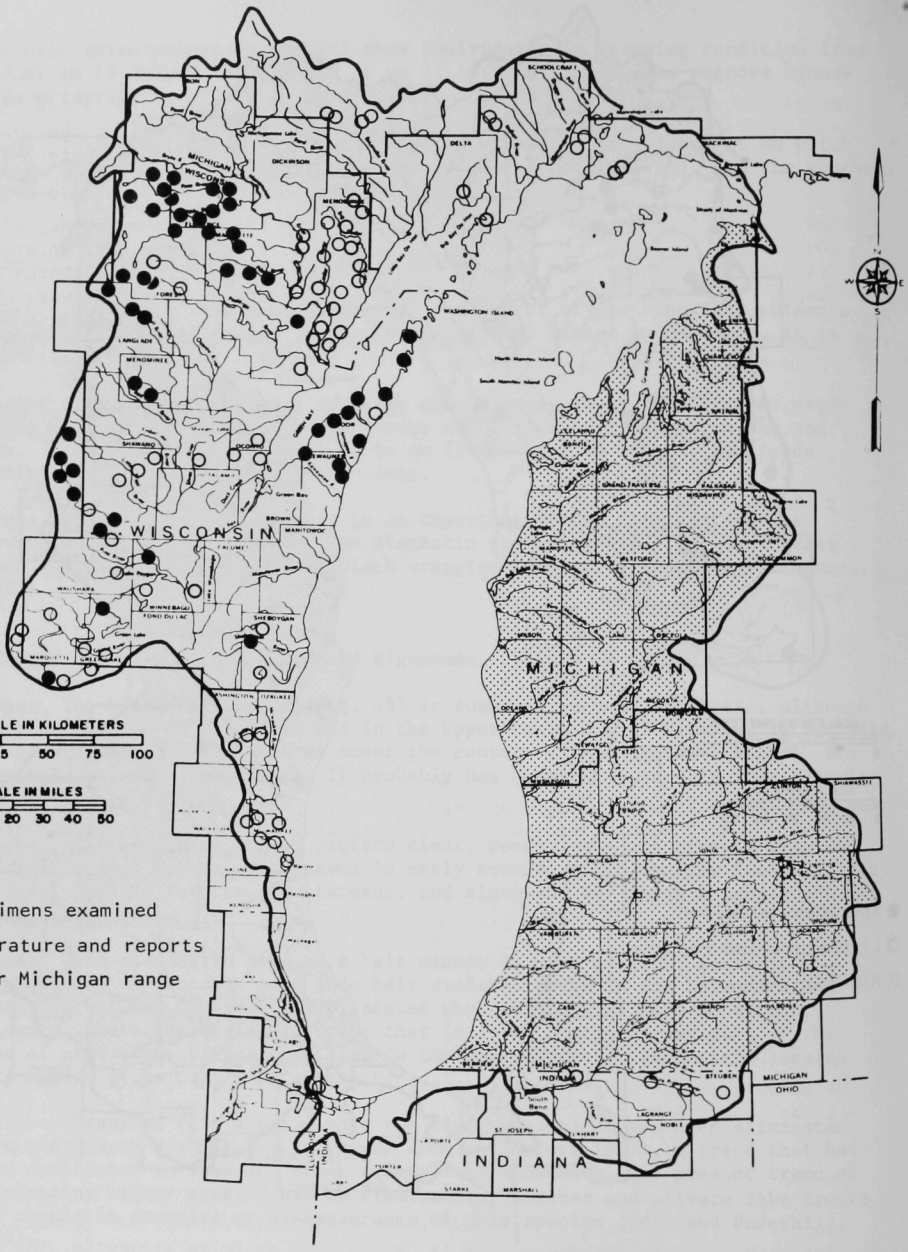

Fig. 48. Distribution of the Blacknose Shiner (*Notropis heterolepis*).

Notropis hudsonius (Clinton). SPOTTAIL SHINER

Range: The spottail shiner (Fig. 49) is found along the shore of Lake Michigan and in its larger tributary streams and lakes. It is present in the lower ends of small tributaries flowing directly into large bodies of water. Its status is common.

Habits: In the Basin, spawning occurs in spring to early summer, depending on the seasonal weather. The spottail shiner seems to prefer either an area with gravelly riffles near mouths of brooks or sandy shoals along the shores of lakes. In the Chesapeake Bay area, ripe (fully mature) specimens were observed in water at 18.3°C (64.9°F) (Mansueti and Hardy, 1967). Small insects and crustaceans form the bulk of the diet. This species reaches over 127 mm (5 in.) in length.

Value: The spottail shiner is undoubtedly an important forage minnow over its range. There are numerous reports of its use as bait for walleyes and other species.

Status: Eddy and Underhill (1974) and Trautman (1957) call attention to limiting factors in the present and future distribution of this species. Those factors are pollution and siltation from industry and agriculture, and the rapid degradation of our larger rivers and lakes, which in the past provided suitable habitat.

Notropis rubellus (Agassiz). ROSYFACE SHINER

Range: Distribution of the rosyface shiner (Fig. 50) is irregular; this species is locally uncommon to common.

Habits: The rosyface shiner is found in medium-sized, clear, swift streams, and occasionally in lakes. Spawning occurs in May to July. Hankinson (1932) considered 17.8°C (64°F) necessary for spawning activities to start. Pfeiffer (1955) reported spawning in New York at temperatures of 24.4-28.9°C (76-84°F). At 21.1°C (70°F) hatching time is 57-59 hr (Reed, 1958). Spawning occurs over the nests of *Nocomis* spp., often in company with *Notropis cornutus* or other *Notropis* spp., resulting in frequent hybridization. Its diet consists of aquatic and terrestrial insects, algae, diatoms, and inorganic material. The rosyface shiner reaches a length of 76 mm (3 in.).

Value: In Wisconsin, the rosyface is occasionally sold as a bait minnow. It is not hardy, and hence does not keep well in crowded tanks. Scott and Crossman (1973) noted that it is sensitive to turbidity, which may make it useful in studies of water quality deterioration. With proper care, a few of these colorful and attractive minnows can be kept in a home aquarium.

Notropis spilopterus (Cope). SPOTFIN SHINER

Range: In the Lake Michigan Basin the spotfin shiner (Fig. 51) is near the northern limit of its range. It is absent from northern Wisconsin, the Upper Peninsula of Michigan, and the northwestern part of lower Michigan, and probably has been extirpated in the Illinois portion of the Basin.

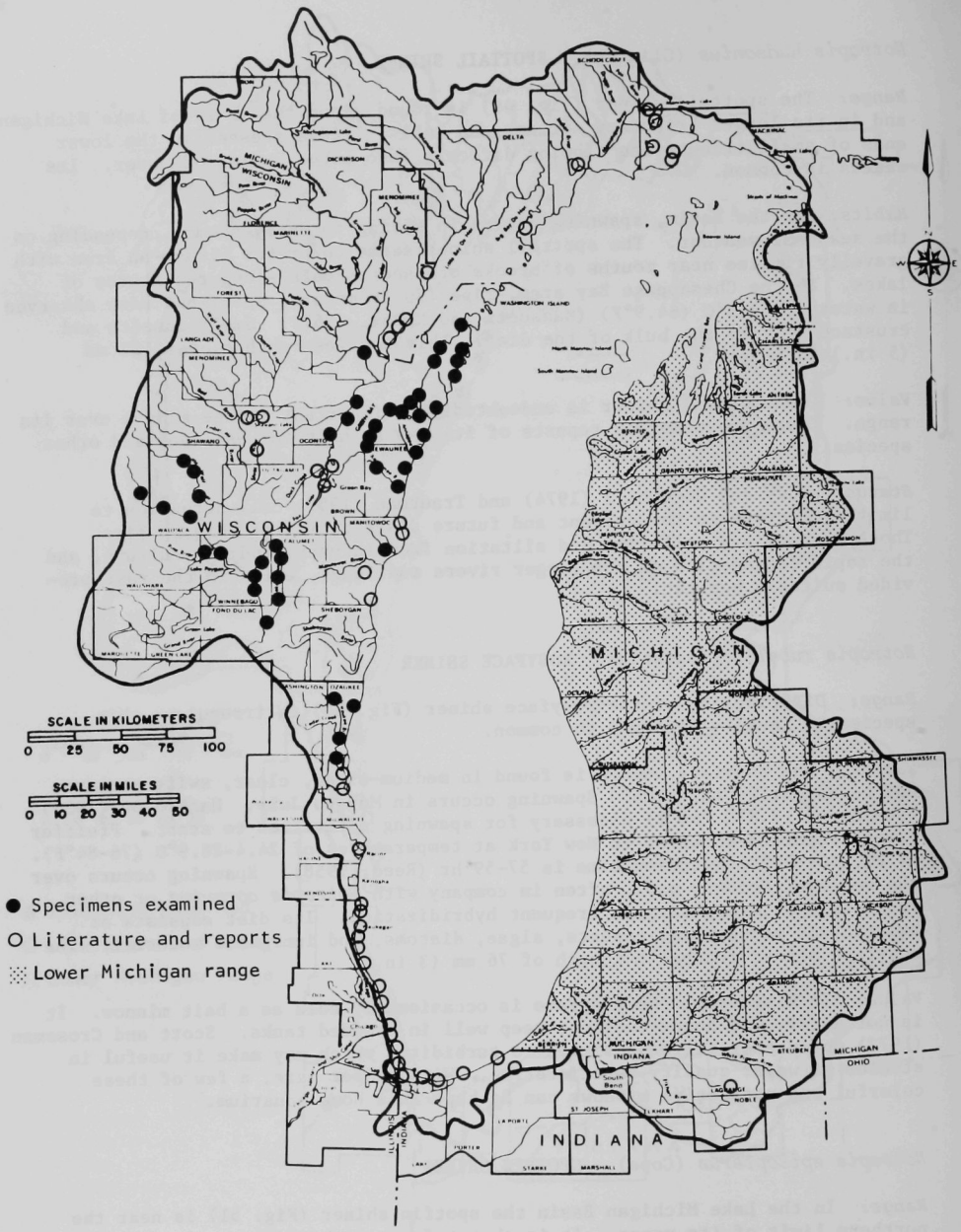

Fig. 49. Distribution of the Spottail Shiner (*Notropis hudsonius*).

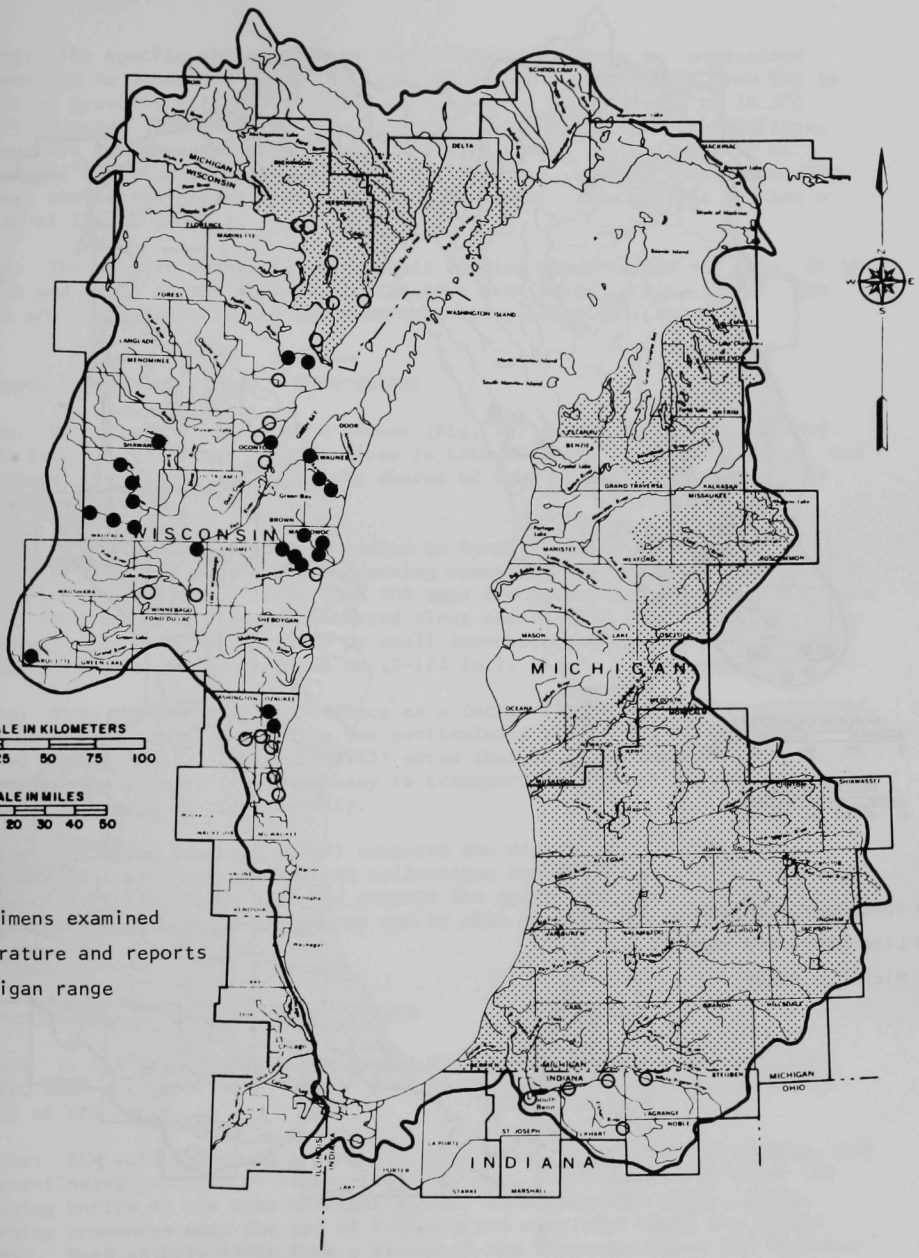

Fig. 50. Distribution of the Rosyface Shiner (*Notropis rubellus*).

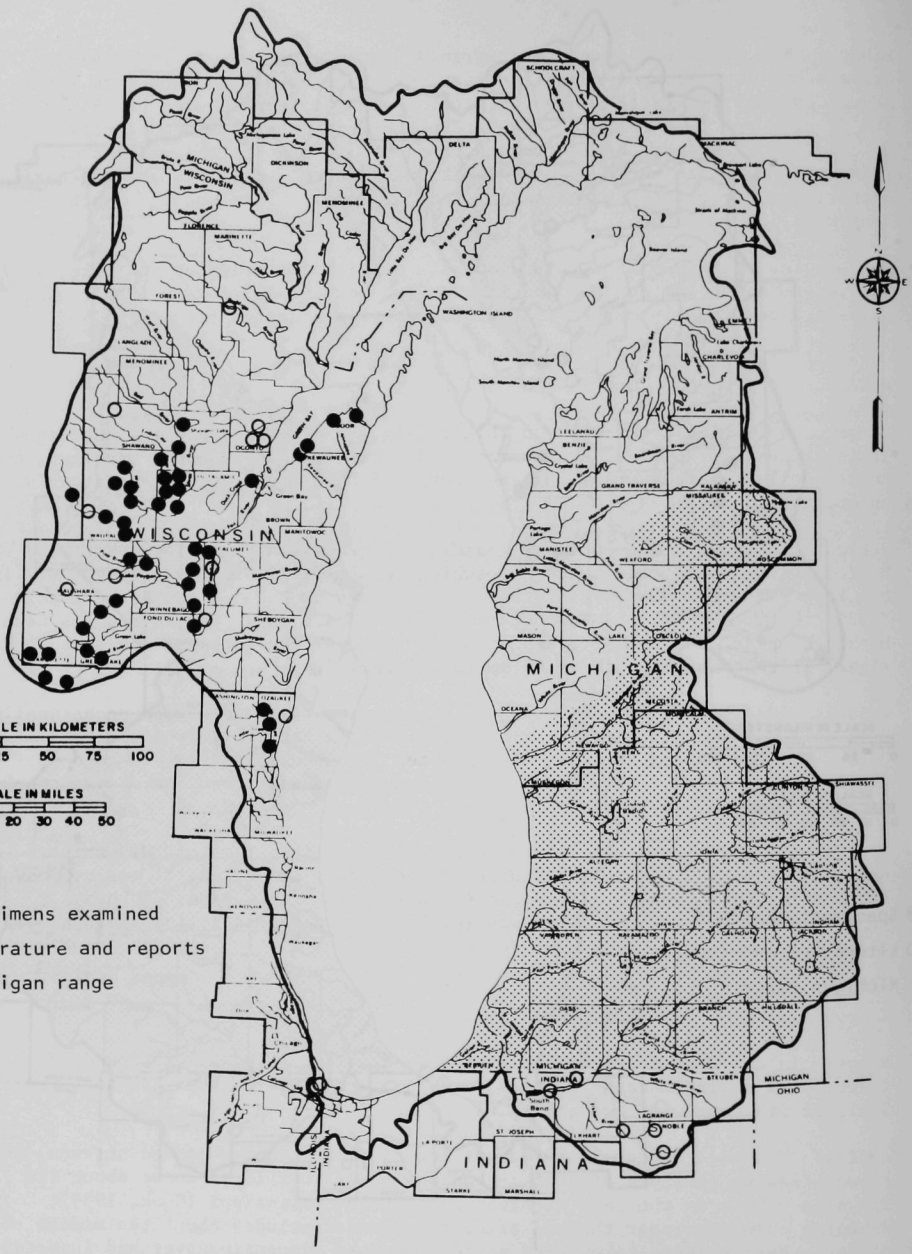

Fig. 51. Distribution of the Spotfin Shiner (*Notropis spilopterus*).

Habits: The spotfin shiner prefers rapid-flowing, medium- to large-sized streams but is sometimes found in clear, weedy lakes. It spawns from May to August on gravelly riffles or over sandy shoals at temperatures of 18.3°C (65°F) or more. The adhesive eggs are often laid on logs and dock pilings, in crevices of submerged tree trunks, and even in old pails (Dobie *et al.*, 1956). It consumes aquatic and terrestrial insects, small fishes, vegetable matter, small crustaceans, plankton, and carp eggs. This species reaches a length of 102 mm (4 in.).

Value: The spotfin shiner is a good bait species for crappies and pike; it is active and hardy on the hook and in the live box (Dobie *et al.*, 1956). The males are beautifully marked and make attractive aquarium fish.

Notropis stramineus (Cope). SAND SHINER

Range: Distribution of the sand shiner (Fig. 52) in Wisconsin is scattered. It is found in tributary streams close to Lake Michigan in upper Michigan, and occasionally in lakes and along the shores of Lake Michigan. Its status is uncommon to common.

Habits: The sand shiner prefers medium to large rivers and lives over sand bottoms with sparse vegetation. Spawning occurs from late May through July in New York (Raney, 1969). Fewer than 300 eggs are produced. Adams and Hankinson (1926) reported that spawning occurred along shoals on 7 July in Douglas Lake, Michigan. The sand shiner feeds on small insects, crustaceans, and some algae; it reaches a length of 64 mm (2-1/2 in.).

Value: This species is of importance as a forage fish and may be occasionally used as a bait minnow, but it is not particularly hardy. In the southern United States, Gould and Irwin (1965) noted that sand shiners were good bioassay animals because they were easy to transport, withstood low oxygen conditions, and took dry food readily.

Status: In Ohio, Trautman (1957) compared the distribution of this shiner prior to 1935 with his more recent collections and found that it was no longer present in riffles where silt had covered the gravel and sand. In heavily populated areas the sand shiner may not be able to adjust to increased erosion and siltation.

Notropis texanus (Girard). WEED SHINER

Range: In the Lake Michigan Basin, the weed shiner (Fig. 53) is found in large, slow-moving streams. It is rare in the Basin, which is the northern limit of its range.

Habits: The weed shiner is a fish of low-gradient, sand-bottomed streams, and slower-flowing portions of higher-gradient ones. Little is known about its spawning habits in the Lake Michigan Basin. In Mississippi (Cook, 1959), spawning commences near the end of February and concludes about the middle of May. Weed shiners taken from a slough on the Wisconsin River had ingested filamentous algae and other plant material. It reaches a length of 51 mm (2 in.).

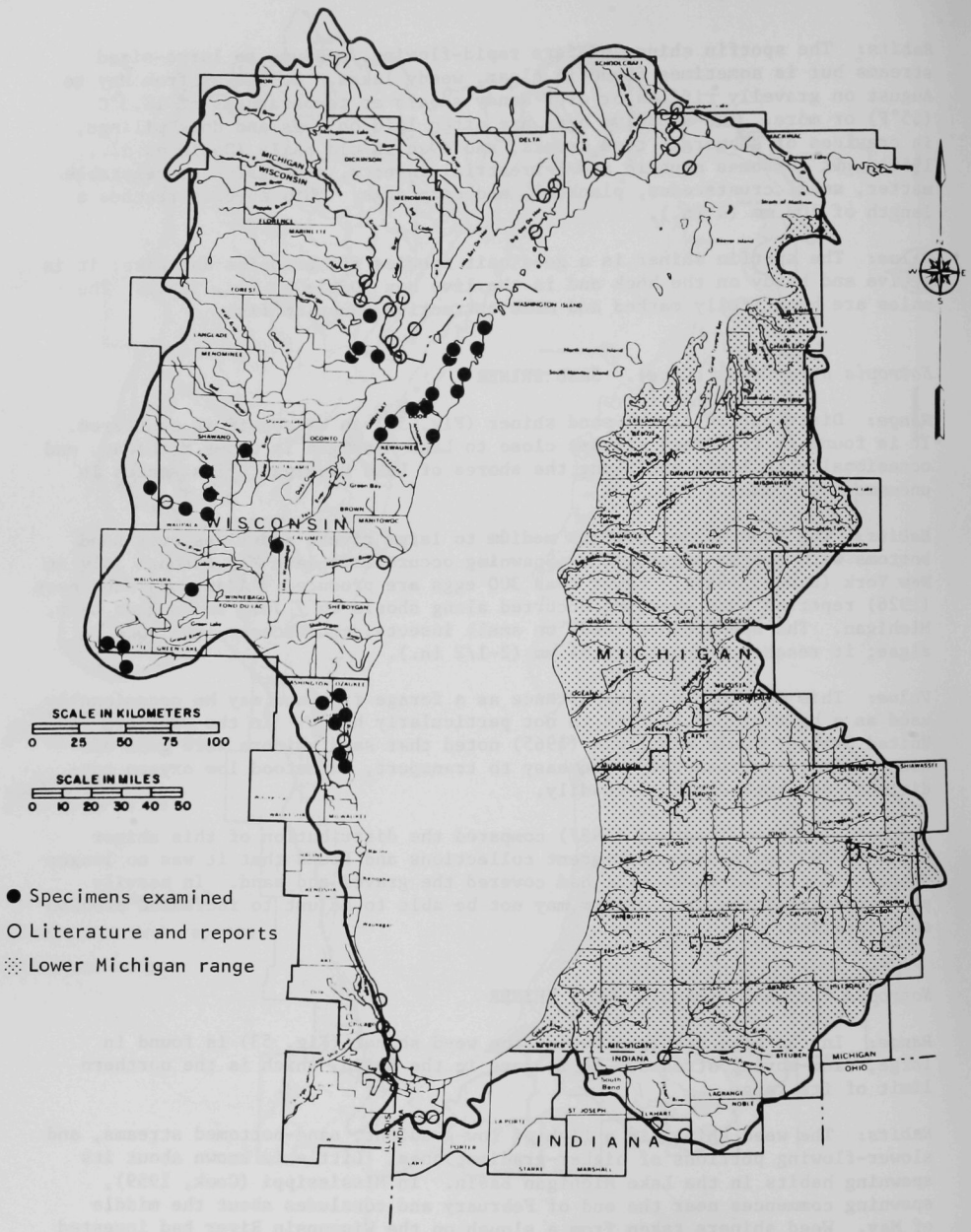

Fig. 52. Distribution of the Sand Shiner (*Notropis stramineus*).

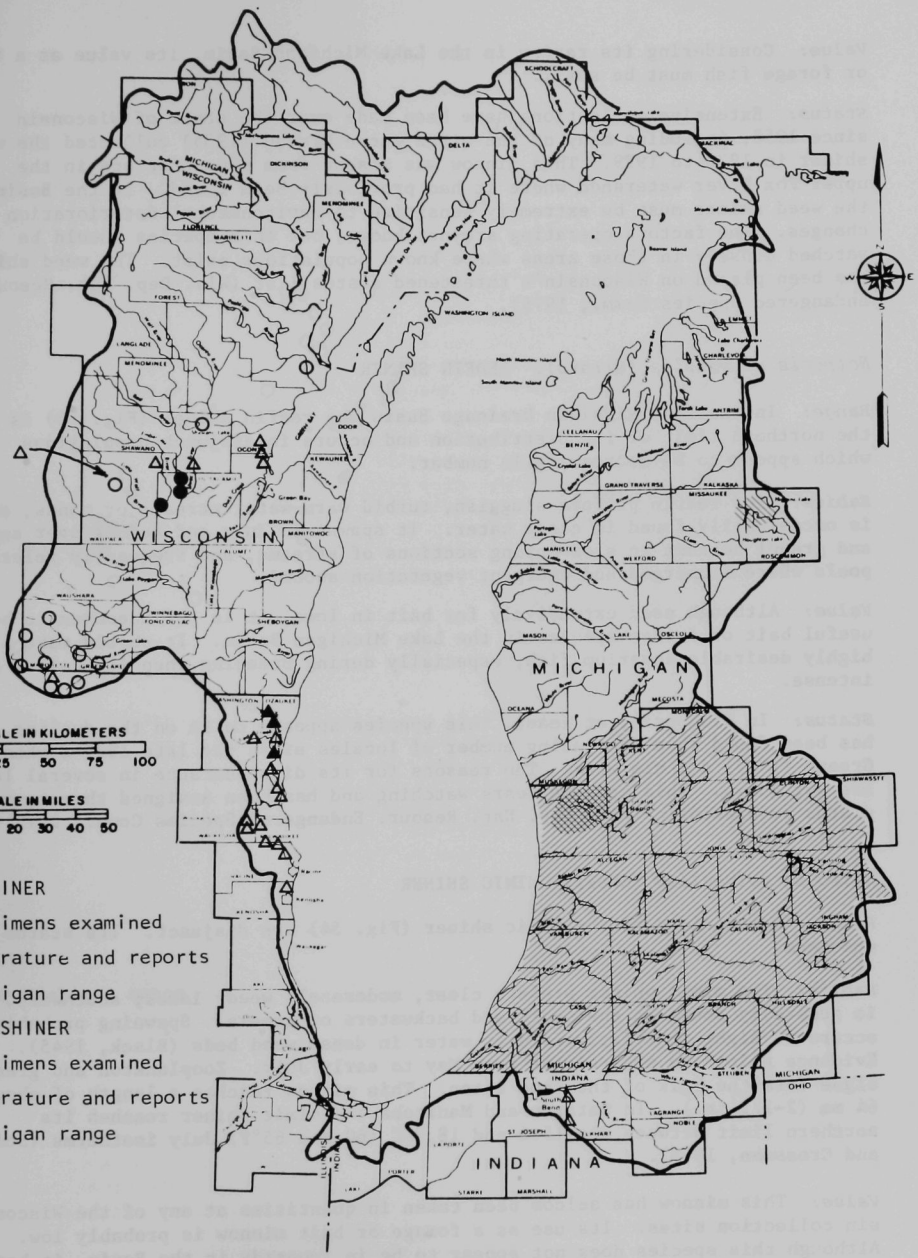

Fig. 53. Distribution of the Weed Shiner (*Notropis texanus*) and Redfin Shiner (*Notropis umbratilis*).

Value: Considering its rarity in the Lake Michigan Basin, its value as a bait or forage fish must be small.

Status: Extensive collections have been made over the state of Wisconsin since 1958, including many of the sites where Greene (1935) collected the weed shiner in 1926 to 1929. This minnow was absent from nine stations in the upper Fox River watershed where it had previously been found. In the Basin, the weed shiner must be extremely sensitive to environmental deterioration or changes. The factors operating are not known, but this species should be watched closely in those areas where known populations exist. The weed shiner has been placed on Wisconsin's threatened status list (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

Notropis umbratilis (Girard). REDFIN SHINER

Range: In the Lake Michigan Drainage Basin the redfin shiner (Fig. 53) is at the northern limit of its distribution and occurs in disjunct populations which appear to be decreasing in number.

Habits: The redfin prefers sluggish, turbid warm-water streams or ponds, and is occasionally found in clear water. It spawns in July and August over sand and gravel bottoms in slow-moving sections of streams, and frequently selects pools where submerged and emergent vegetation abound.

Value: Although used extensively for bait in Iowa, it is too uncommon to be a useful bait or forage species in the Lake Michigan Basin. It should make a highly desirable aquarium fish, especially during breeding when its colors are intense.

Status: In Wisconsin, at least, this species appears to be on the decline. It has been found in a decreasing number of locales since the late 1920's when Greene (1935) did his work. The reasons for its disappearance in several locales are not known. This species bears watching and has been assigned threatened status by Wisconsin (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

Notropis volucellus (Cope). MIMIC SHINER

Range: Populations of the mimic shiner (Fig. 54) are disjunct. Its status is uncommon.

Habits: The mimic shiner prefers clear, moderately weedy lakes; southward, it is generally found in the pools and backwaters of creeks. Spawning probably occurs at night in relatively deep water in dense weed beds (Black, 1945). Evidence points to egg release from May to early July. Zooplankton and green algae form the bulk of the food eaten. This minnow reaches a length of about 64 mm (2-1/2 in.). In Ontario and Manitoba the mimic shiner reaches its northern limit between the 15.6 and 18.3°C (60 and 65°F) July isotherms (Scott and Crossman, 1973).

Value: This minnow has seldom been taken in quantities at any of the Wisconsin collection sites. Its use as a forage or bait minnow is probably low. Although this species does not appear to be in jeopardy in the Basin, it bears close observation.

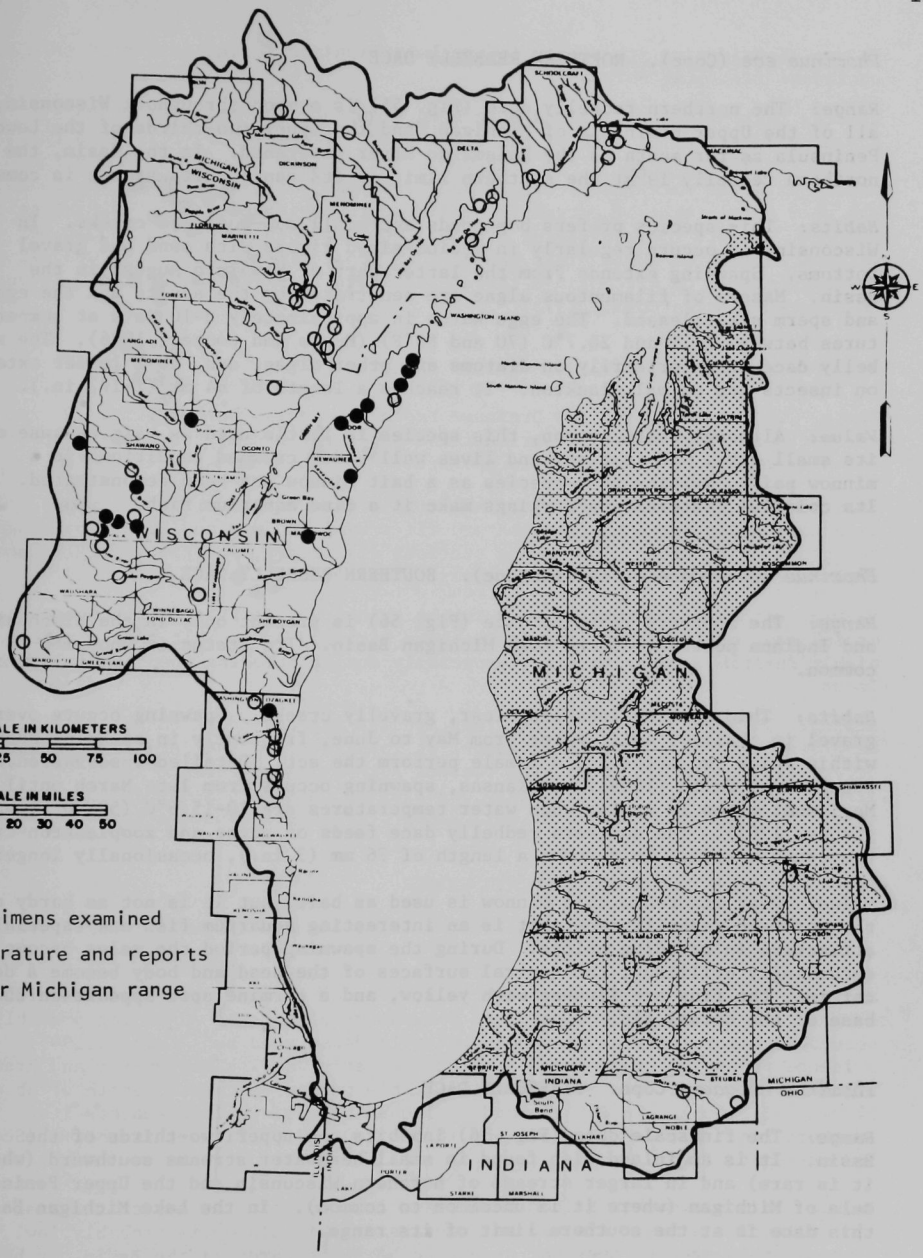

Fig. 54. Distribution of the Mimic Shiner (*Notropis volucellus*).

Phoxinus eos (Cope). NORTHERN REDBELLY DACE

Range: The northern redbelly dace (Fig. 55) is common throughout Wisconsin, all of the Upper Peninsula of Michigan, and the upper two-thirds of the Lower Peninsula as far south as the Kalamazoo River watershed. In the Basin, the northern redbelly is at the southern limit of its range. Its status is common.

Habits: This species prefers bog ponds and small mud-bottomed creeks. In Wisconsin, it occurs regularly in medium-sized rivers with sand and gravel bottoms. Spawning extends from the latter part of May into August in the Basin. Masses of filamentous algae are penetrated by the adults and the eggs and sperm are released. The eggs hatch in approximately 8-10 days at temperatures between 21.1 and 26.7°C (70 and 80°F) (Hubbs and Cooper, 1936). The redbelly dace feeds primarily on diatoms and other algae, and, to a lesser extent, on insects and animal plankton. It reaches a length of 64 mm (2-1/2 in.).

Value: Although quite common, this species is little used as bait because of its small size. It is hardy and lives well under crowded conditions in a minnow pail. Raising this species as a bait minnow has been demonstrated. Its colorful, interesting markings make it a fine aquarium fish.

Phoxinus erythrogaster (Rafinesque). SOUTHERN REDBELLY DACE

Range: The southern redbelly dace (Fig. 56) is present only in the Wisconsin and Indiana portions of the Lake Michigan Basin. Its status is uncommon to common.

Habits: This species inhabits clear, gravelly creeks. Spawning occurs over gravel in shallow, swift water from May to June, frequently in spawning schools within which two males and a female perform the act. Detailed observation was recorded by Smith (1908). In Kansas, spawning occurs from late March until May, most often in April, when water temperatures are 10-15.6°C (50-60°F) (Cross, 1967). The southern redbelly dace feeds on algae and zooplankton from the creek bottom. It reaches a length of 76 mm (3 in.), occasionally longer.

Value: Over its range this minnow is used as bait, but it is not as hardy as the northern redbelly dace. It is an interesting aquarium fish and especially attractive in breeding colors. During the spawning period the males become exceedingly brilliant; the ventral surfaces of the head and body become a deep carmine, the fins are flushed with yellow, and a carmine spot appears on the base of the dorsal fin.

Phoxinus neogaeus Cope. FINESCALE DACE

Range: The finescale dace (Fig. 56) inhabits the upper two-thirds of the Basin. It is an inland fish found in small headwater streams southward (where it is rare) and in larger streams of northern Wisconsin and the Upper Peninsula of Michigan (where it is uncommon to common). In the Lake Michigan Basin, this dace is at the southern limit of its range.

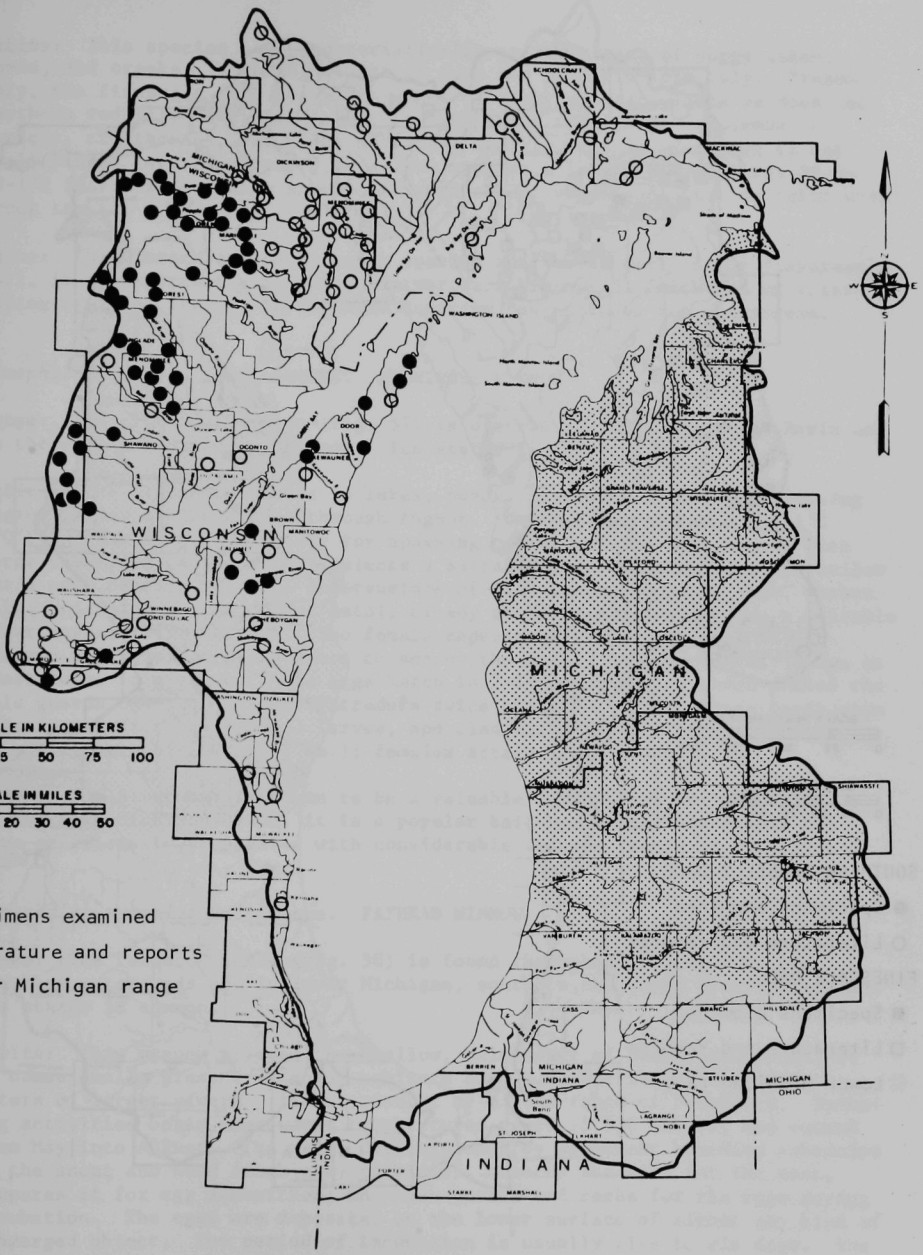

Fig. 55. Distribution of the Northern Redbelly Dace (*Phoxinus eos*).

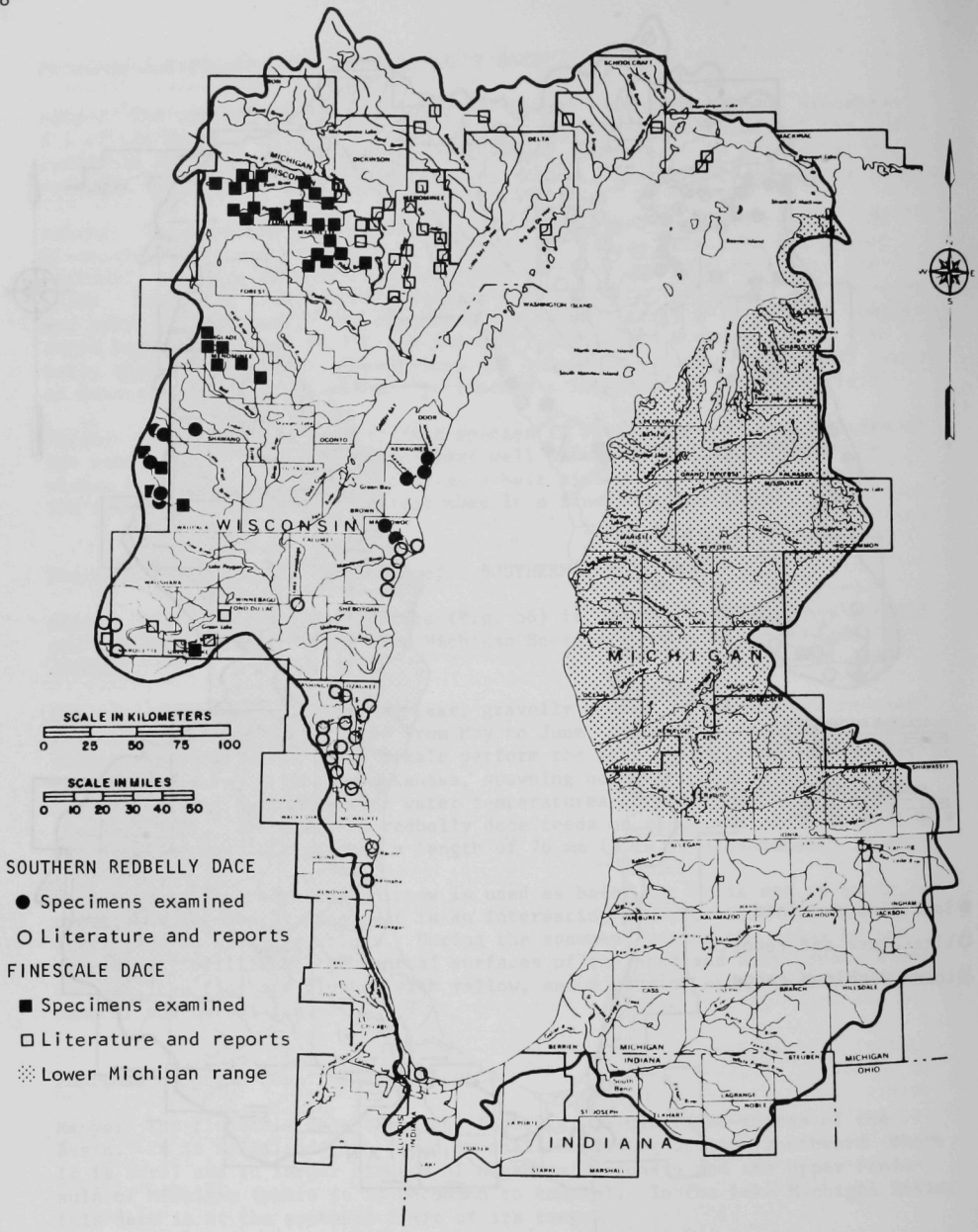

Fig. 56. Distribution of the Southern Redbelly Dace (*Phoxinus erythrogaster*) and Finescale Dace (*Phoxinus neogaeus*).

Habits: This species is characteristically an inhabitant of boggy lakes, ponds, and creeks. Spawning occurs in June and probably into July. Presumably, the finescale dace spawns in algae or other aquatic plants as does the northern redbelly dace, with which it hybridizes regularly. It feeds on insects, crustaceans, and plant materials and, in aquaria, is known to eat small fishes (*e.g.* guppies). It seldom reaches a length of more than 89 mm (3-1/2 in.). This minnow appears to prefer cool water and often is taken with brook trout.

Value: The finescale dace, a hardy species that keeps well in the fisherman's pail, is an important bait minnow in northern Wisconsin. Although an interesting captive, its use in the home aquarium has not been too widespread.

Pimephales notatus (Rafinesque). BLUNTNOSE MINNOW

Range: The bluntnose minnow (Fig. 57) is distributed throughout the Basin and is the most common inland minnow. Its status is abundant.

Habits: The bluntnose occurs in lakes, ponds, rivers, and creeks. Spawning begins in May and continues through August. Water temperatures of 21.1°C (70°F) or higher are necessary for spawning to begin. The male, armed with large tubercles on the snout, selects a suitable stone and commences to hollow out a nest beneath it. The undersurface of flat stones, boards, logs, broken tile, bricks, tin cans, sheet metal, or any other object that offers a suitable lower surface will suffice. The female deposits her adhesive eggs on the cleared underside of the surface chosen by the male. Females usually spawn at least twice in a season. The eggs hatch in 7-14 days, during which period the male guards the eggs against intruders twice his size. This minnow feeds upon organic detritus, chironomid larvae, and cladocerans on the bottom. Males reach a length of 102 mm (4 in.); females attain 76 mm (3 in.).

Value: The bluntnose is known to be a valuable forage fish for game fishes. In the Lake Michigan Basin, it is a popular bait species. This minnow has been artificially propagated with considerable success (Dobie *et al.*, 1956).

Pimephales promelas Rafinesque. FATHEAD MINNOW

Range: The fathead minnow (Fig. 58) is found throughout the western and northern watersheds and in lower Michigan, south to the Grand River watershed. Its status is common.

Habits: This minnow prefers the shallow, calm water of creeks and ponds; it is occasionally present in boggy habitats but is absent from the flowing waters of larger rivers. It is tolerant of a wide range of turbidity. Spawning activities begin when water temperatures reach 15.6°C (60°F), and extend from May into August. The male, distinguished by prominent breeding tubercles on the snout and head (dark gray to black), selects the site for the nest, prepares it for egg deposition, and then guards and cares for the eggs during incubation. The eggs are deposited on the lower surface of almost any kind of submerged object. The period of incubation is usually five to six days. The food consists mainly of algae, fragments of higher plants, insects and their larvae, and mud. The fathead minnow reaches a length of 76 mm (3 in.).

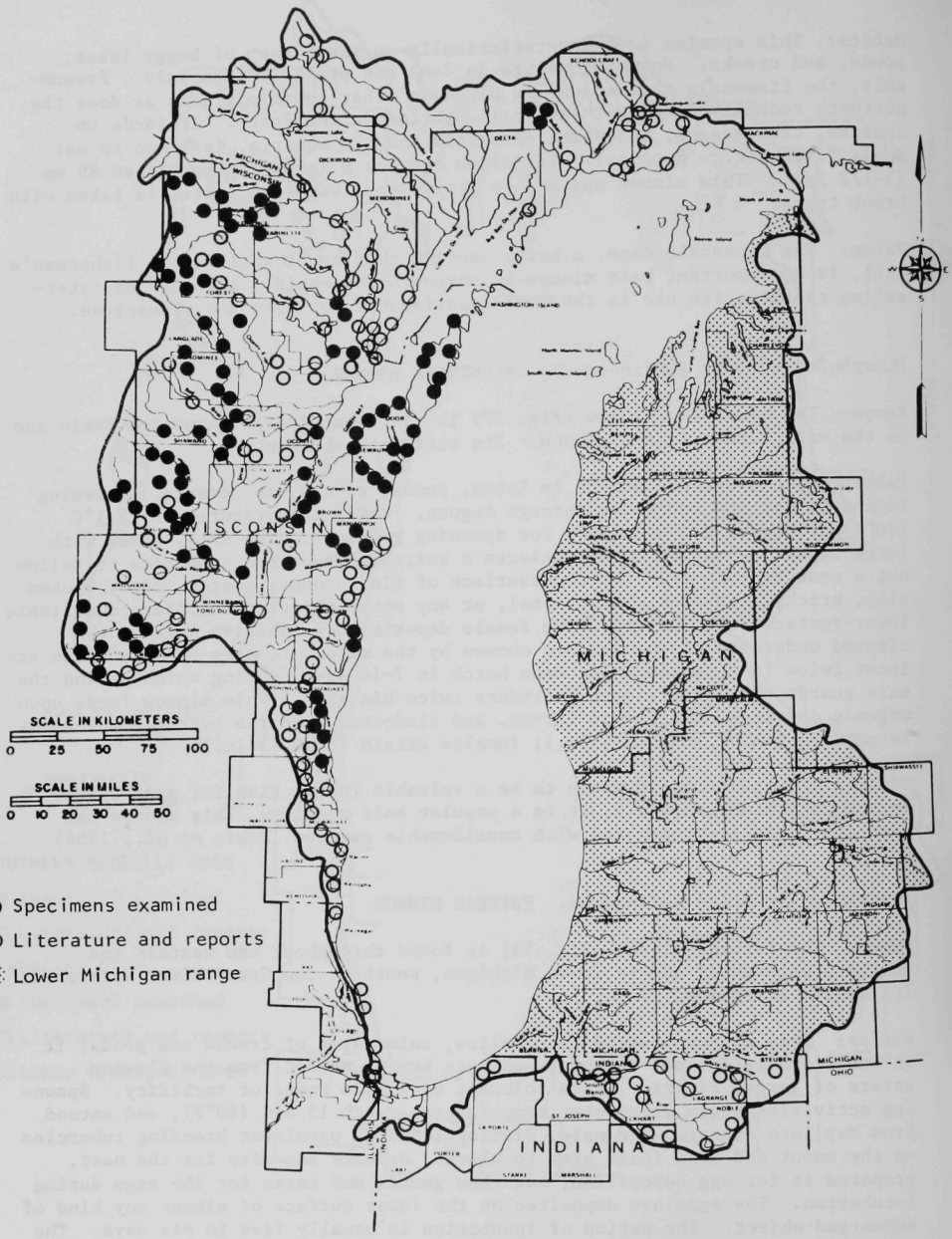

Fig. 57. Distribution of the Bluntnose Minnow (*Pimephales notatus*).

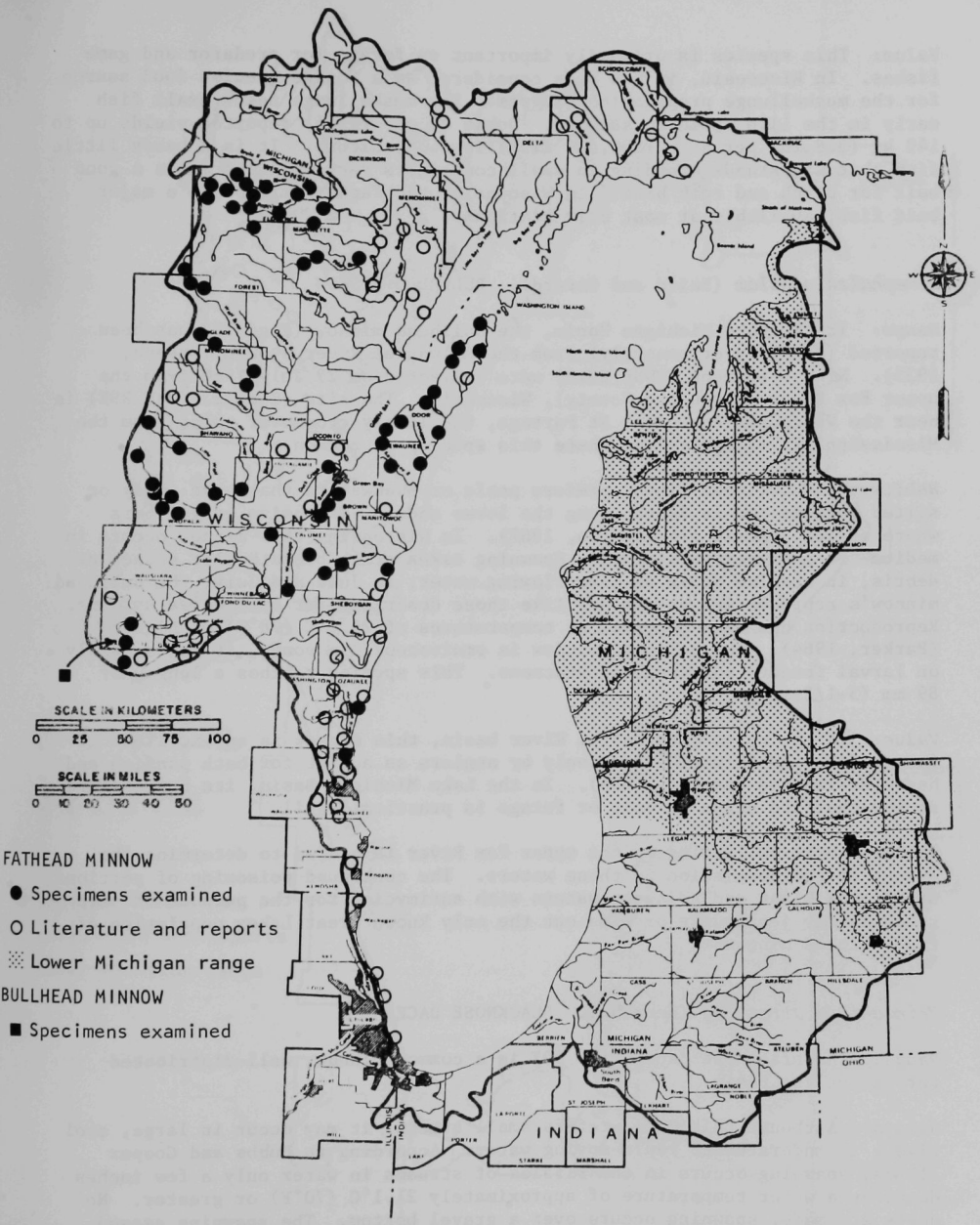

Fig. 58. Distribution of the Fathead Minnow (*Pimephales promelas*) and Bullhead Minnow (*Pimephales vigilax*).

Value: This species is primarily important as forage for predator and game fishes. In Wisconsin, it has been considered as a forage species food source for the muskellunge propagation program. The muskellunge needs small fish early in the life cycle to succeed. Dobie *et al.* (1956) reported yields up to 149 kg (328 lb) per acre (200,000 fish) in pond culture. It is a hardy little fish that withstands crowding in small containers very well and makes a good bait for perch and rock bass. In Wisconsin, the fathead minnow is a major bait fish, available at most bait stations.

Pimephales vigilax (Baird and Girard). BULLHEAD MINNOW

Range: In the Lake Michigan Basin, the bullhead minnow (Fig. 58) has been reported (probably erroneously) from the Milwaukee River system (Greene, 1935). Nine specimens (UWSP 2318) were collected on 29 July 1960 from the upper Fox River (Marquette County), Wisconsin. The site (Sec. 23 T14N R9E) is near the Wisconsin-Fox canal at Portage, the likely crossover point from the Mississippi River watershed, where this species is common.

Habits: The bullhead minnow prefers pools or backwaters that have sandy or silted bottoms and is found along the lower ends of expansive gravel-bars where eddies deposit silt (Cross, 1967). In Wisconsin, this minnow occurs in medium- to large-sized streams. Spawning takes place beneath flat stones or debris, in shallow pools or slow-flowing water, in June and July; the bullhead minnow's reproductive habits are like those described for *Pimephales notatus*. Reproduction has been reported at temperatures of 25.6°C (78°F) or higher (Parker, 1964). The bullhead minnow is omnivorous; in ponds, it feeds mainly on larval insects and small crustaceans. This species reaches a length of 89 mm (3-1/2 in.).

Value: In the upper Mississippi River basin, this minnow is an excellent forage fish and is used extensively by anglers as a bait for both panfish and bass (Harlan and Speaker, 1956). In the Lake Michigan Basin, its numbers are so low that its value as bait or forage is practically nil.

Status: More collecting on the upper Fox River is needed to determine the extent of the population in those waters. The continued poisoning of portions of the Fox River and adjacent waters with antimycin, for the purpose of carp removal, may jeopardize or wipe out the only known Great Lakes population of the bullhead minnow.

Rhinichthys atratulus (Hermann). BLACKNOSE DACE

Range: The blacknose dace (Fig. 59) is a common minnow, well-distributed throughout the Basin.

Habits: Although this dace prefers small creeks, it may occur in large, cool rivers in moderate- to rapid-moving water. According to Hubbs and Cooper (1936), spawning occurs in the riffles of streams in water only a few inches deep, at a water temperature of approximately 21.1°C (70°F) or greater. No nests are made; spawning occurs over a gravel bottom. The spawning season extends from April through the latter part of May and, occasionally, into the first part of June. The blacknose dace feeds primarily on the larvae of

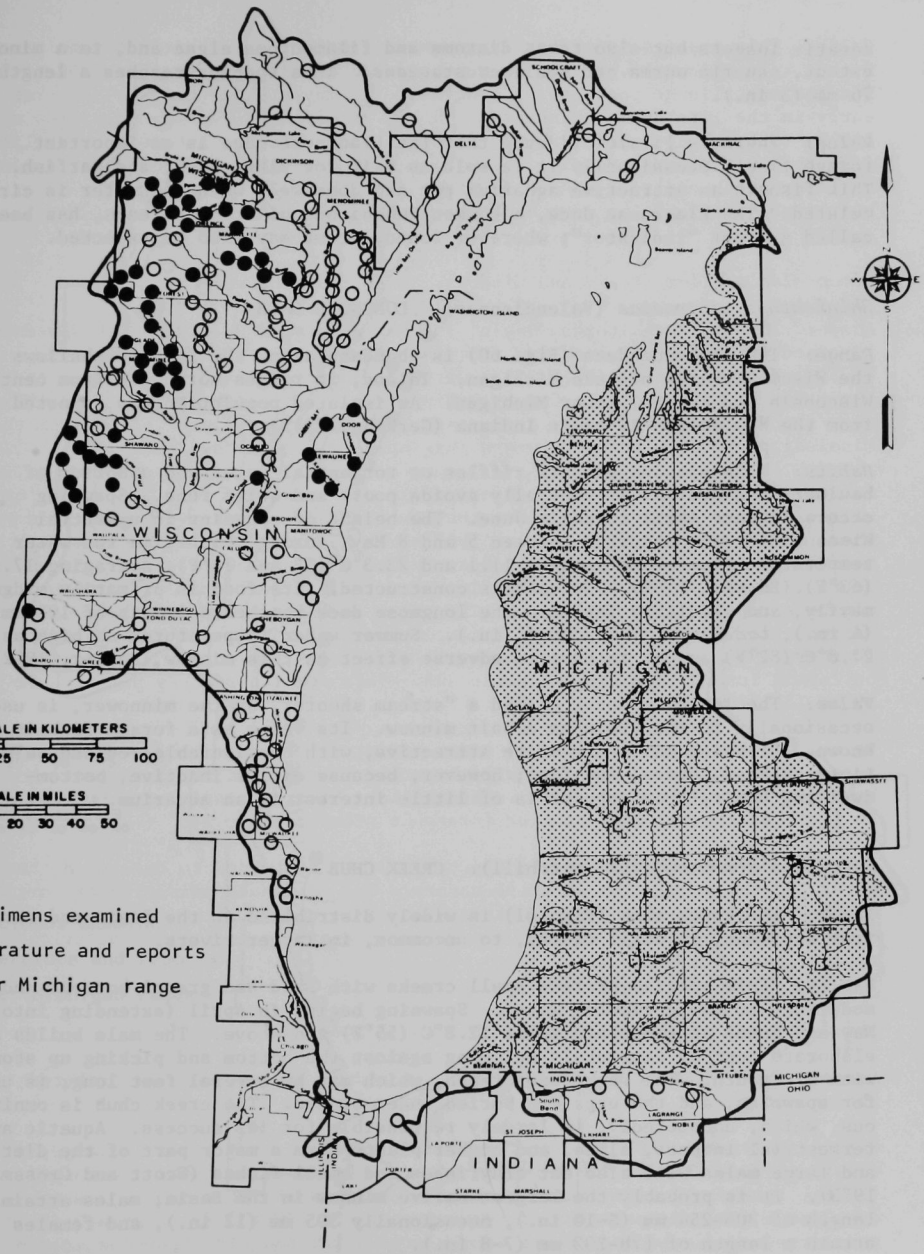

Fig. 59. Distribution of the Blacknose Dace (*Rhinichthys atratulus*).

aquatic insects but also takes diatoms and filamentous algae and, to a minor extent, aquatic worms and small crustaceans. This species reaches a length of 76 mm (3 in.).

Value: There is little evidence that the blacknose dace is an important forage fish. Occasionally it is sold as bait for pike, bass, and catfish. This fish is an attractive aquarium pet and does well when the water is circulated. The blacknose dace, a common inhabitant of trout streams, has been called a trout "indicator"; wherever found, trout may also be expected.

Rhinichthys cataractae (Valenciennes). LONGNOSE DACE

Range: The longnose dace (Fig. 60) is abundant along the inshore shallows of the Wisconsin side of Lake Michigan. Inland, it ranges northward from central Wisconsin and central lower Michigan. An isolated population was reported from the St. Joseph River in Indiana (Gerking, 1945).

Habits: This species prefers riffles or torrential water and a bottom of boulders and gravel; it generally avoids pools and quiet runs. Spawning occurs in late April to early June. The height of spawning in a central Wisconsin stream occurred between 5 and 8 May, during which time the water temperature fluctuated between 11.1 and 23.3°C (52 and 74°F), averaging 17.2°C (63°F) (Becker, 1962). No nest is constructed. Its food is primarily midge, mayfly, and caddisfly larvae. The longnose dace reaches a length of 102 mm (4 in.), occasionally 127 mm (5 in.). Summer water temperatures as high as 27.8°C (82°F) appear to have no adverse effect on this minnow (Becker, 1962).

Value: The longnose dace, called a "stream shooter" by the minnower, is used occasionally in the Basin as a bait minnow. Its value as a forage fish is not known. Breeding males are quite attractive, with considerable red and salmon tints on head, sides, and fins; however, because of its inactive, bottom-dwelling habit, this species is of little interest in an aquarium.

Semotilus atromaculatus (Mitchill). CREEK CHUB

Range: The creek chub (Fig. 61) is widely distributed in the Basin and varies from abundant, in small creeks, to uncommon, in larger rivers.

Habits: This species prefers small creeks with sand and gravel bottoms and moderate- to rapid-flowing water. Spawning begins in April (extending into May and June) at temperatures of 12.8°C (55°F) and above. The male builds an elaborate nest by vigorously swimming against the bottom and picking up stones with his mouth. The resultant trench, which may be several feet long, is used for spawning, and the eggs are buried under stones. The creek chub is omnivorous, which, undoubtedly, is largely responsible for its success. Aquatic and terrestrial insects, algae, and higher plants form a major part of the diet and large males will also eat crayfishes and small fishes (Scott and Crossman, 1973). It is probably the largest native minnow in the Basin; males attain a length of 203-254 mm (8-10 in.), occasionally 305 mm (12 in.), and females attain a length of 178-203 mm (7-8 in.).

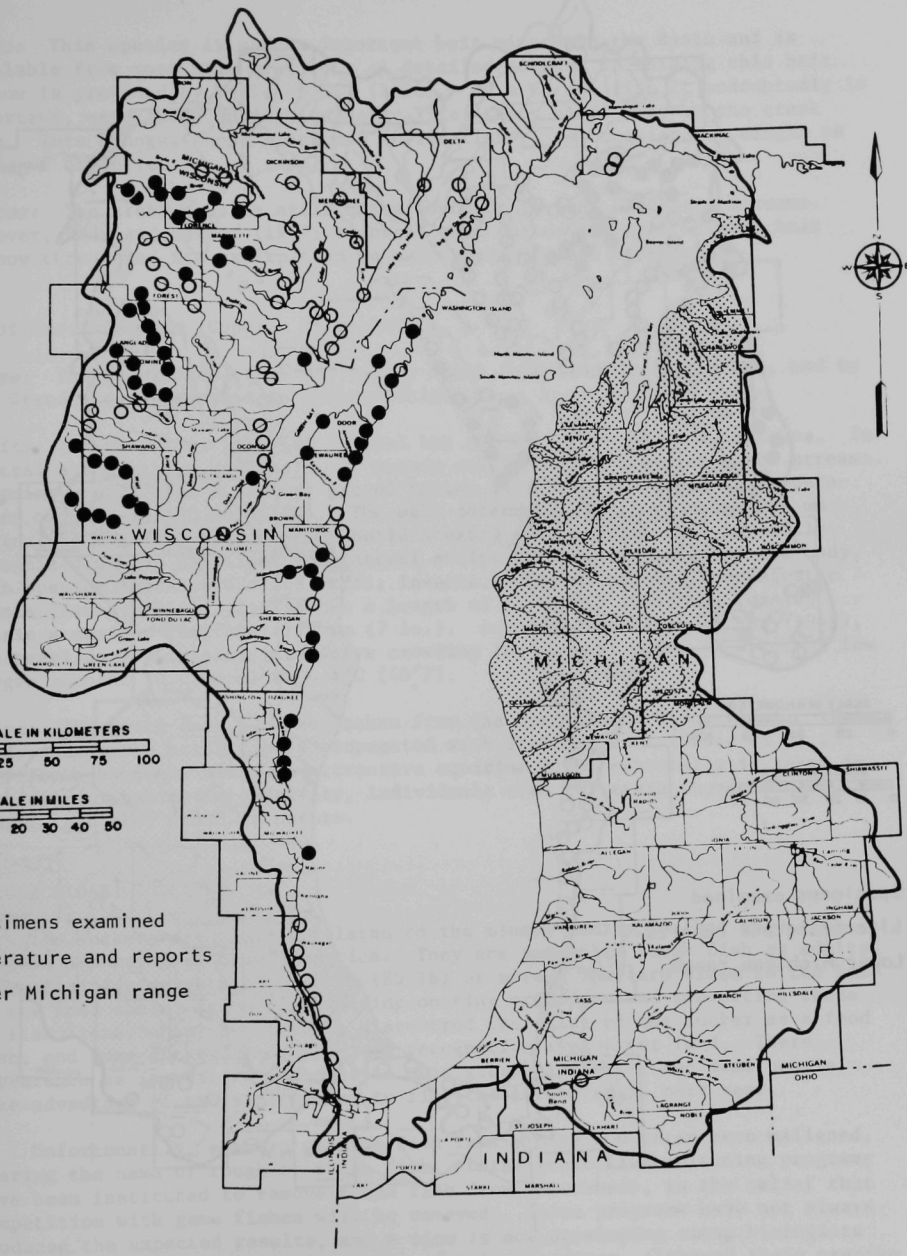

Fig. 60. Distribution of the Longnose Dace (*Rhinichthys cataractae*).

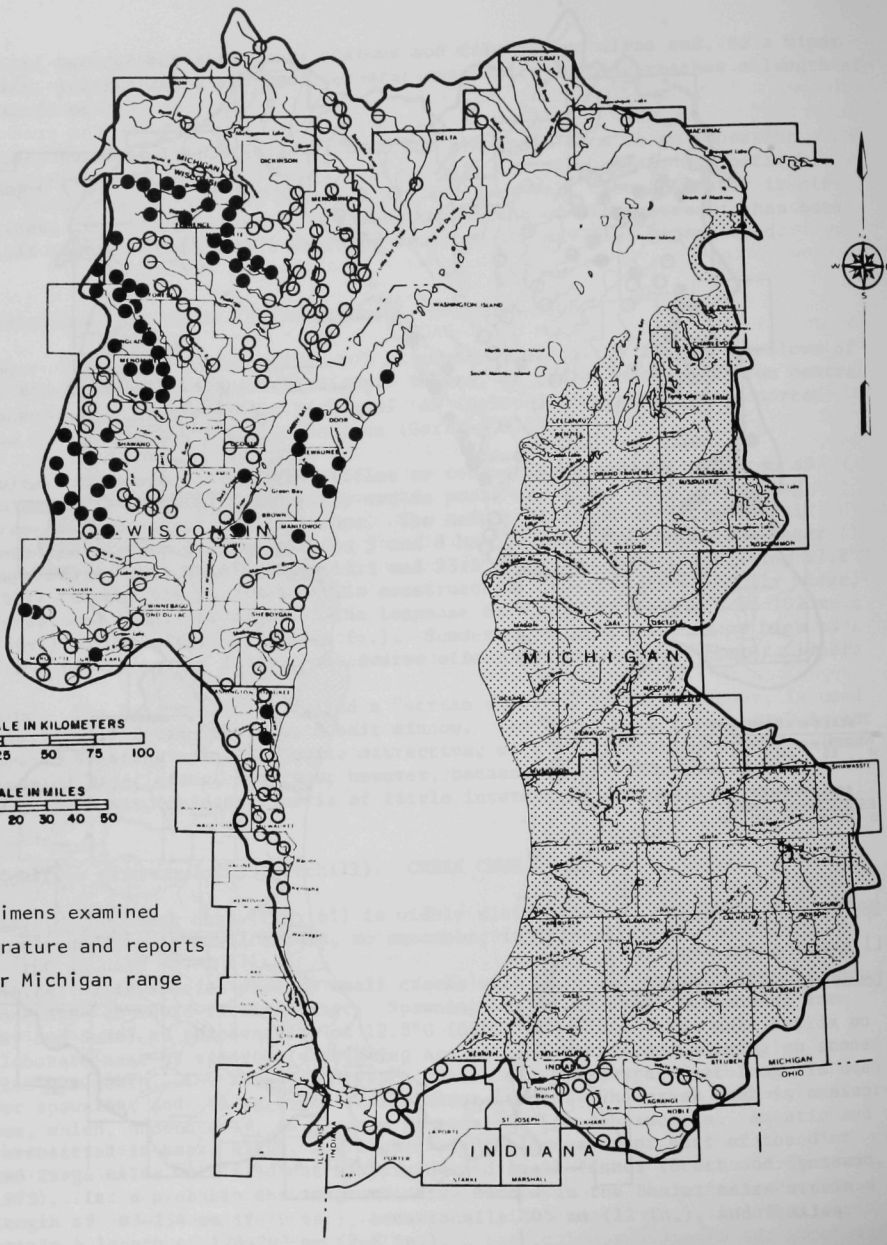

Fig. 61. Distribution of the Creek Chub (*Semotilus atromaculatus*).

Value: This species is a very important bait minnow in the Basin and is available from most bait stations. A detailed account of raising this bait minnow is provided by Dobie *et al.* (1956). As a forage fish it undoubtedly is important, especially during its early life. Many birds prey on the creek chub. This minnow, whose flesh has a fine flavor, is occasionally caught on worms or dry flies.

Status: The creek chub is still quite abundant in many Wisconsin streams. However, Eddy and Surber (1947) reported that the demand upon it as a bait minnow threatened its extirpation in many localities of Minnesota.

Semotilus margarita (Cope). PEARL DACE

Range: The pearl dace (Fig. 62) ranges south to Milwaukee, Wisconsin, and to the Grand River watershed in lower Michigan.

Habits: This species is found in cool bog ponds, in creeks, and in lakes. In central and northern Wisconsin, it occurs occasionally in medium-sized streams. Spawning occurs over a sand or gravel bottom from April to June, at temperatures of 17.2-18.3°C (63-65°F). The male defends a territory about 203 mm (8 in.) in diameter but does not build a nest. The nuptial male is easily recognized by the brilliant red lateral stripe on the lower side of the body. This species feeds on surface drift, insects, water mites, and some aquatic plants (Raney, 1969). It reaches a length of 127 mm (5 in.); old females attain a maximum length of 178 mm (7 in.). According to Dobie *et al.* (1948), the pearl dace withstands excessive crowding for several hours in water of low oxygen content (0.02 ppm) at 4.4°C (40°F).

Value: The pearl dace has been taken from the stomachs of brook trout. It is hardy and may be artificially propagated with little effort (Dobie *et al.*, 1956). This minnow makes an attractive aquarium fish, especially if taken in its colorful habit; in captivity, individuals tend to retain these colors longer than they would in nature.

CATOSTOMIDAE - SUCKERS

The suckers are closely related to the minnow family in that they, too, possess a pharyngeal chewing device. They are generally large fish as adults, some attaining weights of 11.3 kg (25 lb) or more. They are close to the base of the food chain, frequently feeding on tiny organisms and converting these to fish flesh. Many people have discovered the value of the sucker as a food fish, and some suckers have received recognition as gourmet food. There appears to be increasing interest in this group of fishes, and some people take advantage of the sucker runs to fill the larder until next year.

Unfortunately, members of this fish family have too often been maligned, bearing the name of rough or trash fish. Large-scale fish-poisoning programs have been instituted to remove these fish from watersheds, in the belief that competition with game fishes will be removed. These programs have not always produced the expected results, and a view is now developing among biologists that suckers play a vital role in the aquatic ecosystem, although their precise function is not yet known.

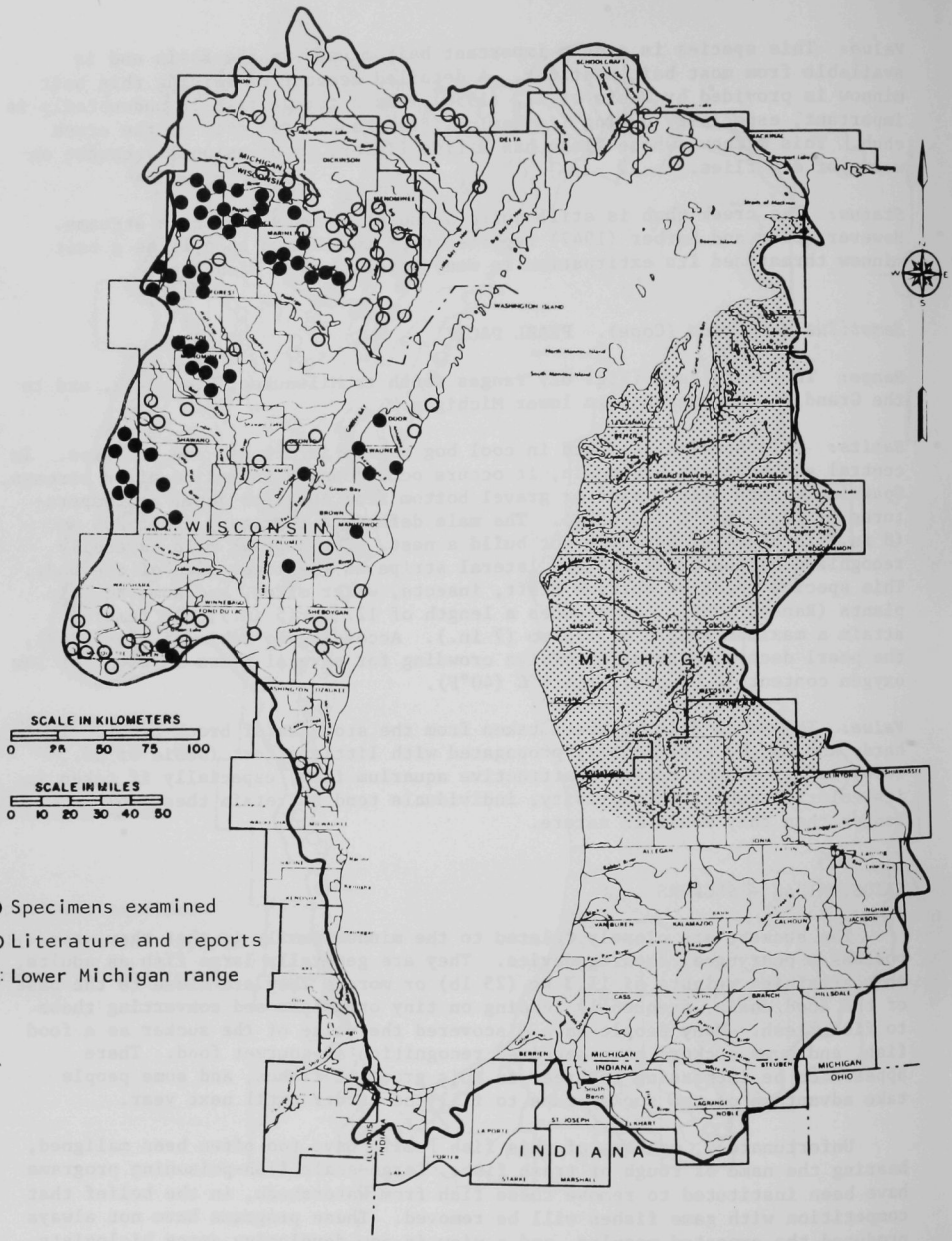

Fig. 62. Distribution of the Pearl Dace (*Semotilus margarita*).

Many suckers, in particular the redhorses, are sensitive indicators of chemical pollution and turbidity. They are among the first fishes to disappear from a river system when the water quality deteriorates. They are the "miner's canary" of the fish world (Becker, 1974--unpublished).

Carpiodes cyprinus (Lesueur). QUILLBACK

Range: Localized populations of the quillback (Fig. 63) occur in lower Green Bay (of Lake Michigan), the lower Fox River lakes (Poygan and Winnebago) in Wisconsin, and the Grand and Macatawa rivers in Michigan.

Habits: The quillback is found in larger, heavily silted rivers (especially the quiet pools and sloughs) and in turbid lakes. It spawns from late April through May in quiet waters of streams (Harlan and Speaker, 1956), depositing its eggs over sand or mud bottoms of the streams or in the overflow bayous. No nest is built and no care is given the young. The quillback feeds on debris in the bottom ooze, and on plant material and insect larvae. It reaches a weight of 2.3-3.2 kg (5-7 lb). In Indiana, Gammon (1973) determined 29.0-31.0°C (84.2-87.8°F) to be the quillback's optimum temperature range.

Value: Generally this species is held in low regard, though the flesh is white, flaky, sweet, and very tasty, particularly in the spring (Scott and Crossman, 1973). Its palatability is marred by the large number of bones which makes it hard to process (by machine or by hand).

Carpiodes velifer (Rafinesque). HIGHFIN CARPSUCKER

Range: The presence of the highfin carpsucker (Fig. 63) in the Lake Michigan Basin is based on two old records (Hubbs and Lagler, 1958): the Calumet watershed in Illinois and the Root River in Wisconsin. It is doubtful that this species now exists in the Basin.

Habits: The highfin carpsucker inhabits the moderate- to swift-flowing waters of larger rivers or quiet water immediately adjacent to the channels. Spawning occurs in early spring, usually in May, at which time the highfin migrates in large numbers to shallow areas and overflow ponds of streams (Harlan and Speaker, 1956). The highfin carpsucker feeds on debris in the bottom ooze, and on plant material and insect larvae. It reaches 356 mm (14 in.) in length.

Value: This species is seldom taken by fishermen on hook and line. The concensus of other authors is that this species has limited value as human food and is generally regarded to have little or no economic value for other uses. The highfin carpsucker allegedly competes with small channel catfish for food and with other fishes for space (Harlan and Speaker, 1956).

Catostomus catostomus (Forster). LONGNOSE SUCKER

Range: In the Basin, the longnose sucker (Fig. 64) is at the southern edge of its range. It is common in Lake Michigan and during spawning is found in many tributary streams.

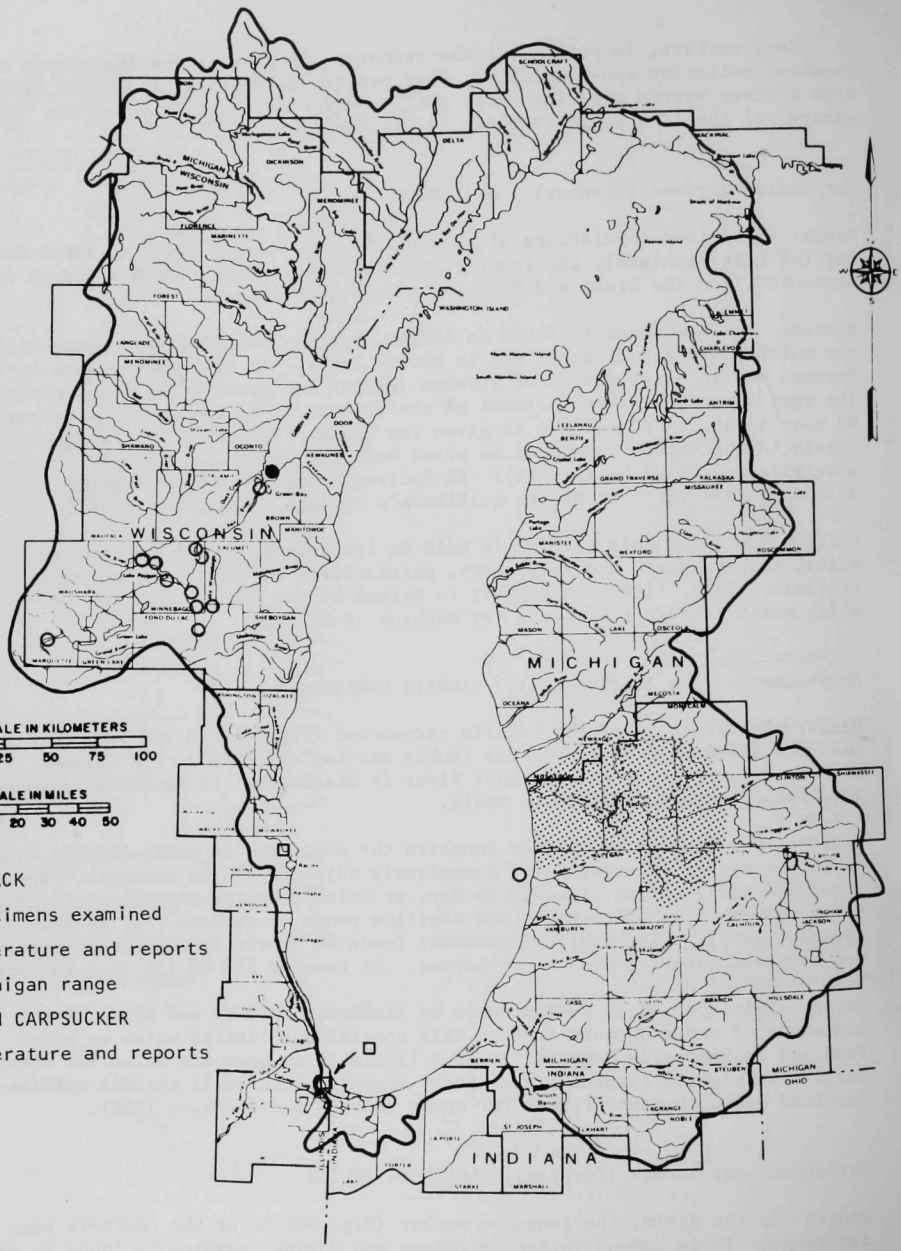

Fig. 63. Distribution of the Quillback (*Carpiodes cyprinus*) and Highfin Carpsucker (*Carpiodes velifer*).

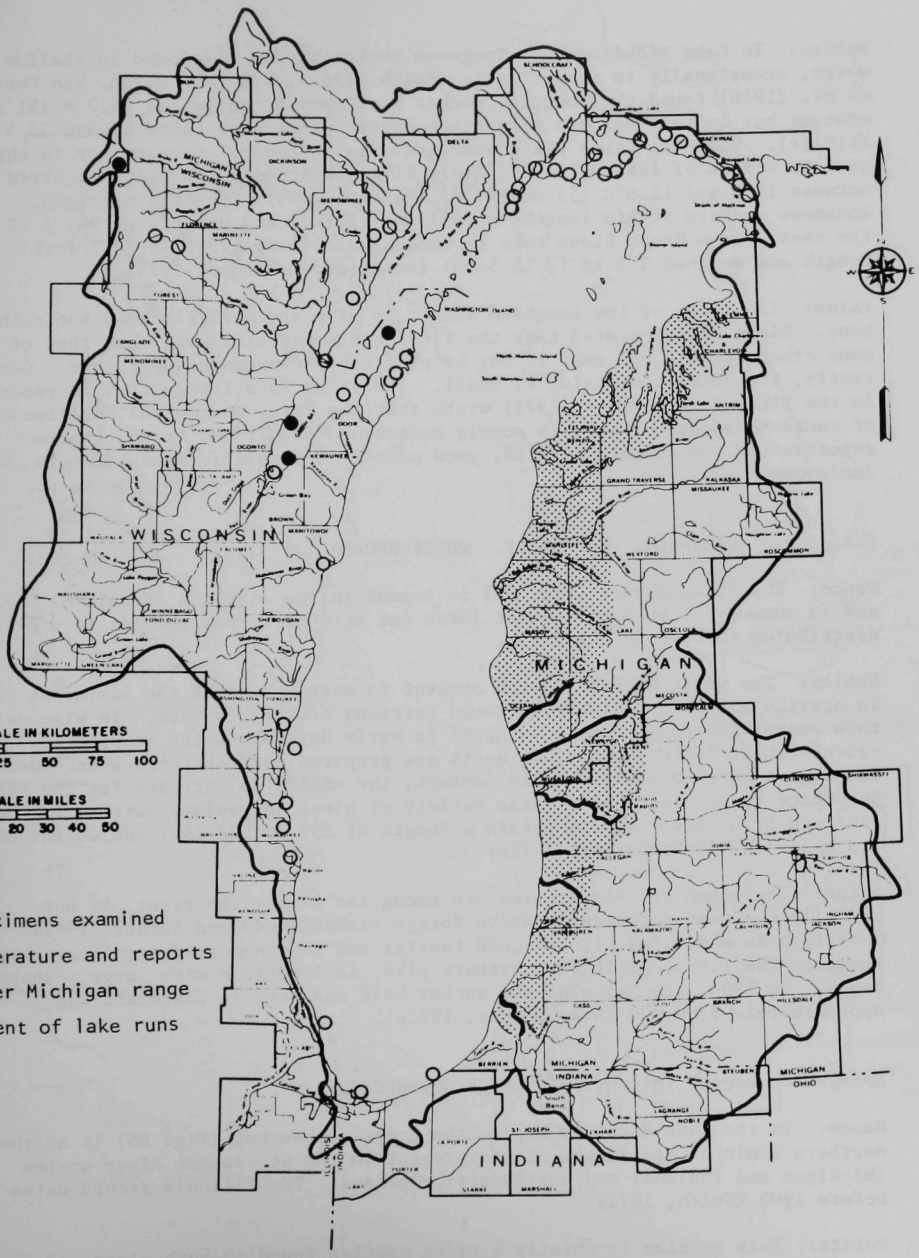

Fig. 64. Distribution of the Longnose Sucker (*Catostomus catostomus*).

Habits: In Lake Michigan, the longnose sucker is usually found in shallow water, occasionally in deeper water (Smith, 1964). In Lake Huron, Van Oosten *et al.* (1946) found the longnose sucker most common inside the 24.7 m (81 ft) contour but in fair numbers at greater depth. None were taken beyond 33.5 m (110 ft). Spawning takes place over gravelly bottoms of streams, or in the shallow waters of lakes. In the Brule River, Wisconsin, spawning occurred between 12.8 and 15.6°C (55 and 60°F) (Bailey, 1969). In Lake Michigan, longnose suckers attain lengths of 457 mm (18 in.) and weights of 907 g (2 lb); the record from Great Slave Lake in Canada was 642 mm (25-3/16 in.) fork length and weighed 3.3 kg (7 lb 5 oz) (Scott and Crossman, 1973).

Value: The flesh of the longnose sucker is firm and well flavored but rather bony. Hinks (1957) stated that the flesh has a better flavor than that of many other suckers and that it may be profitably canned in the future. Currently, its commercial value is small. Its value as a forage fish is recorded in the literature. Brown (1971) wrote that the *"true ecological relationship of suckers and game fishes is poorly understood but it may be that suckers are important to, or compatible with, good game fish populations at least in some instances."*

Catostomus commersoni (Lacépède). WHITE SUCKER

Range: The white sucker (Fig. 65) is common in the shallows of Lake Michigan and is common to abundant in most lakes and streams. This species is widely distributed throughout the Basin.

Habits: The white sucker, though present in most waters of the Basin, is rare in heavily silted and highly polluted portions of large rivers. In Wisconsin, this sucker generally spawns in April to early May when water temperature reaches about 7.2°C (45°F). No nests are prepared nor territories defended. The eggs adhere to whatever they contact; the adults do not care for the eggs. The white sucker feeds on a large variety of plant and animal matter, including fish and fish eggs. Adults attain a length of 559 mm (22 in.) and weight of 2.3 kg (5 lb) (Schneberger, 1972c).

Value: The young of this species are among the highly important, if not actually the most important, native forage fishes (Eddy and Surber, 1947). The flesh is white, sweet, and good tasting and is considered a delicacy when smoked. The flesh, as in the northern pike, is interlain with large y-shaped bones. In 1968, the value of the sucker bait industry in Wisconsin was approximately $300,000 (Schneberger, 1972c).

Erimyzon oblongus (Mitchill). CREEK CHUBSUCKER

Range: In the Lake Michigan Basin, the creek chubsucker (Fig. 66) is at the northern limit of its range. It is present in the St. Joseph River system (Michigan and Indiana) and northwestern Indiana. The Illinois record dates before 1905 (Smith, 1971).

Habits: This species is chiefly a creek species found in both clear and turbid waters over a wide variety of bottom types. Spawning occurs in early spring with movement upstream to riffles where the eggs are released over sand

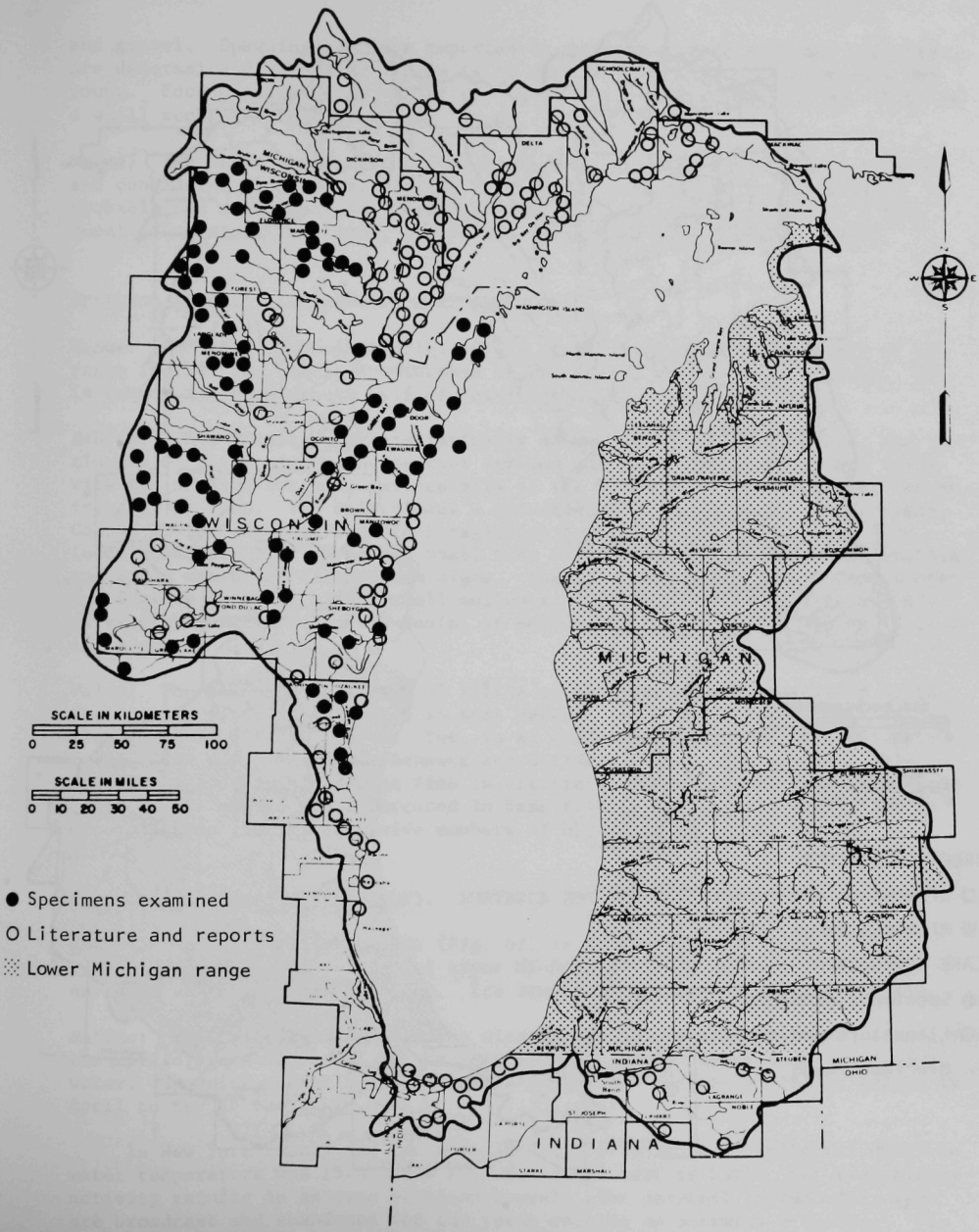

Fig. 65. Distribution of the White Sucker (*Catostomus commersoni*).

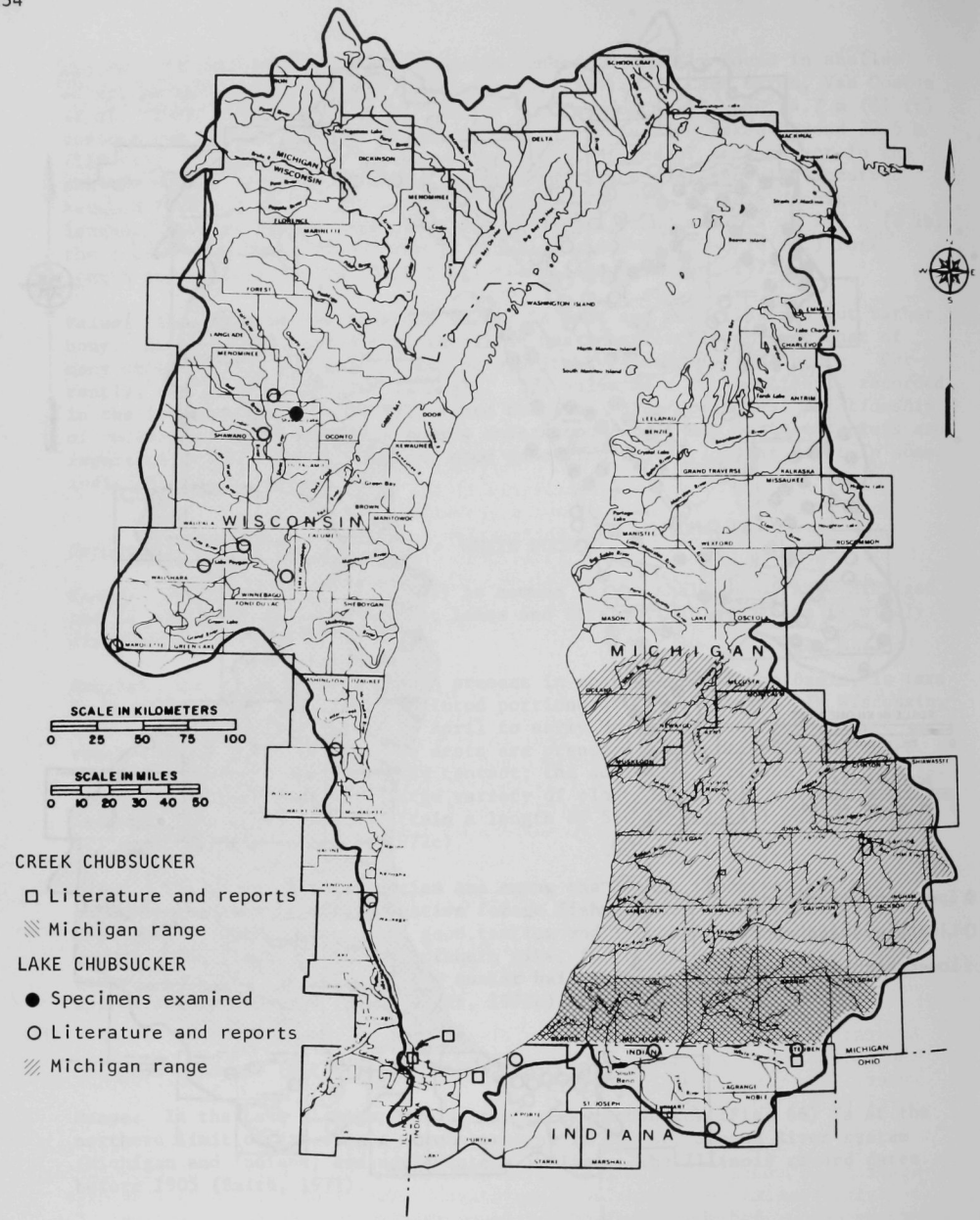

Fig. 66. Distribution of the Creek Chubsucker (*Erimyzon oblongus*) and Lake Chubsucker (*Erimyzon sucetta*).

and gravel. Spawning has been reported in ponds over muck bottoms. The eggs are demersal and adhesive. There is no nest preparation or care of eggs and young. Food consists of a variety of small plants and animal matter. This is a small sucker, seldom exceeding 178 mm (7 in.) in length.

Value: The creek chubsucker has no commercial importance; the flesh is bony and considered flavorless. In New York it is, next to the golden shiner, probably the most important forage fish of the smaller lakes, and is a frequent associate of pickerel, perch, and largemouth bass (Greeley, 1936).

Erimyzon sucetta (Lacépède). LAKE CHUBSUCKER

Range: The lake chubsucker (Fig. 66) is at the extreme northern limit of its range in the Lake Michigan watershed of Wisconsin, where it is uncommon. It is common in the southern half of lower Michigan.

Habits: This species characteristically occurs in lakes, oxbow lakes, and sloughs of large rivers and quieter streams and does well in ponds and lakes with mud or sand bottoms, particularly if the water is clear. Spawning occurs from May to June. The male cleans a gravelled area for a nest. In Michigan, Cooper (1936) reported that in forage-fish ponds the nonadhesive eggs were found scattered over large and small beds of vegetation and dead grass stubble, and among masses of filamentous algae. The lake chubsucker is a bottom feeder and ingests diatoms, algae, small mollusks, insect larvae, and large amounts of vegetable matter. In the Basin, it seldom reaches more than 229 mm (9 in.) in length.

Value: The lake chubsucker is of little or no importance commercially or to the angler, since it is scarce in most waters, is of small size, has bony flesh, and is without flavor. Yet, in an ecological sense, it is a valuable forage fish for predators. Bennett and Childers (1966) have proposed this species as a desirable forage fish in artificial ponds, quarry pits, and small lakes if the owners are interested in bass fishing and are not interested in attempting to control excessive numbers of bluegills and other sunfish.

Hypentelium nigricans (Lesueur). NORTHERN HOG SUCKER

Range: The northern hog sucker (Fig. 67) is at the northern limit of its range in the southern portion of upper Michigan. It is absent from the northern third of lower Michigan. Its status is uncommon to common locally.

Habits: This species frequents the clear parts of streams or rivers, especially the riffle areas where the bottom is gravelly. It is rarely found in muddy water. Spawning, described by Reighard (1920) and Hankinson (1932), occurs in April to May in the Basin.

In New York (Raney and Lachner, 1946), ripe males were collected when the water temperature was 15.6°C (60°F). No actual nest is built, but prespawning activity results in an area of clean gravel. The demersal, nonadhesive eggs are broadcast and abandoned and the young receive no parental attention. The hog sucker is generally inactive in water below 10°C (50°F). This fish is extremely sluggish in water as cold as 4.4°C (40°F) and has been seen lying quietly along the side of a log or stone in a riffle for long periods.

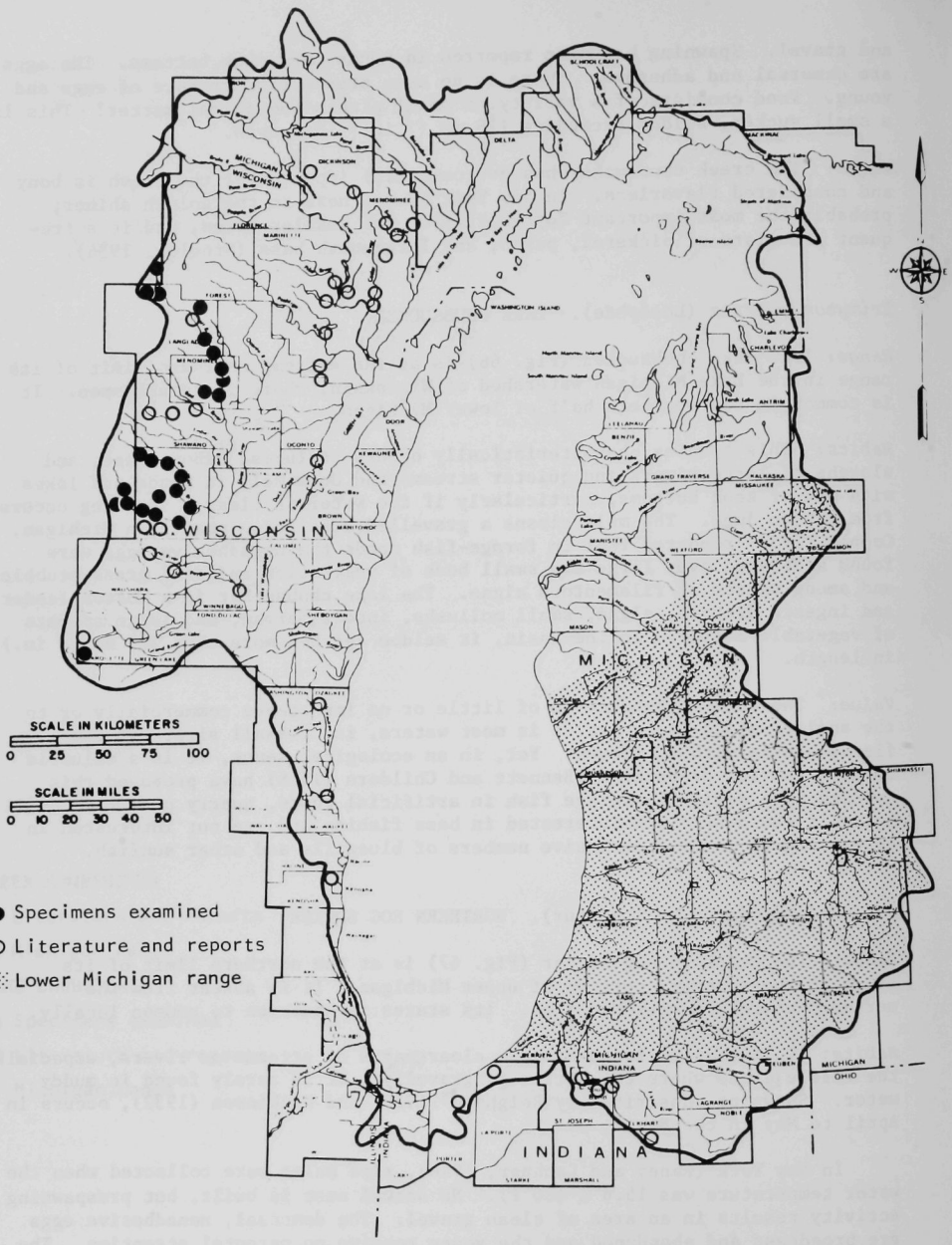

Fig. 67. Distribution of the Northern Hog Sucker (*Hypentelium nigricans*).

The northern hog sucker feeds over rocks, removing bits of vegetation, aquatic insects and their larvae, and small quantities of clams. In the Lake Michigan Basin, it is seldom over 330 mm (13 in.) in length.

Value: Occasionally the hog sucker is taken on worms. I have found this sucker tasty and sweet when dusted with flour and deep-fat fried. This species, while feeding, leaves behind a path of easily available food for minnows and other fish species; this may result in more bait fish. Thus a sucker species, not normally used as food, may benefit man indirectly by providing a means for catching the more highly touted game fish, such as bass and northern pike.

Ictiobus bubalus (Rafinesque). SMALLMOUTH BUFFALO

Range: The smallmouth buffalo (Fig. 68) has been reported twice from the Lake Michigan Basin: from Homer, Michigan (Hubbs, 1930b), and from the Calumet River (locale in question) in northeastern Illinois (Forbes and Richardson, 1920). The Michigan specimen, which had originally been sent to L. Agassiz by T. C. Norton, was catalogued in the Harvard Museum of Comparative Zoology (MCZ 2296) in 1862. Although Hubbs (1930b) reported that this specimen came from the St. Joseph River, all original labels and entries gave only "Homer, Mich." as the locality; Homer lies on the divide between the St. Joseph and Kalamazoo watersheds. The smallmouth buffalo is probably now extirpated in the Basin.

Habits: This species frequents bayous and large rivers; it characteristically prefers channels of clear, clean water. Spawning occurs in May over shallow mud flats at temperatures of 15.6-18.3°C (60-65°F). In Iowa, Harlan and Speaker (1956) reported that eggs are deposited randomly over the bottom or in vegetation. The smallmouth buffalo feeds on zooplankton and attached algae. Occasionally it reaches a weight of over 15.9 kg (35 lb).

Value: Because it is probably extirpated in the Basin, this species is of no importance to commercial or sport fisheries. The smallmouth buffalo is a premium fish to the commercial fisherman on the Mississippi River, frequently earning a better price than catfish.

Ictiobus cyprinellus (Valenciennes). BIGMOUTH BUFFALO

Range: The bigmouth buffalo (Fig. 68) has been reported only from the Wolf and lower Fox river systems of Wisconsin. One record was of a fish identified from pictures; the remainder were unverified reports. In the Lake Michigan Basin, the bigmouth buffalo is at the extreme northern limit of the eastern half of its range.

Habits: This fish is typically an inhabitant of larger rivers, oxbows, floodplain lakes and sloughs, bayous, and shallow lakes. Spawning, from April to June, occurs at temperatures of 15.6-18.3°C (60-65°F) during periods of rising water. Hatching occurs within 9-10 days at 16.7°C (62°F). This buffalo consumes plankton and bottom fauna. It grows to a large size: a 21.8-kg (48-lb) fish was seined from Long Lake (Waupaca County), Wisconsin.

Value: The bigmouth buffalo seldom takes a hook but occasionally will take worms or doughballs. The flesh, though nutritious, is coarse and not highly flavored. It is considered inferior to catfish and smallmouth buffalo but superior to carp (Cross, 1967).

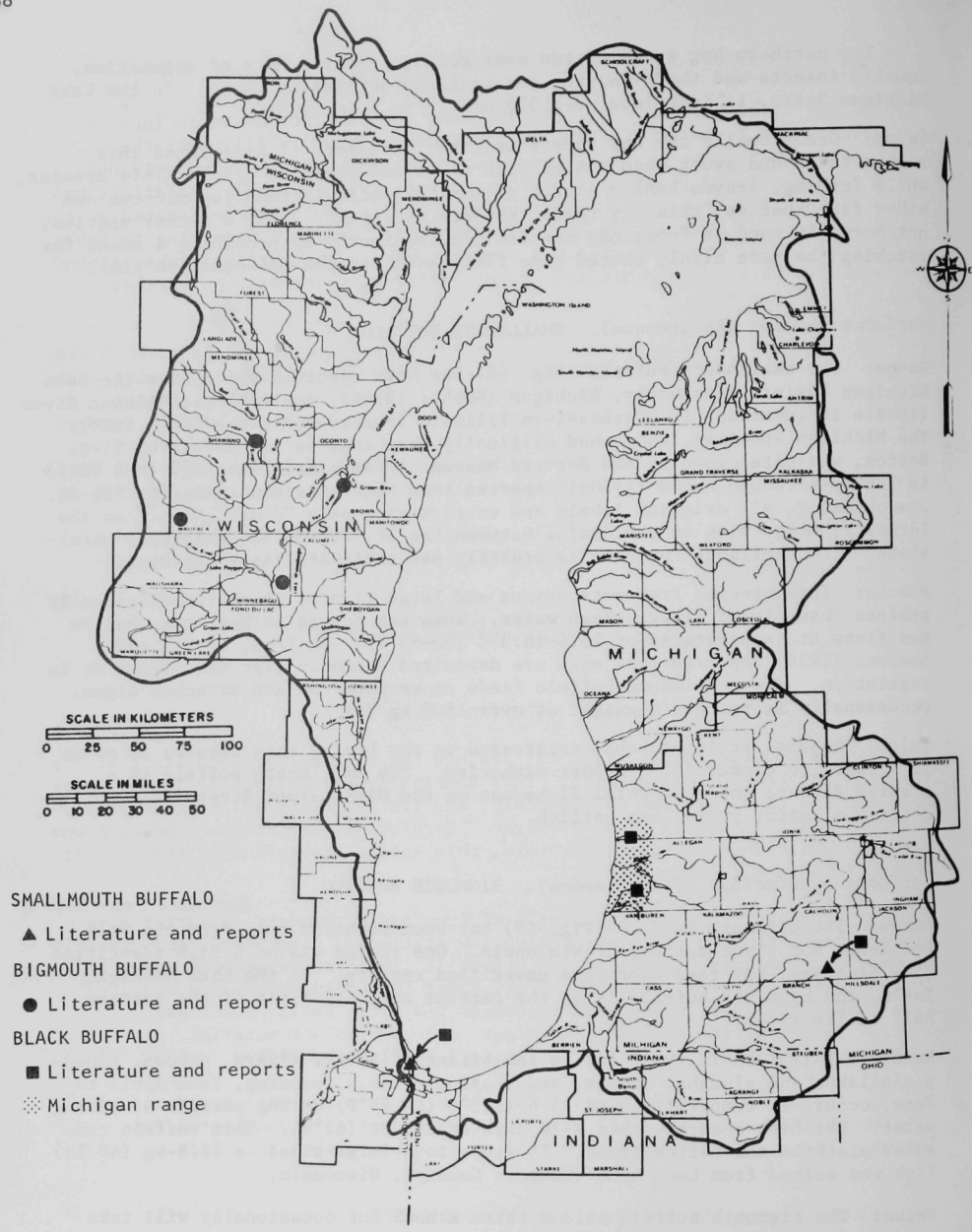

Fig. 68. Distribution of the Smallmouth Buffalo (*Ictiobus bubalus*), Bigmouth Buffalo (*Ictiobus cyprinellus*), and Black Buffalo (*Ictiobus niger*).

Ictiobus niger (Rafinesque). BLACK BUFFALO

Range: The black buffalo (Fig. 68) has been recorded at few Basin locales: the Calumet River system (Forbes and Richardson, 1920) in Illinois; the Macatawa and Kalamazoo river systems and Homer, in Michigan (Hubbs, 1930b), and Michigan's Lower Scott Lake (Frankenberger, 1976--letter). An effort was made to check the Homer, Michigan, specimen but it could not be located at the Harvard Museum of Comparative Zoology (Cambridge, Mass.). According to Hubbs and Lagler (1958), this species was present only in the marginal lakes around the southern part of Lake Michigan (where native), which was the northern limit of its range.

Habits: The black buffalo is found in sloughs and rivers, and is perhaps most common in silty backwaters (Hubbs and Lagler, 1958). Nothing is known about the spawning of this species in the Basin. It feeds on plankton, insect larvae, and vegetation (Harlan and Speaker, 1956). The black buffalo reaches weights of 4.5-6.8 kg (10-15 lb) in the Wisconsin portion of the Mississippi River. It seldom takes natural or artificial lures. A 22.8-kg (50-lb 4-oz) fish was collected in Lower Scott Lake (Allegan County), Michigan, in 1956.

Value: The black buffalo brings the commercial fisherman fancy exvessel prices in the Mississippi basin; however, its commercial value in the Lake Michigan Basin is nil.

Status: Wisconsin has placed this species on watch status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

Minytrema melanops (Rafinesque). SPOTTED SUCKER

Range: The spotted sucker (Fig. 69) reaches the extreme northern limit of its range in the Lake Michigan Basin. This species is common locally in the lower Wolf and Fox river systems in Wisconsin, and its range extends north to the Muskegon River system in lower Michigan. In Michigan and Indiana, populations are widely disjunct and generally rare; this species is common in the Elkhart River of Indiana (Peterson, 1971).

Habits: The spotted sucker occurs in sloughs and backwaters of larger rivers or in those stream sections which have low gradients, clean sand, and gravelly or hard clay bottoms. Phillips and Underhill (1971) reported both sexes in reproductive condition in the St. Croix River (Wisconsin-Minnesota boundary water) on 9 May 1968. Wisconsin specimens had eaten small crustaceans, aquatic insect larvae, filamentous algae, and other plant material. This species attains a length of 457 mm (18 in.) (Carlander, 1969).

Value: The spotted sucker, occasionally caught from the Wolf River on worms or grubs by fishermen who call it a "corncob sucker", is considered fine eating. The young are probably preyed on by other fishes and birds.

Moxostoma anisurum (Rafinesque). SILVER REDHORSE

Range: The silver redhorse (Fig. 70) is scattered throughout the central portion of the Lake Michigan Basin. Populations are disjunct and its status is uncommon.

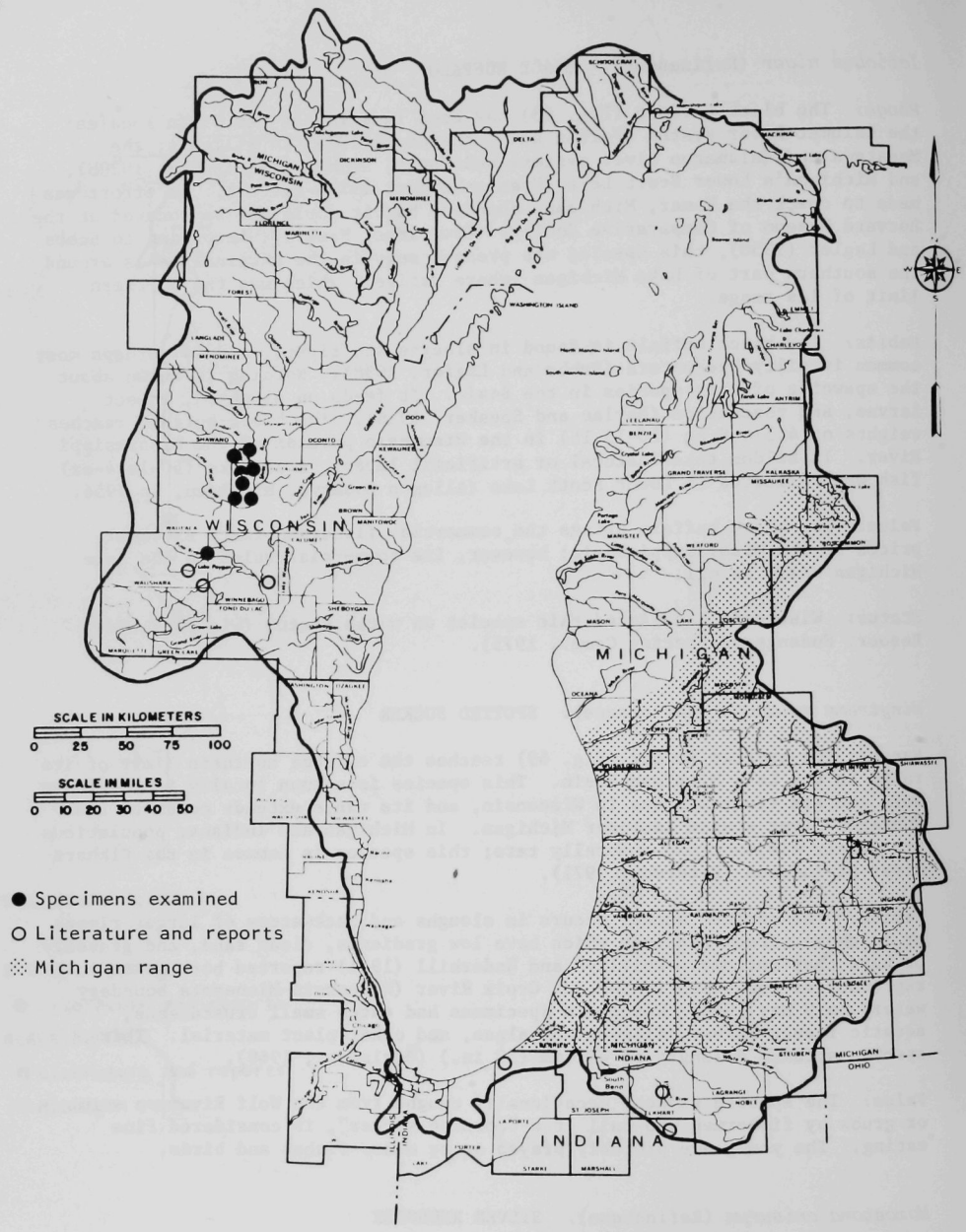

Fig. 69. Distribution of the Spotted Sucker (*Minytrema melanops*).

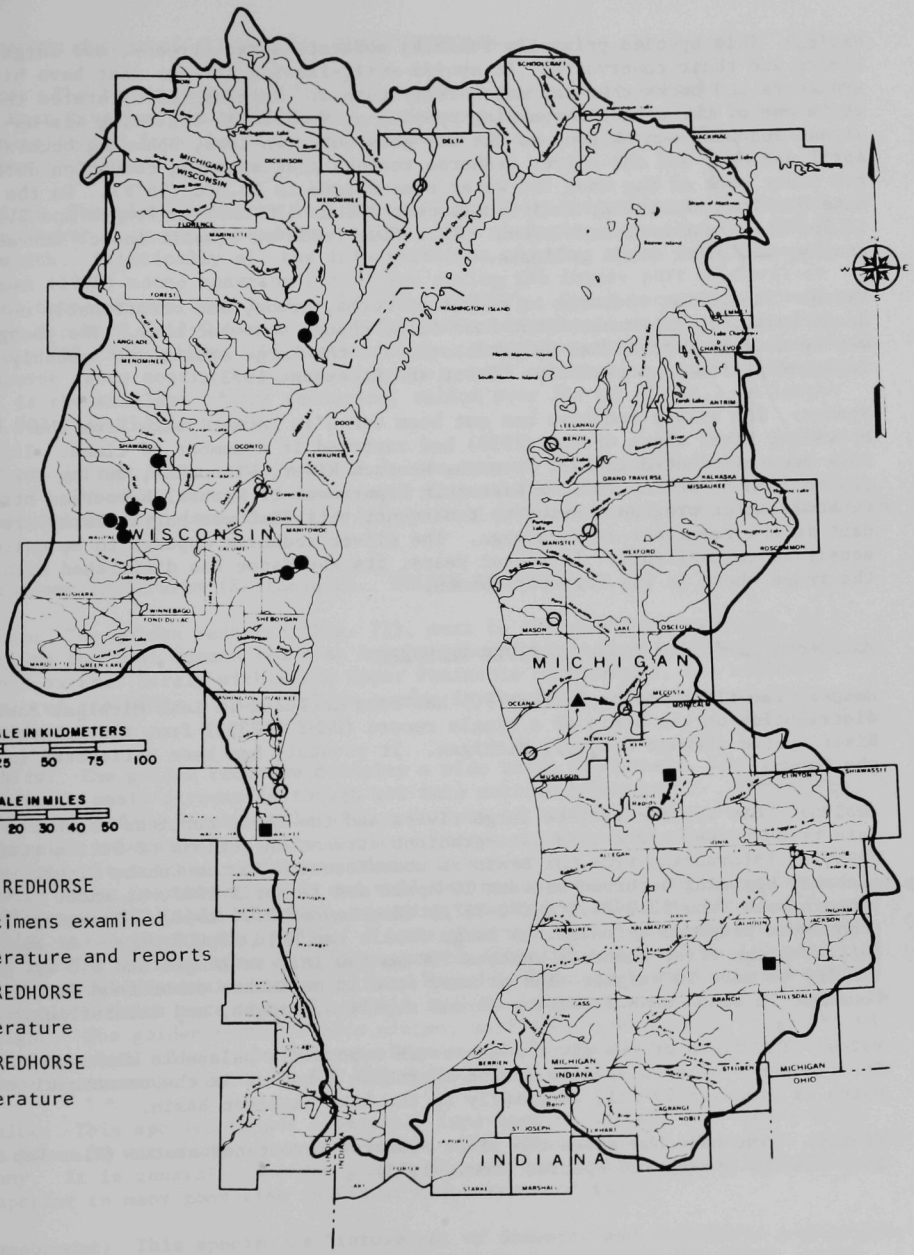

Fig. 70. Distribution of the Silver Redhorse (*Moxostoma anisurum*), River Redhorse (*Moxostoma carinatum*), and Black Redhorse (*Moxostoma duquesnei*).

Habits: This species primarily inhabits moderate-sized streams, and large rivers and their reservoirs. It avoids swift-flowing streams that have high gradients and those that are excessively turbid. Jenkins (1970) stated that it is one of the earliest-spawning species of *Moxostoma*, beginning its upstream spawning run as soon as the ice goes out. In Iowa, spawning occurs in April and May, and the silver redhorse reaches peak spawning condition during the first week of May when the water temperature is 13.3°C (56°F). In the Lake Michigan watershed, individuals over 508 mm (20 in.) in length and 2.3 kg (5 lb) in weight have been taken. This fish feeds on aquatic insect larvae, snails, and other small mollusks.

Value: The silver redhorse is caught on worms, grubs, and occasionally on dough bait. It is an excellent food fish, though somewhat bony. The young may be used as forage fish by predators, but the large adults are probably relatively free from predation (Scott and Crossman, 1973).

Status: The silver redhorse has not been taken in recent years from the Milwaukee River where Greene (1935) had reported it a number of times. It may have been eliminated in 1971 from the Waupaca River, Wisconsin, during the application of antimycin in a Wisconsin Department of Natural Resources stream rehabilitation program. Prior to treatment, this fish was particularly abundant in the reservoir at Weyauwega. The silver redhorse appears to be quite sensitive to toxicants. In recent years, its abundance has diminished within the range where it was formerly common.

Moxostoma carinatum (Cope). RIVER REDHORSE

Range: The river redhorse (Fig. 70) has been included in Lake Michigan Basin distribution on the basis of a single record (UMMZ 112323) from the Muskegon River system (Newago County), Michigan. It probably has been extirpated in the Basin.

Habits: This species prefers large rivers and the lower portions of their main tributaries. It avoids base-gradient streams in regions of little relief. Spawning information from the Basin is nonexistent. In the Cahaba River, Alabama, spawning occurred between 10 April and 17 April 1967, at water temperatures from 22.2-24.4°C (72-76°F) (Hackney *et al.*, 1968). Spawning redds were prepared by males. A large female can hold 23,000 eggs. At Basin latitude, the river redhorse reaches 762 mm (30 in.) in length and 4.5 kg (10 lb) or more in weight. The primary food is mollusks; other food items consumed in small quantities are larval mayflies, midges, and caddisflies.

Value: The flesh of the river redhorse is reportedly palatable although bony. The frequency of this species in the sportsman's bag or in the commercial catch is practically nil, especially in the Lake Michigan Basin.

Status: Wisconsin has given the river redhorse threatened status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

Moxostoma duquesnei (Lesueur). BLACK REDHORSE

Range: The black redhorse (Fig. 70) has been reported in Wisconsin only from the Root River and is now believed extirpated. In Michigan, this species has been collected from the Grand and Kalamazoo rivers (Jenkins, 1970). Its status is rare.

Habits: The black redhorse is present in small to large rivers, but is generally absent from small headwater tributaries averaging less than 3 m (10 ft) in width. Practically all the information on spawning comes from Missouri. Bowman (1970) noted spawning activities during the latter part of April at water temperatures from 13.3 to 22.2°C (56-72°F). Chief requirements were a water depth of 0.15-0.6 m (0.5-2.0 ft) and a substrate composed of approximately 70% fine rubble, 10% coarse rubble, and 20% sand and gravel. The black redhorse feeds mostly on aquatic insects, small crustaceans, and roundworms, and is the smallest of the redhorses, seldom over 381 mm (15 in.) in length and 907 g (2 lb) in weight.

Value: In the Basin, this species is too rare to be of any importance to the angler. However, its persistence as a form of fish life is important, and care must be exercised that this interesting species is not lost from the Basin.

Moxostoma erythrurum (Rafinesque). GOLDEN REDHORSE

Range: The golden redhorse (Fig. 71), next to the shorthead redhorse, is perhaps the most common redhorse in the Lake Michigan Basin. The species range extends barely within the Upper Peninsula of Michigan, the northern limit of its range. This fish is common in the lower two-thirds of lower Michigan.

Habits: The golden redhorse occupies a wide range of streams, from large rivers to small streams (although not into extreme headwaters). The golden redhorse prefers deeper pools with a variety of bottom types and possibly has a greater tolerance for silt- and sand-bottom streams than other redhorse species. It reaches maximum abundance in moderately clear, unpolluted streams having large, permanent pools and well-defined gravelly or rocky riffles (Pflieger, 1971). In Michigan, spawning occurred on 10-11 May in 22.2°C (72°F) water (Hankinson, 1932). I have observed reproductive adults jumping and rolling in fast runs over large gravel (on either side of an island) in a central Wisconsin stream in late May. In Wisconsin, this species occasionally attains more than 457 mm (18 in.) in length and 1.1 kg (2 lb 8 oz) in weight. The golden redhorse eats midges, mayflies, caddisflies, oligochaetes, and fingernail clams. In Indiana, Gammon (1973) determined that its optimum temperature range was 26-29.5°C (78.8-81.5°F).

Value: This species is not especially important to anglers but occasionally is taken on worms and other live baits. The flesh is sweet and tasty, although bony. It is general consensus that redhorses are excellent food fishes and superior to many game fish in flavor and texture of flesh.

Management: This species is *"intolerant of domestic and industrial pollutants, continuous turbidity, and rapid silting of stream bottoms"* (Trautman, 1957). Care must be exercised in fish toxification programs that this potentially

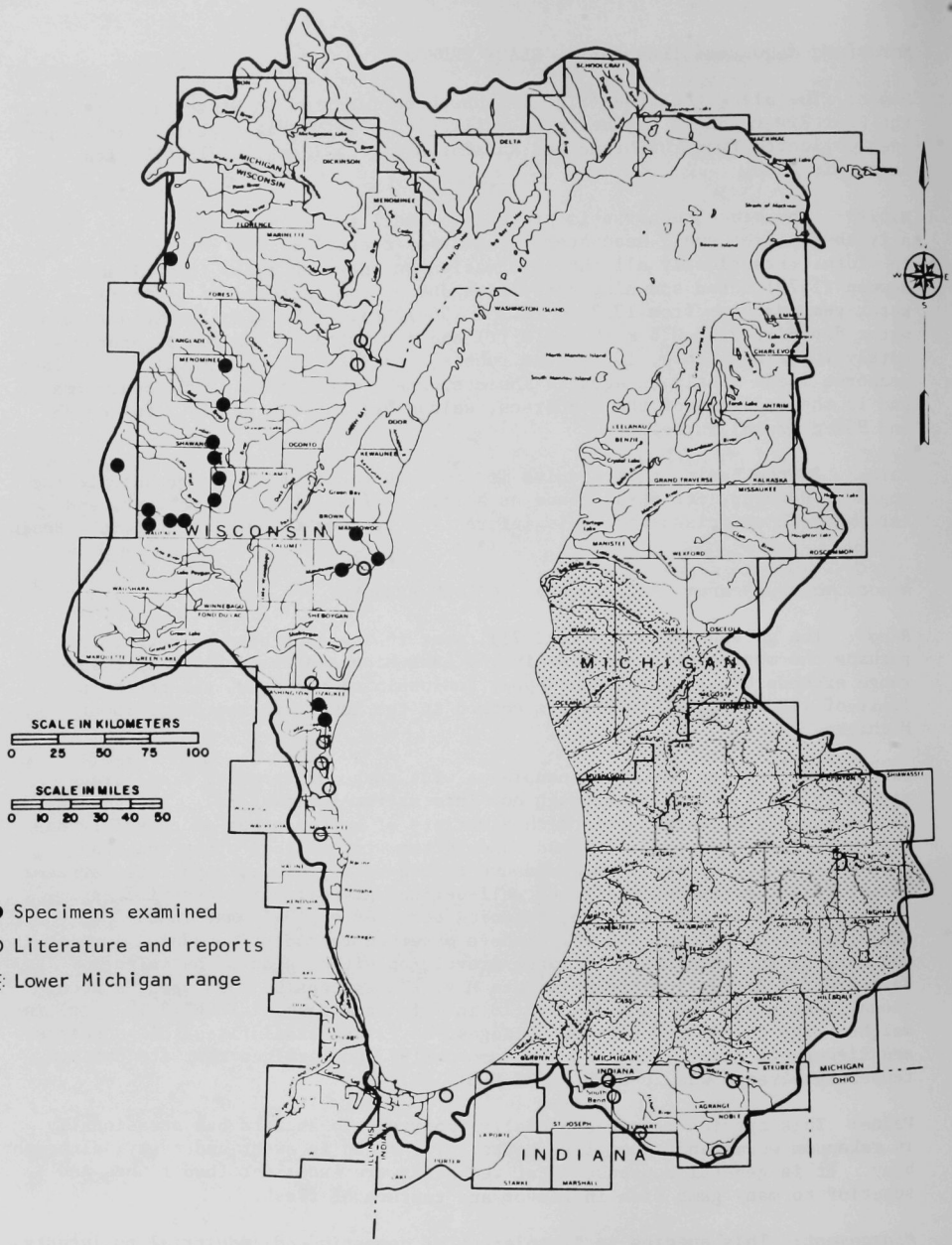

Fig. 71. Distribution of the Golden Redhorse (*Moxostoma erythrurum*).

important food resource is not eliminated. The golden redhorse is particularly sensitive to antimycin and can be completely eliminated from a river system in which this fish toxicant is used.

Moxostoma macrolepidotum (Lesueur). SHORTHEAD REDHORSE

Range: The shorthead redhorse (Fig. 72) is locally uncommon to common in widely disjunct locales throughout the Basin.

Habits: The shorthead shows widest range in habitats of all species of *Moxostoma*. It typically inhabits moderate- to large-sized streams, but is also present in lakes in the northern part of the Basin. The shorthead redhorse prefers relatively silt-free bottoms with some swift water or riffles. A study in the Peshtigo River, Wisconsin, noted that this species had spawned in early May when water temperatures were below 11.1°C (52°F) (Hawley, 1967). In southern Michigan, Reighard (1920) recorded spawning in early and mid-May. No nests are built nor is there care of eggs or young. Its food consists of aquatic insects and mollusks. In the Basin, it may reach a length of 635 mm (25 in.) and a weight of over 2.7 kg (6 lb). In Indiana, Gammon (1973) determined optimum temperature range for this species to be 26-27.5°C (78.8-81.5°F).

Value: Occasionally, the shorthead redhorse is caught on worms, grubs, hoppers, crickets, or small pieces of meat (Harlan and Speaker, 1956). Many regard this fish as the best of the suckers, for the flesh is white and flaky and when baked is an excellent food (Eddy and Surber, 1947). The biggest objection to eating these suckers is the presence of large Y-shaped bones between the muscle layers. This can be avoided by grinding the fillets into patties.

Moxostoma valenciennesi Jordan. GREATER REDHORSE

Range: Populations of the greater redhorse (Fig. 73) are widely disjunct within the Basin as well as within its restricted range. Its status is rare.

Habits: The greater redhorse mainly inhabits large streams and lakes having clear waters and bottoms of clean sand, gravel, or boulders. There is no spawning information from the Lake Michigan Basin. In the St. Lawrence River, Jenkins (1970) observed spawning from the end of June into early July at water temperatures of 16.7-18.9°C (62-66°F). He noted that the St. Lawrence River water in the Thousand Islands area warmed relatively late, and the greater redhorse spawning run closely followed that of the white sucker, *Catostomus commersoni*. In 1945, three tuberculate males collected from the Ausable River (Lake Huron drainage), Michigan, apparently had completed spawning by 23 June. No nest construction has been observed. The greater redhorse feeds principally on aquatic insects and mollusks (Scott, 1967). This species may weigh 3.6 kg (8 lb) or more.

Value: Considering its rarity, this species is seldom taken by man. It has no value as a commercial species. In Wisconsin, the greater redhorse has been accorded endangered status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975). This species has disappeared from numerous locales from which it had been previously reported. In order to secure its future, quick action to provide a suitable sanctuary may be necessary.

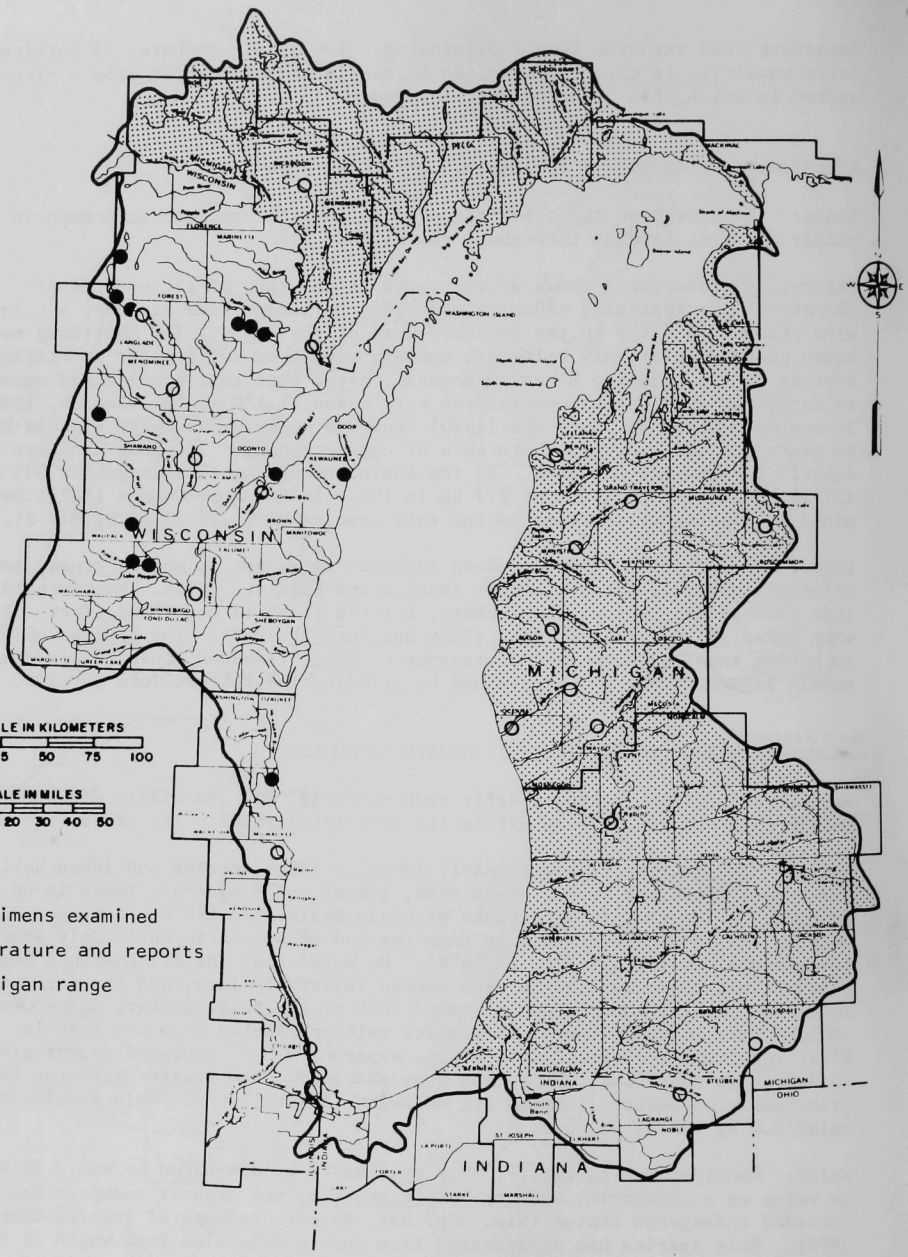

Fig. 72. Distribution of the Shorthead Redhorse (*Moxostoma macrolepidotum*).

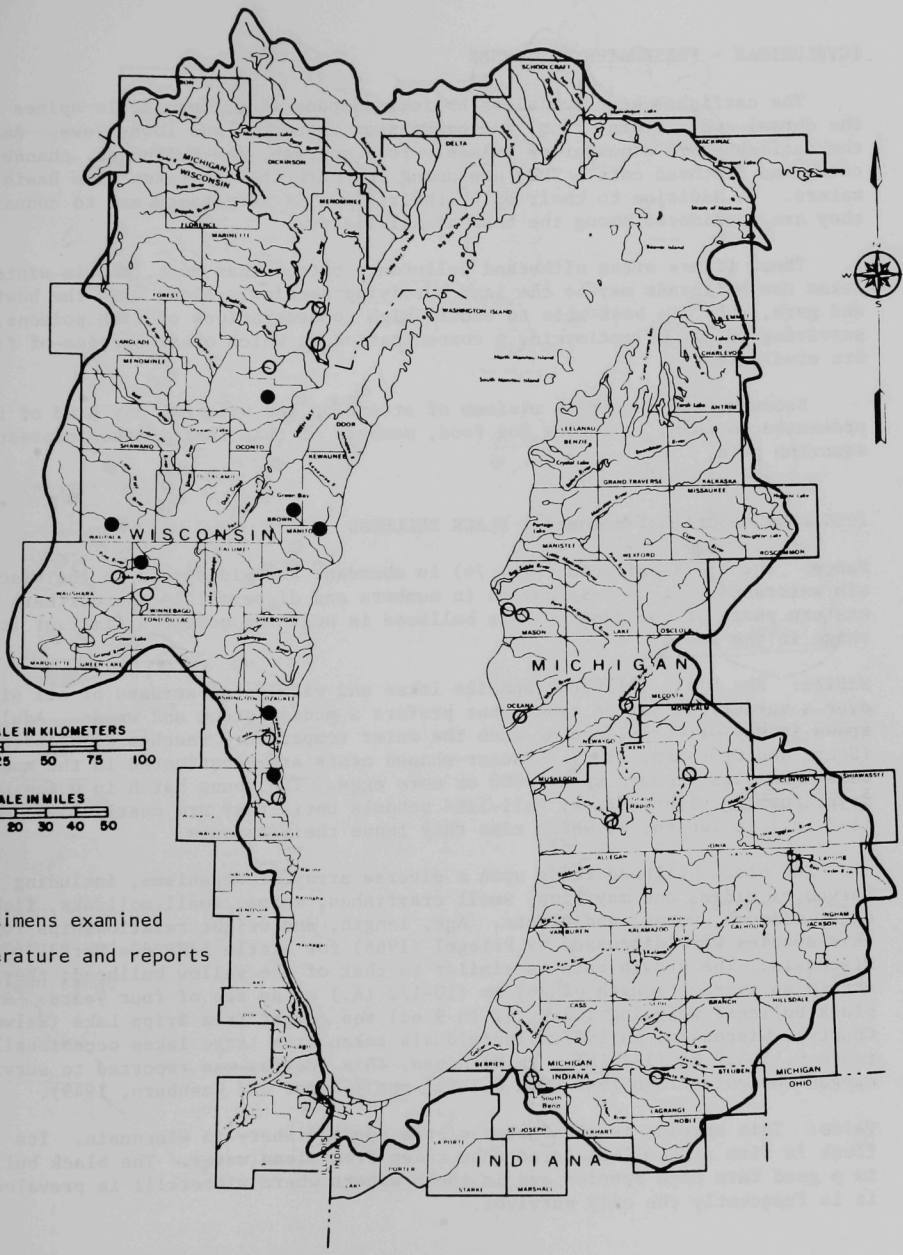

Fig. 73. Distribution of the Greater Redhorse (*Moxostoma valenciennesi*).

ICTALURIDAE - FRESHWATER CATFISHES

The catfishes have scaleless bodies, adipose fins, formidable spines in the dorsal and pectoral fins, and barbels on the upper and lower jaws. Among the catfishes are a number of valuable food species, the bullheads, channel cats, and flathead cats. They are among the largest fish taken from Basin waters. In addition to their bulk, their flesh is very tasty and to connoisseurs they are considered among the best of all fishes.

These fishes often withstand pollutants better than most, and in winterkill lakes the bullheads may be the last surviving species. Along with the bowfins and gars, they are best able to endure high concentrations of fish poisons, surviving 20 ppb of antimycin, a concentration at which other species of fish are eradicated.

Because they require a minimum of attention and will eat any kind of food presented to them, including dog food, members of this family make interesting aquarium pets.

Ictalurus melas (Rafinesque). BLACK BULLHEAD

Range: The black bullhead (Fig. 74) is abundant and widespread in the Wisconsin watershed. It is less common in numbers and dispersal in the northern and eastern parts of the Basin. This bullhead is near the northern limit of its range in the Basin.

Habits: The black bullhead inhabits lakes and warm-water streams of all sizes over a variety of bottom types, but prefers a muddy bottom and weeds. Adults spawn in May or early June or when the water temperature reaches 21°C (69.8°F) (Scott and Crossman, 1973). Saucer-shaped nests are constructed in the mud or sand. Females produce up to 6000 or more eggs. The young hatch in a few days, forming tight, black, ball-like schools until they are nearly 25-51 mm (1-2 in.) in length, at which time they leave their parents.

The black bullhead feeds upon a diverse array of organisms, including larvae of midges and mayflies, small crayfishes, worms, small mollusks, fish eggs, minnows, worms, and plants. Age, length, and weight relationships for this species were discussed by Priegel (1966) for Little Lake des Morts, Wisconsin. The growth rate is similar to that of the yellow bullhead; they attain an average length of 267 mm (10-1/2 in.) at an age of four years. A black bullhead weighing 1.2 kg (2 lb 9 oz) was caught from Tripp Lake (Walworth County), Wisconsin, in 1967. Individuals taken from large lakes occasionally reach 0.45-0.9 kg (1-2 lb). In Michigan, this species was reported to survive oxygen concentrations less than 0.2-0.3 ppm (Cooper and Washburn, 1949).

Value: This species is a mainstay of the sport fishery in Wisconsin. Its flesh is firm and well-flavored when taken from clean water. The black bullhead is a good farm pond species and in those waters where winterkill is prevalent, it is frequently the only survivor.

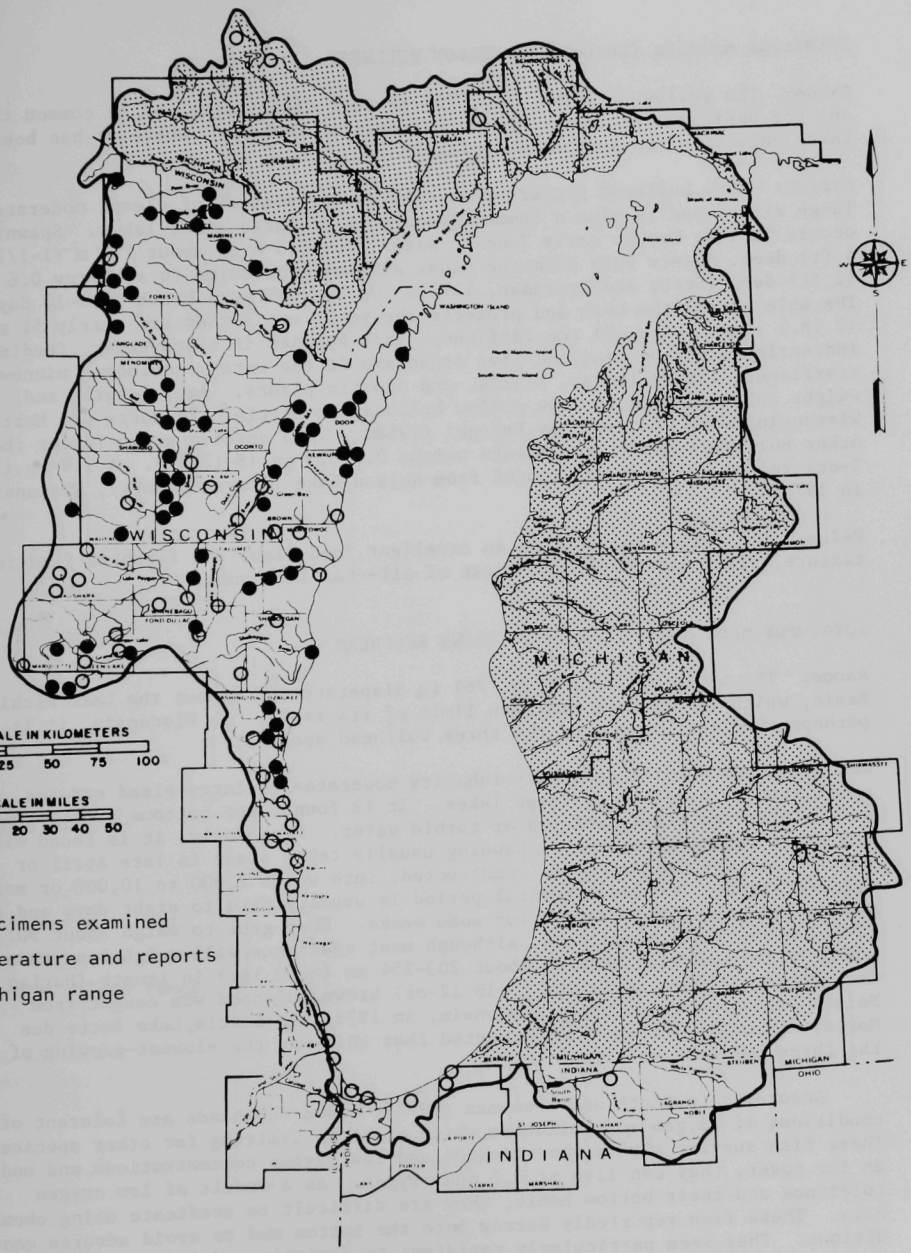

Fig. 74. Distribution of the Black Bullhead (*Ictalurus melas*).

Ictalurus natalis (Lesueur). YELLOW BULLHEAD

Range: The yellow bullhead (Fig. 75) is well distributed and is common throughout the Basin except in the Upper Peninsula of Michigan, where it has been taken only from the southernmost edge.

Habits: This bullhead prefers the quiet, weedy sectors of clean, moderate to large rivers and is also a common inhabitant of large clear lakes. Spawning occurs in late May to early June in water from 0.5 m to about 1.2 m (1-1/2 to 4 ft) deep. Nests vary from the usual shallow depression to a burrow 0.6 m (2 ft) deep (Scott and Crossman, 1973). Up to 7000 eggs hatch in 5-10 days. The male guards the nest and protects the young until they are nearly 51 mm (2 in.) long. Like all the catfishes, this species is a scavenger, feeding indiscriminately on dead and live organisms in the water, including minnows, crayfishes, insect larvae, snails, and aquatic plants. Age, length, and weight relationships for the yellow bullhead in Little Lake Butte des Morts, Wisconsin, were discussed by Priegel (1966). This species grows faster than other bullheads and at four years weighs 0.2-0.3 kg (8-12 oz). A 1.4-kg (3-lb 3-oz) yellow bullhead was caught from Nelson Lake (Sawyer County), Wisconsin, in 1972.

Value: The yellow bullhead is an excellent food fish; the flesh is fine in texture, firm, delicious, and--best of all--has few bones.

Ictalurus nebulosus (Lesueur). BROWN BULLHEAD

Range: The brown bullhead (Fig. 76) is dispersed throughout the Lake Michigan Basin, which is near the northern limit of its range. In Wisconsin, it is perhaps the least common of the three bullhead species.

Habits: This species generally inhabits moderate- to large-sized streams, or small streams adjacent to large lakes. It is found over bottoms of all types and in clear to highly colored or turbid water. Frequently, it is found with the other bullhead species. Spawning usually takes place in late April or May. A saucer-shaped nest is constructed, into which 2,000 to 10,000 or more eggs are laid. The developmental period is usually five to eight days and the young remain in tight schools for some weeks. They grow to weigh about 907 g (2 lb) under ideal conditions, although most specimens will weigh less than 454 g (1 lb) and will average about 203-254 mm (8-10 in.) in length (Harlan and Speaker, 1956). A 1.7-kg (3-lb 12-oz) brown bullhead was caught from Nelson Lake (Sawyer County), Wisconsin, in 1972. In Little Lake Butte des Morts, Wisconsin, Priegel (1966) noted that this was the slowest-growing of the three bullhead species.

According to Scott and Crossman (1973), brown bullheads are tolerant of conditions of oxygen and pollution which might be limiting for other species. These fish survive high carbon dioxide and low oxygen concentrations and under an ice cover, they can live at 0.2 ppm oxygen. As a result of low oxygen tolerance and their bottom habit, they are difficult to eradicate using chemicals. These fish reportedly burrow into the bottom mud to avoid adverse conditions. They seem particularly resistant to domestic and industrial pollution and in many heavily polluted streams near Montreal were the only species present.

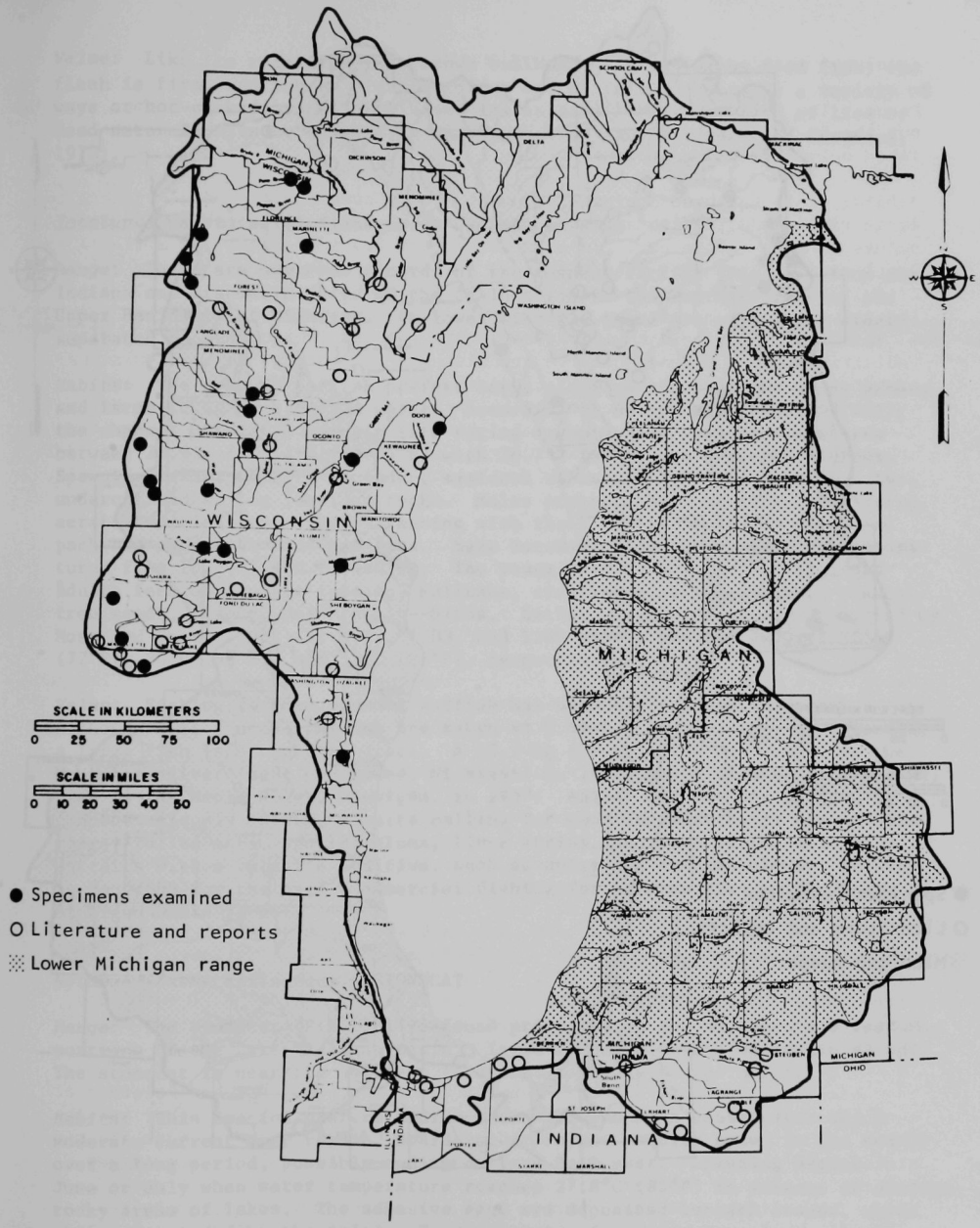

Fig. 75. Distribution of the Yellow Bullhead (*Ictalurus natalis*).

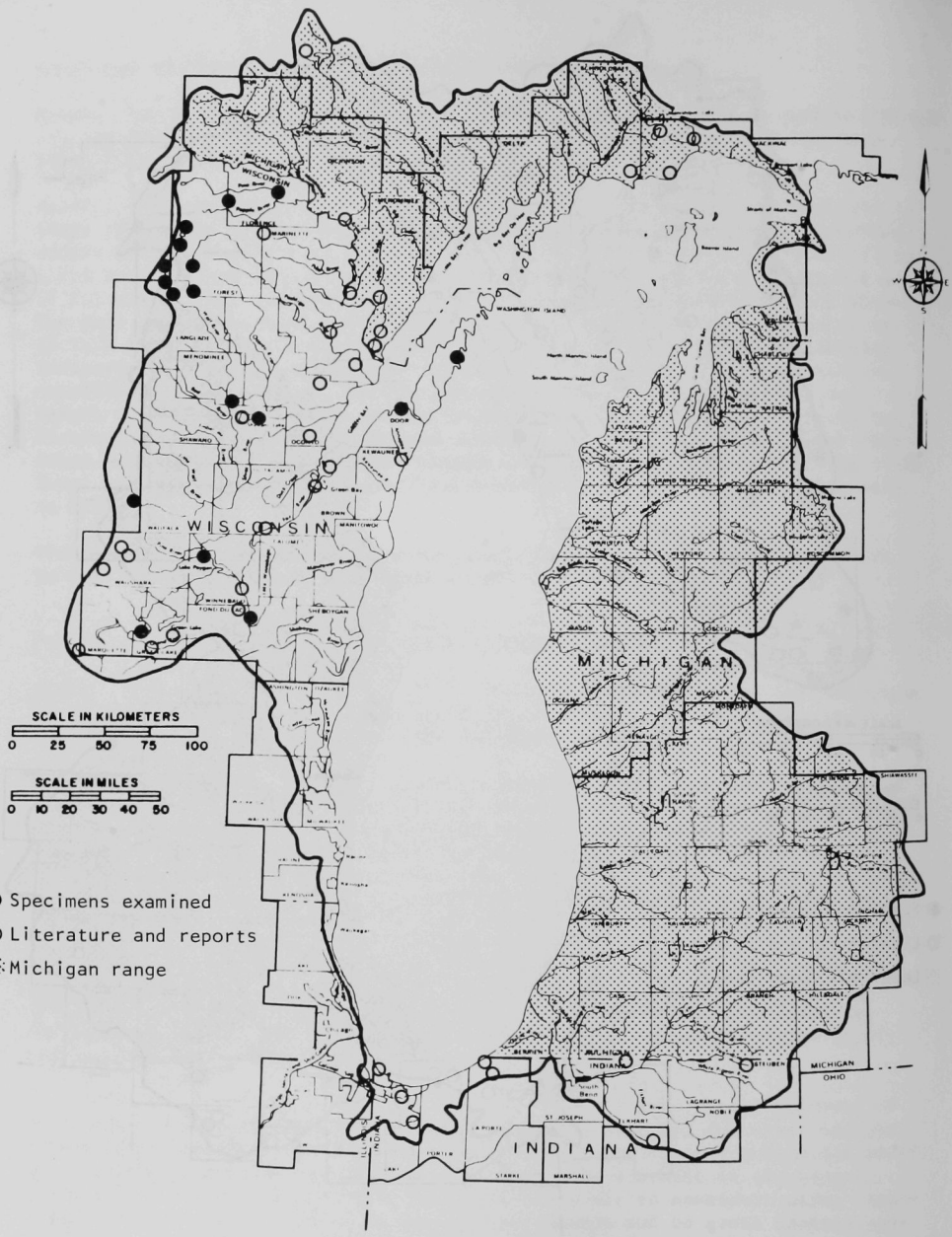

Fig. 76. Distribution of the Brown Builhead (*Ictalurus nebulosus*).

Value: Like its relatives, the brown bullhead is a delicious food fish; the flesh is firm, reddish to pink in color, and delicious cooked in a variety of ways or hot-smoked. Brown bullheads can be taken with a variety of live or dead natural baits or doughballs and are easily caught (Scott and Crossman, 1973).

Ictalurus punctatus (Rafinesque). CHANNEL CATFISH

Range: There are numerous records of the channel catfish (Fig. 77) from the Indiana and Wisconsin parts of the Basin north to the southern edge of the Upper Peninsula of Michigan. In lower Michigan there are only a few widely separated records.

Habits: The channel catfish prefers large sluggish streams, impounded waters, and large lakes with turbid water. According to Scott and Crossman (1973), the channel catfish spawns in late spring or summer at water temperatures between 23.9 and 29.4°C (75-85°F) with 26.7°C (80°F) the apparent optimum. Spawning takes place in secluded, semidark nests built by the male in holes, undercut banks, log jams, or rocks. Males protect the nest after egg-laying, aerate and clean the eggs by fanning with their paired fins, and press and pack the eggs with body and fins. Eggs hatch in five to ten days at temperatures from 15.6-27.8°C (60-80°F). The young feed on aquatic insects; the adults feed on aquatic insects, mollusks, crayfishes, algae, aquatic plants, tree seeds, fishes, and--rarely--birds. Lethal oxygen levels were reported by Moss and Scott (1961) at 0.95, 1.03, and 1.08 ppm at temperatures of 25°C (77°F), 30°C (86°F), and 35°C (95°F), respectively.

Value: Fishing for the channel catfish has become a specialized sport. Although most channel catfish are taken at 0.45-0.9 kg (1-2 lb), occasionally a large fish is brought to creel. A 12.7-kg (28-lb) fish was caught in the Menominee River (near Menominee, Michigan) in 1971, and a 21.6-kg (47-lb 8-oz) fish in the Maple River, Michigan, in 1937. Angler addicts for catfish concoct uniquely odiferous baits calling for such ingredients as cheese trimmings, rolled oats, spoiled clams, liver strips, and fish and/or chicken entrails with a volatile additive, such as anise and chicken blood. Nothing is too good for the cat! Commercial fishing for this species in the Lake Michigan Basin is nil.

Noturus flavus Rafinesque. STONECAT

Range: The stonecat (Fig. 78) is found primarily in the southern and western portions of the Lake Michigan Basin. It is uncommon in the Wisconsin sector. The stonecat is near the northern limit of its range in the Basin.

Habits: This species prefers medium-sized streams with clear water and a moderate current over rubble, boulders, or rocks. Adults spawn in the summer over a long period, possibly ending as late as August. Spawning begins in June or July when water temperature reaches 27.8°C (82°F) in streams or shallow, rocky areas of lakes. The adhesive eggs are deposited beneath stones, where they are guarded by the males. Food consists of aquatic insects, mollusks, minnows, crayfishes and plant material (Scott and Crossman, 1973). The average size attained is 152-203 mm (6-8 in.).

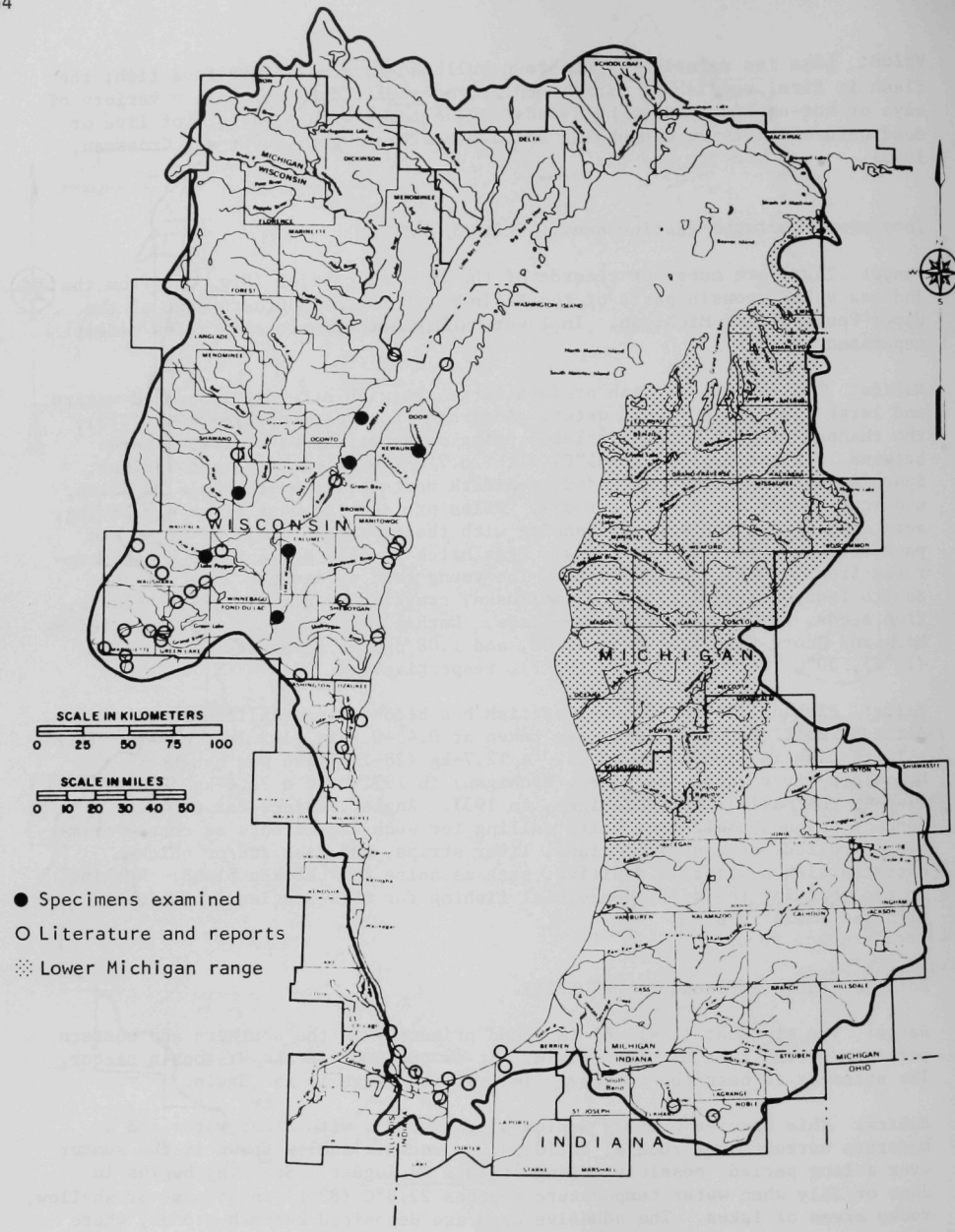

Fig. 77. Distribution of the Channel Catfish (*Ictalurus punctatus*).

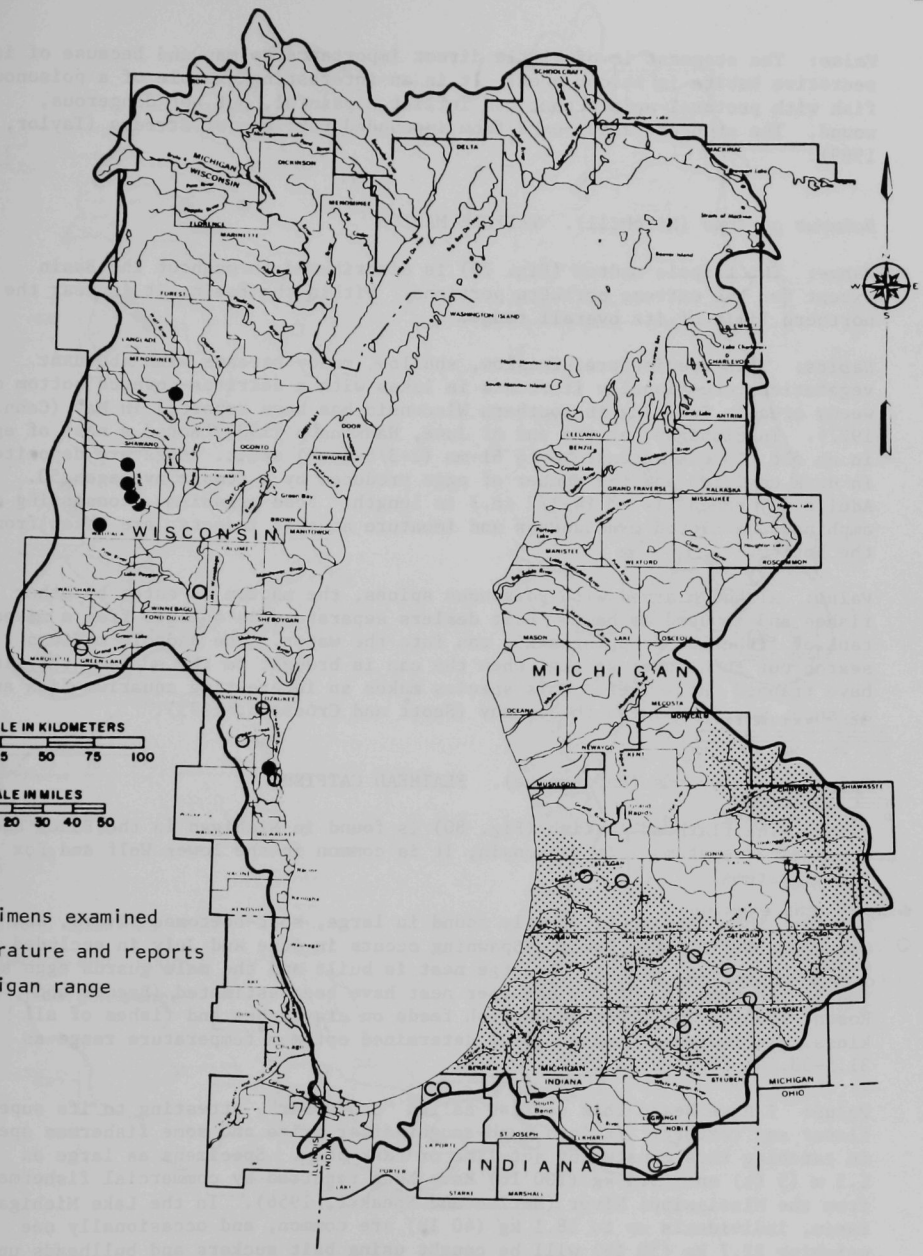

Fig. 78. Distribution of the Stonecat (*Noturus flavus*).

Value: The stonecat is of little direct importance to man and because of its secretive habits is seldom seen. It is an interesting example of a poisonous fish with pectoral spines that can inflict a painful, but not dangerous, wound. The stonecat disappears from impounded portions of streams (Taylor, 1969).

Noturus gyrinus (Mitchill). TADPOLE MADTOM

Range: The tadpole madtom (Fig. 79) is distributed throughout the Basin except for the extreme northern portions. Within the Basin, it is near the northern limit of its overall range.

Habits: This species prefers slow, shallow, muddy streams with abundant vegetation; occasionally it occurs in lakes with a detritus-covered bottom or weedy areas. Spawning in southern Wisconsin has been reported in May (Cahn, 1927). In Michigan, at the end of June, Hankinson (1908) noted a nest of eggs in an old tin can attended by a 61-mm (2-3/8-inch) adult. Eggs are deposited in dark cavities and the number of eggs produced by a female averages 50. Adults may reach 114 mm (4-1/2 in.) in length. Food organisms, consisting of amphipod and isopod crustaceans and immature aquatic insects, are taken from the bottom.

Value: Although armed with poisonous spines, the madtom is eaten by other fishes and is used as bait. Bait dealers separate this species from a mixed tank of fishes by dropping a tin can into the water. The tadpole madtoms search out such cover so that when the can is brought to the surface the fish have trapped themselves. This species makes an interesting aquarium fish and, as such, was introduced to Germany (Scott and Crossman, 1973).

Pylodictis olivaris (Rafinesque). FLATHEAD CATFISH

Range: The flathead catfish (Fig. 80) is found in Michigan in the Black and Grand river systems. In Wisconsin, it is common in the lower Wolf and Fox river systems.

Habits: This catfish is usually found in large, soft-bottomed rivers, and occasionally in large lakes. Spawning occurs in June and July in secluded hides and obscure places. A large nest is built and the male guards eggs and young. As many as 100,000 eggs per nest have been estimated (Breder and Rosen, 1966). The flathead catfish feeds on crayfishes and fishes of all kinds. In Indiana, Gammon (1973) determined optimum temperature range as 31.5-33.5°C (88.7-92.3°F).

Value: I have heard this catfish called "candy bar", attesting to its superb flavor and texture. It is a much-sought-after prize and some fishermen specialize in catching this monster by set-line or bank pole. Specimens as large as 1.5 m (5 ft) and 45.4 kg (100 lb) have been reported by commercial fishermen from the Mississippi River (Harlan and Speaker, 1956). In the Lake Michigan Basin, individuals up to 18.1 kg (40 lb) are common, and occasionally one weighing 22.7 kg (50 lb) will be caught using bait suckers and bullheads up to 356 mm (14 in.) in length. A flathead weighing 27.7 kg (61 lb) was taken from the Fox River, at Eureka, Wisconsin, in 1966.

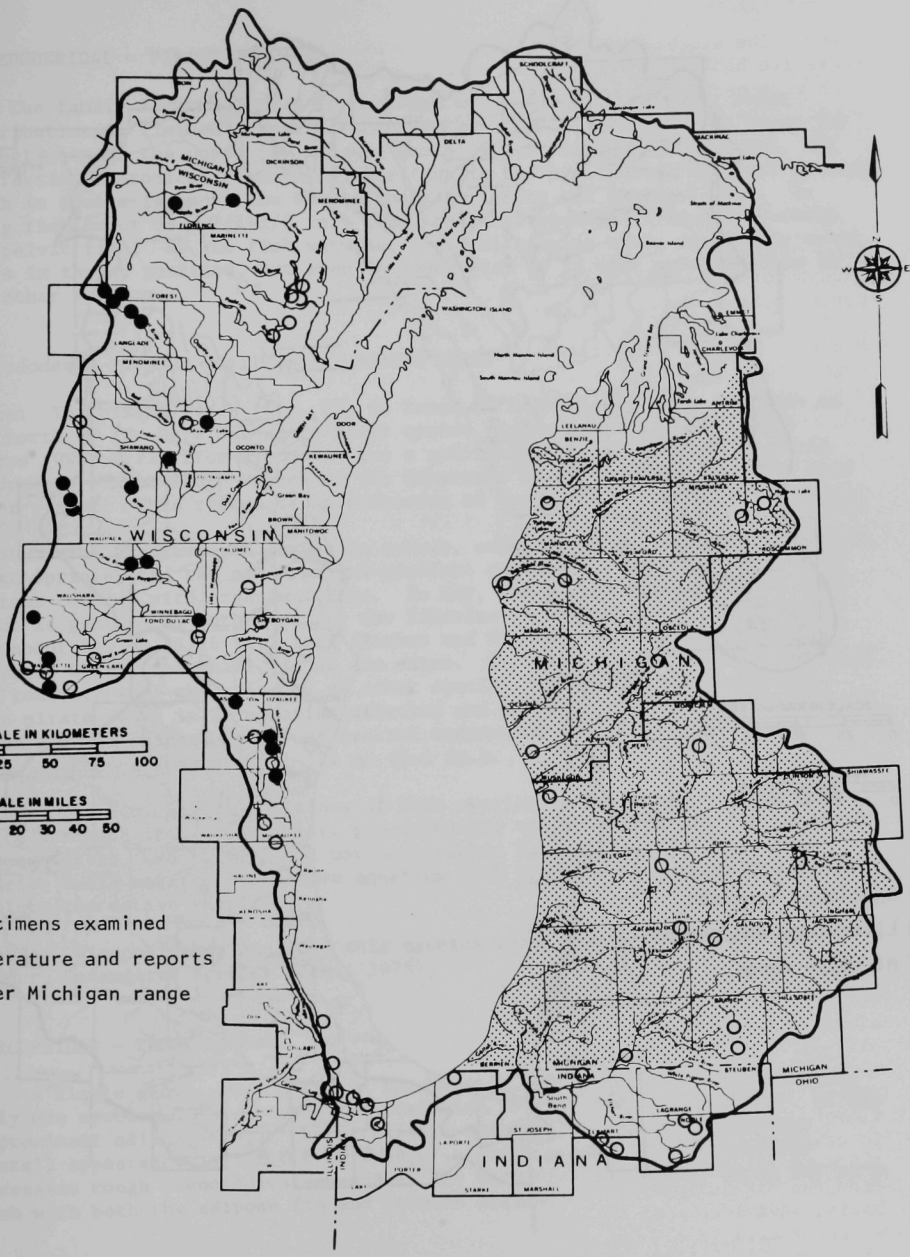

Fig. 79. Distribution of the Tadpole Madton (*Noturus gyrinus*).

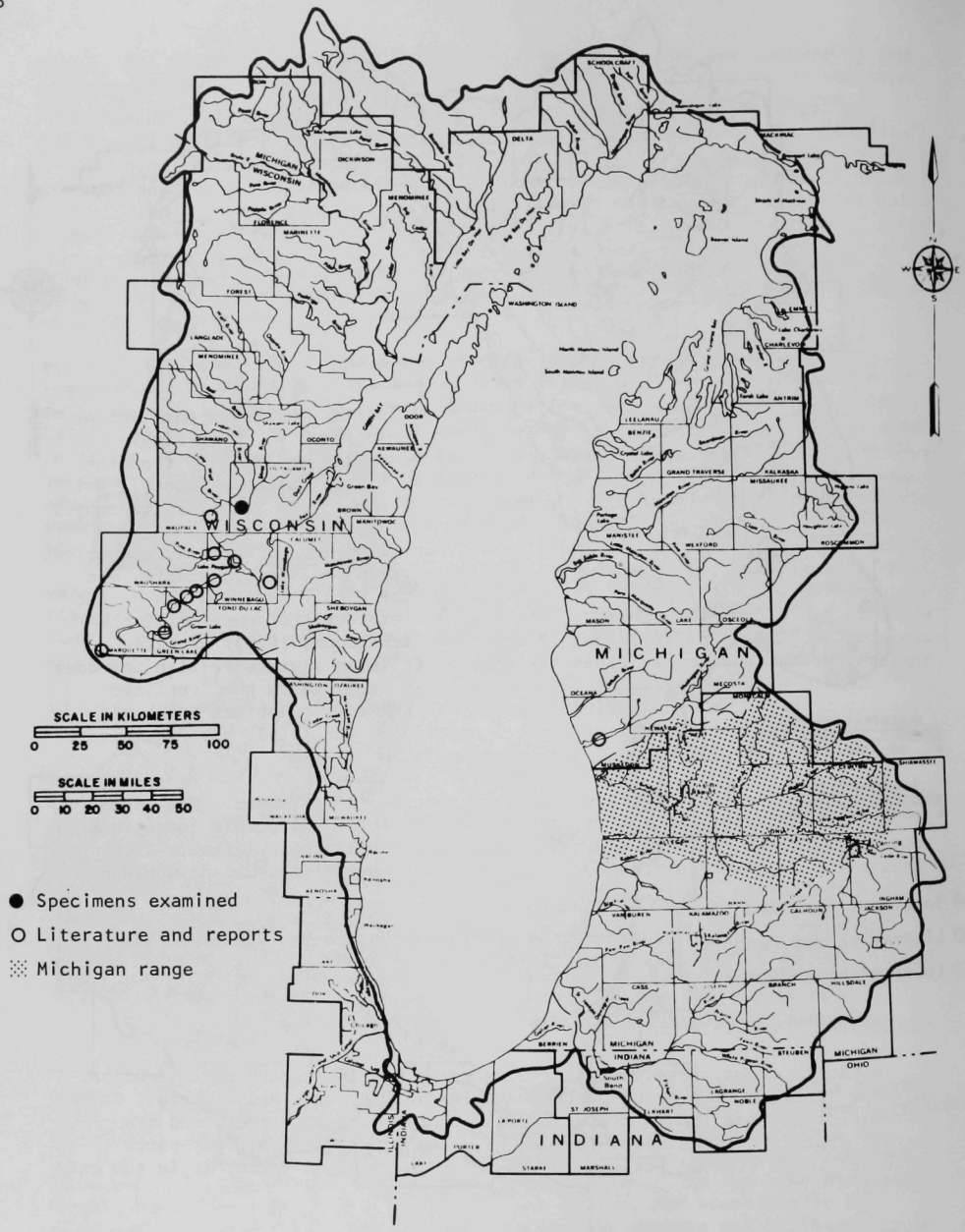

Fig. 80. Distribution of the Flathead Catfish (*Pylodictis olivaris*).

APHREDODERIDAE - PIRATE PERCHES

The family Aphredoderidae is represented by a single species, whose distribution is limited to eastern and southern North America. The lower jaw projects beyond the upper jaw and the mouth is well supplied with teeth. An interesting anatomical feature of this fish is the position of the anal opening, which in adults is under the throat and anterior to the pectoral fins. In young fish under 38 mm (1-1/2 in.) long, the anal opening is usually between the pelvic fins. As the fish matures, the anal opening moves anteriorly until it is in throat position, but even in young fish it is more anterior than in any other species.

Aphredoderus sayanus (Gilliams). PIRATE PERCH

Range: The pirate perch (Fig. 81) is found in Indiana and lower Michigan as far north as the Pere Marquette River system (Mason County). The single record (UWSP 3772) from Wisconsin was a specimen collected in 1970 from the headwaters of the South Branch of the Embarrass River (Marathon County), Wolf River system. This record is an extension of the northern limit of its range.

Habits: The pirate perch occurs in oxbows, overflow ponds, marshes, estuaries, large springs, and the pools of low-gradient streams. It prefers soft, muck bottoms covered with organic debris. In May, the pirate perch builds a nest which is guarded by both parents, who likewise protect the young until they are about 8.3 mm (5/16 in.) long (Forbes and Richardson, 1920). Aquatic insects, worms, and small fishes are eaten. It is an aggressive fish and does not tolerate well the presence of other species, especially when confined. Five pirate perch in an aquarium attacked and killed three black bullheads, three emerald shiners, and four central mudminnows (Small, 1968). The pirate perch reaches a length of 51-102 mm (2-4 in.).

Value: The ecological importance of this species is not known. The pirate perch has much iridescent color, predominantly violet and purple (occasionally copper, green, and silver) and may be mistaken for a tropical fish. This species would make an attractive aquarium fish provided the demand would not deplete the native supply.

Status: Wisconsin has accorded this species watch status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

PERCOPSIDAE - TROUT-PERCHES

A single genus, *Percopsis*, is recognized, and in eastern North America, only one species. The trout-perch resembles both a trout and a perch. It has a prominent adipose fin, a characteristic shared with the trout, and its overall appearance is similar to that of a small perch. The trout-perch possesses rough ctenoid scales, and in the Lake Michigan Basin, it is the only fish with both the adipose fin and ctenoid scales.

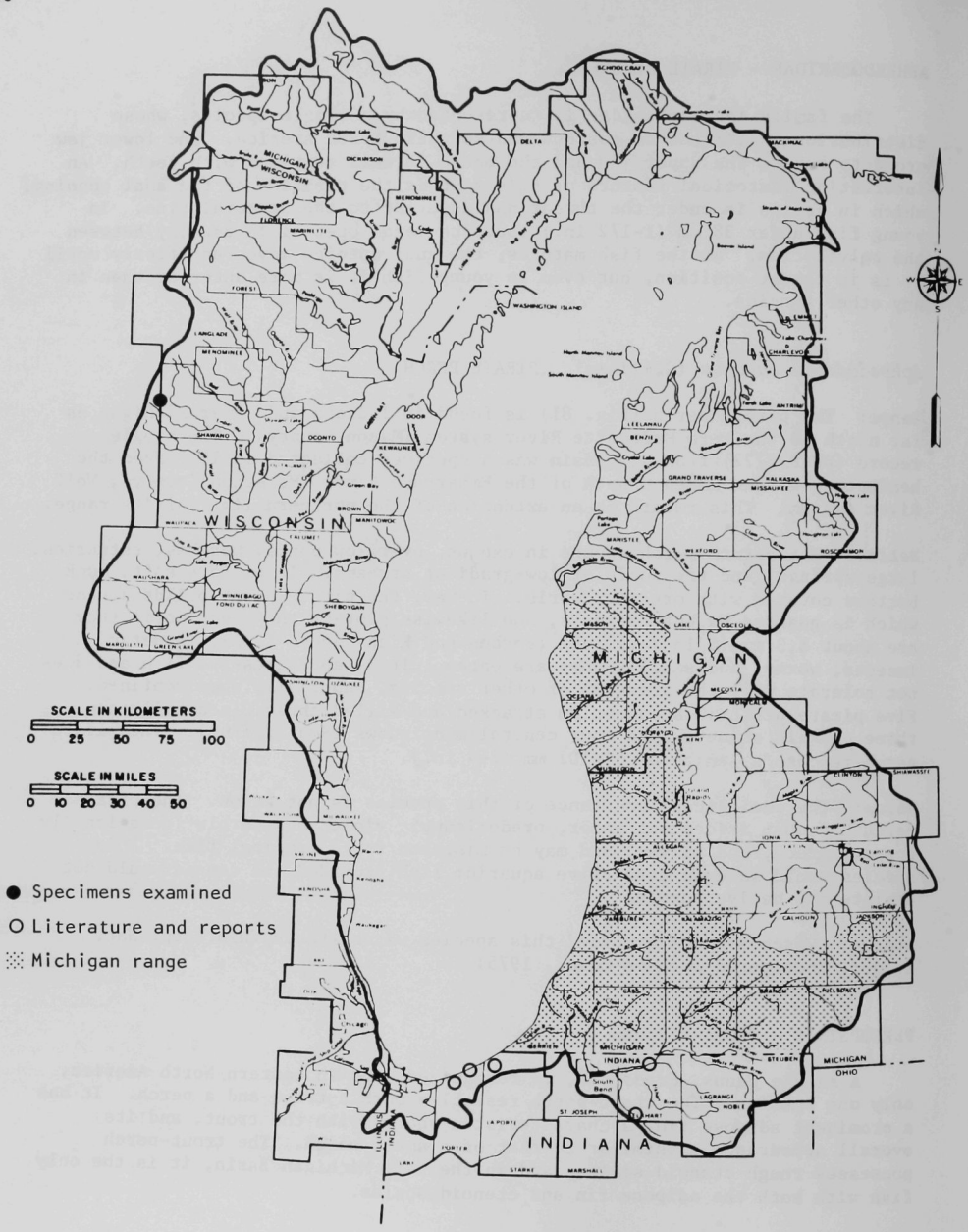

Fig. 81. Distribution of the Pirate Perch (*Aphredoderus sayanus*).

Percopsis omiscomaycus (Walbaum). TROUT-PERCH

Range: The trout-perch (Fig. 82) is found in the shallow waters of Lake Michigan and in the lower extremities of its larger tributaries. It is more common northward.

Habits: This species prefers the shallow and intermediate depths of Lake Michigan and inland lakes, avoiding shallow, mud-filled bays; it is present in tributary streams, particularly during spawning. In Lake Winnebago, Wisconsin, spawning occurs over rocks or sand bars when water temperatures are 15.6-20°C (60-68°F). The trout-perch is a random spawner; no nest is made nor is there any care of eggs or young. After spawning the adults may die (Priegel, 1962). Growth characteristics of a population in Red Lake, Minnesota, were studied by Magnuson and Smith (1963). The largest trout-perch are under 152 mm (6 in.) in length (Priegel, 1962). They feed on aquatic insects and leeches.

Value: In Lake Winnebago, the trout-perch is preyed upon extensively by game fishes; thus the trout-perch plays a valuable role in the fishery of the lake. The fact that this species has large eggs and that lake populations have a prolonged spawning period suggest that it might be a useful laboratory species where eggs are required, and indeed it has been used in a limited way for such studies (Scott and Crossman, 1973).

GADIDAE - CODFISHES

This is a well-known marine family which contains the cod, the haddock, and many other important food species. In the Lake Michigan Basin, only the burbot, a freshwater species, is present. The burbot is snakelike, slender, and has small scales, giving the impression that the fish is scaleless. It possesses a long dorsal fin which extends almost the entire length of the back and an elongated anal fin with about 68 rays. In the middle of the chin is a single barbel, a characteristic shown by no other fish in the Basin.

Lota lota (Linnaeus). BURBOT

Range: The burbot (Fig. 83) is found in Lake Michigan, Green Bay (of Lake Michigan), and their larger tributaries. Its status is common.

Habits: The burbot frequents cool waters of small to large lakes and medium to large streams. In lakes, it inhabits chiefly deep water; in streams, it prefers patches of plants and trash when young, stony-bottomed riffles when half-grown, and undercut banks when adult (Hubbs and Lagler, 1958). In the Lake Michigan Basin, adults spawn under the ice from January to March. In Lake Winnebago, the burbot congregates on rock and gravel reefs for spawning (Weber, 1971). The surface-water temperature is close to freezing; no nest is built and no care is given the young. The actual spawning activity is said to take place in a writhing ball about 0.6 m (2 ft) in diameter, which moves over the bottom and is made up of 10 to 12 interwined and constantly moving individuals (Scott and Crossman, 1973). Adult burbot will range from 0.7 to 2.7 kg (1-1/2 to 6 lb). This species is voracious, feeding on all available fishes and crayfishes, dead or alive. Optimum temperatures (Scott and Crossman, 1973) for this species are 15.6-18.3°C (60-65°F), and 23.3°C (74°F) appears to be its upper limit.

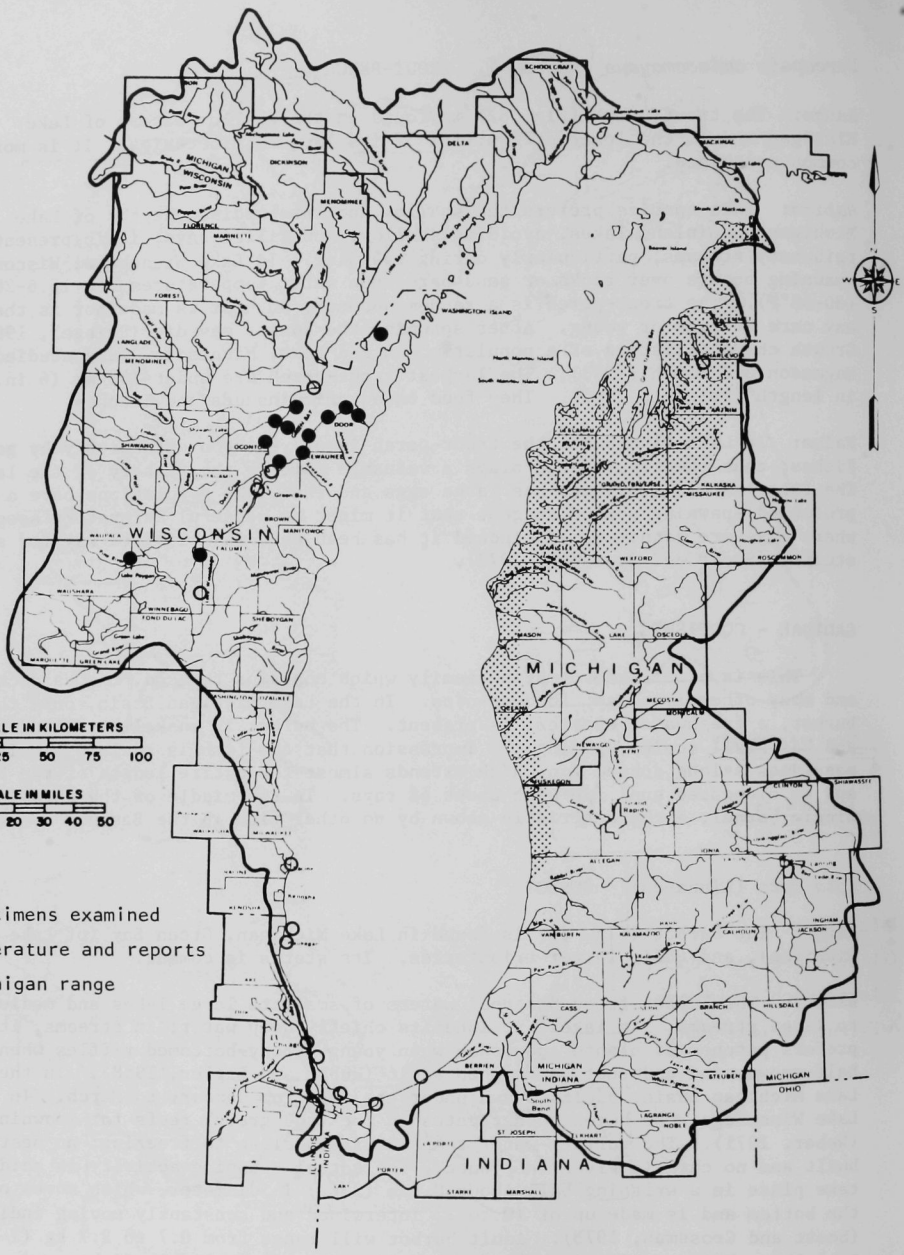

Fig. 82. Distribution of the Trout-Perch (*Percopsis omiscomaycus*).

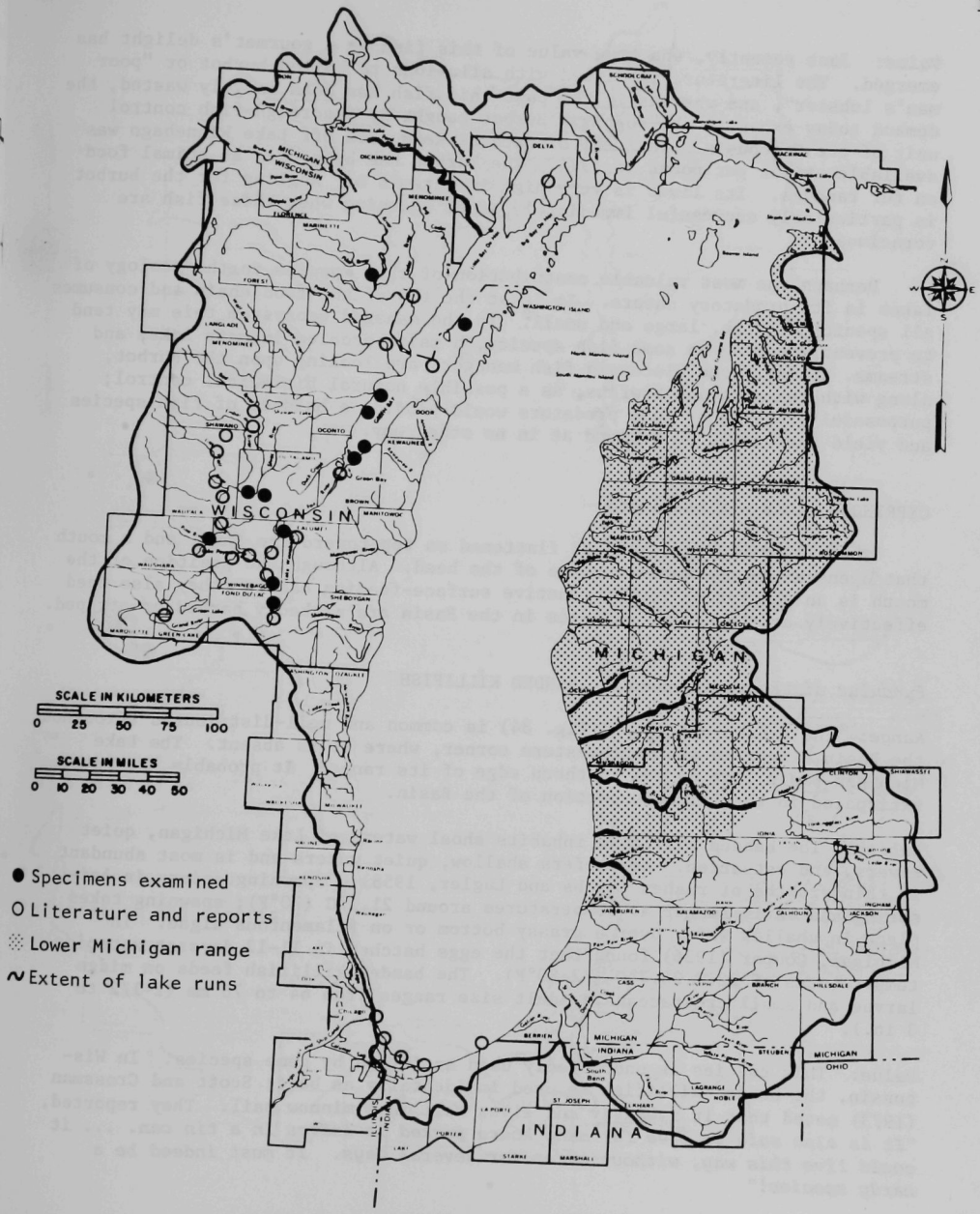

Fig. 83. Distribution of the Burbot (*Lota lota*).

Value: Just recently, the true value of this fish as a gourmet's delight has emerged. The literature is filled with allusions to boiled burbot or "poor man's lobster", and whereas in the past this fish has been largely wasted, the demand today exhausts the supply. Burbot caught by the rough-fish control unit of the Wisconsin Department of Natural Resources off Lake Winnebago was available at 15¢ per pound in 1974. The burbot has been used as animal food on fur ranches. Its liver is very high in Vitamin D. Angling for the burbot is particularly successful immediately after spawning when these fish are voracious.

Perhaps the most valuable contribution of this species to the ecology of lakes is its predatory nature. It is at the top of the food chain and consumes all species of fish, large and small. In the managed ecosystem this may tend to prevent stunting in some fish species, a major problem in many lakes and streams. Today, some Wisconsin fish managers are looking upon the burbot, along with the gars and bowfins, as a possible natural biological control; purposeful stocking of such predators would provide a balance of fish species and yield that could be arrived at in no other way.

CYPRINODONTIDAE - KILLIFISHES

The killifishes have a head flattened on top toward the snout and a mouth that opens along the upper surface of the head. Although the position of the mouth is an adaptation for distinctive surface-feeding habits, they also feed effectively at any depth. Species in the Basin are markedly barred or striped.

Fundulus diaphanus (Lesueur). BANDED KILLIFISH

Range: The banded killifish (Fig. 84) is common and well-distributed throughout the Basin except in the northwestern corner, where it is absent. The Lake Michigan Basin lies on the northern edge of its range. It probably has been extirpated in the Illinois portion of the Basin.

Habits: The banded killifish inhabits shoal waters of Lake Michigan, quiet rivers, and estuaries. It prefers shallow, quiet waters and is most abundant in thin growths of rushes (Hubbs and Lagler, 1958). Spawning occurs in late spring and early summer at temperatures around 21.1°C (70°F); spawning takes place in shallow water over a grassy bottom or on filamentous algae. In Michigan, Cooper (1936) found that the eggs hatched in 11-12 days at water temperatures of 22.2-26.7°C (72-80°F). The banded killifish feeds on midge larvae and small crustaceans. Adult size ranges from 64 to 76 mm (2-1/2 to 3 in.).

Value: This species is undoubtedly used as forage by game species. In Wisconsin, the banded killifish is used incidentally as bait; Scott and Crossman (1973) noted that it is hardy and lives well in a minnow pail. They reported, *"It is also said to live for many hours packed in leaves in a tin can. ... it could live this way, without water for several days. It must indeed be a hardy species!"*

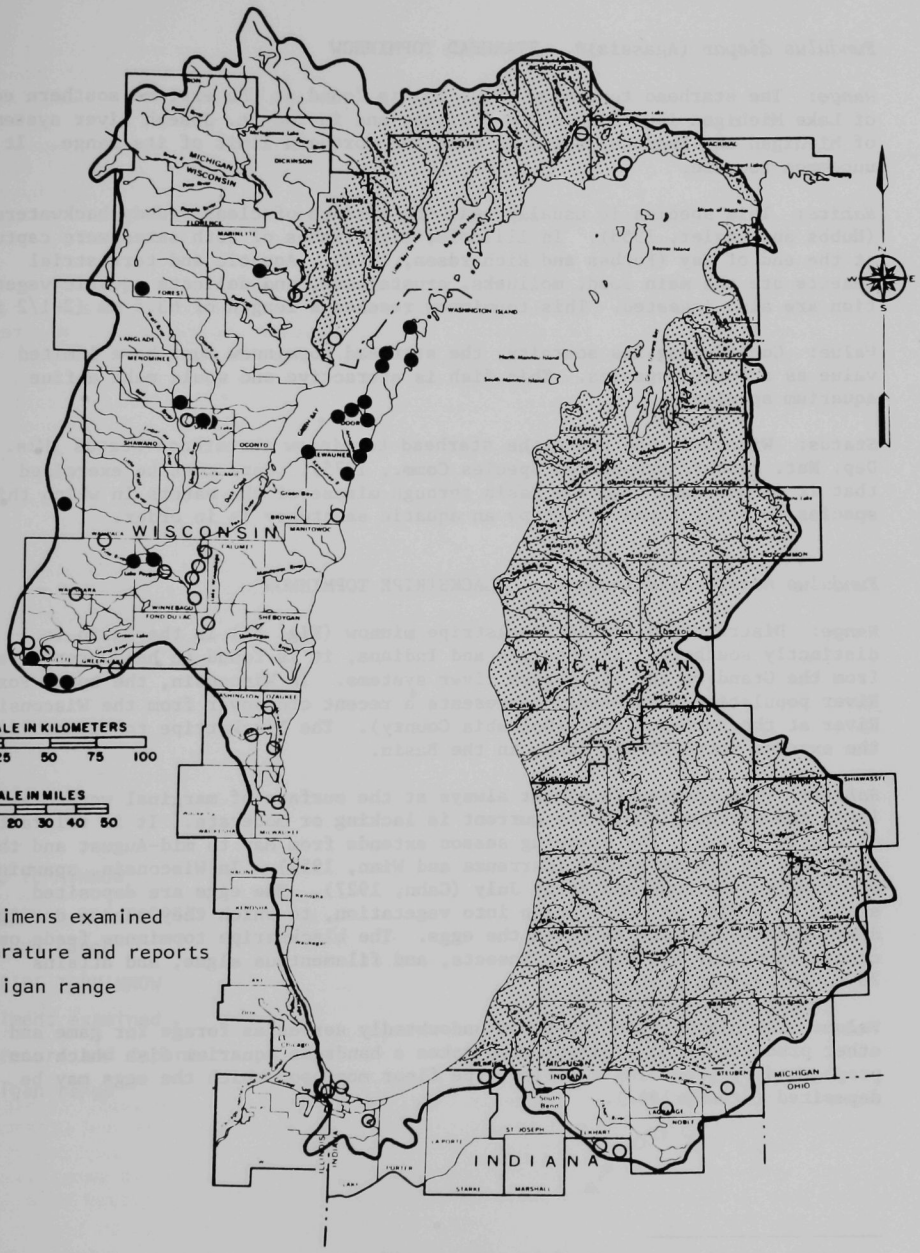

Fig. 84. Distribution of the Banded Killifish (*Fundulus diaphanus*).

Fundulus dispar (Agassiz)*. STARHEAD TOPMINNOW

Range: The starhead topminnow (Fig. 85) is found at the extreme southern edge of Lake Michigan in Illinois and Indiana, and in the St. Joseph River system of Michigan and Indiana, which is near the northern limit of its range. It is uncommon to rare.

Habits: This species is usually near the surface of clear, weedy backwaters (Hubbs and Lagler, 1958). In Illinois, ripe fishes of both sexes were captured at the end of May (Forbes and Richardson, 1920). Aquatic and terrestrial insects are the main food; mollusks, crustaceans, and delicate aquatic vegetation are also ingested. This topminnow reaches a length of 63.5 mm (2-1/2 in.).

Value: Considering its scarcity, the starhead topminnow must have limited value as a forage species. This fish is attractive and would make a fine aquarium species.

Status: Wisconsin has given the starhead topminnow threatened status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975). Care must be exercised that it is not lost from the Basin through misuse of the waters in which this species is still found. Perhaps an aquatic sanctuary is in order.

Fundulus notatus (Rafinesque). BLACKSTRIPE TOPMINNOW

Range: Distribution of the blackstripe minnow (Fig. 85) in the Basin is distinctly southern. In Michigan and Indiana, it is found in headwater streams from the Grand to the St. Joseph river systems. In Wisconsin, the upper Fox River population undoubtedly represents a recent crossover from the Wisconsin River at the Portage Canal (Columbia County). The blackstripe topminnow is at the extreme north of its range in the Basin.

Habits: This species is almost always at the surface of marginal waters in lakes and streams, where the current is lacking or moderate. It is tolerant of turbid waters. The spawning season extends from May to mid-August and the fish tend to remain paired (Carranza and Winn, 1954). In Wisconsin, spawning was reported in June and early July (Cahn, 1927). The eggs are deposited singly by a violent "flip" deep into vegetation, to which they adhere during development. No care is given the eggs. The blackstripe topminnow feeds on crustaceans, surface-dwelling insects, and filamentous algae, and attains 76 mm (3 in.) in length.

Value: The blackstripe topminnow undoubtedly serves as forage for game and other predator fish. This species makes a handsome aquarium fish which can be propagated by providing a string-type floor mop upon which the eggs may be deposited (Cross, 1967).

**Fundulus notii* becomes *Fundulus dispar fide* (Wiley and Hall, 1975).

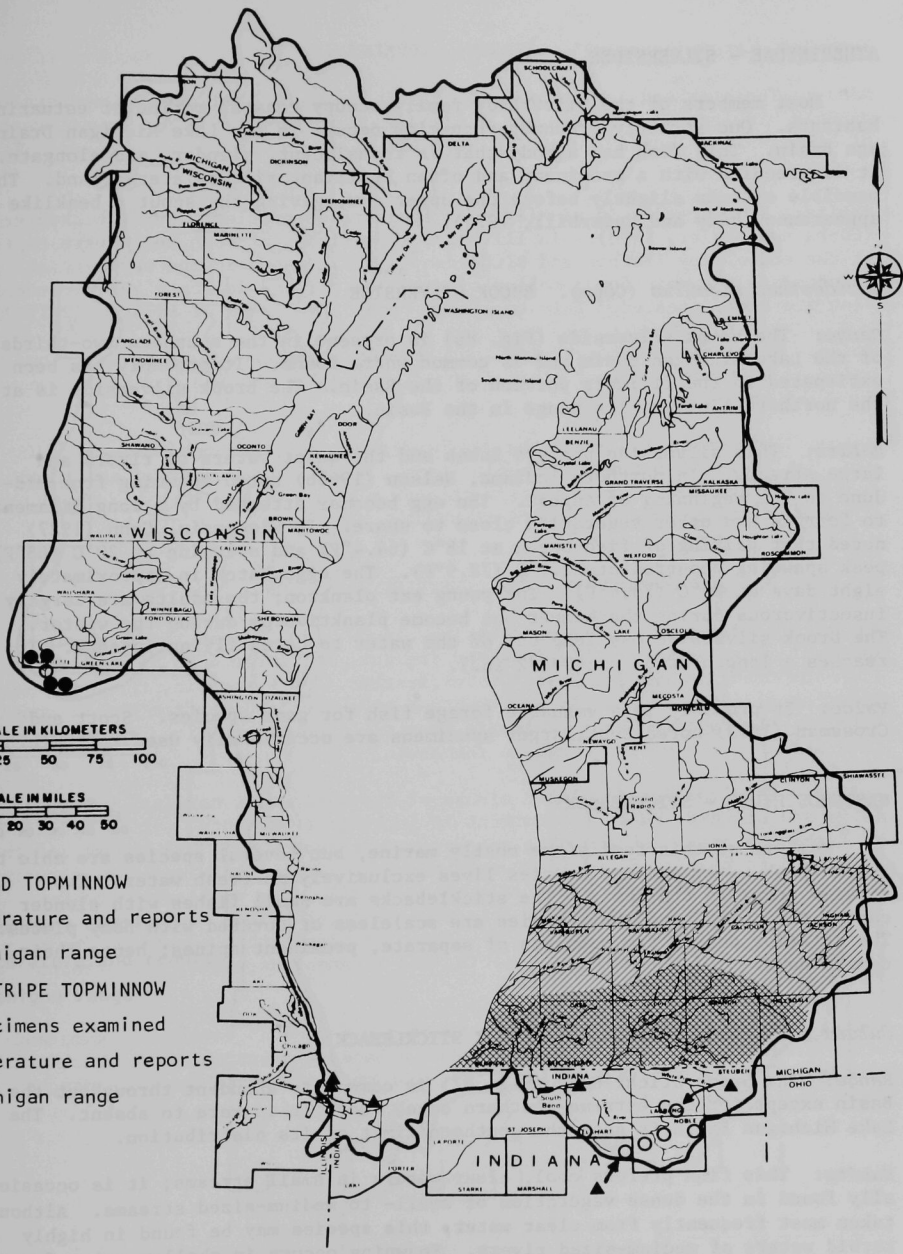

Fig. 85. Distribution of the Starhead Topminnow (*Fundulus dispar*) and Blackstripe Topminnow (*Fundulus notatus*).

ATHERINIDAE - SILVERSIDES

Most members of the silverside family occupy coastal marine or estuarine habitats. One strictly freshwater species occurs in the Lake Michigan Drainage Basin. This fish has a body that is translucent, slender, and elongate. It is greenish with a prominent and often brilliant silver lateral band. The mandible extends slightly before the upper jaw, giving the snout a beaklike appearance (Eddy and Underhill, 1974).

Labidesthes sicculus (Cope). BROOK SILVERSIDE

Range: The brook silverside (Fig. 86) is present in the southern two-thirds of the Lake Michigan Basin and is common where found. It probably has been extirpated in the Illinois portion of the Basin. The brook silverside is at the northern limit of its range in the Basin.

Habits: This silverside prefers lakes and the quiet waters of rivers and large streams. In northern Indiana, Nelson (1968b) noted spawning from mid-June to the beginning of August. The egg becomes attached by a long filament to *Scirpus* and other vegetation close to shore. In Wisconsin, Cahn (1927) noted that pairing of fish began at 18°C (64.4°F) and spawning at 20°C (68°F); peak spawning occurred at 22.7°C (72.9°F). The eggs hatch in approximately eight days at 23°C (73.4°F). The young eat plankton; the adults are largely insectivorous during the summer but become planktivorus during the winter. The brook silverside may leap out of the water to catch flying insects. It reaches a length of 89 mm (3-1/2 in.).

Value: It probably is a valuable forage fish for game species. Scott and Crossman (1973) noted that larger specimens are occasionally used for bait.

GASTEROSTEIDAE - STICKLEBACKS

Members of this family are mostly marine, but several species are able to enter fresh water and one species lives exclusively in fresh water. Two species occur in the Basin. The sticklebacks are small fishes with slender caudal peduncles, and their bodies are scaleless or covered with bony plates. The anterior dorsal fin consists of separate, prominent spines; hence their common name.

Culaea inconstans (Kirtland). BROOK STICKLEBACK

Range: The brook stickleback (Fig. 87) is common to abundant throughout the Basin except for the extreme southern edge, where it is rare to absent. The Lake Michigan Basin is near the southern limit of its distribution.

Habits: This fish prefers cool, clear waters in small streams; it is occasionally found in the dense vegetation of small- to medium-sized streams. Although taken most frequently from clear water, this species may be found in highly turbid waters of medium-sized rivers. Spawning occurs in shallow water from late April to July at water temperatures from 8 to 19°C (46.4-66.2°F) (Scott and Crossman, 1973). An elaborate nest is built by the male from plant fragments

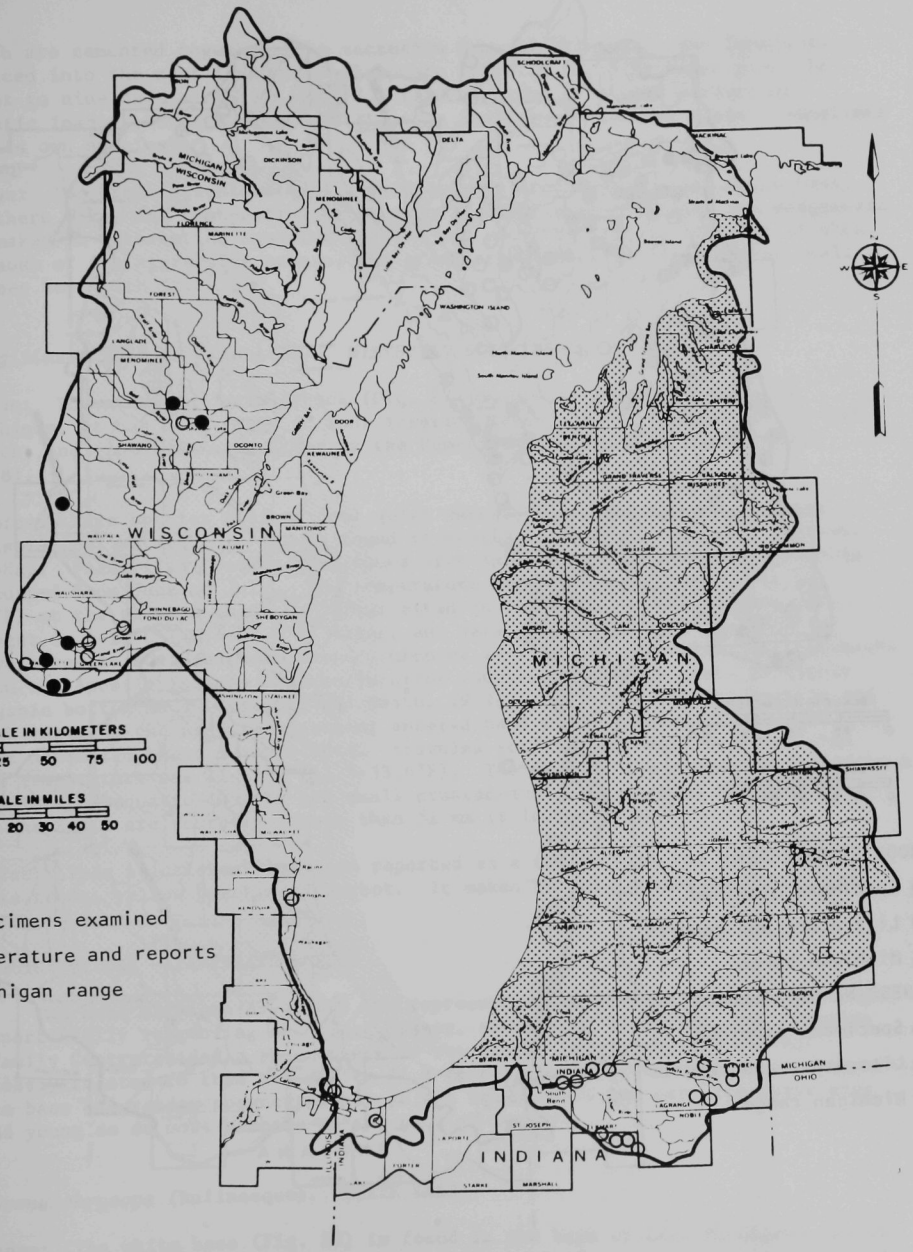

Fig. 86. Distribution of the Brook Silverside (*Labidesthes sicculus*).

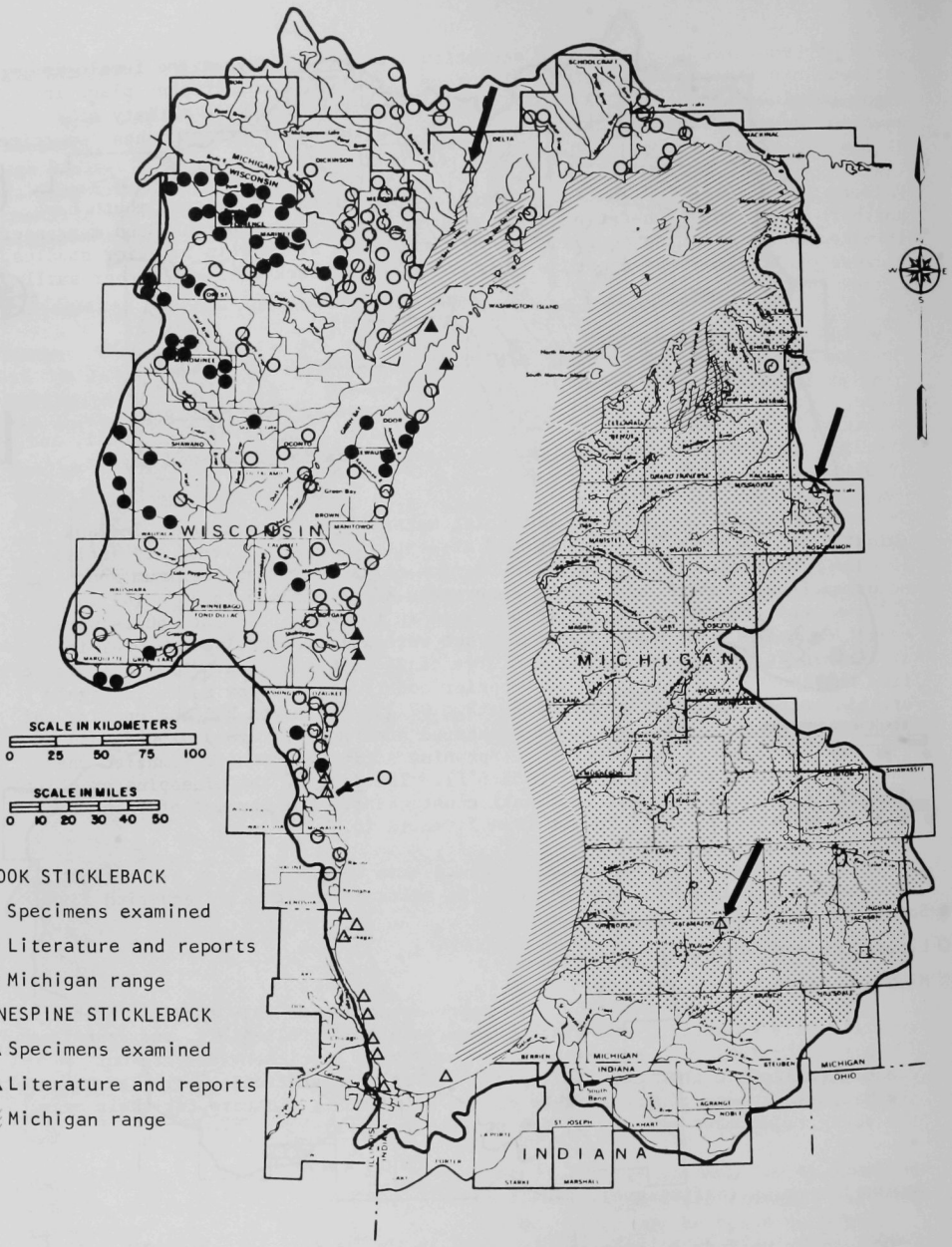

Fig. 87. Distribution of the Brook Stickleback (*Culaea inconstans*) and Ninespine Stickleback (*Pungitius pungitius*).

which are cemented together by a secretion from his kidneys. The female is enticed into the nest through an elaborate ritual. Hatching takes place in eight to nine days at 18.3°C (65°F). Food consists of a wide variety of aquatic insects, crustaceans, and the eggs and larvae of other fishes (sometimes of its own species).

Value: The brook stickleback is preyed upon by brook trout, smallmouth bass, northern pike, and fish-eating birds such as kingfishers, herons, and mergansers. It makes an interesting aquarium species and could be used in behavior studies. Because of its aggressive nature, the brook stickleback will kill other small fishes kept with it.

Pungitius pungitius (Linnaeus). NINESPINE STICKLEBACK

Range: The ninespine stickleback (Fig. 87) occurs in Lake Michigan. In Michigan, it has been found in four interior lakes: Burt, Higgins, Gull, and Birch; and from the Rapid River in the Upper Peninsula (Hubbs and Lagler, 1958).

Habits: This species prefers cool quiet waters. In Crooked Lake, Indiana (Mississippi watershed), it was found at depths of 5-30 m (16-98 ft) (Nelson, 1968a). Fully ripe females were found from April to August; maximum spawning occurred from June to July. The temperature ranged from 5 to 25°C (41 to 77°F) at the stratum where *Pungitius* lived in the summer. Most adults were caught in 6-12°C (42.8-53.6°F) water, but were able to survive one week in live boxes at surface shore temperatures of 24-28°C (75.2-82.4°F). Sticklebacks from the Apostle Islands of Lake Superior constructed burrow nests in highly organic bottom muds (Griswold and Smith, 1972). The nests had one opening and fish entering the nest for spawning entered head first, turned around, and then deposited their sex products. Spawning activity was most frenzied when the temperature was 11-12°C (51.8-53.6°F). The diet of the ninespine stickleback consists of aquatic insects and small crustaceans. The largest of these fish in the Basin are scarcely longer than 51 mm (2 in.).

Value: This stickleback has been reported as a forage fish for brook trout, lake trout, yellow perch, and burbot. It makes an interesting aquarium fish.

PERCICHTHYIDAE - TEMPERATE BASSES

The Lake Michigan Basin has two representatives of this family. Although superficially resembling the black basses, sunfishes, bluegills, and crappies (Family Centrarchidae), the members of the Family Percichthyidae are not closely related to them and differ in a number of characteristics. The temperate bass are random spawners; they do not build nests nor care for their eggs and young as do most members of the sunfish family.

Morone chrysops (Rafinesque). WHITE BASS

Range: The white bass (Fig. 88) is found in the bays of Lake Michigan. It is common in the upper and lower Fox and the lower Wolf river systems in Wisconsin. Disjunct populations have been reported in Illinois (where this species probably now is extirpated), Indiana, and Michigan.

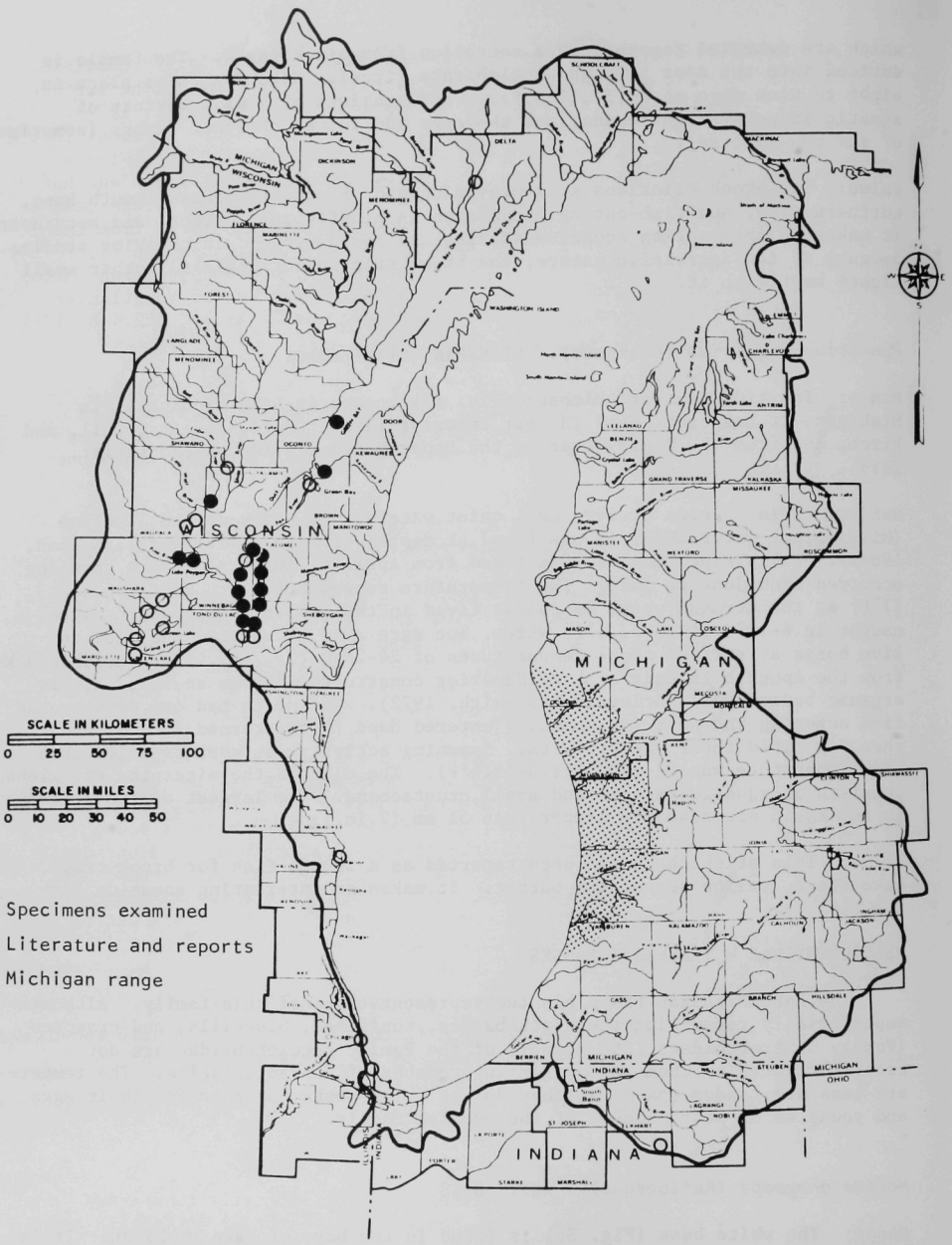

Fig. 88. Distribution of the White Bass (*Morone chrysops*).

Habits: This bass prefers clear water rather than turbid or silty conditions. It frequents large rivers and their connecting lakes, feeding at the surface on aquatic and other insects and small fishes (Eddy and Underhill, 1974). The white bass spawns from late April to June when the temperature is about 15.6°C (60°F). Spectacular runs are reported yearly from the Wolf River, Wisconsin. The eggs are scattered at random on shallow bars and gravelly reefs and hatch in 46 hr at 15.6°C (60°F) (Scott and Crossman, 1973). The white bass reaches a length of 457 mm (18 in.). A 1.6-kg (3-lb 9-oz) bass was taken from the Wisconsin River in 1962, and a 964-g (2-lb 5-oz) fish was caught in Little Bay de Noc, Lake Michigan, in 1972. The food habits of young and yearling white bass in Lake Mendota, Wisconsin, were discussed by Wissing and Voigtlander (1974). In Indiana, the optimum temperature range is 28-29.5°C (82.4-85.1°F) (Gammon, 1973).

Value: The white bass is a fair-to-good food fish; the flesh is firm, white, and palatable either fresh or smoked. Because white bass concentrate in numbers, fishing for them (as on the Wolf River, Wisconsin) often assumes carnival proportions, with boats so close to each other that one can almost walk from shore to shore.

Morone mississippiensis Jordan and Eigenmann. YELLOW BASS

Range: The yellow bass (Fig. 89) is found from central Wisconsin to Illinois, entirely on the west side of the Lake Michigan Basin. In Wisconsin, establishment is believed to be the result of fish rescue operations of Mississippi River fishes during the 1930's (Helm, 1958). It probably has been extirpated in the Illinois portion of the Basin. The yellow bass is at the northern limit of its range in the Basin.

Habits: This bass inhabits large rivers and lakes, preferring wide expanses of open water free of weeds. Spawning occurs in May, in shallow water over gravel bars and rock reefs at temperatures of 16-20°C (60-68°F). The eggs are minute, up to one million per female; no care is given to eggs or young. Adults reach a length of 305 mm (12 in.) or more. Young bass feed on aquatic insects, small crustaceans and terrestrial insects (Forbes and Richardson, 1920). Adults eat primarily fish along with some crustaceans and insects (Shields, 1965). The largest yellow bass on record from Wisconsin waters was taken in a state fish management trap net from Lake Poygan in January 1964. It was a six-year-old, 411 mm (16-3/16 in.) long and weighing 1.4 kg (3 lb 2 oz) (Becker, 1964).

Value: This species is a moderately good food fish and is frequently taken along with the white bass. Its flesh usually is considered superior to that of the white bass.

CENTRARCHIDAE - SUNFISHES

The sunfish species have more or less deep and laterally compressed bodies. A number of strong spines are found in the anterior dorsal fin and the anterior portion of the anal fin.

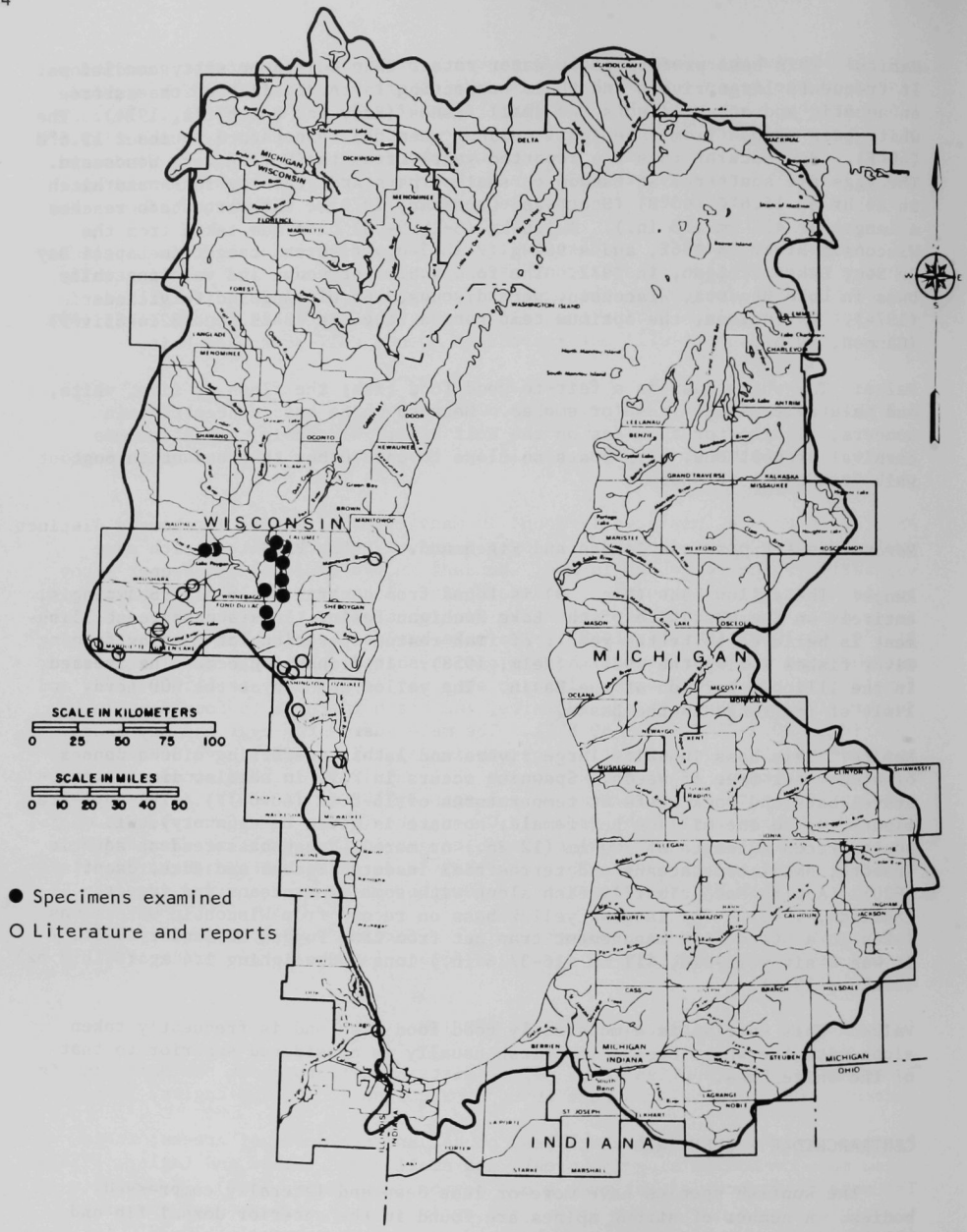

Fig. 89. Distribution of the Yellow Bass (*Morone mississippiensis*).

Fishes in this family include a number of the most important game and pan fishes in the Basin. Sunfishes and crappies are standby fishes for a shore lunch or that easy meal when the larger game fishes are not biting. Because of their popularity, the sunfishes have been widely stocked. Species like the bluegill and largemouth bass are commonly planted together in farm ponds and small lakes. Generally, these are netted from nearby waters since natural propagation is sufficient to supply a new aquatic home with brood stock.

All species tend to be nest builders although occasionally some species use the nests of other fishes that have already spawned. The male generally builds the nest, cares for the eggs and young, and often is quite vicious in his protective role. During the cold months, the sunfishes become inactive and for the most part will not respond to even a well-presented bait.

Ambloplites rupestris (Rafinesque). ROCK BASS

Range: The status of the rock bass (Fig. 90) is common to abundant throughout the Basin.

Habits: Although this bass is found in many types of water, it shows a distinct preference for clear, cool waters over a gravel or rocky bottom with some vegetation. The rock bass is most abundant in the cool, clear, deeper lakes and in clear, rocky streams of moderate size (Schneberger, 1973). Spawning takes place during late May and early June when water temperatures reach 15.6-21.1°C (60-70°F) (Skille, 1968). The male builds the circular nest by fanning out the sand and debris until he has a dish-shaped spawning bed. The average female lays about 5000 eggs, although some may lay as many as 11,000 (Eddy and Surber, 1947). The eggs are adhesive, and hatch in three to four days in aquaria at 20.5-21°C (68.9-69.8°F). The male guards the eggs and may guard the young for a short time. Growth studies on this species have been done in Michigan (Beckman, 1949) and Wisconsin (Hile, 1942). In both studies, a fast-growing five-year-old fish reached a length of 178 mm (7 in.). A 794-g (1-lb 12-oz) rock bass was caught from Big Green Lake (Green Lake County), Wisconsin, in 1971. A 1.5-kg (3-lb 5-oz) fish was caught in Lake Cadillac (Wexford County), Michigan, in 1946. The rock bass feeds on aquatic insects, crayfishes, and small fishes, in that order of preference.

Value: The rock bass is a common panfish affording much sport and a delicacy at the table. Undoubtedly it serves as forage for the larger predators.

Lepomis cyanellus Rafinesque. GREEN SUNFISH

Range: The green sunfish (Fig. 91) is distributed throughout the Basin and is uncommon to common. It is rare in upper Michigan (Hubbs and Lagler, 1958).

Habits: This sunfish selects lakes, ponds, and the pools of creeks; it is often most common in sluggish creeks and small ponds (Hubbs and Lagler, 1958). The male constructs a nest over a mud bottom (Hankinson, 1908). Spawning takes place once during the spring and again in late summer; peak spawning occurs during the first three weeks in June at temperatures of 20-28°C (68.0-82.4°F) (Hunter, 1963). The adhesive eggs hatch in three to five days. The green sunfish grows slowly, reaching a length of 152 mm (6 in.) at age seven

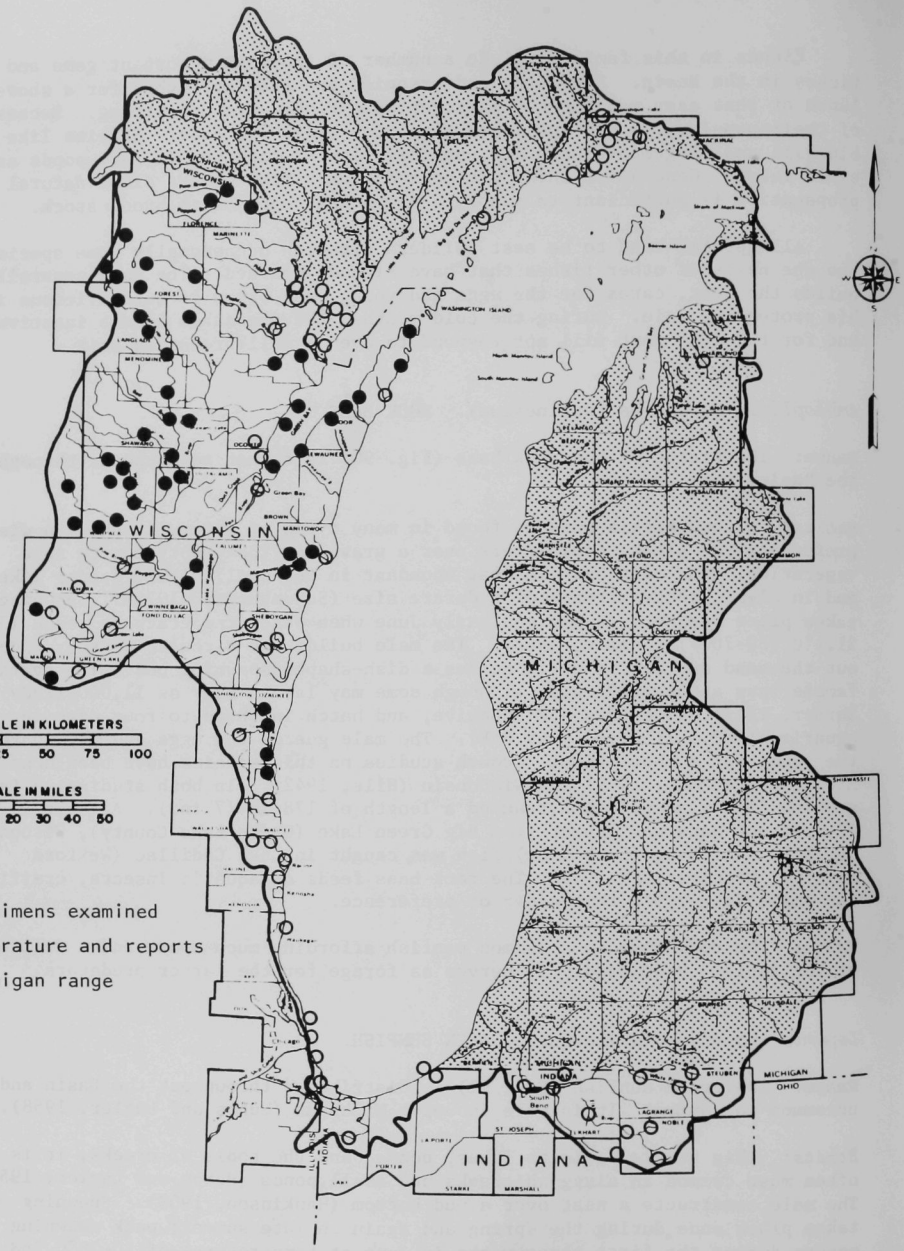

Fig. 90. Distribution of the Rock Bass (*Ambloplites rupestris*).

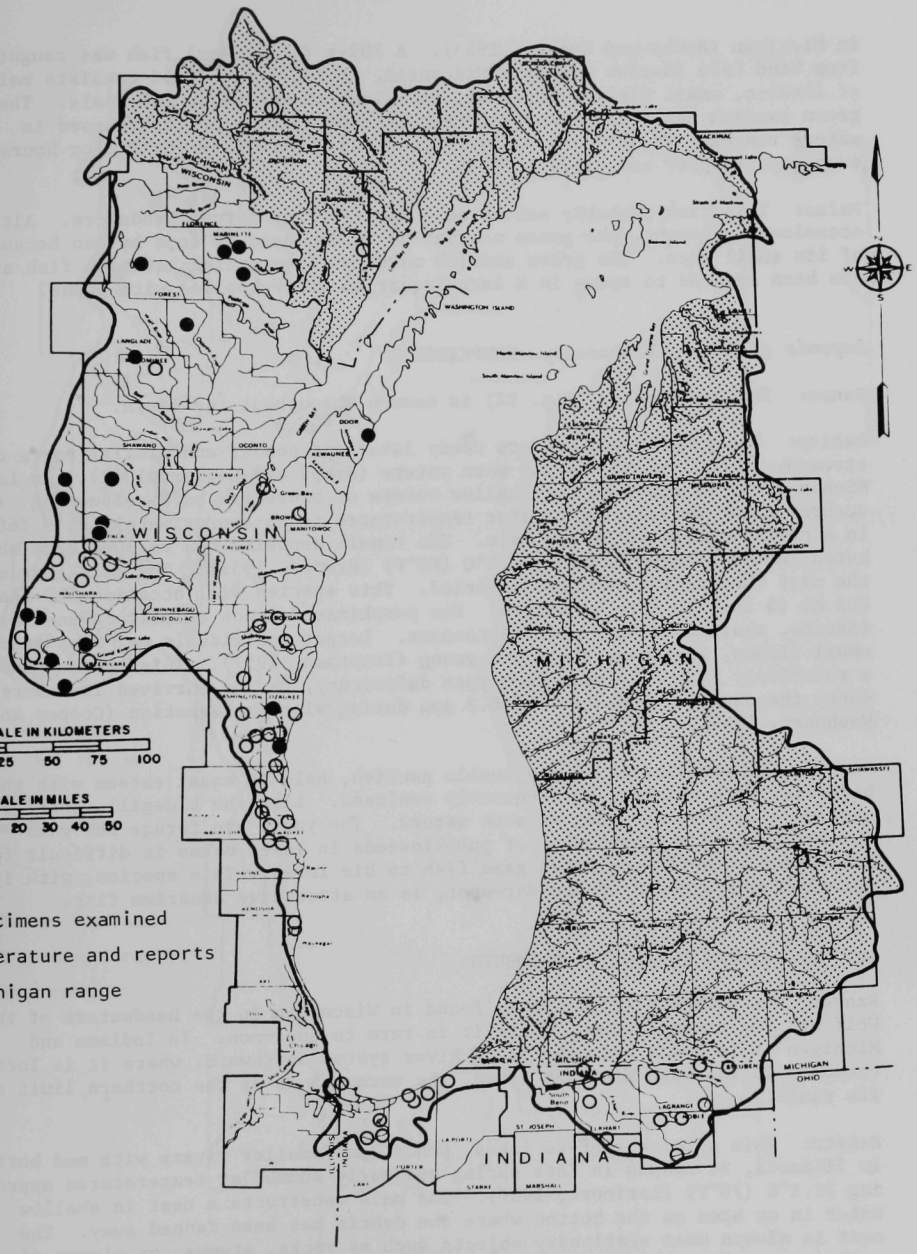

Fig. 91. Distribution of the Green Sunfish (*Lepomis cyanellus*).

in Michigan (Hubbs and Cooper, 1935). A 709-g (1-lb 9-oz) fish was caught from Wind Lake (Racine County), Wisconsin, in 1967. Its food consists mainly of insects, small fishes, mollusks, and--less often--plant materials. The green sunfish has a wide temperature tolerance. It is not distressed in waters reaching 29-32°C and can survive at 33.3-34.4°C (92-94°F) for hours or even days (Sigler and Miller, 1963).

Value: This fish probably serves as forage for the larger predators. Although occasionally caught, the green sunfish is seldom used as food by man because of its small size. The green sunfish makes an interesting aquarium fish and has been induced to spawn in a large aquarium well supplied with weeds.

Lepomis gibbosus (Linnaeus). PUMPKINSEED

Range: The pumpkinseed (Fig. 92) is common throughout the Basin.

Habits: The pumpkinseed prefers weedy lakes and ponds, and similar parts of streams, in cool to moderately warm waters (Hubbs and Lagler, 1958). In Lake Michigan, it is found in the shallow waters of protected bays. Spawning occurs in May to July, when water temperatures reach approximately 20°C (68°F), in a nest constructed by the male. The female deposits 600 to 3000 eggs which hatch in about three days at 27.8°C (82°F) (Breder, 1936). The male guards the nest through the incubation period. This species will occasionally reach 203 mm (8 in.) or more in length. The pumpkinseed feeds chiefly on aquatic insects, small mollusks, and crustaceans. Larger individuals may also feed on small fishes, including their own young (Trautman, 1957). This species shows a relatively high tolerance to oxygen deficiency, having survived in waters where the oxygen dropped to 0.2-0.3 ppm during winter stagnation (Cooper and Washburn, 1949).

Value: The pumpkinseed is a valuable panfish, held in equal esteem with the bluegill, with which it is frequently confused. Like the bluegill, this species will show stunting in some waters. The young are forage for game species, and an overabundance of pumpkinseeds in lakes makes it difficult for the angler to entice well-fed game fish to his lures. This species, with its colorful markings and orange ear-spot, is an attractive aquarium fish.

Lepomis gulosus (Cuvier). WARMOUTH

Range: The warmouth (Fig. 93) is found in Wisconsin in the headwaters of the Wolf and Fox river systems, where it is rare to uncommon. In Indiana and Michigan it is found from the White River system southward, where it is locally common. In the Lake Michigan Basin, the warmouth is at the northern limit of its range.

Habits: This species prefers lakes, ponds, and smaller rivers with mud bottoms. In Illinois, it spawns in late spring and early summer at temperatures approaching 21.1°C (70°F) (Larimore, 1957). The male constructs a nest in shallow water in an area on the bottom where the debris has been fanned away. The nest is always near stationary objects such as rocks, stumps, or clumps of vegetation. The male protects and fans the eggs. Hatching time is about 35 hr at temperatures of 25° and 26.4°C (77.0 and 79.5°F). In Illinois, a five-year-old fish may be 152-221 mm (6 to 8-11/16 in.) in length. Trautman (1957)

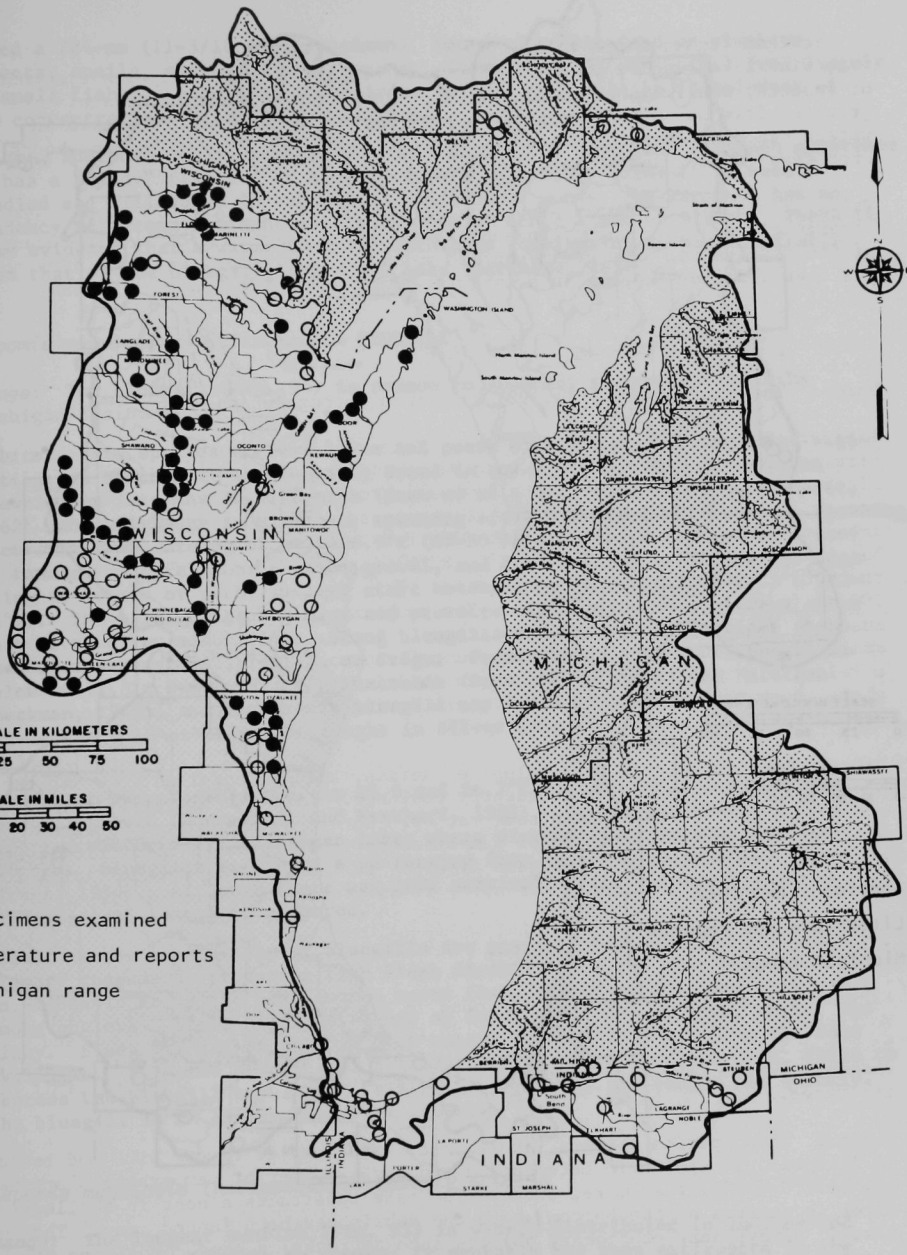

Fig. 92. Distribution of the Pumpkinseed (*Lepomis gibbosus*).

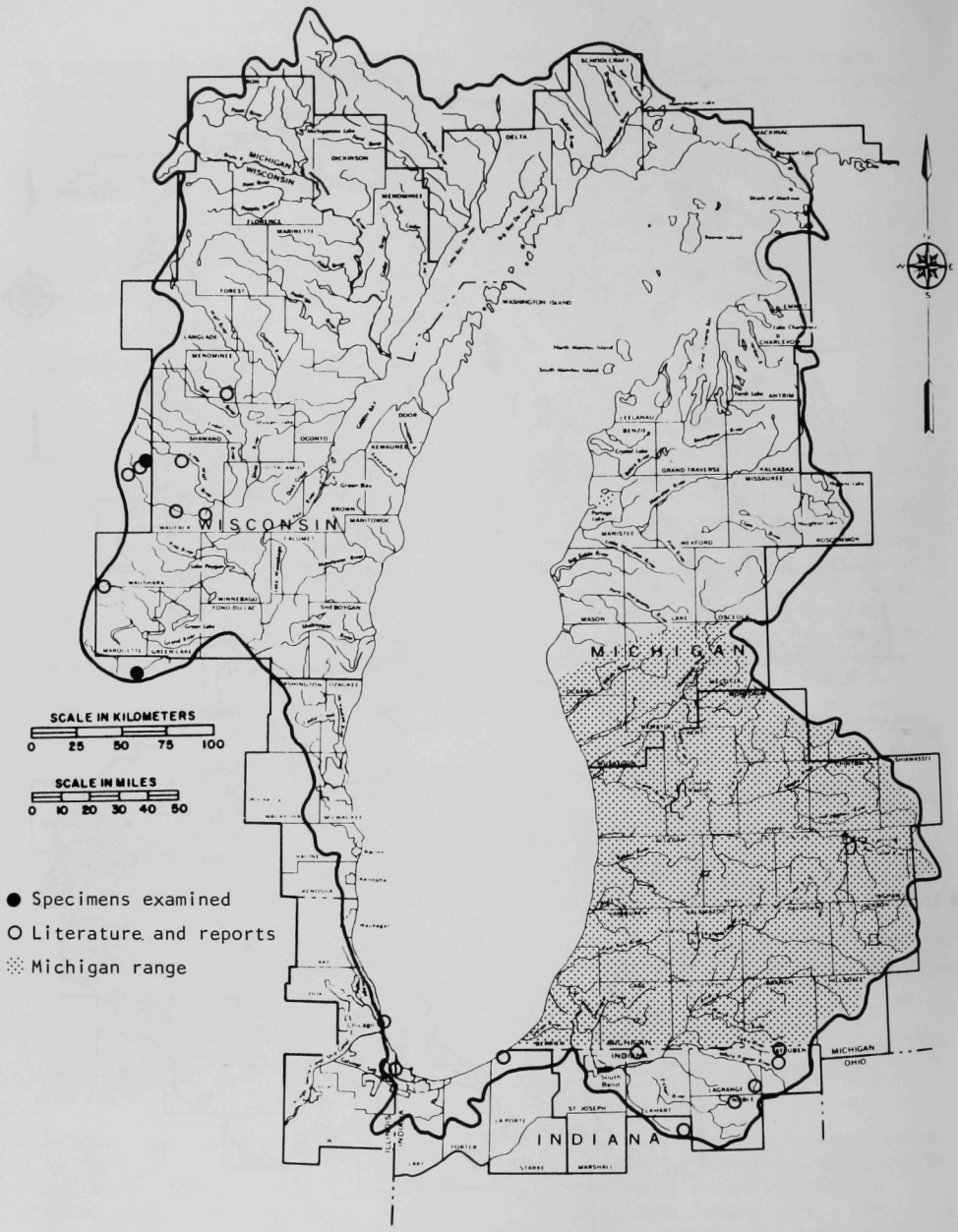

Fig. 93. Distribution of the Warmouth (*Lepomis gulosus*).

noted a 284-mm (11-3/16 in.) specimen. Young warmouths feed on plankton, insects, snails, and small crustaceans. Those over 127 mm (5 in.) feed largely on small fishes. According to Larimore (1957), this species is tolerant of low concentrations of dissolved oxygen.

Value: The warmouth is generally considered a good food fish although sometimes it has a "muddy" flavor. It is a desirable laboratory fish; it is easily handled and will spawn in captivity. In stocked ponds, the warmouth has no tendency to become dominant at the expense of other kinds of fishes. There is some evidence that a warmouth-largemouth bass combination is more desirable than that of the bluegill-largemouth bass (Larimore, 1957).

Lepomis macrochirus Rafinesque. BLUEGILL

Range: The bluegill (Fig. 94) is common to abundant throughout the Lake Michigan Basin.

Habits: This species prefers lakes and ponds with a moderate amount of vegetation; in streams it is generally found in quiet water. Bluegills begin spawning in late May in Wisconsin (Snow *et al.*, 1962) and Illinois (Bennett, 1962) and early June in Michigan; spawning often extends until autumn. Spawning occurs at temperatures of 19.4-26.7°C (67-80°F). The male constructs a nest by fanning a depression in sand, gravel, and dead leaves. The adhesive eggs cling to debris or pebbles; they start hatching in 32 hr at 22.2-23.3°C (72-74°F). The male guards the nest and protects the fry for several days after they hatch (Trautman, 1957). Young bluegills feed on plankton; older fish feed on insects, small fishes, or frogs. Feeding decreases at temperatures below 10-12.8°C (50-55°F). In Wisconsin (Snow *et al.*, 1962) and Michigan (Beckman, 1949), a six-year-old bluegill may reach 102-229 mm (4-9 in.). A 1.2-kg (2-lb 10-oz) fish was caught in Silver Lake (Cheboygan County), Michigan, in 1945.

Water temperatures between 15.6 and 26.7°C (60 and 80°F) are best for bluegill growth (Rounsefell and Everhart, 1953). Cooper and Washburn (1949) reported winterkill in Michigan lakes where dissolved oxygen was less than 0.6 ppm. Bluegills tolerated a pH ranging from 4.00 ± 0.15 to 10.35 ± 0.15 (Trama, 1954). Although there was 100% survival at these ranges, adverse physiological reactions occurred.

Value: Dense populations of bluegills are possible because they are largely primary consumers, producing fish flesh directly from the most basic of foods. In Wisconsin it is the most common sport fish, easily caught, and a favorite among anglers. It is highly esteemed as food; the flesh is firm, white, and flaky. Bluegills are stunted in many waters because they outstrip the food available. Even the stocking of a predator fish, like northern pike, fails to depress the bluegill population, since the predators are caught too quickly. The bluegill is an easily cared-for aquarium fish.

Lepomis megalotis (Rafinesque). LONGEAR SUNFISH

Range: The longear sunfish (Fig. 95) is widely distributed in Indiana and lower Michigan, where it is common; it probably has been extirpated in the Illinois portion of the Basin. In Wisconsin, it is found only in the Green Bay and Milwaukee areas, where it is uncommon to rare.

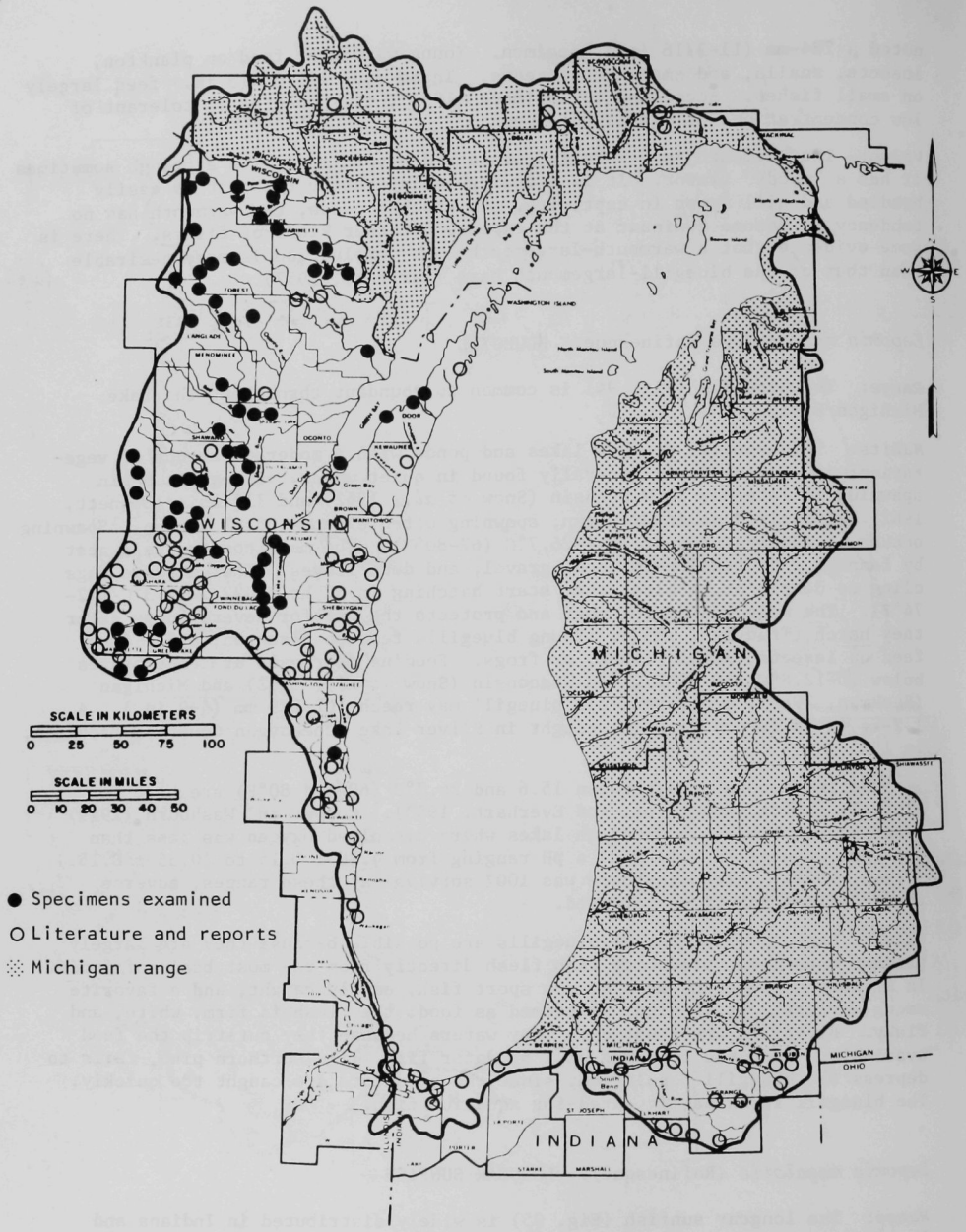

Fig. 94. Distribution of the Bluegill (*Lepomis macrochirus*).

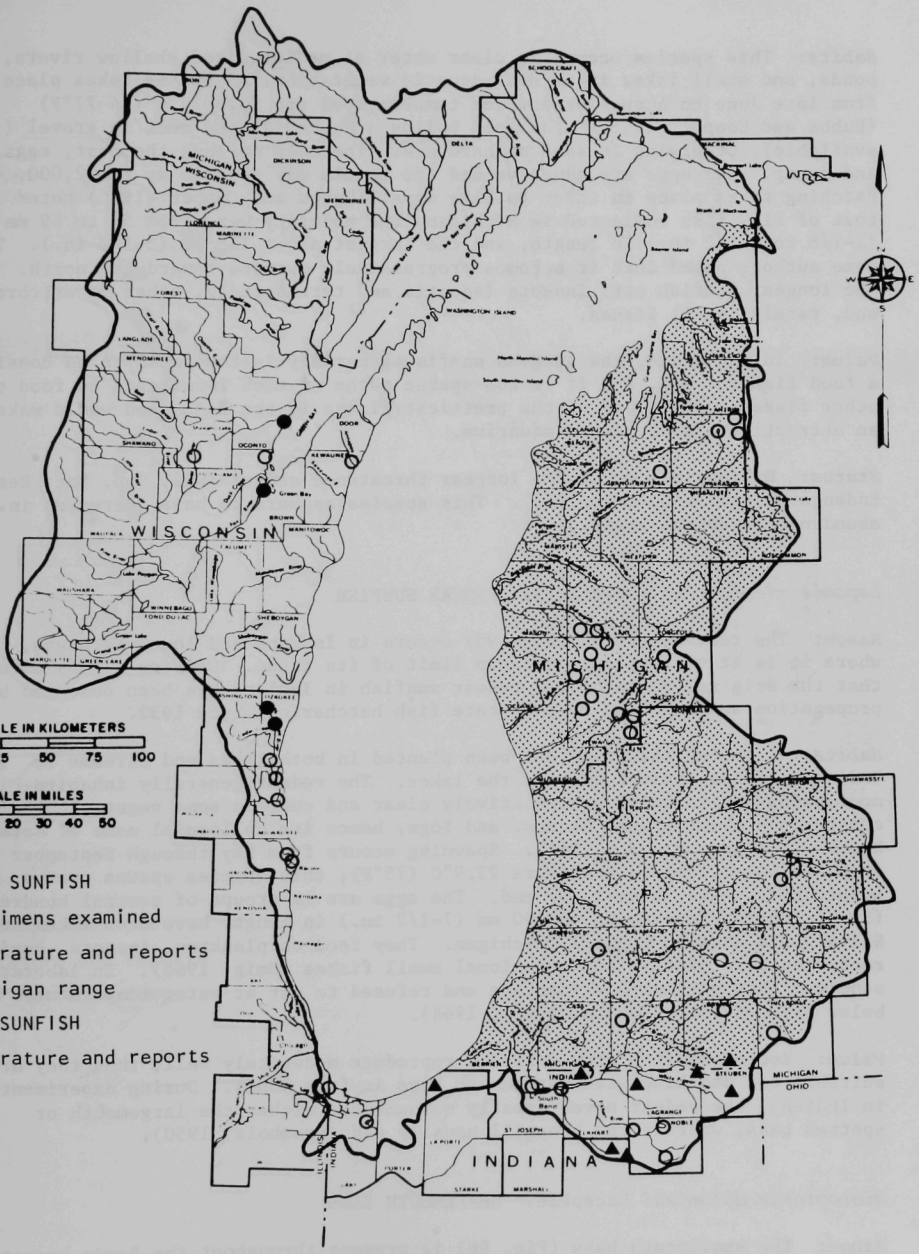

Fig. 95. Distribution of the Longear Sunfish (*Lepomis megalotis*) and Redear Sunfish (*Lepomis microlophus*).

Habits: This species occurs in clear water of medium-sized shallow rivers, ponds, and small lakes in or near aquatic vegetation. Spawning takes place from late June to August when water temperatures are 23.3-25°C (74-77°F) (Hubbs and Cooper, 1935). The male builds a saucer-shaped nest in gravel (if available), otherwise in sand or hard mud. The male defends the nest, eggs, and young. The eggs are adhesive and the female may deposit up to 22,000. Hatching takes place in three to five days. Hubbs and Cooper (1935) noted that of 1129 fish collected in Michigan, the majority were from 53 to 89 mm (2-1/8 to 3-1/2 in.) in length, and the largest about 140 mm (5-1/2 in.). The same authors noted that it becomes progressively dwarfed toward the north. The longear sunfish eats insects (aquatic and terrestrial), other invertebrates, and, rarely, small fishes.

Value: In the Basin, the longear sunfish generally is too small to be considered a food fish for man, and it is too sparse to be of much importance as food to other fishes. It is one of the prettiest fishes in the Basin and would make an attractive display in an aquarium.

Status: Wisconsin accords the longear threatened status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975). This species appears to have decreased in abundance in recent years.

Lepomis microlophus (Guenther). REDEAR SUNFISH

Range: The redear sunfish (Fig. 95) occurs in Indiana and lower Michigan, where it is at the extreme northern limit of its range. Gerking (1945) noted that the original range of the redear sunfish in Indiana has been obscured by propagation and stocking by the state fish hatcheries since 1932.

Habits: Although this fish has been planted in both lakes and streams in Indiana, it has thrived only in the lakes. The redear generally inhabits nonflowing waters which are relatively clear and contain some vegetation. It congregates about brush, stumps, and logs, hence its colloquial name of "stump-knocker" (Fukano *et al.*, 1964). Spawning occurs from May through September when the water temperature nears 23.9°C (75°F); this species spawns over a substrate of sand, gravel, or mud. The eggs are in groups of several hundred (Emig, 1966). Redears up to 190 mm (7-1/2 in.) in length have been taken from Silver Lake (Branch County), Michigan. They feed on plankton, insects, snails, rooted aquatic plants, and occasional small fishes (Emig, 1966). In laboratory studies, this species was inactive and refused to eat at water temperatures below 6.7°C (44°F) (Fukano *et al.*, 1964).

Value: Redear sunfish grow well and reproduce moderately well; thus they are suitable for stocking with largemouth bass in farm ponds. During experiments in Indiana, the redear never greatly outnumbered either the largemouth or spotted bass, whereas the bluegill usually did (Krumholz, 1950).

Micropterus dolomieui Lacépède. SMALLMOUTH BASS

Range: The smallmouth bass (Fig. 96) is present throughout the Basin except in Illinois. It is more common northward.

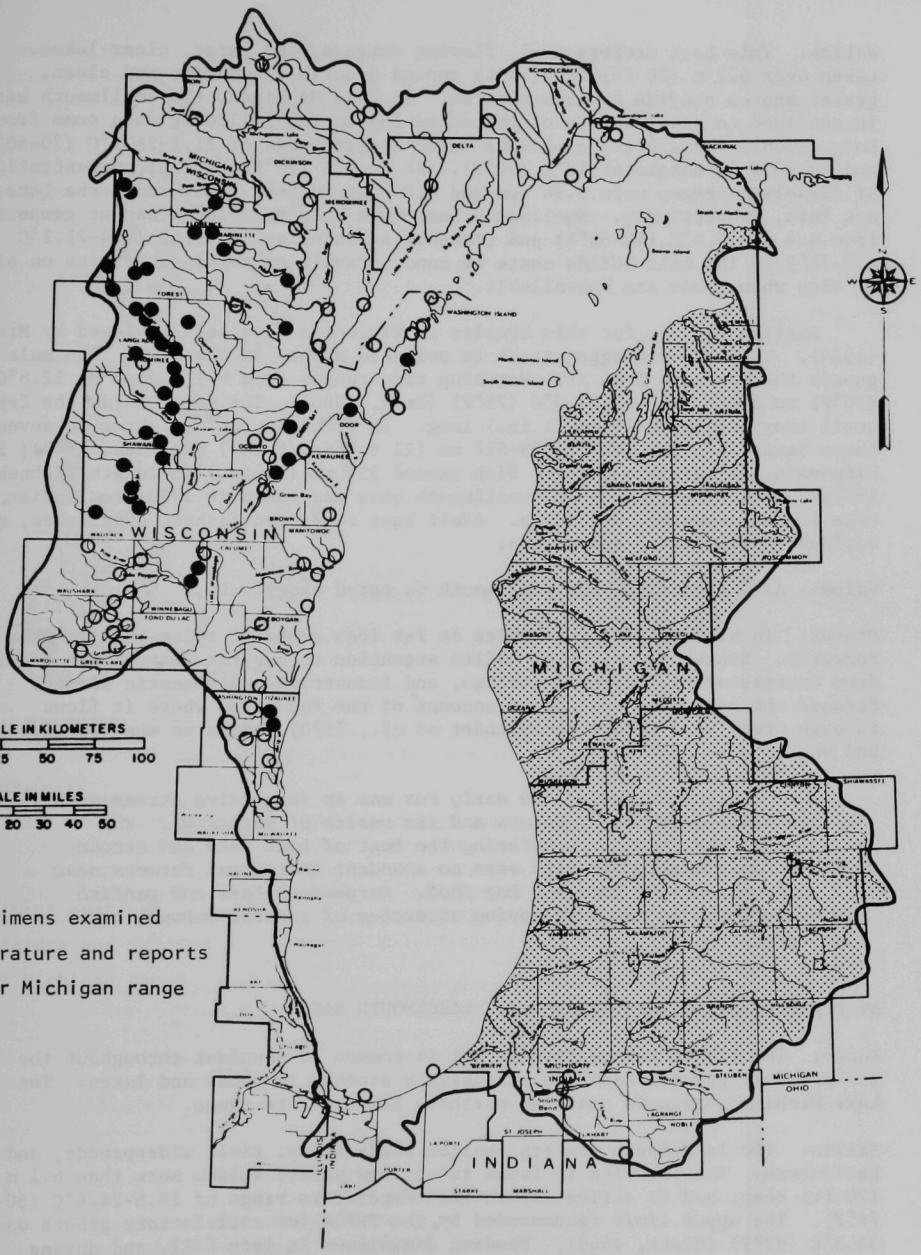

Fig. 96. Distribution of the Smallmouth Bass (*Micropterus dolomieui*).

Habits: This bass prefers cool, flowing streams, and large, clear lakes. Lakes over 6.1 m (20 ft) deep, with rooted aquatic vegetation and clean, gravel shores provide optimum habitat. In Lake Michigan, the smallmouth bass is confined to shoal waters of protected bays. The following data come from Emig (1966). This species prefers water temperatures of 21.1-26.7°C (70-80°F) and becomes lethargic at 10°C (50°F). At 21.1°C (70°F), lethal concentrations of dissolved oxygen were 0.96 ppm and 0.87 ppm in Deer River and Beebe Lake, New York, respectively. Smallmouth bass move into spawning areas at temperatures from 4.4 to 15.6°C (40-60°F) and commence spawning activity at 14.4-21.1°C (58-70°F). The male builds nests on sand, gravel, or rocks, otherwise on silt or clay when these are unavailable.

Nesting details for this species in Wisconsin have been reviewed by Mraz (1964). The adhesive eggs attach to polished stones in the nest. The male guards the nest and fans it. Hatching time ranges from 9-1/2 days at 12.8°C (55°F) to 2-1/4 days at 23.9°C (75°F) (Emig, 1966). The male guards the fry until they are about 25 mm (1 in.) long. In Michigan, at age three to seven, these bass reach lengths of 279-417 mm (11 to 16-3/8 in.) (Beckman, 1949); in Wisconsin, at age three, these fish exceed 254 mm (10 in.) in length (Schneberger, 1972d). A 4.1-kg (9-lb 1-oz) smallmouth bass was taken in 1950 from Indian Lake (Oneida County), Wisconsin. Adult bass feed upon fishes, crayfishes, and various insect larvae and adults.

Value: As a food fish, the smallmouth is rated excellent.

Status: In Wisconsin, this species is far less abundant today than it was formerly. Schneberger (1972d) called attention to habitat destruction resulting from overpasturing, improper tillage, and industrial and domestic sewage. Perhaps the following historical account of the Fox River where it flows through Green Lake County (Fassbender *et al.*, 1970) indicates what was lost and what can be regained:

> *"Quite obviously, the early Fox was an impressive stream with its clear slow moving waters and its wealth of waterfowl. The fishery was unique ... offering the best of both lake and stream fishing. Smallmouth bass were so abundant that local farmers near Princeton netted them for hog food. Largemouth bass and panfish were common in the slow moving stretches of rivers, oxbows, and bayous."*

Micropterus salmoides (Lacépède). LARGEMOUTH BASS

Range: The largemouth bass (Fig. 97) is common to abundant throughout the Basin. This species has been extensively stocked in ponds and lakes. The Lake Michigan Basin is near the northern limit of its range.

Habits: The largemouth prefers shallow weedy lakes, river widespreads, and backwaters. This species is found in shallow water, seldom more than 6.1 m (20 ft) deep, and is active within the temperature range of 15.6-24.4°C (60-76°F). The upper limit recommended by the FWPCA for satisfactory growth was 33.3°C (92°F) (Clark, 1969). Feeding diminishes in late fall, and during winter the bass is relatively inactive. This species will not tolerate low dissolved oxygen concentrations; thus it often becomes a victim of winterkill in its weedy, high-oxygen-demand habitat (Mraz *et al.*, 1961).

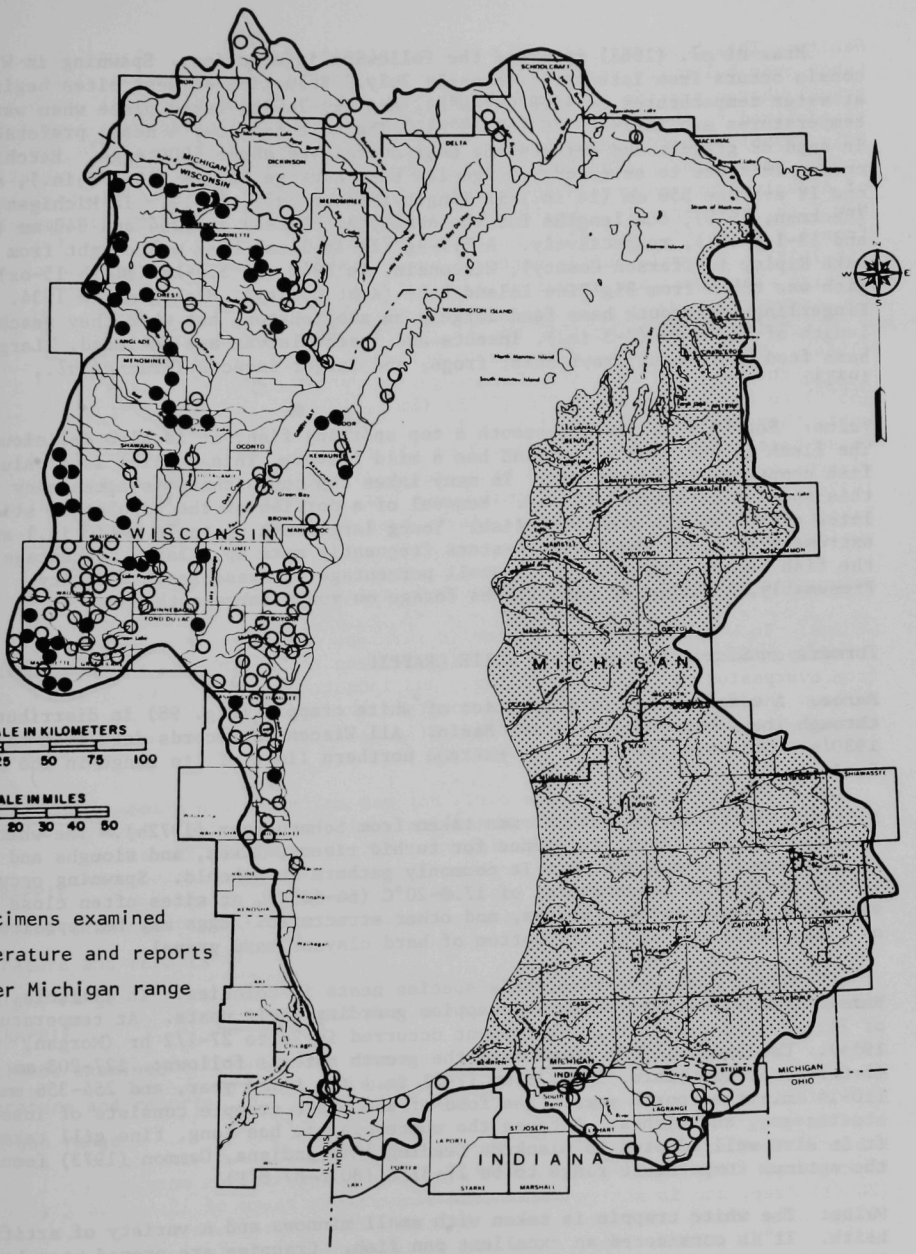

Fig. 97. Distribution of the Largemouth Bass (*Micropterus salmoides*).

Mraz *et al.* (1961) reported the following information. Spawning in Wisconsin occurs from late April to early July. Selection of nest sites begins at water temperatures of 15.6°C (60°F), and egg-laying takes place when water temperatures are 16.7-18.3°C (62-65°F). The male fans out a nest, preferably in sand or gravel, and defends the nest containing about 5000 eggs. Hatching occurs in three to seven days. Age III bass average 267 mm (10-1/2 in.), and age IV average 356 mm (14 in.) in length (Mraz *et al.*, 1961). In Michigan (Beckman, 1949), the lengths for the same year classes are 254 and 343 mm (10 and 13-1/2 in.), respectively. A 5.1-kg (11-lb 3-oz) bass was caught from Lake Ripley (Jefferson County), Wisconsin, in 1940. A 5.4-kg (11-lb 15-oz) fish was taken from Big Pine Island Lake (Kent County), Michigan, in 1934. Fingerling largemouth bass feed largely on zooplankton, but when they reach a length of 51-76 mm (2-3 in.), insects and insect larvae are included. Large bass feed on fishes, crayfishes, frogs, and larger insects (Mraz *et al.*, 1961).

Value: Not only is the largemouth a top sporting fish, it is also delicious. The flesh is moderately firm and has a mild flavor. This species is a valuable fish component in farm ponds. In many lakes and ponds there is a tendency for this species to become stunted. Removal of a portion of the population stimulates growth of the remaining fish. Young largemouth up to 76 mm (3 in.) are extremely abundant and in many waters frequently make up a large percentage of the fish taken; however, only a small percentage of these reach maturity. Presumably, a number of game fishes forage on young largemouth bass.

Pomoxis annularis Rafinesque. WHITE CRAPPIE

Range: A widely disjunct population of white crappie (Fig. 98) is distributed through the southern half of the Basin. All Wisconsin records date from the 1930's. This species is at the extreme northern limit of its range in the Basin.

Habits: The following account was taken from Schneberger (1972b). The white crappie has a distinct preference for turbid rivers, lakes, and sloughs and is not adverse to a mud bottom. It commonly gathers in schools. Spawning occurs in May or June at temperatures of 17.8-20°C (64-68°F), at sites often close to vegetation, embankments, stumps, and other structures. Eggs may be deposited on plant materials or on the bottom of hard clay or hard gravel.

Solitary nests are rare; this species nests in colonies. In Illinois, Hansen (1965) observed 60 to 70 crappies guarding their nests. At temperatures of 21.1-23.3°C (70-74°F), development occurred in 24 to 27-1/2 hr (Morgan, 1954). Carlander (1950) summarized the growth rate as follows: 127-203 mm (5-8 in.) at two years, 178-279 mm (7-11 in.) the third year, and 254-356 mm (10-14 in.) the fourth year. The food of the white crappie consists of insects, crustaceans, and fishes. Because the white crappie has long, fine gill rakers, it is also well adapted to plankton feeding. In Indiana, Gammon (1973) found the optimum temperature range to be 27-31°C (80.6-87.8°F).

Value: The white crappie is taken with small minnows and a variety of artificial baits. It is considered an excellent pan fish. Crappies are preyed upon by large game fishes including largemouth bass, smallmouth bass, northern pike, and muskellunge.

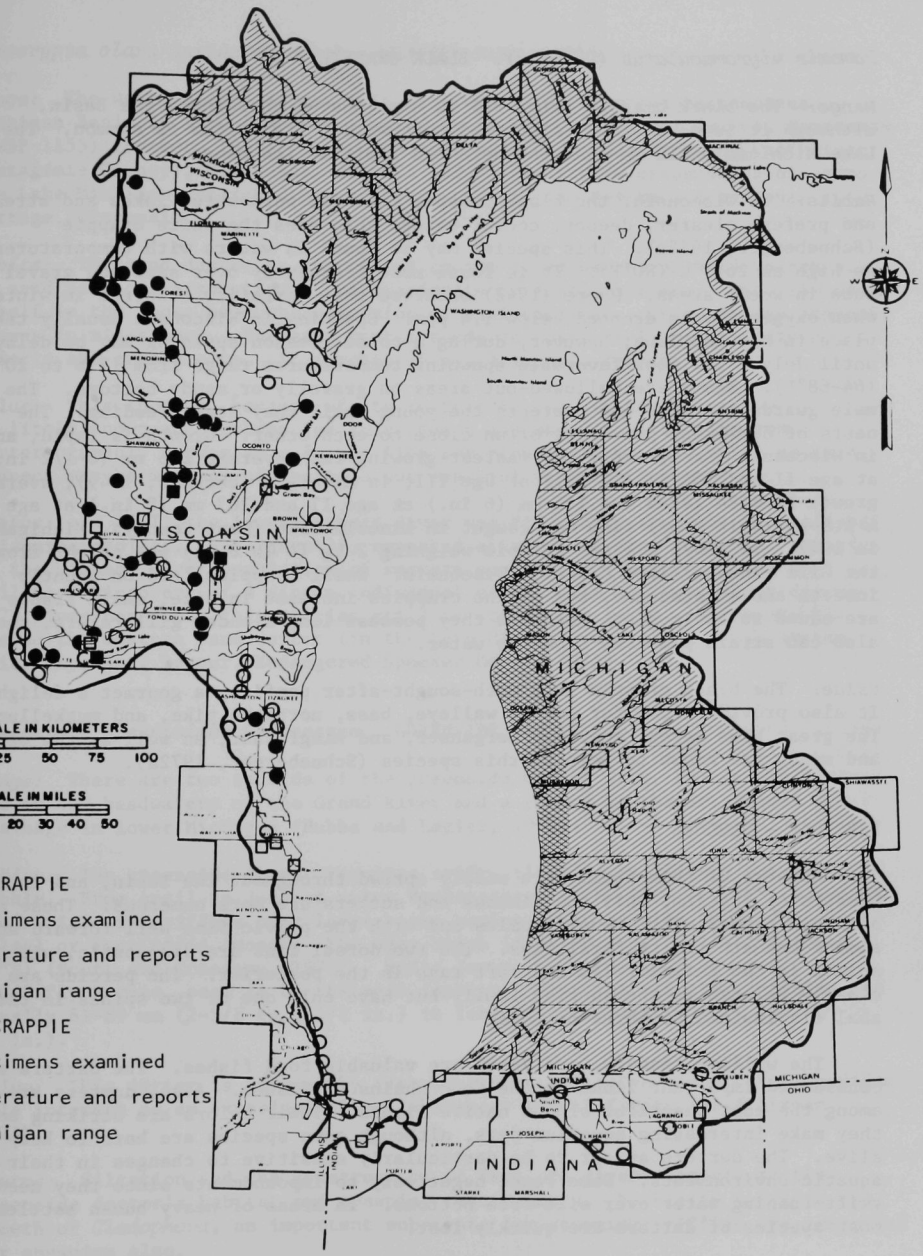

Fig. 98. Distribution of the White Crappie (*Pomoxis annularis*) and Black Crappie (*Pomoxis nigromaculatus*).

Pomoxis nigromaculatus (Lesueur). BLACK CRAPPIE

Range: The black crappie (Fig. 98) is distributed throughout the Basin, although it is more widely dispersed northward. Its status is common. The Lake Michigan Basin is near the northern limit of its range.

Habits: In Wisconsin, the black crappie inhabits warm-water lakes and streams and prefers clearer, deeper, cooler waters than does the white crappie (Schneberger, 1972a). This species may be found in waters with temperatures as high as 26.7°C (80°F). It is found more frequently over sand and gravel than in weedy areas. Moore (1942) observed that mortality occurred in winter when oxygen levels dropped below 1.4 ppm. Spawning in Wisconsin usually takes place in May and June; however, during a colder season spawning may be delayed until July. The most favorable spawning temperatures range from 17.8 to 20°C (64-68°F). Nests are hollowed-out areas on gravelly or sandy bottoms. The male guards the nest and protects the young until they start feeding. The nests of different pairs are often close to each other. Growth is rapid, and in Wisconsin (Snow, 1969) the fastest-growing fish average 216 mm (8-1/2 in.) at age II and 254 mm (10 in.) at age III; in Michigan (Beckman, 1949), average growth from 84 lakes was 152 mm (6 in.) at age II and 203 mm (8 in.) at age III. A 1.9-kg (4-lb 2-oz) fish was caught in Lincoln Lake (Kent County), Michigan, in 1947. In 1967, a black crappie weighing 2 kg (4 lb 8 oz) was caught from the Gile Flowage (Iron County), Wisconsin. Small crappies feed on aquatic insects and crustaceans, but as the crappies increase in size, small fishes are added to their diet. Because they possess long slender gill rakers, they also can strain plankton from the water.

Value: The black crappie is a much-sought-after panfish, a gourmet's delight. It also provides food for perch, walleye, bass, northern pike, and muskellunge. The great blue heron, American merganser, and kingfisher, as well as the otter and mink, are known to feed on this species (Schneberger, 1972a).

PERCIDAE - PERCHES

Members of this family are widely spread throughout the Basin, and in numbers of species, only the minnows and suckers are more numerous. These are advanced fishes with ctenoid scales and with the pelvic fins well forward and almost beneath the pectoral fins. The two dorsal fins are diagnostic, with spines in the anterior fin and soft rays in the posterior. The percids are closely related to the sunfish family but have only one or two spines in the anal fin instead of three or more.

The walleye, sauger, and perch are valuable food fishes. The darters are considered important links in the food chains of fishes. Also, darters are among the most beautiful of our native fishes. Their colors are striking and they make interesting aquarium pets, although some species are hard to keep alive. The darters appear to be particularly sensitive to changes in their aquatic environments. Some react negatively to impoundments since they need swift-running water over silt-free bottoms. In areas of heavy human settlement most species of darters are quickly lost.

Ammocrypta clara Jordan and Meek. WESTERN SAND DARTER

Range: The western sand darter (Fig. 99) was first reported in the Lake Michigan Basin in 1960 from the lower Waupaca River (Waupaca County), Wisconsin (UWSP 1155) (Becker, 1965). A second collection was made from the Wolf River (Outagamie County), Wisconsin, in 1973 (UWSP 4404). The dispersal route into the Lake Michigan watershed was probably through the Fox-Wisconsin Canal at Portage, Wisconsin.

Habits: The sand darter is restricted to the clear waters of sandy beaches, or sand bars of large streams, with moderate to swift currents. It will bury itself in the loose sand while resting or awaiting prey. This species probably spawns in mid-summer. The sand darter feeds on small or immature aquatic insects and crustaceans. It reaches 76 mm (3 in.) in length.

Value: This species, because of its restricted habitat and secretive habits, is little known and perhaps for this reason has special value. The sand darter probably serves as a forage fish for predators, but its value in this respect may be minimal since it is not especially common anywhere.

Status: In 1971, the lower Waupaca River was drawn down severely for a fish-poisoning project. Subsequently, repeated attempts to find surviving members of the Waupaca River population of western sand darters have resulted in failure. Discovery of a single individual close by in the Wolf River during 1973 gives hope that this species still exists in the Basin. Wisconsin has placed the western sand darter (in the Lake Michigan Basin) on watch status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

Etheostoma blennioides Rafinesque. GREENSIDE DARTER

Range: There are two records of the greenside darter (Fig. 99) in the Basin: one in the headwaters of the Grand River and a second in the St. Joseph River drainage in lower Michigan (Hubbs and Lagler, 1958).

Habits: The greenside darter requires swift, clear water, with a substrate of rubble. From April to June at water temperatures of 10.6°C (51.1°F), spawning occurs in swift riffles over large rocks having heavy growths of *Cladophora* (alga) or *Fontinalis* (moss). The eggs hatch in 18-20 days at 13-15°C (55.4-59°F) (Scott and Crossman, 1973). Midge larvae, supplemented by mayfly and caddisfly larvae, seem to be the most important food for all ages. Adults are usually 61-89 mm (2-3/8 to 3-1/2 in.) in length, occasionally over 102 mm (4 in.).

Value: This darter is foraged by fish predators. It also could be of considerable interest as an experimental or laboratory animal (Scott and Crossman, 1973).

Status: Siltation and the construction of dams are direct threats to the greenside darter's habitat and spawning requirements. Turbidity inhibits the growth of *Cladophora*, an important substrate for spawning; riffles are essential for spawning also.

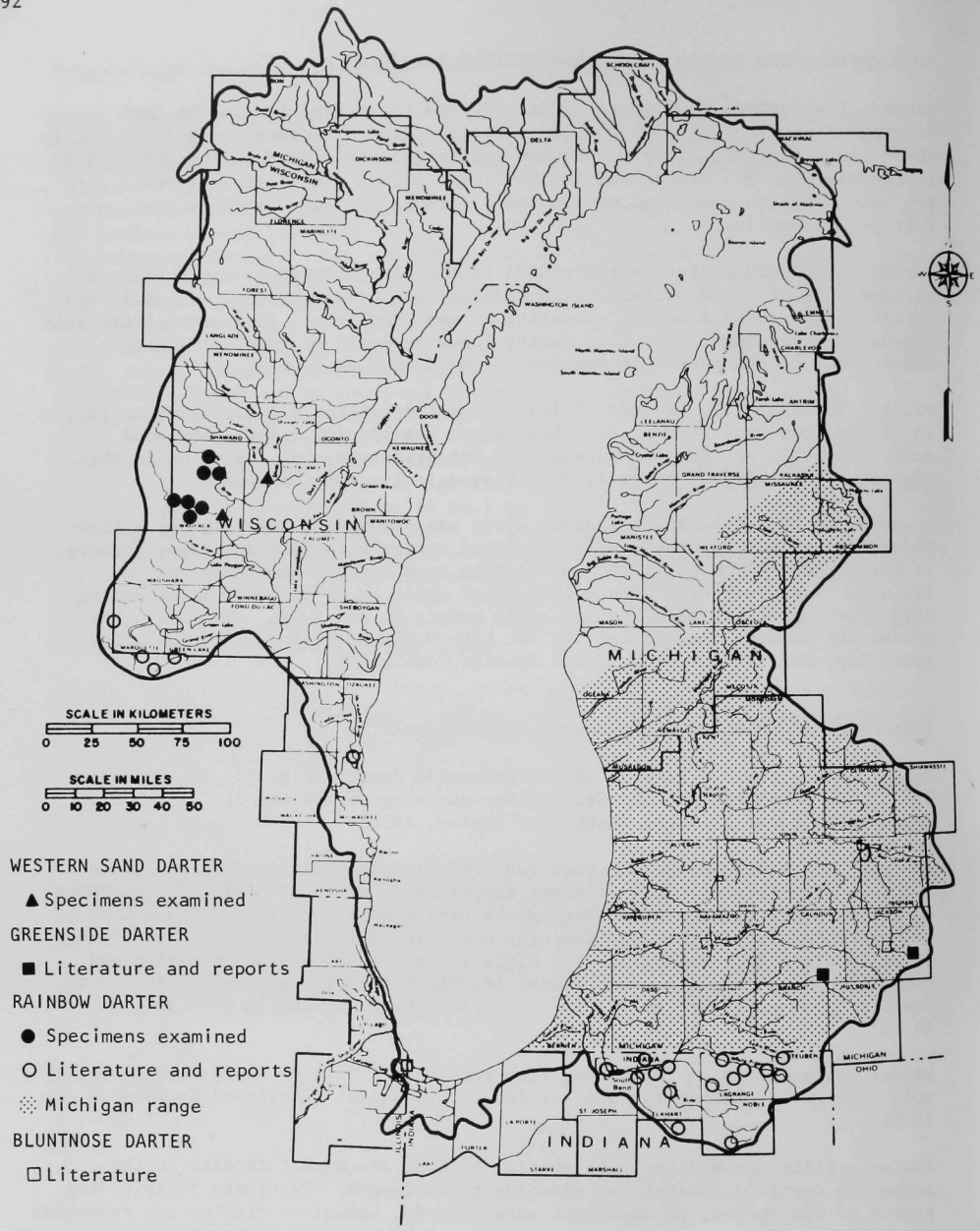

Fig. 99. Distribution of the Western Sand Darter (*Ammocrypta clara*), Greenside Darter (*Etheostoma blennioides*), Rainbow Darter (*Etheostoma caeruleum*), and Bluntnose Darter (*Etheostoma chlorosomum*).

Etheostoma caeruleum Storer. RAINBOW DARTER

Range: The rainbow darter (Fig. 99) is found in the southern half of the Lake Michigan Basin, which is the northern limit of its range. In lower Michigan and Indiana, there are numerous records of the rainbow darter; in Wisconsin, this fish is rare to uncommon.

Habits: This darter prefers small rivers and streams of clear, rapid waters. Spawning occurs only in riffles over coarse to fine gravel, or rubble, between early April and late May (Winn, 1958), at water temperatures of 15°C (59°F) or above (Breder and Rosen, 1966). According to Winn (1958), hatching occurs in 10-12 days at 17-18.5°C (62.6-65.3°F). This species feeds on midge, mayfly, and caddisfly larvae as well as snails and small crayfishes; Reighard (1920) observed the rainbow darter feeding on white sucker eggs. Adults reach 64 mm (2-1/2 in.) in length, occasionally longer.

Value: The rainbow undoubtedly serves as a forage species for game fishes. It responds negatively to siltation and chemical pollutants; hence it is an indicator of water quality. This species is very colorful and makes an attractive aquarium species, but is hard to keep.

Status: The rainbow darter is now absent from streams where it was once reported, undoubtedly the victim of environmental changes. In Wisconsin, the treatment of streams with antimycin has resulted in the immediate removal of the rainbow darter from the faunal list because it is extremely sensitive to toxicants. Moreover, this fish does not readily reestablish in such treated areas. The retention of this species as part of the Basin fish fauna will require careful management.

Etheostoma chlorosomum (Hay). BLUNTNOSE DARTER

Range: There is one record of the bluntnose darter (Fig. 99) from the Illinois portion of the Basin before 1905 (Forbes and Richardson, 1920). Hubbs and Lagler (1958) stated that this record was in need of verification, but Smith (1975a--letter) of the Illinois Natural History Survey accepted it by calling attention to the fact that the species was formerly distributed almost statewide in Illinois. It probably has been extirpated in the Basin.

Habits: This darter prefers quiet sluggish waters of slow-moving streams, sloughs, and backwaters, and a mud bottom (Eddy and Underhill, 1974). In Kansas, Cross (1967) noted that this darter came into breeding condition in April. Its eggs are laid on plants or debris (Winn, 1958). This darter reaches a length of 47 mm (1-7/8 in.).

Value: Although the bluntnose darter undoubtedly serves as a forage species to predatory fishes, it is of little consequence because of its sparse numbers here at the northern limit of its range. So little is known about this species that a challenge remains for the research biologist to document its life history before it becomes a mere statistic.

Etheostoma exile (Girard). IOWA DARTER

Range: The Iowa darter (Fig. 100) is well distributed throughout the Basin and is locally uncommon to common.

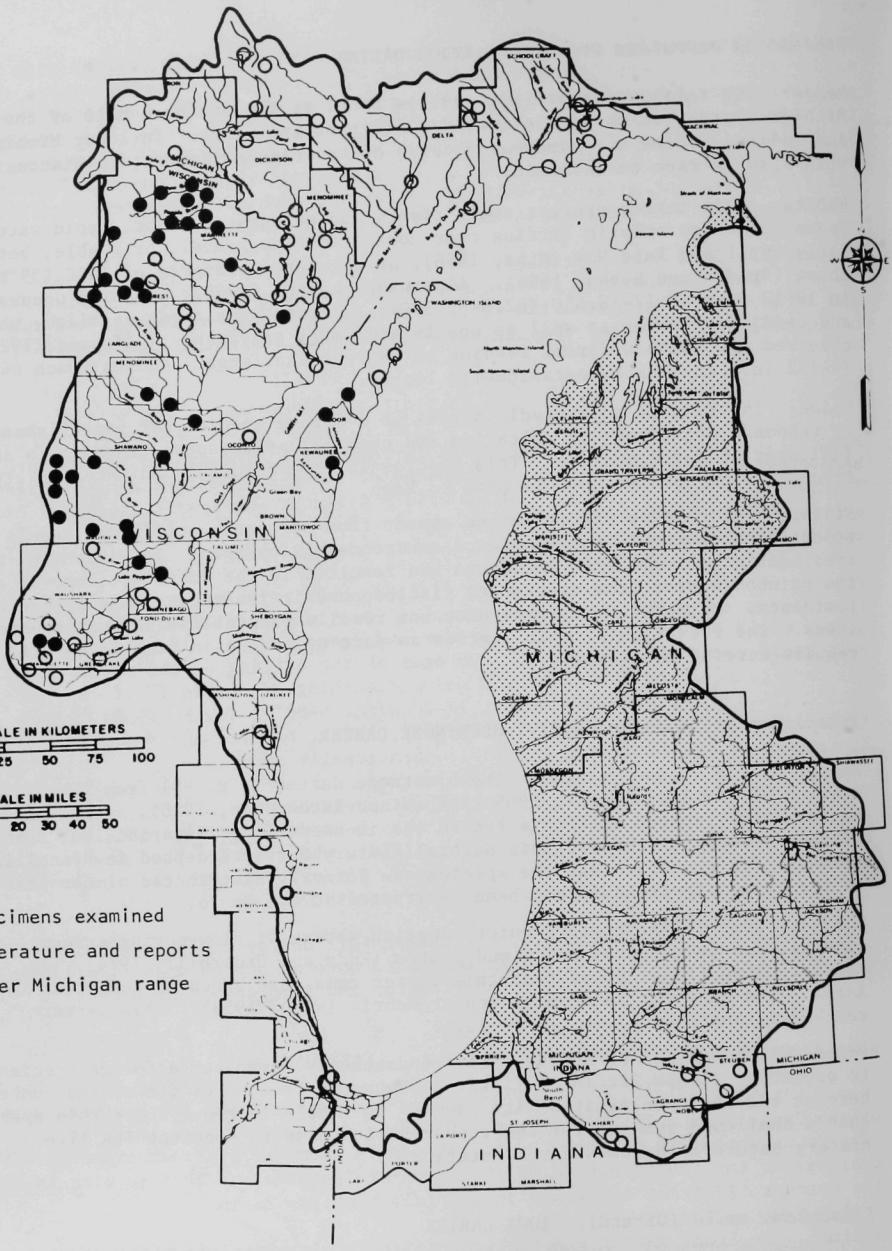

Fig. 100. Distribution of the Iowa Darter (*Etheostoma exile*).

Habits: This species prefers clear, cool lakes and sluggish streams with sandy or muddy substrate and rooted aquatic vegetation. Spawning occurs in shallows, over fibrous roots, stones, or pebbles, during May and early June. The male guards the nesting site. Hatching occurs in 18-26 days at temperatures of 13-16°C (55.4-60.8°F) (Winn, 1958). This species has been reported to survive in waters with less than 0.2 ppm dissolved oxygen (Cooper and Washburn, 1949). Adults eat midge larvae, mayfly larvae, amphipods, and some snails and corixid nymphs. It reaches 64 mm (2-1/2 in.) in length.

Value: The Iowa darter probably contributes to the diet of piscivorous fishes. During spawning, it is one of the most beautiful fishes in the Basin and is an easily kept aquarium pet. Trautman (1957) noted that it was intolerant of turbid, muddy waters, conditions which seem to limit its food supply.

Etheostoma flabellare Rafinesque. FANTAIL DARTER

Range: The fantail darter (Fig. 101) is found in Wisconsin and in scattered headwater streams along the southern edge of the Upper Peninsula of Michigan. In lower Michigan, it is present in widely disjunct locales in the Grand River system and the headwaters of the Kalamazoo River drainage. This species is at the northern limit of its range in the Lake Michigan Basin.

Habits: The fantail darter prefers riffles, over rocks and gravel, in small- to medium-sized streams. Spawning occurs from late April into June at temperatures of 18.9-24.4°C (66-76°F) (Breder and Rosen, 1966). The male builds the nest under rocks and the female lays eggs on the ceiling of the nest. The eggs are guarded and fanned by the male. Hatching occurs in 14-16 days at 23.5°C (74.3°F), and 30-35 days at 17-20°C (62.6-68°F) (Winn, 1958). The fantail darter feeds on mayfly, caddisfly, snail, beetle, and mosquito larvae. It reaches a length of 76 mm (3 in.), occasionally more.

Value: This darter probably is forage for predator fishes. It has a complex and fascinating spawning behavior which has been well documented (Winn, 1958). Eddy and Underhill (1974) cited Jordan (1888), who remarked that the fantail was the *"'darter of darters'--the hardiest, wiriest, and wariest of them all and the one most expert in catching other creatures."*

Status: Cross (1967) suggested that the fantail darter probably cannot tolerate intermittence of water flow, being forced to move or perish when flow ceases. This darter responds negatively to siltation and impoundment of waters.

Etheostoma microperca Jordan and Gilbert. LEAST DARTER

Range: The least darter (Fig. 102) occurs in Wisconsin and the southern edge of the Upper Peninsula of Michigan, in widely disjunct locales where it is rare to uncommon; in lower Michigan, it occurs from the Little Manistee River drainage to the southern edge of the Lake Michigan Basin. This species is at the northern limit of its range in the Lake Michigan Basin.

Habits: The least darter prefers weed-filled pools underlain with rocks in small- to medium-sized streams. It also is found in lakes. Spawning territories are established by the male who uses weeds to delimit the boundaries. In

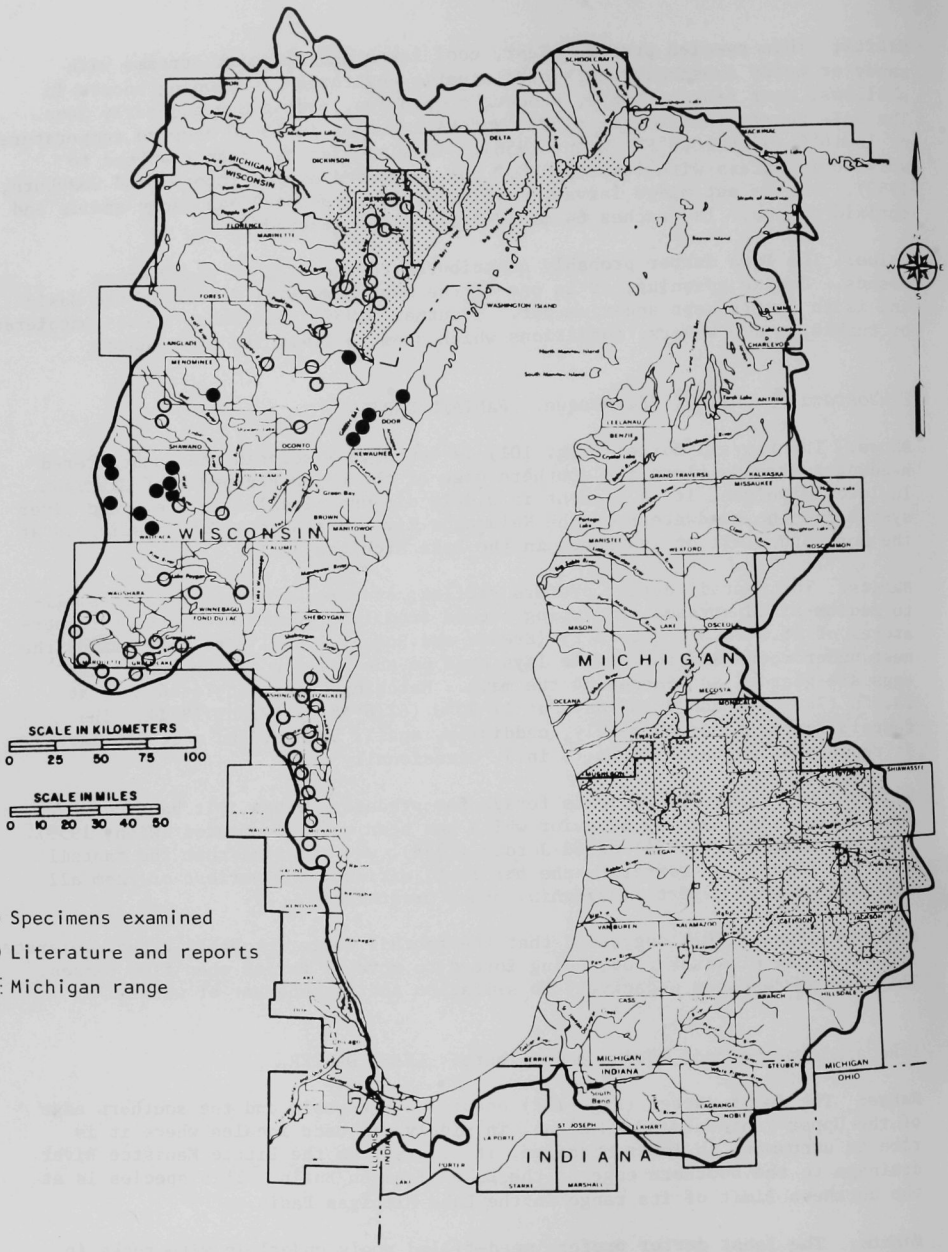

Fig. 101. Distribution of the Fantail Darter (*Etheostoma flabellare*).

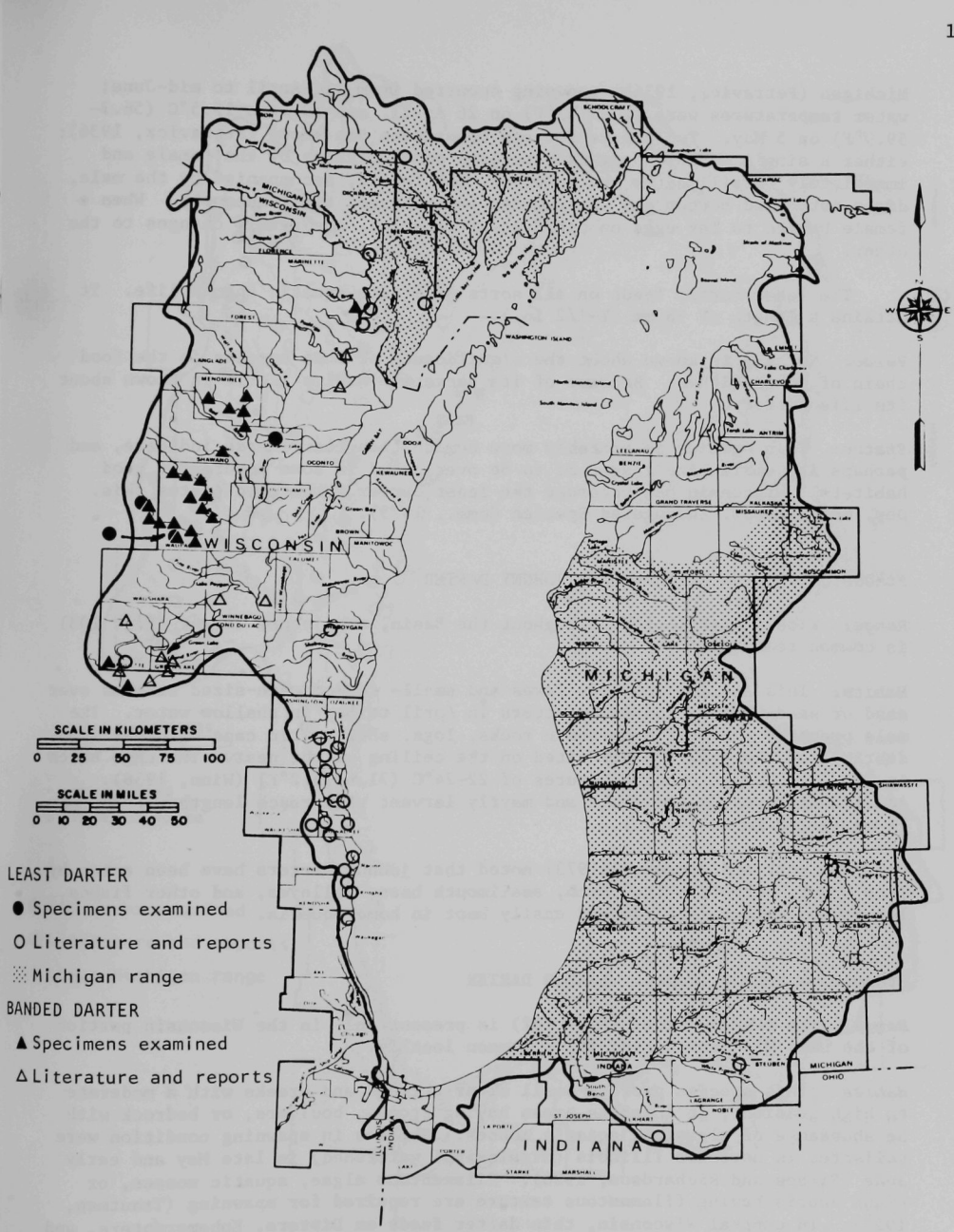

Fig. 102. Distribution of the Least Darter (*Etheostoma microperca*) and Banded Darter (*Etheostoma zonale*).

Michigan (Petravicz, 1936), spawning occurred from mid-April to mid-June; water temperatures were 12°C (53°F) on 26 April, and 13.5 to 15.5°C (56.3-59.9°F) on 5 May. Two places for egg deposition are known (Petravicz, 1936): either a single adhesive egg is deposited on vegetation by the female and immediately fertilized by the male; or, the female, accompanied by the male, dives into sand bottom and the gametes are released simultaneously. When a female begins to lay eggs on one type of material, she rarely changes to the other.

The least darter feeds on all sorts of minute aquatic animal life. It attains a length of 38 mm (1-1/2 in.).

Value: Nothing is known about the significance of this species in the food chain of other fishes. Because of its secretive habits little is known about its life history.

Status: This species is probably more common than the records indicate, and perhaps its small size causes it to be overlooked in some apparently good habitats. Wisconsin has accorded the least darter threatened status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

Etheostoma nigrum Rafinesque. JOHNNY DARTER

Range: Widely distributed throughout the Basin, the johnny darter (Fig. 103) is common to abundant.

Habits: This species inhabits lakes and small- to moderate-sized streams over sand or sand-gravel. Spawning occurs in April to May in shallow water. The male prepares the nest underneath rocks, logs, shells, tin cans or other debris, and the eggs are deposited on the ceiling of the nest. The eggs hatch in 5-1/2 to 8 days at temperatures of 22-24°C (71.6-75.2°F) (Winn, 1958). Adults eat copepods and midge and mayfly larvae; they reach lengths of 38-71 mm (1-1/2 to 2-3/4 in.).

Value: Scott and Crossman (1973) noted that johnny darters have been eaten by lake trout, burbot, white perch, smallmouth bass, walleyes, and other fishes. The johnny darter is hardy and easily kept in home aquaria.

Etheostoma zonale (Cope). BANDED DARTER

Range: The banded darter (Fig. 102) is present only in the Wisconsin portion of the Lake Michigan Basin; it is common locally.

Habits: This species prefers small clear streams and creeks with a moderate to high gradient; it inhabits areas having stones, boulders, or bedrock with an abundance of algae and aquatic mosses. Females in spawning condition were collected in northern Illinois (Mississippi watershed) in late May and early June (Forbes and Richardson, 1920). Filamentous algae, aquatic mosses, or plant debris having filamentous texture are required for spawning (Trautman, 1957). In central Wisconsin, this darter feeds on Diptera, Ephemeroptera, and some Coleoptera larvae (Duchrow, 1967). Adults are usually 51-64 mm (2 to 2-1/2 in.) in length.

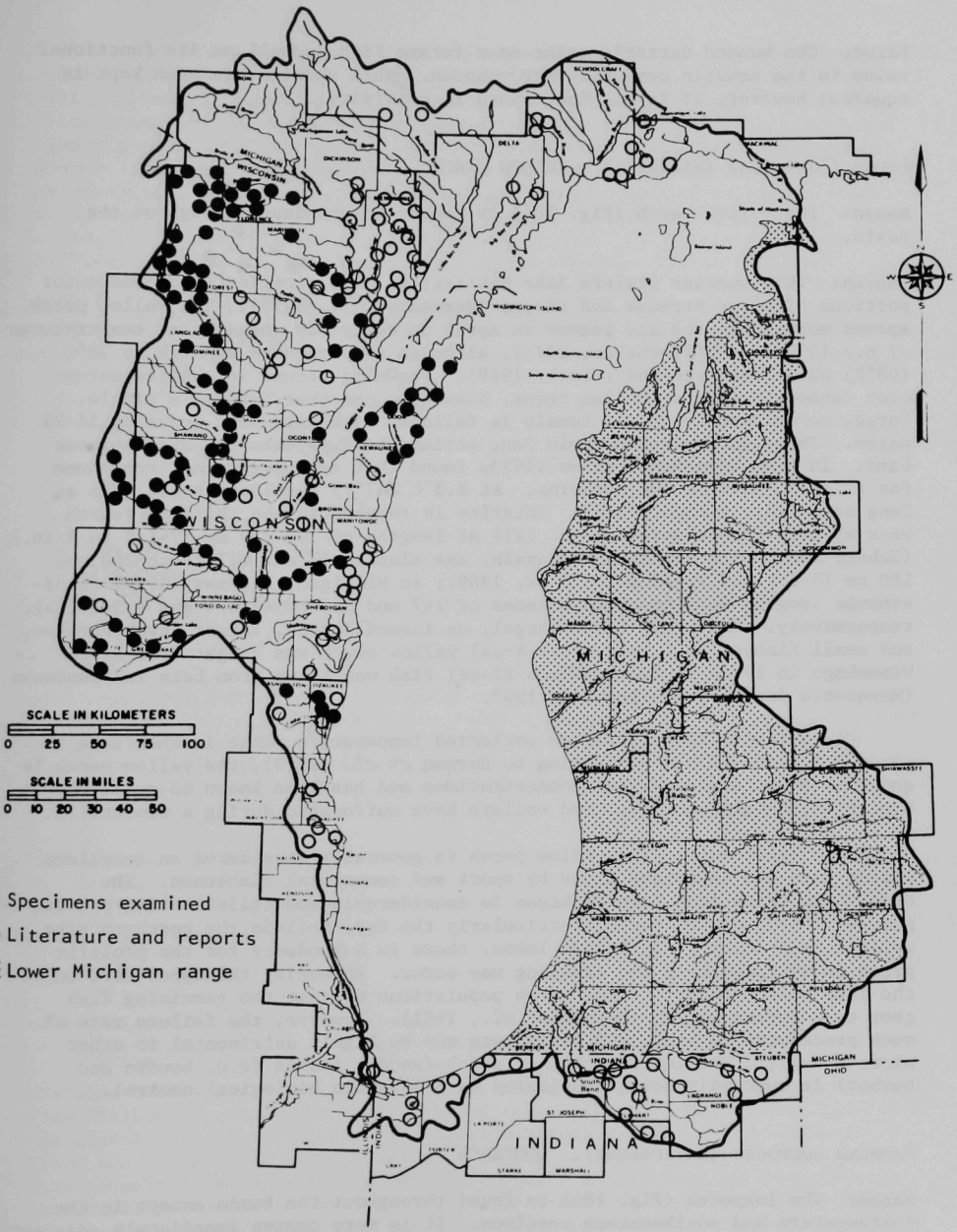

Fig. 103. Distribution of the Johnny Darter (*Etheostoma nigrum*).

Value: The banded darter's value as a forage fish as well as its functional roles in the aquatic community are unknown. This species has been kept in aquaria; however, it is not long-lived in captivity.

Perca flavescens (Mitchill). YELLOW PERCH

Range: The yellow perch (Fig. 104) is common to abundant throughout the Basin.

Habits: This species prefers lake habitat; it also occupies ponds and quiet portions of large streams and rivers (Herman *et al.*, 1959). The yellow perch spawns soon after the ice leaves in April or early May, usually at temperatures of 6.7-15°C (44-59°F) (Weber, 1975), although temperatures as high as 20°C (68°F) have been recorded (Clark, 1969). Spawning occurs in shallow water over submerged plants, fallen trees, branches, or other debris; a single, large, conspicuously gravid female is followed by a yard-long queue of 15-25 males. The eggs are released in long strings held together by a gelatinous band. In Lake Winnebago, Weber (1975) found that egg development continues for 17 to 20 days before hatching. At 8.3°C (47°F) development can take as long as 27 days (Leach, 1928). Maturity is reached in the third or fourth year of life (age classes II and III) at lengths of 190-229 mm (7-1/2 to 9 in.) (Weber, 1975). In northern Wisconsin, age classes II and III reach 140 and 180 mm (5-1/2 and 7-1/8 in.) (Snow, 1969); in Michigan, Beckman (1949) found average lengths for those age classes of 147 and 163 mm (5-3/4 and 6-3/8 in.), respectively. The perch feeds largely on insect larvae, larger invertebrates, and small fishes. A 1.5-kg (3-lb 4-oz) yellow perch was caught from Lake Winnebago in 1954. A 1.7-kg (3-lb 12-oz) fish was taken from Lake Independence (Marquette County), Michigan, in 1947.

Clark (1969) noted that the preferred temperature range in the field is 19.4-21.1°C (67-70°F). According to Herman *et al.* (1959), the yellow perch is quite tolerant of low oxygen concentrations and has been known to survive when bluegills, largemouth bass, and walleye have suffocated during a winterkill.

Value and Management: The yellow perch is generally considered an excellent eating fish and is sought after by sport and commercial fishermen. The commercial catch from Lake Michigan is considerable and fillets bring premium prices. Predators of perch, particularly the fry, include the northern pike, walleye, and burbot. In inland lakes, there is a tendency for the prolific perch to overpopulate, and stunting may occur. Poisoning the upper stratum of the lake will markedly reduce perch populations so that the remaining fish grow to a better weight (Lennon *et al.*, 1971). However, the failure rate of such procedures is high, and treatments may be highly detrimental to other biota as well. The introduction of perch-feeding fishes (*e.g.* bowfin and burbot) is currently being considered as a possible biological control.

Percina caprodes (Rafinesque). LOGPERCH

Range: The logperch (Fig. 105) is found throughout the Basin except in the northwestern and southeastern portions. It is more common immediately adjacent to Lake Michigan.

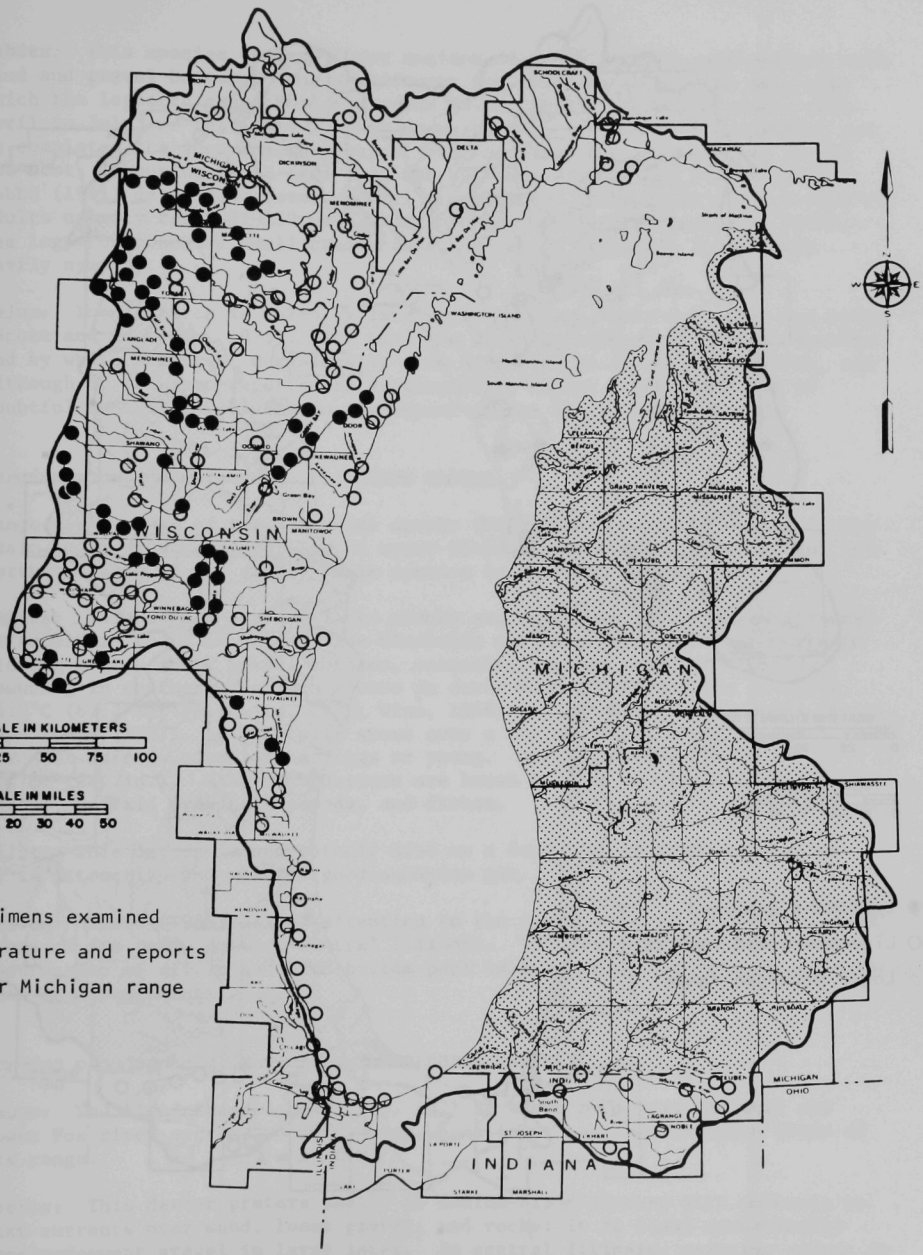

Fig. 104. Distribution of the Yellow Perch (*Perca flavescens*).

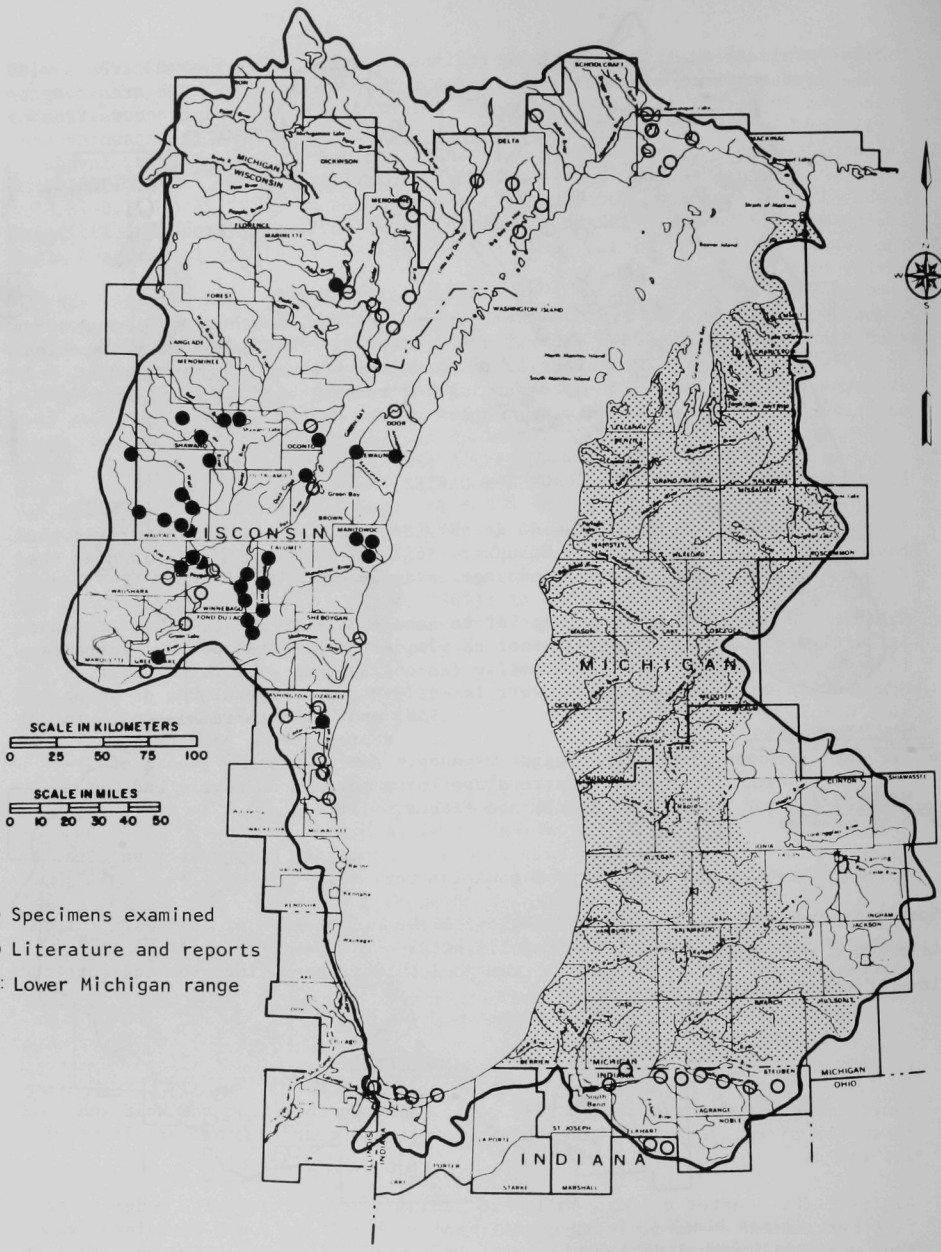

Fig. 105. Distribution of the Logperch (*Percina caprodes*).

Habits: This species prefers those regions of lakes, rivers, and streams with sand and gravel bottoms. One requirement for spawning is a large area over which the logperch can school and spawn (Winn, 1958). Spawning occurs from April to July; no territory or nest is prepared. As soon as the spawning act is completed the supernumerary males, and sometimes the mating pair, invade the nest, devouring those eggs that can be found (Breder and Rosen, 1966). Hubbs (1961) determined developmental temperatures to be 22-26°C (71.6-78.8°F). Adults usually reach 71-152 mm (2-3/4 to 6 in.) in length (Trautman, 1957). The logperch consumes small crustaceans, midge and caddisfly larvae, and mayfly nymphs.

Value: The logperch is eaten by lake trout, walleye, northern pike, and terns (Scott and Crossman, 1973). Its eggs are eaten by members of its own species and by white suckers. Occasionally this large darter is caught on worms, and although it has been reported as growing large enough to be eaten, it is doubtful that it is so used to any extent in the Basin.

Percina maculata (Girard). BLACKSIDE DARTER

Range: The range of the blackside darter (Fig. 106) extends northward in the Basin to the lowermost portion of upper Michigan; in the Basin it is near the northern limit of its range. This species is uncommon to common.

Habits: This darter prefers large creeks and small- to medium-sized streams; it rarely is found in lakes. The blackside darter prefers moderate currents flowing over sand or gravel bottoms, occasionally over detritus or silt. Spawning in southern Michigan occurs in early May at temperatures of about 16.5°C (61.7°F) (Petravicz, 1938; Winn, 1958) and in southern Wisconsin in June (Cahn, 1927). A pair will spawn over a depression in sand or gravel. No parental care is given either eggs or young. Adults reach a length of 51-102 mm (2-4 in.). Blackside darters are known to feed on mayfly and midge larvae, corixid nymphs, copepods, and fishes.

Value: This darter is undoubtedly used as a food fish by predator species. It is attractive and makes a good aquarium pet.

Status: Smith (1968) called attention to the extirpation of this darter from parts of its range in east-central Illinois. This was attributed to the destruction of riffle and hard-bottom pool habitat resulting from the construction of impoundments.

Percina phoxocephala (Nelson). SLENDERHEAD DARTER

Range: The slenderhead darter (Fig. 107) is known only from the Wolf and lower Fox river systems of Wisconsin, where it is near the northern limit of its range.

Habits: This darter prefers small- to medium-sized streams with moderate to fast currents over sand, loose gravel, and rocks; it is found occasionally over waveswept gravel in large lakes. In central Illinois, spawning occurs in June (Page and Smith, 1971). Cross (1967) reported spawning activity at water temperatures of 21.1°C (70°F). Development and growth in central Illinois is

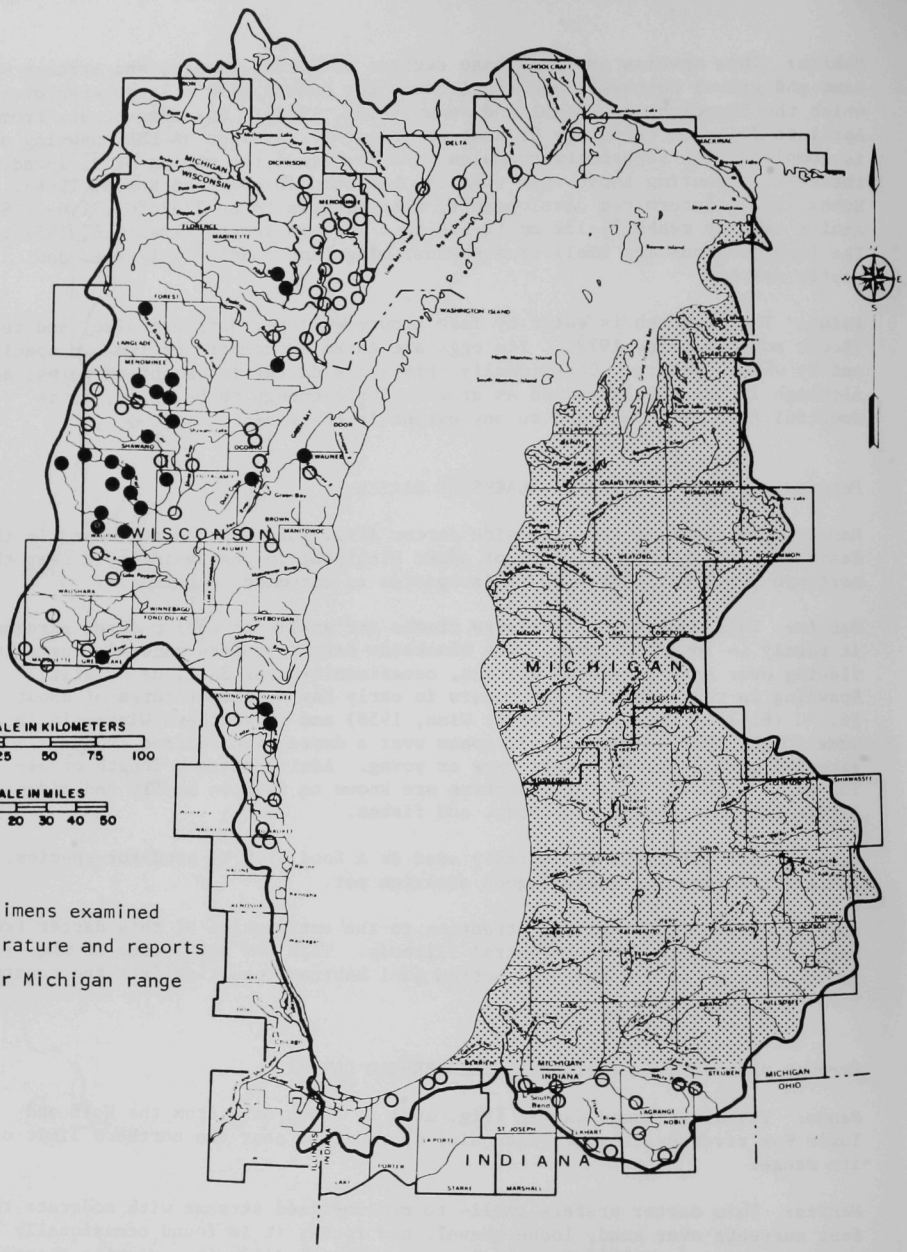

Fig. 106. Distribution of the Blackside Darter (*Percina maculata*).

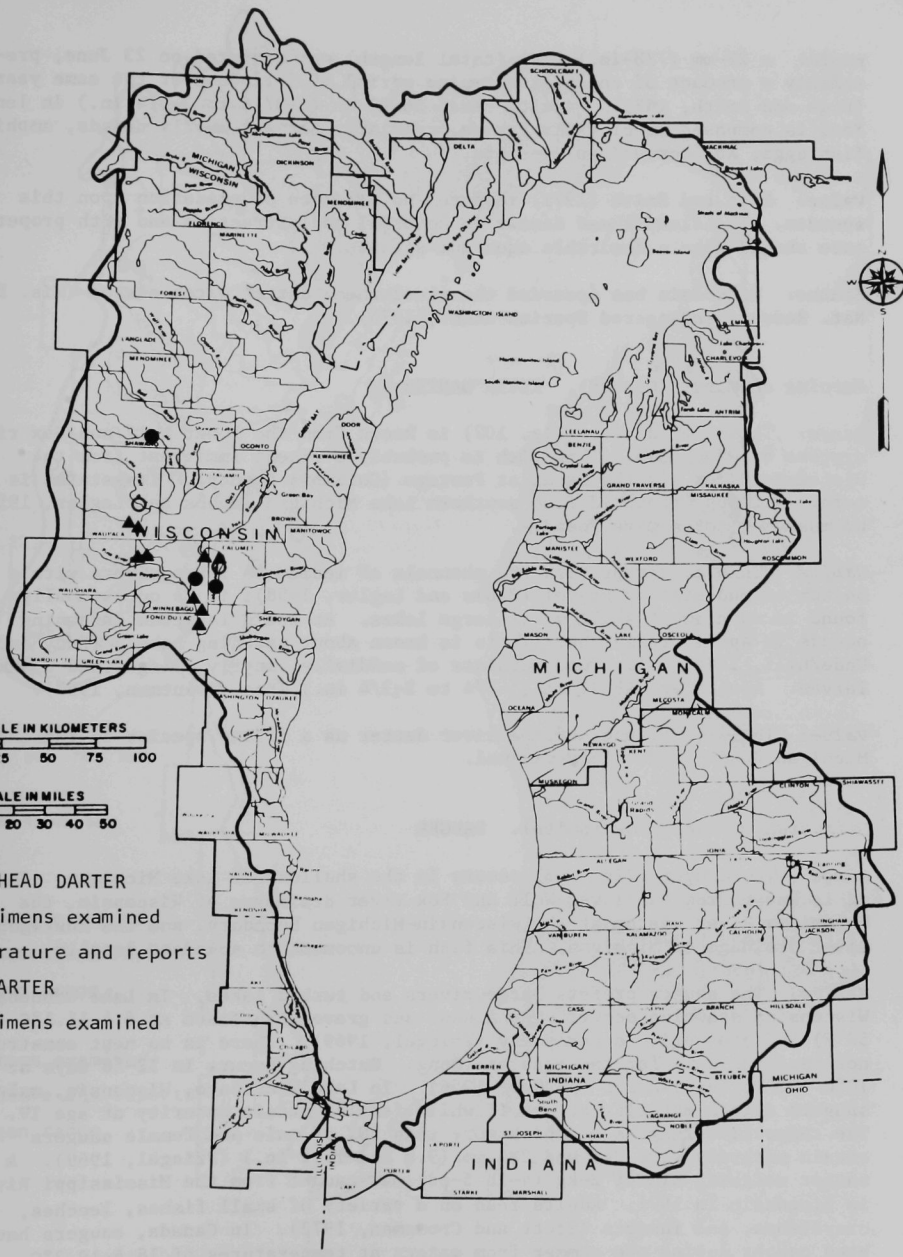

Fig. 107. Distribution of the Slenderhead Darter (*Percina phoxocephala*) and River Darter (*Percina shumardi*).

rapid: a 22-mm (7/8-in.) fish (total length) was captured on 23 June, presumably a product of the peak spawning period of 5-12 June of the same year (Page and Smith, 1971). Adults reach 56-97 mm (2-3/16 to 3-3/4 in.) in length. Food is composed of blackfly larvae, caddisfly larvae, mayfly naiads, amphipods, fish eggs, and terrestrial insects.

Value: Page and Smith (1971) reported no evidence of predation upon this species. The slenderhead darter is colorful and attractive and with proper care should make a desirable aquarium species.

Status: Wisconsin has accorded the slenderhead darter watch status (Wis. Dep. Nat. Resour. Endangered Species Comm., 1975).

Percina shumardi (Girard). RIVER DARTER

Range: The river darter (Fig. 107) is known from the lower Wolf and Fox river systems of Wisconsin. This fish is probably a recent immigrant from the Wisconsin River via the canal at Portage (Columbia County). Its status is rare. Although reported from southern Lake Michigan (Hubbs and Lagler, 1958), no museum records were found.

Habits: This darter prefers the channels of medium to large rivers with a bottom of mud-silt or gravel (Hubbs and Lagler, 1958); it is occasionally found in wave-swept shallows of large lakes. At Basin latitude, spawning occurs in April or May, but little is known about spawning habits (Eddy and Underhill, 1974). Its food consists of caddisfly, mayfly, midge, and blackfly larvae. Adults are 46-71 mm (1-3/4 to 2-3/4 in.) long (Trautman, 1957).

Value: The significance of the river darter as a forage species in the Lake Michigan Basin is probably minimal.

Stizostedion canadense (Smith). SAUGER

Range: The sauger (Fig. 108) occurs in the shallows of Lake Michigan. Inland, it is known from the lower Wolf and Fox river drainages of Wisconsin, the Menominee River system at the Wisconsin-Michigan boundary, and the Muskegon River drainage of Michigan. This fish is uncommon to abundant locally.

Habits: The sauger prefers large rivers and turbid lakes. In Lake Winnebago, Wisconsin, spawning occurs over a sand and gravel substrate at 6.1-11.1°C (43-52°F) in late April to early May (Priegel, 1969). There is no nest construction nor parental care for the eggs or young. Hatching occurs in 12-18 days at 10°C (50°F) (Harlan and Speaker, 1956). In Lake Winnebago, Wisconsin, male saugers attain maturity at age II while females attain maturity at age IV. The respective lengths at which more than 50% of male and female saugers attain maturity were 249 and 284 mm (9.8 and 11.2 in.) (Priegel, 1969). A sauger weighing almost 2-kg (4-lb 5-oz) was caught from the Mississippi River in Wisconsin in 1971. Adults feed on a variety of small fishes, leeches, crayfishes, and insects (Scott and Crossman, 1973). In Canada, saugers have been caught during the summer from waters at temperatures of 18.6-19.2°C (65.5-66.6°F) (Scott and Crossman, 1973). In Indiana, the optimum temperature range was found to be 27°-29°C (80.6-84.2°F) (Gammon, 1973).

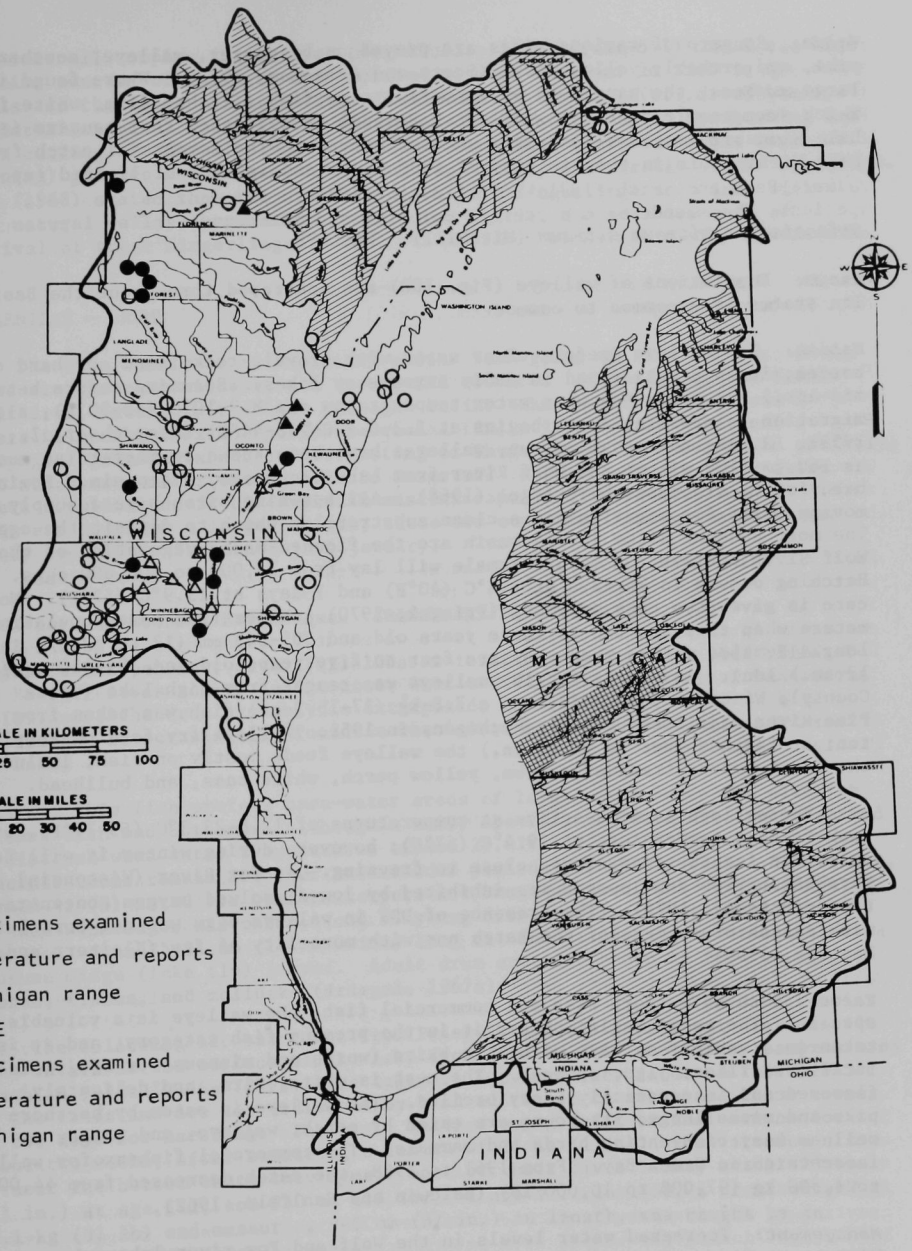

Fig. 108. Distribution of the Sauger (*Stizostedion canadense*) and Walleye (*Stizostedion vitreum vitreum*).

Value: Saugers of various sizes are preyed on by sauger, walleye, northern pike, and probably yellow perch (Scott and Crossman, 1973). Where found in large numbers, the sauger is an important game fish. It has firm, white flesh which some people prefer to walleye. Priegel (1969) noted that saugers in Lake Winnebago could withstand a greater harvest. The commercial catch from Lake Michigan is in the vicinity of 1000 lb/yr and is thus of limited importance.

Stizostedion vitreum vitreum (Mitchill). WALLEYE

Range: Populations of walleye (Fig. 108) are scattered throughout the Basin. Its status is uncommon to common.

Habits: The walleye prefers clear water with gravel, rock, sand, or hard clay bottom; it is rarely found in muddy streams or lakes. Spawning occurs between mid-April and early May when water temperatures are 8.9-10°C (48-50°F), although migration to spawning areas begins at 3.3-6.7°C (38-44°F) (Niemuth *et al.*, 1959). During the spawning run, walleyes have been known to migrate as much as 160 km (100 mi) up the Wolf River from Lake Winnebago, Wisconsin. Homing behavior is discussed by Priegel (1968). All spawning sites have a supply of moving water for aeration and a clean substrate on which to deposit the eggs. The most unusual sites in Wisconsin are the flooded marsh vegetation of the Wolf River bottoms. A mature female will lay from 35,000 to 600,000 eggs. Hatching occurs in 26 days at 4.4°C (40°F) and 7 days at 13.9°C (57°F). No care is given the eggs or young (Priegel, 1970). Males from most populations mature when they are two to three years old and 305-343 mm (12 to 13-1/2 in.) long. Females mature when they are four to five years old and 381-432 mm (15-17 in.) long. An 8.2 kg (18-lb) walleye was caught from High Lake (Vilas County), Wisconsin, in 1933, and a 7.8-kg (17-lb 3-oz) fish was taken from Pine River (Manistee County), Michigan, in 1951. Walleye fry feed on zooplankton; at lengths over 76 mm (3 in.) the walleye feeds mostly on fish, including the trout-perch, freshwater drum, yellow perch, white bass, and bullhead.

The walleye is most active at temperatures of 12.8-23.3°C (55-74°F), with peak feeding temperature at 19.4°C (67°F); however, during winter it will feed under the ice at temperatures close to freezing. In Fox River (Wisconsin) marshes, embryo development was inhibited by low dissolved oxygen concentrations (Priegel, 1970). The presence of DDT in walleye eggs was not correlated with a lack of success of the hatch nor with mortality of fry (Kleinert and Degurse, 1968).

Value: Both as a sport fish and commercial fish, the walleye is a valuable species. The sport angler places it in the premium-fish category, and it is taken in a variety of ways with live baits (worms and minnows) or artificial lures (wet flies, jigs, spoons). The meat is white, firm, and delicately flavored and is especially tasty broiled. The walleye is eaten by northern pike and muskellunge; its young are eaten by perch, walleye, and sauger as well as many fish-eating birds and mammals. The commercial fishery for walleye is centered in Green Bay. From 1961 to 1968, the catch decreased from 44,000 to 4,500 kg (97,000 to 10,000 lb) (Baldwin and Saalfeld, 1962).

Management: Increased water levels in the Wolf and Fox river lakes above Lake Winnebago, Wisconsin, resulted in a decline of emergent and submergent aquatic vegetation; a walleye-white bass fishery developed, replacing a "*bass, perch*

and pickerel" complex (Niemuth *et al.*, 1959). Also, Priegel (1970) noted that spawning success of walleyes was improved by the retention of high water levels and that severe fluctuation of water level curtailed egg development and larval survival locally. He recommended the use of controlled burning and brush cutting to curtail plant succession on marshes where desirable (for spawning) grasses and sedges were being replaced by undesirable woody vegetation. Mraz (1968) stated that the stocking of walleye fingerlings in a lake with a good natural walleye population contributed little, due to a low rate of survival of these fingerlings.

SCIAENIDAE - DRUMS

The drum family is an important marine fish group of many species; among these are the channel bass, sea trout, and croaker. One species, the freshwater drum, occurs in the Lake Michigan Basin. Characteristics include a lateral line which extends onto the caudal fin, a large scaly head, and a pharyngeal grinding apparatus consisting of large ventral plates (fused medially) into which many molariform teeth are inserted. Most species in this family have a complicated air bladder with muscles capable of producing sounds. The inner ear contains a large otolith; these are sometimes removed and kept as "lucky stones" or fashioned into jewelry.

Aplodinotus grunniens Rafinesque. FRESHWATER DRUM

Range: The freshwater drum (Fig. 109) is found in the southern two-thirds of the Basin: it is common in the lower Wolf and Fox river systems of Wisconsin; in Illinois, the drum probably is extirpated; in Indiana and lower Michigan, the species is occasionally found in the lowermost portions of tributaries to the Lake.

Habits: This fish prefers open-water areas of large, warm lakes and sluggish streams with mud bottoms. Although a hardy species, the drum has been observed in distress when water temperatures exceed 25.6°F (78°F) and dissolved oxygen concentrations remain low over an extended period (Priegel, 1967a). In Indiana, Gammon (1973) noted its optimum temperature range as 29-31°C (84.2-87.8°F). In Lake Winnebago, Wisconsin, food of young drum consists of crustacean zooplankton; drum 25-51 mm (1- to 2-in.) long eat insect larvae, and the adults consume midge (lake fly) larvae. Adult drum are also known to feed on crayfishes, fishes, and mollusks (Priegel, 1967a).

The following account comes from Priegel (1967a). Spawning occurs in open waters at the surface of the lake from June to July when water temperatures reach 18.9-22.2°C (66-72°F). The eggs are buoyant; they float on the surface of the water and are carried about by wind and water currents and require one to two days for hatching. The newly hatched young drift at the surface for about two weeks; after attaining a length of 25 mm (1 in.), they are found on or near the bottom where they remain most of their lives. They reach 279 mm (11 in.) at age III, and 330 mm (13 in.) at age VI. In 1958, a drum, weighing 14.1 kg (31 lb) and measuring 940 mm (37 in.) in length, was caught by an angler on Lake Winnebago.

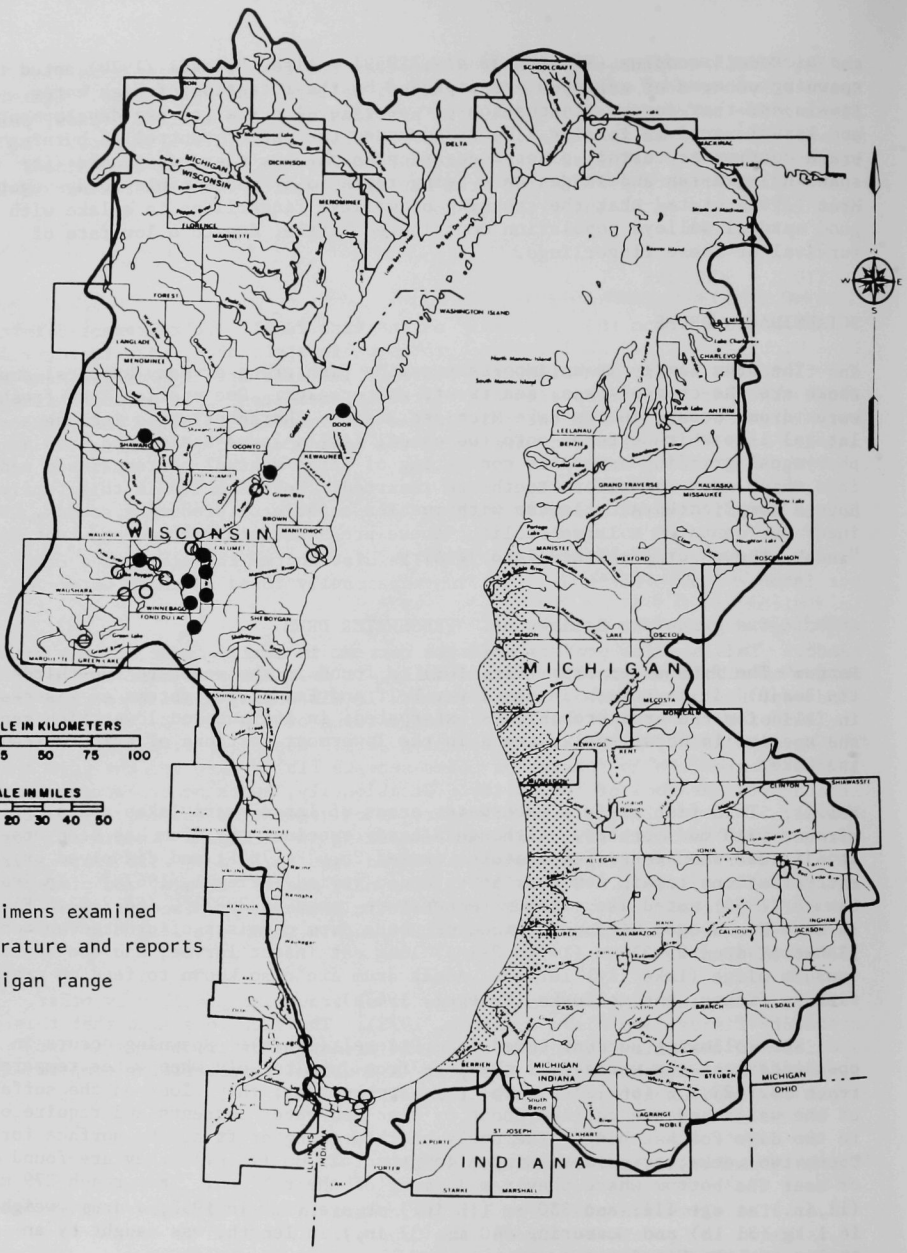

Fig. 109. Distribution of the Freshwater Drum (*Aplodinotus grunniens*).

Value: In Lake Winnebago, the drum competes for food with most game fish. However, young drum are forage for sauger, walleye, and white bass. Commercial fishing for this species in Wisconsin provides over two million pounds, part of which is sold as food fish, and part of which goes into mink food. In recent years, its value as high-protein food for man has been recognized (Gebken and Wright, 1972). The drum has firm, white, flaky meat about 16-18% protein, and is excellent fried or smoked.

COTTIDAE - SCULPINS

Two genera from this basically marine fish family are represented in the Lake Michigan Basin. Sculpins are grotesque in appearance, with large, wide and flattened heads, and elongated bodies. The eyes are high on the head and close together. Basin species are virtually scaleless. The pectoral fins are very large and prominent; the pelvic fins are immediately below the pectoral and are small. The sculpins are among the most advanced of fishes.

Cottus bairdi Girard. MOTTLED SCULPIN

Range: The mottled sculpin (Fig. 110) is distributed throughout the Basin, but is more common northward. It is occasionally found in shoal waters of Lake Michigan.

Habits: This species prefers moderate current in small, clear streams with a bottom of rubble or gravel. Occasionally, it is taken over hard bottom of windswept shores of large, inland lakes. In Wisconsin, spawning occurs from the end of March to April at water temperatures of 9.4-13.9°C (49-57°F) (Ludwig and Norden, 1969); in Michigan, spawning occurs during April and May (Smith, 1922). Nests usually consist of holes beneath flat rocks, and the eggs are attached to the roof of the cavity. Occasionally, nests occur between large gravel, 51-76 mm (2-3 in.) in diameter, or on vegetation (*Elodea*) (Ludwig and Norden, 1969). Smith (1922) discussed nesting in Michigan. Ludwig and Norden (1969) observed hatching of aquarium-reared eggs in 17 days with temperatures maintained at 11.1-12.8°C (52-55°F). The male guards the nest and protects the newly hatched young. Adults eat aquatic insects, crustaceans, and--rarely--the eggs of fishes. The mottled sculpin reaches a length of 127-152 mm (5-6 in.).

Value: This sculpin is eaten by large brook trout and possibly by other predatory fishes (Scott and Crossman, 1973). The view long held that this species and the slimy sculpin are serious predators of trout eggs is not supported by available data. Also, it is doubtful that sculpins compete with trout for food except under unusual conditions.

Cottus cognatus Richardson. SLIMY SCULPIN

Range: The slimy sculpin (Fig. 111) is common in Lake Michigan. In Wisconsin, it is known in Green Lake (Green Lake County). This fish is common in streams of the upper half of lower Michigan.

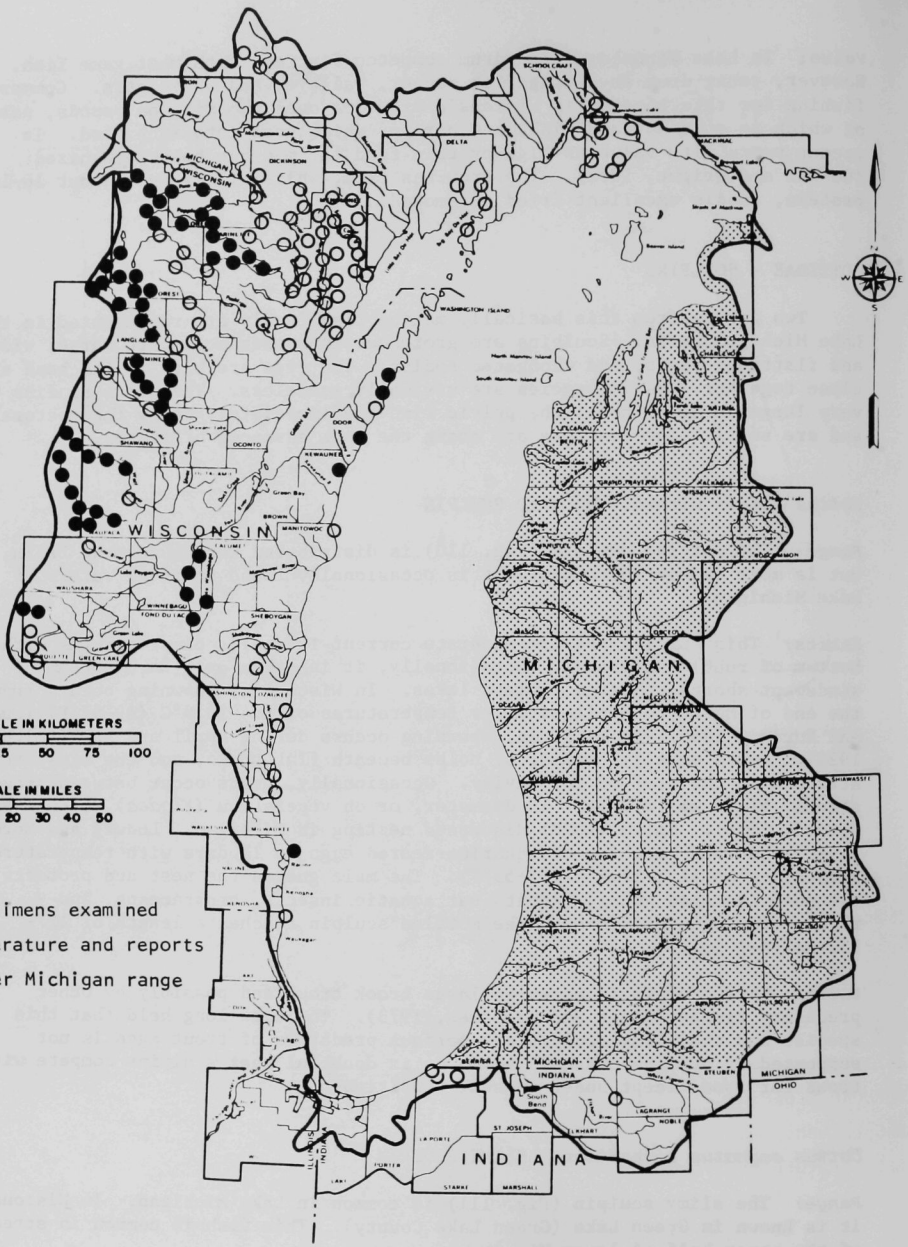

Fig. 110. Distribution of the Mottled Sculpin (*Cottus bairdi*).

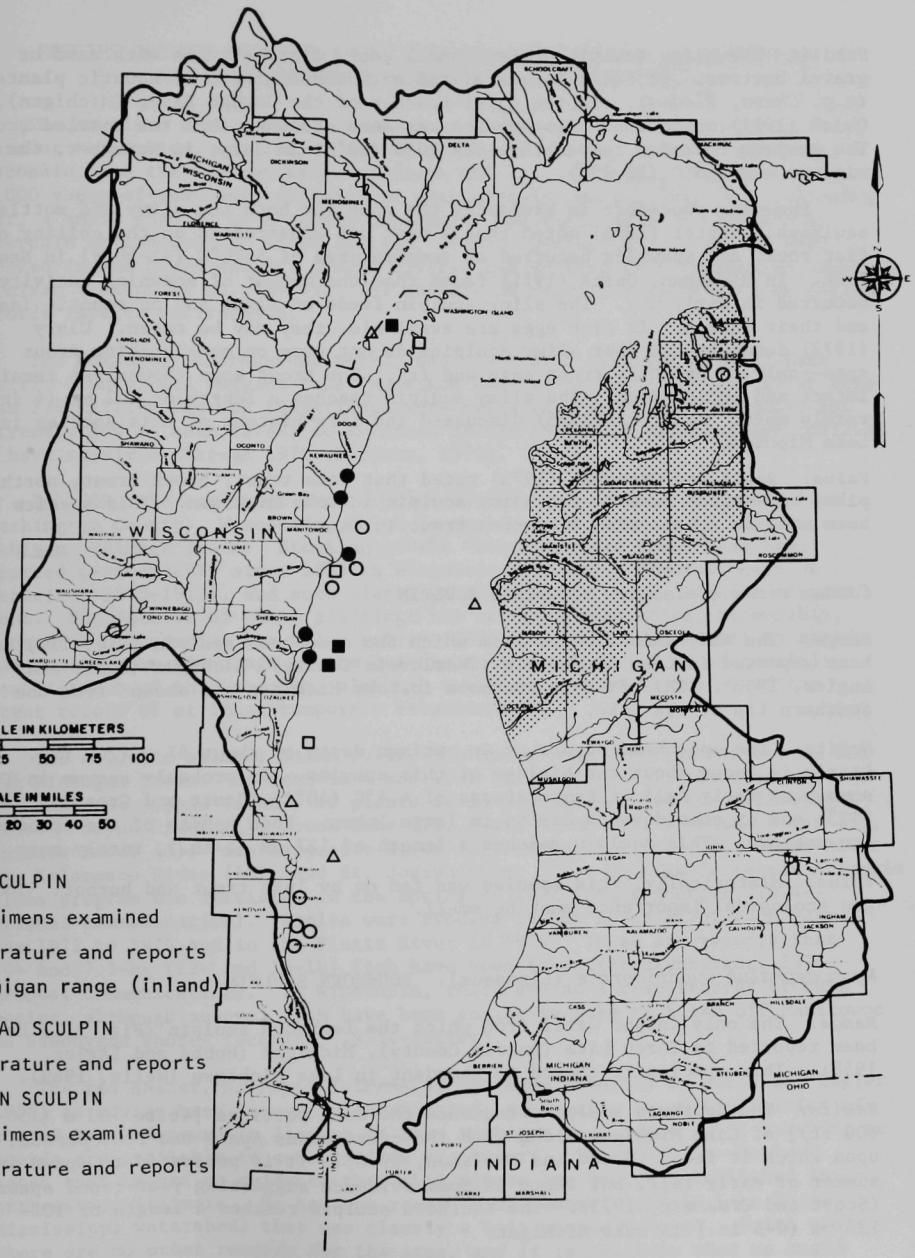

Fig. 111. Distribution of the Slimy Sculpin (*Cottus cognatus*), Spoonhead Sculpin (*Cottus ricei*), and Fourhorn Sculpin (*Myoxocephalus quadricornis*).

Habits: The slimy sculpin prefers small cool, clear streams with sand or gravel bottoms. It often is associated with dense growth of aquatic plants (*e.g. Chara, Elodea*). In the upper reaches of the Jordan River (Michigan), Quick (1971) noted that this species was more abundant than the mottled sculpin. The maximum recorded temperature was 20°C (68°F) in July; in November, the minimum was 3.5°C (38.3°F).

Spawning procedure is basically the same for both the slimy and mottled sculpins. Koster (1936) noted that a nest was constructed on the ceiling of a flat rock, and spawning occurred at temperatures of 5-10°C (41-50°F) in New York. In Michigan, Quick (1971) found that the height of spawning activity occurred in early May. The slimy sculpin feeds on algae and on aquatic insects and their larvae. If fish eggs are available, they may be eaten. Clary (1972) demonstrated that slimy sculpins do not prey on non-hatching trout eggs--only on hatching trout eggs and fry. The trout eggs themselves remain intact and undisturbed. The slimy sculpin reaches a length of 102 mm (4 in.), rarely more. Rottiers (1965) discussed the life history of this species in Lake Michigan.

Value: Scott and Crossman (1973) noted that lake trout, brook trout, northern pike, and burbot feed on the slimy sculpin in Lake Michigan. This species has been used as a bait fish for brook trout in Canada.

Cottus ricei (Nelson). SPOONHEAD SCULPIN

Range: The only inland water from which the spoonhead sculpin (Fig. 111) has been reported is Lake Charlevoix (Charlevoix County), Michigan (Hubbs and Lagler, 1958). This fish is uncommon in Lake Michigan and absent from the southern tip of the Lake.

Habits: The spoonhead occurs at an optimum depth of about 61 m (200 ft). Little is known about the biology of this species. It probably spawns in late summer or early fall at temperatures of 4.4°C (40°F) (Scott and Crossman, 1973) and at considerable depths in large lakes. Food habits of the spoonhead are unknown. This sculpin reaches a length of 127 mm (5 in.), rarely more.

Value: Historically, this species was fed on by lake trout and burbot. Today, its ecological importance must be small.

Myoxocephalus quadricornis (Linnaeus). FOURHORN SCULPIN

Range: The only inland water from which the fourhorn sculpin (Fig. 111) has been reported is Torch Lake (Antrim County), Michigan (Hubbs and Lagler, 1958). This species is common to abundant in Lake Michigan (Wells, 1969).

Habits: The fourhorn sculpin frequents the deep portions [46 to 183 m (150-600 ft)] of Lake Michigan along with the crustaceans *Mysis* and *Pontoporeia*, upon which it feeds (Scott and Crossman, 1973). It is purported to spawn in summer or early fall, but there is some evidence suggesting year-round spawning (Scott and Crossman, 1973). The fourhorn sculpin reaches a length of 102-127 mm (4-5 in.) in Lake Michigan.

Value: Deep-water predators such as the lake trout and burbot have been known to feed on this species.

SPECIES RECORDS FROM THE BASIN THAT ARE IN ERROR AND SPECIES WHICH FAILED TO ESTABLISH POPULATIONS AFTER STOCKING

The American shad, *Alosa sapidissima*, native of the Atlantic Coast from Labrador to Florida, was introduced in 1873 into the Fox River at Appleton, Wisconsin, and the Calumet River at South Chicago, Illinois. Approximately 70,000 young-of-year were released at each site (Milner, 1874). The following year, a small shad *"3 or 4 inches in length"* was captured in a hoop-net at Riverdale on the Calumet River (Nelson, 1878). During 1873, shad fry were stocked in the Grand and St. Joseph rivers, and in Long Lake (Kalamazoo County), Michigan (Fukano *et al.*, 1964). The absence of reports following these early records implies extirpation.

The kokanee, *Oncorhynchus nerka*, was planted in Michigan's Torch Lake (Antrim County) and Higgins Lake (Muskegon County) in 1965-1967 and 1970; more than 3.9 million fry and fingerlings were released. Survival apparently was extremely low in both lakes; no kokanees of the 1965-1967 planting are believed to have survived through 1970 (Parsons, 1973).

In 1959, the cutthroat trout, *Salmo clarki*, was stocked in Friess Lake (Washington County), Wisconsin, which is immediately adjacent to the Lake Michigan Drainage Basin. Stocking of the "black-spotted trout" has been reported periodically since 1895 in Wisconsin (Wisconsin Commissioners of Fisheries, 1875-1912), and such plantings may well be those of the cutthroat trout. The success of these plantings has not been publicized; presumably, successful propagation was nil. Bailey (1975--personal communication) noted that none of the plantings of the cutthroat in Michigan led to successful establishment of that species, although Hubbs and Lagler (1958) noted one recent record of at least temporary establishment.

The Atlantic salmon, *Salmo salar*, has had a long stocking history in the Lake Michigan Basin. Between 1874 and 1932 (Parsons, 1973), the State of Michigan made plants (number of plants is in parentheses) in the following waters: Boyne River (1), Torch Lake (7), Rapid River (5), Boardman River (3), Manistee River (6), Pere Marquette River (2), Muskegon River (12), Grand River (2), Kalamazoo River (10), and St. Joseph River (7). Michigan's recent Atlantic salmon program was initiated in the spring of 1972 (Frankenberger, 1974--personal communication). Smolts were stocked in the Boyne River each year from 1972 to 1974 and in the Platte River in 1974. There are reports that 5.4- and 7.3-kg (12- and 16-lb) fish have been taken (Frankenberger, 1974--personal communication). In Wisconsin, there are no stream records of this species, although several fish have been caught in Lake Michigan off Manitowoc and Sheboygan shores (Schultz, 1975--letter).

The red shiner, *Notropis lutrensis*, has been reported by Hubbs and Lagler (1958) as having been *"recently established, presumably by multiplication of escaped bait minnows, in lagoons of Lake Michigan in Chicago ..."*; however, no records are available to substantiate the report. Smith (1975a--letter) stated that he had no evidence that this minnow has become established in northeastern Illinois. He had one record from Channel Lake in Lake County (Mississippi watershed) that was clearly a bait minnow release. Smith wrote: *"There are no other records for the area, and it is unlikely that we could have overlooked this species."*

The mosquitofish, *Gambusia affinis*, has been introduced into the southern part of the Lake Michigan Basin from Illinois to Michigan. Smith (1975a--letter) related that this fish was stocked in the Cook County Forest Preserves by Louis Krumholz in the late 1930's, but it soon disappeared. Smith stated that there are *"no records for northeastern Illinois, but the species does have a habit of appearing suddenly in unexpected places."* The mosquitofish was introduced into Michigan during the early 1940's (Hubbs and Lagler, 1958).

A number of tropical fishes, from aquaria, are introduced every year into warmwater ponds. Occasionally these will produce a brood or two during the summer they are released. None of these fish are known to survive temperate latitude winters.

I have a recent report of two specimens of the grass carp, *Ctenopharyngodon idella*, taken from a pond treated with fish poison in eastern Wisconsin. Such introductions exemplify man's desire to introduce new fishes into Basin waters in the hope of "improving" fishing.

ACKNOWLEDGEMENTS

Special contributions came from Reeve M. Bailey, University of Michigan; Wayne Tody, Jerry Peterson, David Johnson, B. G. Jacob, L. Frankenburger, Leland R. Anderson, and E. J. Trimberger, all of the Michigan Department of Natural Resources; Carroll Norden, University of Wisconsin--Milwaukee; Marlin Johnson, University of Wisconsin--Waukesha; C. W. Threinen, James Addis, Ronald Piening, Donald W. Tills, James Baumgart, Russell Daly, Lee Kernen, E. R. Schumacher, and Paul T. Schultz, all of the Wisconsin Department of Natural Resources; Philip W. Smith and Brooks M. Burr, Illinois Natural History Survey; James R. Gammon, DePauw University; David G. Frey, Indiana University; Edward R. Braun, Gene Bass, and Robert Koch, Indiana Department of Natural Resources; Robert A. Braem, U. S. Fish and Wildlife Service; Ted Cavender, Ohio State University; Charles A. Long, Fred Copes, Paul Peeters, Robert F. Quick, Gary Lutterbie, Linda Nestler, Fran Komarmy and Sharon Newlun, all of the University of Wisconsin--Stevens Point.

Special thanks go to Don L. McGregor, Argonne National Laboratory, who sparked the development of this report.

This paper is dedicated to my wife Sylvia who kept the external machinery going during production.

GLOSSARY OF ABBREVIATIONS AND TERMINOLOGY

Abbreviations for Museums

MCZ - Museum of Comparative Zoology, Harvard University, Cambridge, Mass.

UMMZ - University of Michigan, Museum of Zoology, Ann Arbor

UWSP - Museum of Natural History, University of Wisconsin--Stevens Point

Scale of Abundance (Johnson and Becker, 1970)

Rare - species taken at highly infrequent intervals with one or two specimens per collection

Uncommon - species taken infrequently and in very small numbers

Common - species taken frequently and in moderate numbers

Abundant - species taken frequently and in large numbers

Age Classes

Age 0 - young-of-year, first year of life

Age I - one-year-old, second year of life

Age II - two-year-old, third year of life ... etc.

CREDITS

The author and the Argonne National Laboratory gratefully acknowledge the courtesy of the individuals and organizations who granted permission to use illustrations or, where appropriate, other material in the ANL/ES-40 series. Sources of illustrations used in Volume 17 are listed below.

Figure

Hough, J. L. 1958. *Geology of the Great Lakes*. University of Illinois Press. Copyright 1958 by the Board of Trustees of the University of Illinois. Figures 2 and 3 reproduced with permission of the University of Illinois Press, Urbana.

2 p. 286 (*Fig. 57*)

3 p. 294 (*Fig. 70*)

REFERENCES CITED

Unpublished references and personal communications are indicated by an asterisk (*).

Adams, C. C., and T. L. Hankinson. 1926. *Annotated list of Oneida lake fish.* Roosevelt Wildl. Ann. 50(1-2):283-542.

Ahsan, S. N. 1966. *Effects of temperature and light on the cyclical changes in the spermatogenetic activity of the lake chub Couesius plumbeus (Agassiz).* Can. J. Zool. 44(1966):161-171.

*Anderson, L. R. 1975. Letter, 29 January (Michigan Department of Natural Resources, Newberry).

Avery, E. L. 1974. *Reproduction and recruitment of anadromous salmonids in Wisconsin tributaries of Lake Michigan.* Wisconsin Department of Natural Resources, Madison. 32 pp.

Bailey, M. M. 1969. *Age, growth and maturity of the longnose sucker Catostomus catostomus of Western Lake Superior.* J. Fish. Res. Board Can. 26:1289-1299.

Bailey, R. M. 1959. *Distribution of the American cyprinid fish Notropis anogenus.* Copeia 1959(2):119-123.

*_____. 1975. Personal communication, 16 January (Museum of Zoology, University of Michigan, Ann Arbor).

_____, J. E. Fitch, E. S. Herald, E. A. Lachner, C. C. Lindsey, C. R. Robins, and W. B. Scott. 1970. *A list of common and scientific names of fishes from the United States and Canada.* American Fisheries Society, Washington, D. C. 149 pp.

Baldwin, N. S. 1968. *Sea lamprey in the Great Lakes.* Limnos 1(3):20-27.

_____, and R. W. Saalfeld. 1962. *Commercial fish production in the Great Lakes 1867-1960 (supplement from 1961-1968).* Great Lakes Fish. Comm. Tech. Rep. No. 3. 166 pp. and Suppl.

Becker, G. C. 1961. *Fading fins.* Trans. Wis. Acad. Sci. Arts Lett. 50:239-248.

_____. 1962. *Intra-specific variation in Rhinichthys c. cataractae (Valenciennes) and Rhinichthys atratulus meleagris (Agassiz) and anatomical and ecological studies of Rhinichthys c. cataractae.* Ph.D. Thesis. Univ. Wisconsin--Madison. 279 pp.

_____. 1964. *The fishes of lakes Poygan and Winnebago.* Trans. Wis. Acad. Sci. Arts Lett. 53:39-52.

_____. 1965. *The western sand darter, Ammocrypta clara, in the Great Lakes basin.* Copeia 1965(2):241.

_____. 1971. *The pugnose shiner - a dodo?* Passenger Pigeon 33:199-201. [Corrections in 34(2):84].

*_____. 1974. *Northern suckers.* University of Wisconsin--Stevens Point, Dep. Biol. (manuscript in preparation).

Beckman, W. C. 1949. *The rate of growth and sex ratio for seven Michigan fishes.* Trans. Am. Fish. Soc. 57(1946):63-81.

Bennett, G. W. 1962. *Management of artificial lakes and ponds.* Reinhold Publishing Co., New York. 283 pp.

_____, and W. F. Childers. 1966. *The lake chubsucker as a forage species.* Prog. Fish-Cult. 28(2):89-92.

Black, J. D. 1945. *Natural history of the northern mimic shiner, Notropis volucellus volucellus Cope.* Invest. Indiana Lakes Streams 2(16):449-469.

Bodola, A. 1966. *Life history of the gizzard shad, Dorosoma cepedianum (Le Sueur), in western Lake Erie.* U. S. Fish. Wildl. Serv. Fish. Bull. 65(2):391-425.

Borell, A. E., and P. M. Scheffer. 1961. *Trout in farm and ranch ponds.* U. S. D. A. Farmer's Bull. No. 2154. 17 pp.

Borgeson, D. P., and W. H. Tody. 1967. *Status report on Great Lakes fisheries.* Mich. Dep. Conserv. Fish Manage. Rep. No. 2. 35 pp.

Bowman, M. L. 1970. *Life history of the black redhorse, Moxostoma duquesnei (Lesueur), in Missouri.* Trans. Am. Fish. Soc. 99(3):546-559.

Branson, B. A. 1966. *The gar, a plea for a heritage of past.* Kentucky Happy Hunting Ground 22:16-19.

Brasch, J., J. McFadden, and S. Kmiotek. 1973. *Brook trout - life history, ecology, and management.* Wis. Dep. Nat. Resour. Publ. 226. 15 pp.

Braun, E. R. 1973a. *Report on fall salmonid runs in Trail Creek, LaPorte County, Indiana.* Indiana Department of Natural Resources, Div. Fish Wildl. 12 pp. (mimeo).

_____. 1973b. *Trail Creek stream survey report, LaPorte County, Indiana.* Indiana Department of Natural Resources, Div. Fish Wildl. 81 pp., 5 maps (mimeo).

_____. 1974. *Stream survey report, Little Calumet River - east arm, Porter and LaPorte counties, Indiana.* Indiana Department of Natural Resources, Div. Fish Wildl. 47 pp., 5 maps (mimeo).

Breder, C. M., Jr. 1936. *The reproductive habits of the North American sunfishes (family Centrarchidae).* Zoologica 21(1):1-48.

_____, and D. E. Rosen. 1966. *Modes of reproduction in fishes*. Natural History Press, New York. 941 pp.

Brown, C. J. D. 1971. *Fishes of Montana*. Agricultural Experiment Station, Montana State University, Bozeman. 207 pp.

Brynildson, O. M., V. A. Hacker, and T. A. Klick. 1963. *Brown trout - life history, ecology and management*. Wis. Dep. Nat. Resour. Publ. 234. 16 pp.

Burdick, G. E., M. Lipschuetz, H. F. Dean, and E. F. Harris. 1954. *Lethal oxygen concentrations for trout and smallmouth bass*. N. Y. Fish Game J. 1(1):84-97.

Cahn, A. R. 1927. *An ecological study of southern Wisconsin fishes. The brook silverside (Labidesthes sicculus)* and the cisco (*Leucichthys artedi*) *in their relations to the region*. Ill. Biol. Monogr. 11(1). 151 pp.

Carbine, W. F. 1942. *Observations on the life history of the northern pike, Esox lucius L., in Houghton Lake, Michigan*. Trans. Am. Fish. Soc. 71(1941):149-164.

Carlander, K. D. 1950. *Handbook of freshwater fishery biology*. Wm. C. Brown Co., Dubuque, Iowa. 281 pp.

_____. 1969. *Handbook of freshwater fishery biology*. Iowa State University Press, Ames. 752 pp.

Carranza, J., and H. E. Winn. 1954. *Reproductive behavior of the blackstripe topminnow, Fundulus notatus*. Copeia 1954(4):273-278.

Clark, J. R. 1969. *Thermal pollution and aquatic life*. Sci. Am. 220(3):19-27.

Clary, J. R. 1972. *Predation on the brown trout by the slimy sculpin*. Prog. Fish-Cult. 34(2):91-95.

Cook, F. A. 1959. *Freshwater fishes in Mississippi*. Mississippi Game and Fish Commission, Jackson. 239 pp.

Cooper, G. P. 1936. *Some results of forage fish invesigations in Michigan*. Trans. Am. Fish. Soc. 65(1935):132-142.

_____, and G. N. Washburn. 1949. *Relation of dissolved oxygen to winter mortality of fish in Michigan lakes*. Trans. Am. Fish. Soc. 76(1946):23-33.

Copes, F. 1975. *Ecology of the brassy minnow, Hybognathus hankinsoni Hubbs*. In: *Reports on the fauna and flora of Wisconsin*. Rep. No. 10, Museum of Natural History, University of Wisconsin--Stevens Point. pp. 46-72, part 3.

Cross, F. B. 1967. *Handbook of fishes of Kansas*. Univ. Kans. Mus. Nat. Hist. Misc. Publ. 45. 357 pp.

Daly, R. 1968a. *Preliminary notes on management of the rainbow trout in western Lake Michigan*. Wisconsin Department of Natural Resources, Fish Manage. Div., Oshkosh. 4 pp. (mimeo).

_____. 1968b. *Progress report of fish management on Lake Michigan 1968*. Wisconsin Department of Natural Resources, Fish Manage. Div., Oshkosh. 18 pp. (mimeo).

_____. 1971. *Chinook: the big one*. Wis. Conserv. Bull. 36(5):22-23.

_____, V. A. Hacker, and L. Wiegert. 1962. *The lake trout - its life history, ecology and management*. Wis. Conserv. Dep. Publ. No. 233. 15 pp.

Dobie, J. R., O. L. Meehean, and G. N. Washburn. 1948. *Propagation of minnows and other bait species*. U. S. Fish Wildl. Serv. Circ. 12. 113 pp.

_____, O. L. Meehean, S. F. Sniezko, and G. N. Washburn. 1956. *Raising bait fishes*. U. S. Fish Wildl. Serv. Circ. 35. 121 pp.

Downs, W. 1974. *Fish of Lake Michigan*. University of Wisconsin--Madison, Sea Grant Communications Office. 32 pp.

Duchrow, R. 1967. *A study of the life history of the eastern banded darter Etheostoma zonale zonale (Cope)*. University of Wisconsin--Stevens Point, Dep. Biol. 18 pp. (mimeo).

Dudley, S., J. T. Graikoski, H. L. Seagran, and P. M. Earl. 1970. *Sportsman's guide to handling, smoking, and preserving Great Lakes coho salmon*. U. S. Fish Wildl. Serv. Circ. 346. 28 pp.

Eddy, S., and T. Surber. 1947. *Northern fishes*. University of Minnesota Press, Minneapolis. 276 pp.

_____, and J. C. Underhill. 1974. *Northern fishes*. University of Minnesota Press, Minneapolis. 414 pp.

Edsall, T. A. 1964. *Feeding by three species of fishes on the eggs of spawning alewives*. Copeia 1964(1):226-227.

Eigenmann, C. H., and C. H. Beeson. 1894. *Fishes of Indiana*. Proc. Indiana Acad. Sci. (1895) 11:204-278.

Embody, G. C. 1934. *Relation of temperature to the incubation periods of eggs of four species of trout*. Trans. Am. Fish. Soc. 64:281-291.

Emig, J. 1966. *Red-ear sunfish* and *Smallmouth bass*. In: A. Calhoun (ed.), *Inland fisheries management*. California Department of Fish and Game, Sacramento. pp. 392-399 and pp. 354-366.

Eschmeyer, P. H. 1957. *The lake trout (Salvelinus namaycush)*. U. S. Fish Wildl. Serv. Fish. Leafl. 441. 11 pp.

Fagot, D. 1973. *The northern's finicky spawning needs*. Wis. Conserv. Bull. 38(2):18-19.

Fassbender, R. L., J. J. Weber, and L. M. Nelson. 1970. *Surface water resources of Green Lake County*. Lake and Stream Classification Project, Wisconsin Department of Natural Resources, Madison. 72 pp.

Flittner, G. A. 1964. *Morphometry and life history of the emerald shiner, Notropis atherinoides Rafinesque*. Ph.D. Thesis. Univ. Michigan, Ann Arbor. 239 pp. Diss. Abstr. 25(6):3759.

Forbes, S. A., and R. E. Richardson. 1920. *The fishes of Illinois*. Ill. Nat. Hist. Surv. Bull. 3. cxxxvi, 357 pp.; 102 maps.

*Frankenberger, L. 1974. Personal communication (Michigan Department of Natural Resources, Lansing).

*_____. 1976. Letter, 26 July (Michigan Department of Natural Resources, Lansing).

Fukano, K. G., H. Gowing, M. J. Hansen, and L. N. Allison. 1964. *Introduction of exotic fish into Michigan*. Institute for Fisheries Research, Mich. Dep. Conserv. Rep. No. 1689. 50 pp.

Gammon, J. R. 1973. *The effect of thermal inputs on the populations of fish and macroinvertebrates in the Wabash River*. Purdue Univ. Water Resour. Cent. Tech. Rep. No. 32. 106 pp.

Gebken, D. F., and K. J. Wright. 1972. *Try the drum*. Wis. Conserv. Bull. 37(2):23.

Gerking, S. D. 1945. *The distribution of the fishes of Indiana*. Invest. Indiana Lakes Streams 3(1). 137 pp.

_____. 1955. *Key to the fishes of Indiana*. Invest. Indiana Lakes Streams 4(2):49-86.

Gilbert, C. R. 1961. *Hybridization versus integration; an inquiry into the relationship of two cyprinid fishes*. Copeia 1961(2):181-192.

Gould, W. R., III, and W. H. Irwin. 1965. *The suitabilities and relative resistances of twelve species of fish as bio-assay animals for oil-refinery effluents*. Proc. S. E. Assoc. Game Fish Comm. 16:333-348.

Great Lakes Basin Commission. 1975. *Great Lakes Basin Framework Study. App. 8, Fish*. Ann Arbor, Mich. 290 pp.

Greeley, J. R. 1936. *Fishes of the area with annotated list*. In: *A biological survey of the Delaware and Susquehanna watersheds*. Suppl., 25th Annu. Rep. (1935), N. Y. State Conserv. Dep. pp. 45-88.

_____, and C. W. Greene. 1931. *Annotated list of fishes occurring in the St. Lawrence watershed*. In: *A biological survey of the St. Lawrence watershed*. Suppl., 20th Annu. Rep. (1930), N. Y. State Conserv. Dep. pp. 44-94.

Greene, C. W. 1935. *The distribution of Wisconsin fishes*. Wisconsin Conservation Commission, Madison. 235 pp.

Griswold, B. L., and L. L. Smith. 1972. *Early survival and growth of the ninespine stickleback.* Trans. Am. Fish. Soc. 101(2):350-352.

Hacker, V. A. 1957. *Biology and management of lake trout in Green Lake, Wisconsin.* Trans. Am. Fish. Soc. 86(1956):1-13.

Hackney, P. A., W. M. Tatum, and S. L. Spencer. 1968. *Life history study of the river redhorse, Moxostoma carinatum (Cope), in the Cahaba River, Alabama, with notes on the management of the species as a sport fish.* Proc. S. E. Assoc. Game Fish Comm. 19:324-332.

Hankinson, T. L. 1908. *A biological survey of Walnut Lake, Michigan.* State Biol. (Geol.) Surv. Mich. Rep. 1907:153-288.

_____. 1932. *Observations on the breeding behavior and habitats of fishes in southern Michigan.* Pap. Mich. Acad. Sci. Arts Lett. 15:411-425.

Hansen, D. F. 1965. *Further observations on nesting of the white crappie, Pomoxis annularis.* Trans. Am. Fish. Soc. 94(2):182-184.

Harlan, J. R., and E. B. Speaker. 1956. *Iowa fish and fishing.* Iowa State Conservation Commission, Des Moines. 377 pp.

Hawley, M. G. 1967. *A study of the northern redhorse (Moxostoma macrolepidotum) in the Plover River and Peshtigo River, Wisconsin.* University of Wisconsin--Stevens Point, Dep. Biol. 30 pp. (mimeo).

Helle, J. H. 1970. *Biological characteristics of intertidal and freshwater spawning pink salmon at Olsen Creek, Prince William Sound, Alaska, 1962-63.* U. S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. No. 602. 19 pp.

Helm, W. T. 1958. *A "new" fish in Wisconsin.* Wis. Conserv. Bull. 23(7):10-12.

Herman, E., W. Wisby, L. Wiegert, and M. Burdick. 1959. *The yellow perch - its life history, ecology and management.* Wis. Conserv. Dep. Publ. 228. 14 pp.

Hile, R. 1936. *Age and growth of the cisco Leucichthys artedi (Le Sueur) in the lakes of the northeastern highlands, Wisconsin.* U. S. Bur. Fish. Bull. 48(19):211-317.

_____. 1942. *Growth of rock bass, Ambloplites rupestris (Rafinesque), in five lakes of northeastern Wisconsin.* Trans. Am. Fish. Soc. 71:131-143.

Hinks, D. 1957. *The fishes of Manitoba (reprinted with supplement by J. J. Keleher and B. Kooyman).* Manitoba Department of Mines and Natural Resources. 117 pp.

Hough, J. L. 1958. *Geology of the Great Lakes.* University of Illinois Press, Urbana. 313 pp.

Hubbs, C. 1961. *Developmental temperature tolerances of four Etheostomatinae fishes occurring in Texas.* Copeia 1961(2):195-198.

Hubbs, C. L. 1930a. *Further additions and corrections to the list of fishes of the Great Lakes and tributary waters.* Pap. Mich. Acad. Sci. Arts Lett. 11(1929):425-436.

_____. 1930b. *Materials for a revision of the catostomid fishes of eastern North America.* Univ. Mich. Mus. Zool. Misc. Publ. No. 20. 47 pp.

_____. 1963. *Cyclostome.* In: Encyclopedia Britannica.

_____, and G. P. Cooper. 1935. *Age and growth of the long-eared and the green sunfishes in Michigan.* Pap. Mich. Acad. Sci. Arts Lett. 20(1934): 669-696.

_____, and G. P. Cooper. 1936. *Minnows of Michigan.* Cranbrook Inst. Sci. Bull. No. 8. 95 pp.

_____, and C. W. Greene. 1935. *Two new subspecies of fishes from Wisconsin.* Trans. Wis. Acad. Sci. Arts Lett. 29:89-101.

_____, and K. F. Lagler. 1958. *Fishes of the Great Lakes region.* Cranbrook Inst. Sci. Bull. No. 26. 213 pp.

Hunter, J. R. 1963. *The reproductive behavior of the green sunfish, Lepomis cyanellus.* Zoologica 48(1):13-24.

Jenkins, R. E. 1970. *Systematic studies of the catostomid fish tribe Moxostomatini.* Ph.D. Thesis. Cornell Univ., Ithaca, N. Y. 799 pp.

Jobes, F. W. 1949. *The age, growth, and bathymetric distribution of the bloater Leucichthys hoyi (Gill) in Lake Michigan.* Pap. Mich. Acad. Sci. Arts Lett. 33(1947):135-172.

John, K. 1956. *Onset in spawning activities of the shallow water cisco, Leucichthys artedi (Le Sueur), in Lake Mendota, Wisconsin, relative to water temperatures.* Copeia 1956(2):116-118.

Johnson, M., and G. Becker. 1970. *Annotated list of the fishes of Wisconsin.* Trans. Wis. Acad. Sci. Arts Lett. 58:265-300.

Jordan, D. S. 1888. *Science sketches.* A. C. McClurg and Co., Chicago, Ill. 276 pp. (As cited by Eddy and Underhill, 1974).

Kernen, L. T. 1974a. *Fishery investigations on the lower Fox River and south Green Bay in 1973-1974.* Wisconsin Department of Natural Resources, Madison. 6 pp. (mimeo).

*_____. 1974b. Letter, 16 December (Wisconsin Department of Natural Resources, Green Bay).

Kleinert, S. J., and P. E. Degurse. 1968. *Survival of walleye eggs and fry of known DDT residue levels from ten Wisconsin waters in 1967.* Wis. Dep. Nat. Resour. Res. Rep. 37. 30 pp.

_____, and D. Mraz. 1966. *Life history of the grass pickerel (Esox americanus vermiculatus) in southeastern Wisconsin.* Wis. Conserv. Dep. Tech. Bull. No. 37. 41 pp.

Koch, R. A. 1972. *Interspecies relationships of fish in the Indiana waters of Lake Michigan.* Final Report, Project 4-43-R, Indiana Department of Natural Resources, Div. Fish Wildl. 44 pp. (mimeo).

_____. 1974. *A creel census of the Indiana waters of Lake Michigan, 1973.* Indiana Department of Natural Resources, Div. Fish Wildl. 14 pp. (mimeo).

Koelz, W. 1929. *Coregonid fishes of the Great Lakes.* Bull. U. S. Bur. Fish 43(1927) Pt.2:297-643.

_____. 1931. *The coregonid fishes of northeastern America.* Pap. Mich. Acad. Sci. Arts Lett. 13(1930):303-432.

Koster, W. J. 1936. *The life history and ecology of the sculpins (Cottidae) of Central New York.* Ph.D. Thesis. Cornell Univ., Ithaca, N. Y. (As cited by Scott and Crossman, 1973).

Krumholz, L. A. 1950. *New fish stocking policies for Indiana ponds.* Trans. N. Am. Wildl. Conf. 15:251-270.

Langlois, T. H. 1941. *Bait culturists guide.* Ohio Div. Conserv. Nat. Resour. Bull. No. 137. 18 pp.

Larimore, R. W. 1957. *Ecological life history of the warmouth (Centrarchidae).* Ill. Nat. Hist. Surv. Bull. 27(1). 84 pp.

Leach, G. C. 1928. *Artificial propagation of pike perch, yellow perch, and pikes.* U. S. Comm. Fish. Rep. (1927):1-27.

Lennon, R. E., and P. S. Parker. 1960. *The stoneroller, Campostoma anomalum (Rafinesque), in Great Smoky Mountains National Park.* Trans. Am. Fish. Soc. 89(3):263-270.

_____, J. B. Hunn, R. A. Schnick, and R. M. Burress. 1971. *Reclamation of ponds, lakes and streams with fish toxicants: a review.* U. S. Fish Wildl. Serv. FAO Fish. Tech. Pap. 100. 99 pp.

Long, C. A. 1974. *Mammals of the Lake Michigan Drainage Basin.* Environmental Status of the Lake Michigan Region, Vol 15. Argonne National Laboratory ANL/ES-40. 108 pp.

Lopinot, A. C. 1970. *1969 creel survey of the Illinois portion of Lake Michigan.* Ill. Dep. Conserv. Spec. Fish. Rep. No. 32. 46 pp.

Ludwig, G. M., and C. R. Norden. 1969. *Age, growth and reproduction of the northern mottled sculpin (Cottus bairdi bairdi) in Mt. Vernon Creek.* Milwaukee Public Mus. Occas. Pap. Nat. Hist. No. 2. 67 pp.

Magnuson, J. J., and L. L. Smith, Jr. 1963. *Some phases of the life history of the trout perch, Percopsis omiscomaycus.* Ecology 4(1):83-95.

Manion, P. J., and H. A. Purvis. 1971. *Giant American brook lamprey, Lampetra lamottei, in the upper Great Lakes.* J. Fish. Res. Board Can. 28(4):616-620.

Mansueti, A. J., and J. D. Hardy, Jr. 1967. *Development of fishes of the Chesapeake Bay Region, an atlas of egg, larval, and juvenile stages, part 1.* University of Maryland, Nat. Resour. Inst. 202 pp.

Marshall, N. 1947. *Studies on the life history and ecology of Notropis chalybaeus (Cope).* Q. J. Fla. Acad. Sci. 9(3-4):163-188.

Martin, L. 1932. *The physical geography of Wisconsin.* Wis. Geol. Nat. Hist. Surv. Bull. No. 36, Educ. Ser. No. 4. 608 pp.

McCarraher, D. V. 1960. *Pike hybrids (Esox lucius × E. vermiculatus) in a sandhill lake, Nebraska.* Trans. Am. Fish. Soc. 89:82-83.

McCauley, R. W. 1963. *Lethal temperatures of the developmental stages of the sea lamprey.* J. Fish. Res. Board Can. 20(2):483-490.

Meek, S. E., and S. F. Hildebrand. 1910. *A synoptic list of the fishes known to occur within fifty miles of Chicago.* Field Mus. Nat. Hist. Publ. No. 142, Zool. Ser. 7(9):223-338.

Miller, R. R. 1957. *Origin and dispersal of the alewife, Alosa pseudoharengus and Dorosoma cepedianum in the Great Lakes.* Trans. Am. Fish. Soc. 86:97-111.

_____. 1960. *Systematics and biology of the gizzard shad (Dorosoma cepedianum) and related fishes.* U. S. Fish Wild. Serv. Fish Bull. 173, 60:371-392.

Milner, J. W. 1874. *Report on the propagation of the shad (Alosa sapidissima) and its introduction into new waters.* Report of the Commissioner of Fish and Fisheries for 1872 and 1873, Part 2, Appendix B. pp. 419-451.

Moore, W. G. 1942. *Field studies on oxygen requirements of certain fresh water fishes.* Ecology 23(3):319-329.

Morgan, G. D. 1954. *The life history of the white crappie (Pomoxis annularis) of Buckeye Lake, Ohio.* J. Sci. Lab. Denison Univ. 43(618):113-144.

Mortimer, C. H. 1975. *Physical limnology of Lake Michigan. Part 1, Physical characteristics of Lake Michigan and its responses to applied forces.* Environmental status of the Lake Michigan region, Vol. 2. Argonne National Laboratory ANL/ES-40. pp. 13-102.

Moss, D. D., and D. C. Scott. 1961. *Dissolved-oxygen requirements of three species of fish.* Trans. Am. Fish. Soc. 90(4):377-393.

Mraz, D. 1964. *Observations on large and smallmouth bass nesting and early life history.* Wis Conserv. Dep. Res. Rep. No. 11. 13 pp. (mimeo).

_____. 1968. *Recruitment, growth, exploitation and management of walleyes in a southeastern Wisconsin lake.* Wis. Dep. Nat. Resour. Tech. Bull. No. 40. 38 pp.

_____, S. Kmiotek, and L. Frankenberger. 1961. *The largemouth bass - its life history, ecology and management.* Wis. Conserv. Dep. Publ. No. 232. 13 pp.

Nelson, E. W. 1878. *Fisheries of Chicago and vicinity.* Report of the U. S. Commissioner of Fish and Fisheries for 1875-1876, Part 4, Appendix B. pp. 783-800.

Nelson, J. S. 1968a. *Deep-water ninespine sticklebacks, Pungitius pungitius, in the Mississippi drainage.* Copeia 1968(2):326-334.

_____. 1968b. *Life history of the brook silverside, Labidesthes sicculus, in Crooked Lake, Indiana.* Trans. Am. Fish. Soc. 97(3):293-296.

Niemuth, W., W. Churchill, and T. Wirth. 1959. *The walleye - life history, ecology and management.* Wis. Conserv. Dep. Publ. No. 227. 14 pp.

Oehmcke, A. A., L. Johnson, J. Klingbiel, and C. Wistrom. 1965. *The Wisconsin muskellunge - its life history, ecology and management.* Wis. Conserv. Dep. Publ. No. 225. 12 pp.

Page, L. M., and P. W. Smith. 1971. *The life history of the slenderhead darter, Percina phoxocephala, in the Embarras River, Illinois.* Ill. Nat. Hist. Surv. Bio. Notes No. 74. 14 pp.

Parker, H. L. 1964. *Natural history of Pimephales vigilax (Cyprinidae).* Southwest. Nat. 8(4):228-235.

Parsons, J. W. 1973. *History of salmon in the Great Lakes, 1850-1970.* U. S. Bur. Sport Fish. Wildl. Tech. Pap. No. 68. 80 pp.

*Peterson, J. 1975. Letter, 20 January (Michigan Department of Natural Resources, Escanaba).

Peterson, R. S. 1971. *Elkhart River basin stream survey report.* Indiana Department of Natural Resources, Div. Fish Wildl. 52 pp. (mimeo).

_____. 1974. *Little Elkhart River fisheries survey report.* Indiana Department of Natural Resources, Div. Fish Wildl. 26 pp. (mimeo).

Petravicz, J. J. 1936. *The breeding habits of the least darter, Microperca punctulata Putnam.* Copeia 1936(2):77-82.

Petravicz, W. P. 1938. *The breeding habits of the blackside darter, Hadropterus maculatus Girard.* Copeia 1938(1):40-44.

Pfeiffer, R. A. 1955. *Studies on the life history of the rosyface shiner, Notropis rubellus (Agassiz).* Copeia 1955(2):95-104.

Pflieger, W. L. 1971. *A distributional study of Missouri fishes.* Univ. Kansas Publ. Mus. Nat. Hist. 20(3):225-570.

Phillips, G. L., and J. C. Underhill. 1971. *Distribution and variation of the Catostomidae of Minnesota*. Univ. Minn. Bell Mus. Nat. Hist. Occas. Pap. No. 10. 45 pp.

Priegel, G. R. 1960. *Sturgeon studies*. In: *Research in Wisconsin*. Wisconsin Conservation Department, Madison. 115 pp. (mimeo). p. 19.

_____. 1962. *Plentiful but unknown*. Wis. Conserv. Bull. 27(3):13.

_____. 1963. *Dispersal of the shortnose gar, Lepisosteus platostomus, into the Great Lakes drainage*. Trans. Am. Fish. Soc. 92(2):178.

_____. 1964. *Review of Lake Poygan sturgeon management problems*. Wisconsin Department of Natural Resources, Bur. Fish Manage. 6 pp. (mimeo).

_____. 1966. *Age-length and length-weight relationship of bullheads from Little Lake Butte des Morts, 1959*. Wis. Conserv. Dep. Res. Plann. Div. Res. Rep. No. 17 (Fisheries). 6 pp. (mimeo).

_____. 1967a. *The freshwater drum - its life history, ecology and management*. Wis. Dep. Nat. Resour. Publ. 236. 15 pp.

_____. 1967b. *A list of the fishes of Lake Winnebago*. Wis. Conserv. Dep. Res. Plann. Div. Res. Rep. No. 27 (Fisheries). 6 pp. (mimeo).

_____. 1968. *The movement, rate of exploitation and homing behavior of walleyes in Lake Winnebago and connecting waters, Wisconsin, as determined by tagging*. Wis. Acad. Sci. Arts Lett. 56:207-223.

_____. 1969. *The Lake Winnebago sauger - age, growth, reproduction, food habits and early life history*. Wis. Dep. Nat. Resour. Tech. Bull. No. 43. 63 pp.

_____. 1970. *Reproduction and early life history of the walleye in the Lake Winnebago region*. Wis. Dep. Nat. Resour. Tech. Bull. No. 45. 105 pp.

_____. 1973. *Lake sturgeon management on the Menominee River*. Wis. Dep. Nat. Resour. Tech. Bull. No. 67. 20 pp.

_____, and T. L. Wirth. 1971. *The lake sturgeon - its life history, ecology and management*. Wis. Dep. Nat. Resour. Publ. 240-70. 19 pp.

Purkett, C. A., Jr. 1961. *Reproduction and early development of the paddlefish*. Trans. Am. Fish. Soc. 90(2):125-129.

Quick, R. F. 1971. *The age and growth of brown trout (Salmo trutta) and sculpin (Cottus spp.) as it relates to eutrophication in the Jordan and Ausable rivers*. M. S. Thesis. Michigan State Univ., East Lansing. 86 pp.

Raney, E. C. 1939. *The breeding habits of the silvery minnow, Hybognathus regius Girard*. Am. Midl. Nat. 21(3):674-680.

_____. 1969. *Minnows of New York, parts I and II*. Conservationist 23(5):22-29 and 23(6):21-29.

_____, and E. A. Lachner. 1946. *Age, growth and habits of the hogsucker, Hypentelium nigricans (Le Sueur), in New York.* Am. Midl. Nat. 36(1):76-86.

Reed, R. J. 1958. *The early life history of two cyprinids, Notropis rubellus and Campostoma anomalum pullum.* Copeia 1958(4):325-327.

Reighard, J. 1920. *The breeding behavior of suckers and minnows.* Biol. Bull. 38(1):1-32.

_____. 1943. *The breeding habits of the river chub, Nocomis micropogon (Cope).* Pap. Mich. Acad. Sci. Arts Lett. 28:397-423.

Rottiers, D. V. 1965. *Some aspects of the life history of Cottus cognatus in Lake Michigan.* M. S. Thesis. Univ. Michigan. 49 pp.

Rounsefell, G. A., and W. H. Everhart. 1953. *Fishery science, its methods and applications.* John Wiley and Sons, Inc., New York. 444 pp.

Schneberger, E. 1972a. *The black crappie - its life history, ecology and management.* Wis. Dep. Nat. Resour. Publ. 243-72. 16 pp.

_____. 1972b. *White crappie - life history, ecology and management.* Wis. Dep. Nat. Resour. Publ. 244. 14 pp.

_____. 1972c. *The white sucker - its life history, ecology and management.* Wis. Dep. Nat. Resour. Publ. 245-72. 18 pp.

_____. 1972d. *Smallmouth bass - life history, ecology and management.* Wis. Dep. Nat. Resour. Publ. 242. 16 pp.

_____. 1973. *Rock bass - life history, ecology and management.* Wisconsin Department of Natural Resources, Madison. 16 pp.

*Schultz, P. 1975. Letter, 12 February (Wisconsin Department of Natural Resources, Plymouth).

Schumacher, R. E., and S. Eddy. 1960. *The appearance of pink salmon, Oncorhynchus gorbuscha (Walbaum), in Lake Superior.* Trans. Am. Fish. Soc. 89(4):371-373.

_____, and J. G. Hale. 1962. *Third generation pink salmon, Oncorhynchus gorbuscha (Walbaum), in Lake Superior.* Trans. Am. Fish. Soc. 91(4):421-422.

Scott, W. B. 1967. *Freshwater fishes of eastern Canada.* University of Toronto Press, Toronto. 137 pp.

_____, and E. J. Crossman. 1973. *Freshwater fishes of Canada.* Bull. Fish. Res. Board Can. No. 184. 966 pp.

Shields, J. T. 1965. *Yellow bass Roccus mississippiensis.* In: A. J. McClane (ed.), *McClane's standard fishing encyclopedia.* Holt, Rinehart and Winston, New York. pp. 1023-1024.

Sigler, W. F., and R. R. Miller. 1963. *Fishes of Utah.* Utah Department of Fish and Game, Salt Lake City. 203 pp.

Skille, J. 1968. *A study of the rock bass, Ambloplites rupestris (Rafinesque).* University of Wisconsin--Stevens Point, Dep. Biol. 13 pp. (mimeo).

Small, J. 1968. *A study and life history of the pirate-perch, Aphredoderus sayanus (Gilliams).* University of Wisconsin--Stevens Point, Dep. Biol. 17 pp. (mimeo).

Smith, B. G. 1908. *The spawning habits of Chrosomus erythrogaster Rafinesque.* Biol. Bull. (Woods Hole) 15:9-18.

_____. 1922. *Notes on the nesting habits of Cottus.* Pap. Mich. Acad. Sci. Arts Lett. 2:221-224.

Smith, P. W. 1965. *A preliminary annotated list of the lampreys and fishes of Illinois.* Ill. Nat. Hist. Surv. Biol. Notes No. 54. 12 pp.

_____. 1968. *An assessment of changes in the fish fauna of two Illinois rivers and its bearing on their future.* Trans. Ill. State Acad. Sci. 61(1):31-45.

_____. 1971. *Illinois streams: a classification based on their fishes and an analysis of factors responsible for disappearance of native species.* Ill. Nat. Hist. Surv. Biol. Notes No. 76. 14 pp.

_____. 1973. *A key to the fishes of Illinois.* Ill. Dep. Conserv. Fish. Bull. No. 6. 43 pp.

*_____. 1975a. Letter, 17 January (Illinois Natural History Survey, Urbana).

*_____. 1975b. Letter, April (Illinois Natural History Survey, Urbana).

Smith, S. H. 1964. *Status of the deepwater cisco populations of Lake Michigan.* Trans. Am. Fish. Soc. 93(2):155-163.

_____. 1968. *The alewife.* Limnos 1(2):12-20.

Snow, H. E. 1969. *Comparative growth of eight species of fish in thirteen northern Wisconsin lakes.* Wis. Dep. Nat. Resour. Res. Rep. 46. 23 pp.

_____, A. Ensign, and J. Klingbiel. 1962. *The bluegill - its life history, ecology and management.* Wis. Conserv. Dep. Publ. 230. 14 pp.

Starrett, W. C., W. J. Harth, and P. W. Smith. 1960. *Parasitic lampreys of the genus Ichthyomyzon in the rivers of Illinois.* Copeia 1960(4):337-346.

Stautz, F. F., and G. C. Gerdman. 1967. *Report of an investigation of a fish kill in Lake Wisconsin - Wisconsin River.* Department of Resource Development, Madison, Wis. 4 pp. (mimeo).

Tait, H. 1973. *The impact of Great Lakes power generating plants on fish populations.* U. S. Bureau of Sport Fisheries and Wildlife, Fifth Annual Salmon Seminar, Michigan City, Indiana, 27 April. 12 pp. (mimeo).

Taylor, W. R. 1954. *Records of fishes in the John N. Lowe collection from the Upper Peninsula of Michigan.* Univ. Mich. Mus. Zool. Misc. Publ. No. 87. 50 pp.

_____. 1969. *A revision of the catfish genus Noturus Rafinesque with an analysis of higher groups in the Ictaluridae.* U. S. Nat. Mus. Bull. 282. 315 pp.

Threinen, C. W. 1958. *Life history, ecology, and management of the alewife.* Wis. Conserv. Dep. Publ. 223. 8 pp.

_____, and E. Herman. 1958. *Some notes on northern pike management.* Wisconsin Department of Natural Resources, Madison. 2 pp. (mimeo).

_____, C. Wistrom, B. Apelgren, and H. Snow. 1966. *The northern pike - life history, ecology, and management.* Wis. Conserv. Dep. Publ. 235. 16 pp.

*Thuemler, T. 1974. Letter, 7 January (Wisconsin Department of Natural Resources, Wausaukee).

*_____. 1975. Personal communication (Wisconsin Department of Natural Resources, Wausaukee).

Todd, D. K. 1970. *The water encyclopedia.* Water Information Center, Port Washington, N. Y. 559 pp.

Tody, W. H., and H. A. Tanner. 1966. *Coho salmon for the Great Lakes.* Mich. Dep. Conserv. Fish. Manage. Rep. No. 1. 38 pp.

Trama, F. B. 1954. *The pH tolerance of the common bluegill (Lepomis macrochirus Rafinesque).* Phil. Acad. Nat. Sci. Not. Nat. No. 256. 13 pp.

Trautman, M. 1957. *The fishes of Ohio.* Ohio State University Press, Columbus. 683 pp.

U. S. Department of the Interior Office of Endangered Species and International Activities. 1973. *Threatened wildlife of the United States.* U. S. Bur. Sport Fish. Wildl. Resour. Publ. 114. 289 pp.

U. S. Geological Survey. 1974. *1972 water resources data for Wisconsin.* Water Resour. Div., Madison. 262 pp.

Van Oosten, J., R. Hile, and F. W. Jobes. 1946. *The whitefish fishery of lakes Huron and Michigan with special reference to the deep-trap-net fishery.* U. S. Fish Wildl. Serv. Fish. Bull. 50:297-394.

Vladykov, V. D. 1949. *Quebec lampreys, list of species and their economical importance.* Que. Dep. Fish. Contrib. No. 26. 67 pp.

Wagner, W. C. 1976. *Pink salmon in Michigan tributaries of the Great Lakes, 1975.* Michigan Department of Natural Resources, Marquette Fish. Res. Stn. 3 pp. (mimeo).

_____, and T. M. Stauffer. 1962. *Sea lamprey larvae in lentic environments*. Trans. Am. Fish. Soc. 91(4):384-387.

_____, and T. M. Stauffer. 1975. *Occurrence of pink salmon in Michigan, 1963-1973*. Mich. Dep. Nat. Resour. Fish. Div. Tech. Rep. No. 75-3. 8 pp. (mimeo).

Wallace, D. C. 1973. *Reproduction of the silverjaw minnow, Ericymba buccata Cope*. Trans. Am. Fish. Soc. 102(4):786-793.

Weber, J. 1971. *Winnebago's bonus cod*. Wis. Conserv. Bull. 36(6):23.

_____. 1975. *Golden strands*. Wis. Conserv. Bull. 40(2):18-19.

Wells, L. R. 1969. *Seasonal depth distribution of fish in southeastern Lake Michigan*. U. S. Fish Wildl. Serv. Fish. Bull. 67(1):1-15.

_____, and A. L. McLain. 1973. *Lake Michigan - man's effects on native fish stocks and other biota*. Great Lakes Fish. Comm. Tech. Rep. No. 20. 55 pp.

*White, W. S. 1976. *Tributaries to Lake Michigan*. Environmental status of the Lake Michigan region, Vol. 18. Argonne National Laboratory ANL/ES-40 (manuscript in preparation).

Wiley, E. O., III, and D. D. Hall. 1975. *Fundulus blairae, a new species of the Fundulus nottii complex (Teleostei, Cyprinodontidae)*. Am. Mus. Novit. No. 2577. 13 pp.

Winn, H. E. 1958. *Comparative reproductive behavior and ecology of fourteen species of darters (Pisces-Percidae)*. Ecol. Monogr. 28(2):155-191.

Wisconsin Commissioners of Fisheries. 1875-1912. *Annual and biennial reports of the Commissioners of Fisheries of Wisconsin*. Madison, Wis.

Wisconsin Department of Natural Resources. 1961 to present. *Surface water resources of each Wisconsin county*. Lake and Stream Classification Project, Wis. Dep. Nat. Resour., Madison.

_____. 1974. *Wisconsin lakes*. Wis. Dep. Nat. Resour. Publ. 7-3600(74). 79 pp.

Wisconsin Department of Natural Resources Endangered Species Committee. 1975. *Endangered animals in Wisconsin*. Madison, Wis. 10 pp. (mimeo).

Wissing, T. E., and C. W. Voigtlander. 1974. *Food habits of young and yearling white bass in Lake Mendota, Wisconsin*. Trans. Am. Fish. Soc. 103(1):25-31.

Woods, L. P. 1970. *The changing Great Lakes (in two parts)*. Field Mus. Nat. Hist. Bull. Part I, July (1970):7-10; Part II, August (1970):6-9.

ADDITIONAL REFERENCES

Acres, H. G. 1970. *Thermal inputs to the Great Lakes 1968-2000*. Inland Waters Branch, Department of Energy, Mines, and Reservoirs, Canada Centre for Inland Waters, Niagara Falls, Ontario. 93 pp.

Amend, D. F. 1970. *Retention of mercury by salmon*. Prog. Fish-Cult. 32(4): 192-194.

Ashley, L. M. 1970. *Action of iron salts in solution on goldfish*. Prog. Fish-Cult. 32(2):109.

Baptist, J. P. 1966. *Uptake of mixed fission products by marine fishes*. Trans. Am. Fish. Soc. 95(2):145-152.

Becker, C. D., and T. O. Thatcher. 1973. *Toxity of power plant chemicals to aquatic life*. U. S. Atomic Energy Commission, Battelle Pacific Northwest Laboratories, Richland, Washington. 250 pp.

Beltz, J. R., J. E. Johnson, D. L. Cohen, and F. B. Pratt. 1974. *An annotated bibliography of the effects of temperature on fish with special reference to the freshwater and anadromous species of New England*. Mass. Agric. Exp. Stn. Bull. No. 605. 97 pp.

Bennett, D. H., and J. W. Gibbons. 1975. *Reproductive cycles of largemouth bass (Micropterus salmoides) in a cooling reservoir*. Trans. Am. Fish. Soc. 104(1):77-82.

Beyers, R. J. 1962. *Relationship between temperature and the metabolism of experimental ecosystems*. Science 136:980-982.

Brungs, W. A. 1969. *Chronic toxicity of zinc to the fathead minnow, Pimephales promelas Rafinesque*. Trans. Am. Fish. Soc. 98(2):272-279.

Burton, D. T., E. L. Morgan, and J. Cairns, Jr. 1972. *Mortality curves of bluegills (Lepomis macrochirus Rafinesque) simultaneously exposed to temperature and zinc stress*. Trans. Am. Fish. Soc. 101(3):435-441.

Champ, M. A., J. T. Lock, C. D. Bjork, W. G. Klussmann, and J. D. McCullough, Jr. 1973. *Effects of anhydrous ammonia on a central Texas pond, and a review of previous research with ammonia in fisheries management*. Trans. Am. Fish. Soc. 102(1):73-82.

Colby, P. J., and L. T. Brooke. 1969. *Cisco (Coregonus artedii) mortalities in a southern Michigan lake*. Limnol. Oceanogr. 14:958-960.

Copeland, R. A., R. H. Beethe, and W. W. Prater. 1973. *Trace element distributions in Lake Michigan fish: a baseline study with calculations of concentration factors and equilibrium radioisotope distributions*. Environmental Research Group, Inc. (Commonwealth Edison Co., Consumers Power Company, Indiana and Michigan Electric Company, Northern Indiana Public Service Company, Madison Gas and Electric Company). 139 pp.

Davies, P. H., and W. H. Everhart. 1973. *Effects of chemical variations in aquatic environments. Vol. III, Lead toxicity to rainbow trout and testing application factor concept.* U. S. Environmental Protection Agency, Off. Res. Monit., Washington, D. C. Ecol. Res. Ser., EPA-R3-73. 81 pp.

Eaton, J. G. 1974. *Chronic cadmium toxicity to the bluegill (Lepomis macrochirus Rafinesque).* Trans. Am. Fish. Soc. 103(4):729-735.

Environmental Protection Agency (Cincinnati) and Ohio Cooperative Fishery Unit. 1971. *Collection of papers presented at the Fish Kill Investigation Seminar, 12-14 January.* Ohio Cooperative Fishery Unit, Columbus. 120 pp.

Freeman, R. A. 1973. *Recovery of rainbow trout from aluminum poisoning.* Trans. Am. Fish. Soc. 102(1):152-154.

_____, and W. H. Everhart. 1971. *Toxicity of aluminum hydroxide complexes in neutral and basic media to rainbow trout.* Trans. Am. Fish. Soc. 100(4):644-658.

Friend, G., H. Story, C. R. Henderson, and A. Busch. 1965. *Behavior of certain radionuclides released into freshwater environments.* U. S. Public Health Serv. Publ. 999-r-h-13. 90 pp.

Gammon, J. R. 1971. *The response of fish populations in the Wabash River to heated effluents.* Proc. 3rd Nat. Symp. Radioecol. 1971:513-523.

Gibbons, J. W., J. T. Hook, and D. L. Forney. 1972. *Winter responses of largemouth bass to heated effluent from a nuclear reactor.* Prog. Fish-Cult. 34(2):88-90.

*Holland, W. E., M. H. Smith, J. W. Gibbons, and D. H. Brown. 1976. *Thermal tolerances of fish from a reservoir receiving heated effluent from a nuclear reactor.* Physiol. Zool. (in press).

Huckabee, J. W., and N. A. Griffith. 1974. *Toxicity of mercury and selenium to the eggs of carp (Cyprinus carpio).* Trans. Am. Fish. Soc. 103(4): 822-825.

Hunn, J. B., and P. O. Froom. 1966. *In vivo uptake of radioiodide by rainbow trout.* J. Water Pollut. Control Fed. 38(12):1981-1985.

Jensen, A. L. 1972. *Variation in results of identical bioassays of minnows subjected to instant temperature increase.* Trans. Am. Fish Soc. 101(3): 403-407.

Kania, H. J., and J. O'Hara. 1974. *Behavioral alterations in a simple predator-prey system due to sublethal exposure to mercury.* Trans. Am. Fish. Soc. 103(1):134-136.

Kelso, J. R. M., and R. Frank. 1974. *Organochlorine residues, mercury, copper and cadmium in yellow perch, white bass and smallmouth bass, Long Point Bay, Lake Erie.* Trans. Am. Fish. Soc. 103(3):577-581.

Knepp, G. L., and G. F. Arkin. 1973. *Ammonia toxicity levels and nitrate tolerance of channel catfish.* Prog. Fish-Cult. 35(4):221-224.

Korn, S. 1973. *The uptake and persistence of carbaryl in channel catfish.* Trans. Am. Fish. Soc 102(1):137-139.

Liao, P. B. 1971. *Water requirements of salmonids.* Prog. Fish-Cult. 33(4): 210-215.

Locke, M. P. 1972. *Status report on thermal effects studies at the Quad-cities Station.* Industrial Bio-Test Laboratories, Inc., Northbrook, Ill. 17 pp.

MacPhee, C., and R. Ruelle. 1969. *Lethal effects of 1888 chemicals upon four species of fish from western North America.* Idaho For. Wildl. Range Exp. Stn. Bull. No. 3. 112 pp.

Macek, K. J., and W. A. McAllister. 1970. *Insecticide susceptibility of some common fish family representatives.* Trans. Am. Fish. Soc. 99(1):20-27.

McNeely, D., and D. Pearson. 1974. *Distribution and condition of fishes in a small reservoir receiving heated waters.* Trans. Am. Fish. Soc. 103(3): 518-530.

Mount, D. I. 1964. *An autopsy technique for zinc-caused fish mortality.* Trans. Am. Fish. Soc. 93(2):174-182.

Nash, C. E. 1974. *Residual chlorine retention and power plant fish farms.* Prog. Fish-Cult. 36(2):92-98.

Nebeker, A. V., F. A. Puglisi, and D. L. DeFoe. 1974. *Effect of poly-chlorinated biphenyl compounds on survival and reproduction of the fathead minnow and flagfish.* Trans. Am. Fish. Soc. 103(3):562-568.

Neill, W. H., and J. J. Magnuson. 1974. *Distributional ecology and behav-ioral thermoregulation of fishes in relation to heated effluent from a power plant at Lake Monona, Wisconsin.* Trans. Am. Fish. Soc. 103(4): 663-710.

Neuhold, J. M., and W. F. Sigler. 1962. *Chlorides affect the toxicity of fluorides to rainbow trout.* Science 125(3505):732-733.

Olmsted, L. L., and D. G. Cloutman. 1974. *Severe fish kill in Mud Creek, Arkansas.* Trans. Am. Fish. Soc. 103(1):79-87.

Olson, T. A. 1968. *Biological aspects of heat pollution.* J. Minn. Acad. Sci. 35(1):25-28.

Oseid, D., and L. L. Smith, Jr. 1972. *Swimming endurance and resistance to copper and malathion of bluegills treated by long-term exposure to sublethal levels of hydrogen sulfide.* Trans. Am. Fish. Soc. 101(4): 620-625.

Parker, E. D., M. F. Hirshfield, and J. W. Gibbons. 1973. *Ecological comparisons of thermally affected aquatic environments*. J. Water Pollut. Control Fed. 45(4):726-733.

Pickering, Q. H., and W. Vigor. 1965. *The acute toxicity of zinc to eggs and fry of the fathead minnow*. Prog. Fish-Cult. 27(3):153-157.

Piper, R. G., and C. E. Smith. 1973. *Factors influencing formalin toxicity in trout*. Prog. Fish-Cult. 35(2):78-81.

Rachlin, J. W., and A. Perlmutter. 1970. *Response of rainbow trout cells in culture to selected concentrations of zinc sulfate*. Prog. Fish-Cult. 32(1):16.

Smith, C. E., and W. G. Williams. 1974. *Experimental nitrite toxicity in rainbow trout and chinook salmon*. Trans. Am. Fish. Soc. 103(2):389-391.

Smith, L. S., J. B. Saddler, R. C. Cardwell, A. J. Mearns, H. M. Miles, T. W. Newcomb, and K. C. Watters. 1971. *Responses of teleost fish to environmental stress*. U. S. Environmental Protection Agency, Fed. Wat. Qual. Admin., Water Pollut. Control Res. Ser. 18050EBK02/71. 114 pp.

Swingle, H. S. 1966. *Fish kills caused by phytoplankton blooms and their prevention*. FAO World Symposium on Warm-Water Pond Fish Culture. Auburn University, Agric. Exp. Stn. 7 pp.

U. S. Atomic Energy Commission. 1974. *Heated effluents and effects on aquatic life with emphasis on fishes*. Springfield, Va. TID-3918.

Wellborn, L., Jr. 1971. *Toxicity of some compounds to striped bass fingerlings*. Prog. Fish-Cult. 33(1):32-36.

Westin, D. T. 1974. *Nitrate and nitrite toxicity to salmonid fishes*. Prog. Fish-Cult. 36(2):86-89.

Yardley, D., J. C. Avise, J. W. Gibbons, and M. H. Smith. 1974. *Biochemical genetics of sunfish. III. Genetic subdivision of fish populations inhabiting heated waters*. In: J. W. Gibbons and R. R. Sharitz (eds.), *Thermal ecology*. U. S. A. E. C. Symp. Ser. CONF-730505. pp. 255-263.

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