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# NEW DISTRIBUTION RECORDS FOR EXOTIC AND NON-INDIGENOUS FISH SPECIES IN THE LAKE MICHIGAN DRAINAGE, INDIANA

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ABSTRACT: Exotic and non-indigenous fish species are surviving in tributary mouths, industrial ports, and the nearshore zone of Lake Michigan. Exotic species have invaded the nearshore and have colonized niches which have recently been restored. The decline in toxic sediments, efforts to restore Great Lake harbors, and chemical load reductions from tributaries have enabled areas previously toxic to sustain viable populations of European and Asian fishes and non-indigenous North American species. Our field collections during 1992-1998 resulted in new distribution records for 6 fishes in the nearshore of Lake Michigan. New records for exotic species from Europe and Asia include: grass carp (*Ctenopharyngodon idella*), rudd (*Scardinius erythrophthalmus*), and round goby (*Neogobius melanostomus*). In addition, the white perch (*Morone americana*), striped bass (*Morone saxatilis*), and three-spine stickleback (*Gasterosteus aculeatus*), all non-indigenous species, have extended their range into the Grand Calumet River, Little Calumet River, and Lake Michigan nearshore.

KEYWORDS: Cyprinidae, exotic species, Gasterosteidae, Gobiidae, Moronidae, non-indigenous species.

## INTRODUCTION

The presence of exotic and non-indigenous species in the interior waters of Indiana has mirrored those of adjacent Great Lakes' States (Mills, *et al.,* 1993),

including Illinois (Burr, *et al.*, 1996), Wisconsin (Becker, 1983), and Ohio (Trautman, 1982). Around the turn of the century, goldfish (*Carassius auratus*) and carp (*Cyprinus carpio*) were the first exotic species to become established in Indiana. Since these initial introductions, numerous reports of the establishment of exotic and non-indigenous species in Lake Michigan have appeared in regional newspapers and the published literature (Mills, *et al.*, 1993). Johnston (1991) reported the first record of the three-spined stickleback (*Gasterosterus aculeatus*) from Lake Michigan; round goby (*Neogobius melanostomus*) and possibly the tubenose goby (*Proterirhinus marmoratus*), have been reported as being abundant in southern Lake Michigan (Burr, *et al.*, 1996); oriental weatherfish (*Misgurnus anguillicaudatus*), an ornamental aquarium fish, has apparently become established in streams in northeastern Illinois (Page and Laird, 1993); grass carp (*Ctenopharyngodon idella*) has been reported to be firmly established in the large rivers of the Mississippi and Ohio River systems (Raibley, 1995; Burr, *et al.*, 1996). Simon and Stewart (in press) report that 60% to 80% of the total number of individuals at some locations in the Lake Michigan drainage may be non-indigenous or exotic species.

The fishes of the Indiana nearshore zone of Lake Michigan have not been well studied. In our efforts to investigate the species distribution of fishes in Indiana (Simon, *et al.*, 1992; Simon, 1992), we evaluated the nearshore zone of Lake Michigan between 1992 and 1998. Simon, *et al.* (1992) provided a list of 199 species known to have existed in Indiana. The addition of five of these new exotic and non-indigenous species increases the number of species known to have occurred in the State to 204 (*Ctenopharyngodon idella* was already on the list (Simon, *et al.*, 1992, p. 100)).

Fish collection investigations within the nearshore of Lake Michigan included surveys by the Indiana Department of Natural Resources that evaluated the salmonids (*Oncorhynchus kisutch, O. mykiss, O. tschawytscha,* and *Salvelinus namaycush*; Brazo, 1989, 1990), yellow perch (*Perca flavescens*; Francis, *et al.*, 1996; McComish, *et al.*, 1994), and smallmouth bass (*Micropterus dolomieu*; Francis, unpubl. data) populations. In addition, researchers at Ball State University have studied the yellow perch population at two sites near Michigan City, Indiana, for nearly 25 years (McComish, *et al.*, 1994). The U.S. Army Corps of Engineers has conducted annual monitoring near the breakwalls of the Federal Channels (P.B. Moy, unpubl. data) near the Indiana Harbor Canal, Port of Indiana, and Trail Creek. Unfortunately, recent efforts in Lake Michigan are inadequate both spatially and temporally to provide the necessary monitoring to evaluate the nearshore fish community.

Our surveys were conducted to develop baseline biological community data for the nearshore of Lake Michigan. This survey is the most recent attempt to collect community data for the northwestern Indiana nearshore (Meek and Hildebrand, 1910; Gerking, 1945). Our purpose was to document distributional trends and present locality information for 6 newly discovered species of fish in northwestern Indiana (Table 1).

Table 1. New records for exotic and non-indigenous species along the nearshore of Lake Michigan and its tributaries.

| Species | County | *n* | Collection Sites |
|---|---|---|---|
| *Ctenopharyngodon idella* | Porter | 1 | Little Calumet River, 2 miles southeast of Ogden Dunes, Ogden Dunes Township, Sec. 31, T37N, R6W |
| | Porter | 2 | Rice Lake, 2 miles east of Chesterton, Westchester Township, Sec. 5, T35N, R5W |
| *Scardinius erythrophthalmus* | Lake | 1 | West Branch of the Grand Calumet River, Hammond, North Township, Sec. 31, T37N, R9W |
| | Lake | 18 | West Branch of the Grand Calumet River, East Chicago, North Township, Sec. 32, T37N, R9W |
| | Lake | 10 | West Branch of the Grand Calumet River, East Chicago, downstream from Indianapolis Boulevard, Sec. 32, T37N, R9W |
| | Lake | 33 | East Branch of the Grand Calumet River, Broadway Street, Gary, Calumet Township, Sec. 34, T37N, R8W |
| | Lake | 3 | East Branch of the Grand Calumet River, Bridge Street, Gary, Calumet Township, Sec. 36, T37N, R6W |
| | Lake | 8 | East Branch of the Grand Calumet River, Gary, Calumet Township, Sec. 36, T37N, R9W |
| *Neogobius melanostomus* | Lake | 15 | Lake Michigan, Calumet Harbor, Whiting, North Township, Sec. 25, T38N, R10W |
| | Lake | 1 | Lake Michigan, Hammond Marina, Whiting, North Township, Sec. 31, T37N, R9W |
| *Gasterosteus aculeatus* | Lake | 2 | Lake Michigan, Pastrick Harbor, East Chicago, Calumet Township, Sec. 23, T37N, R9W |
| | Lake | 20 | Lake Michigan, Buffington Harbor, Gary, Calumet Township, Sec. 27, T37N, R6W |
| | Lake | 20 | Lake Michigan, Calumet Harbor, Whiting, North Township, Sec. 25, T38N, R10W |
| | Lake | 8 | Lake Michigan, Indiana Harbor Canal, East Chicago-Whiting, North Township, Sec. 10, T37N, R9W |
| | LaPorte | 5 | Lake Michigan, Washington Park Harbor breakwater, Michigan City, Cool Spring Township, Sec. 20, T38N, R4W |
| | Porter | 7 | Lake Michigan, Burns Harbor – Port of Indiana, Burns Harbor, Portage Township, Sec. 18/19, T37N, R6W |
| *Morone americana* | Lake | 1 | Lake Michigan, Calumet Harbor breakwall, Whiting, North Township, Sec. 25, T38N, R10W |
| | Lake | 1 | East Branch of the Grand Calumet River, Bridge Street, Gary, Calumet Township, Sec. 36, T37N, R6W |
| | Lake | 3 | Cedar Lake, north-northwestern corner of Cedar Lake, Cedar Lake Township, Sec. 22, T34N, R9W |
| | Lake | 11 | Cedar Lake, northeastern corner of Cedar Lake, Cedar Lake Township, Sec. 23/24, T34N, R9W |
| | LaPorte | 1 | Lake Michigan, Michigan City breakwall, Michigan City, Cool Springs Township, Sec. 20, T38N, R4W |
| | LaPorte | 1 | Lake Michigan, Washington Park Harbor, Michigan City, Cool Springs Township, Sec. 20, T38N, R4W |
| *Morone saxatilis* | Porter | 4 | Lake Michigan, Burns Harbor - Port of Indiana, Burns Harbor, Portage Township, Sec. 18/19, T37N, R6W |

## MATERIALS AND METHODS

Sampling was conducted at 28 locations between 1992 and 1998. A total of 16 locations were sampled in the Lake Michigan nearshore, and 12 locations were sampled in the Grand Calumet River. Some stations were selected based on historic collection efforts (Meek and Hildebrand, 1910; Gerking, 1945), and equal effort was given to both areas (Simon, 1992). At each location, a representative sample was collected from the available habitats within a longitudinal distance 15 times the river's width up to a maximum of 500 m for tributaries and 500 m of shoreline for the Lake Michigan sampling sites (Simon, 1992). The specimens were collected either using a net while wading, from a boat using various-sized, 1/8-inch mesh minnow seines or pulsed DC electroshocking gear (T & J Model 1780 DCV, capable of 300 volt output), or by SCUBA diving along a series of grid transects over a distance of 500 $m^2$.

## RESULTS AND DISCUSSION

***Ctenopharnygodon idella.*** Grass carp is a species native to Asia that has been introduced into the United States for vegetation control and management in small farm ponds and interior lakes. The species was first introduced into experimental ponds in Arkansas in 1963 and then into the reservoirs and impoundments of that State. The species escaped almost immediately and dispersed into the majority of rivers in Mississippi and Missouri (Pflieger, 1978).

In Indiana, triploid grass carp have been stocked extensively in farm ponds and some lakes in an effort to control aquatic vegetation. The first Indiana records of grass carp from portions of the Lake Michigan drainage were from the Little Calumet River near Portage in Porter County. Staff from EA Science and Technology collected a single individual (a large adult male) near the outfall of Bethlehem Steel in the fall of 1984 (T. Simon, unpubl. data). In 1992, Simon (unpubl. data) collected specimens from Rice Lake, an impounded tributary of the Little Calumet River near Chesterton in Porter County. Two large adult specimens, 844 to 1100 mm total length (TL), were collected from depths of 5 m along an area with significant amounts of woody debris.

Adult grass carp feed extensively on aquatic macrophytes, algae, and aquatic macroinvertebrates (Robison and Buchanan, 1988; Page and Laird, 1993). The removal of vegetation and cover for young-of-the-year fishes and the reduction of waterfowl habitat may cause increased indirect effects on native species. Grass carp have very specific reproductive requirements; they need large, fast-flowing rivers where turbulence and flow ensure suspension of their semipelagic eggs (Lin, 1935). In addition, two days after hatching, their larvae enter a critical stage when they leave the drift to invade quiet aquatic macrophyte nursery habitats (Vladimirov, 1975). With the impoundment of most of our major rivers, researchers assumed that few escaped diploid grass carp would ever reproduce successfully. Conner, *et al.* (1980) reported the first reproduction of grass carp from the lower Mississippi River. Zimpfer, *et al.* (1987) reported additional reproduction from the lower Mississippi, Red, and Atchaflaya Rivers. The successful

reproduction of grass carp in the lower Illinois River (Raibley, 1995), Mississippi River (Raibley, 1995), Cache River (Burr and Warren, 1993), and Horseshoe Lake and its outlet, Lake Creek, in Illinois (Burr, *et al.*, 1996) has also been reported. No substantiated reproduction has been documented from the Lake Michigan nearshore or interior streams of Indiana.

***Scardinius erythrophthalmus.*** The rudd is native to Europe, Asia, and Russia. The species was imported as bait by the Arkansas fish farming industry (Burkhead and Williams, 1991). The species was subsequently distributed and stocked in at least 14 states and has been captured from eight states, including the Kankakee and Des Plaines River drainages in Illinois (Burr, *et al.*, 1996).

In Indiana, the species was first collected from the West Branch of the Grand Calumet River in 1992. By 1994, the rudd had dispersed into the East Branch of the Grand Calumet River. Hybrids between the golden shiner and rudd were collected from the upper five miles of the East Branch. A total of 73 specimens have been collected over a four year span. A survey of the Grand Calumet River during 1998 found that rudd were the dominant cyprinid species. It does not appear that the species has expanded its range outside of the Grand Calumet River. The species has been prevented from colonizing the Calumet River in Illinois by the low dissolved oxygen content in the West Branch of the Grand Calumet River (T.P. Simon, unpubl. data).

The rudd is a lentic species, occurring in surface and mid-water column. The rudd is similar to the golden shiner in feeding habits, switching between an insectivorous and omnivorous diet. Burkhead and Williams (1991) provided information on the identification of the rudd, their hybrids, and separation from the native golden shiner.

***Neogobius melanostomus.*** The round goby was first collected from the St. Clair River near Sarnia, Ontario, during June 1990 (Crossman, *et al.*, 1992; Jude, *et al.*, 1992). The species is thought to have been brought into the United States in ballast water. From the St. Clair River, the species spread into the Detroit River, Lake Erie, and, recently, Lake Michigan near Calumet Harbor (T.P. Simon, unpubl. data).

The first Indiana specimens were collected in 1994 from Calumet Harbor (J. Janssen, unpubl. data). Reports that the species has spread throughout the southern shore of Lake Michigan are unsubstantiated. However, additional sightings have been verified from Hammond Harbor (J. Francis, pers. comm.). Moy (unpubl. data) collected eight specimens, ranging in length from 57 to 110 mm, from Calumet Harbor in August 1995 and an additional seven specimens from Calumet Harbor between August and October 1996. Additional surveys are being conducted by the authors to document the species' distribution along the Indiana shoreline of Lake Michigan (Simon and Barnes, in prep.).

The round goby's native habitat includes coarse gravel, shell, and sand inshore areas up to 20 m in depth in the Black, Caspian, and Aral Seas (Miller, 1986). In the St. Clair River, gobies are present over large cobble substrates to a depth of 3 m and were typically associated with macrophytes (Jude, *et al.*, 1992; Jude,

*et al.*, 1995). In Calumet Harbor, round gobies were abundant on cobble and sandy substrates, although adults were less abundant on sand than were juveniles. The disappearance of several native species, including the mottled sculpin (*Cottus bairdi*) and logperch (*Percina caprodes*), is coincident with the arrival of the round goby. Competition with native species may favor the larger, more pugnacious round goby (T.P. Simon, unpubl. data).

***Gasterosteus aculeatus.*** The three-spine stickleback has a nearly circumpolar distribution and occurs widely in the Northern Hemisphere in marine and freshwater habitats. Until recently, the species was believed restricted to waters below Niagra Falls, but then it was collected in upper Lake Huron and the Straits of Mackinaw (Smith, 1985). The three-spine stickleback has been collected from the Lake Erie nearshore near Pelee Island (Burgess and Lee, 1980) and from the mouth of the Maumee River (Simon, unpubl. data). The species was first collected in Cook County, Illinois, from the Sanitary and Ship Canal, Trident Harbor, North Shore Channel, and Calumet River (Johnston, 1991).

We first collected three-spine sticklebacks in late May 1996 from Calumet, Burns, and Buffington Harbors as well as the Indiana Harbor Canal. A total of 55 specimens, ranging in total length from 53 to 66 mm, were collected along the breakwalls between May and July 1996. In September 1996, we collected five three-spine sticklebacks from aquatic macrophyte beds along the rock riprap in Washington Park Harbor, Michigan City. In addition, four large adults were collected along the revetment wall during SCUBA surveys in Calumet Harbor during July 1996.

The three-spine stickleback is commonly collected from nearshore shallows and is typically associated with aquatic macrophyte beds. The species may be one of the best-known fishes; an extensive published literature exists accounting for every aspect of the species' life history (Wooton, 1976).

***Morone americana.*** The white perch was originally native to the Atlantic Coast drainage (Burgess, 1980a). The species has dispersed widely through the Mohawk Valley and Erie Canal into Lake Ontario (Scott and Christie, 1963) and is now common in Lake Erie and its interior tributaries, especially the Maumee River (Trautman, 1982; Simon, pers. obs.). Busch, *et al.* (1977) found the first specimens in Lake Erie in 1975. Savitz, *et al.* (1989) found the first specimen taken from Lake Michigan in Belmont Harbor in 1988. By 1990-1991, *M. americana* had dispersed into the upper Illinois River and the Lake Calumet system; in 1992, the species was captured near the mouth of the Illinois River (Burr, *et al.*, 1996). In addition, the collection of 11 adult and juvenile specimens from the Calumet River (RM 328-330) in Cook County, Illinois, from early September to early October 1994 revealed that reproduction had occurred there.

To date, the distribution of the white perch in Indiana has been sporadic. The first record of the species from Indiana waters was a single, 152-mm-TL (Total Length) specimen collected during June 1993 from along a breakwall in Michigan City Harbor in LaPorte County. A second specimen, 174 mm TL, was collected in June 1994 from Calumet Harbor in Lake County. During the fall of

1995, a specimen about 80 mm in length was observed by Indiana Department of Environmental Management personnel in the East Branch of the Grand Calumet River in Lake County during monitoring downstream from Bridge Street (R. Dufour, pers. comm.). A second specimen was observed during a SCUBA survey on 12 October 1996 along the harbor barrier wall (inside the northwest corner) of Washington Park Harbor near Michigan City in LaPorte County (D. Barnes, unpubl. data). This specimen was about 100 mm in length and was observed moving between the rock rip-rap adjacent to the Michigan City beach. A reproducing population occurs in Cedar Lake in Lake County, and a large number of specimens were collected in the northern half of the lake in 1998.

The white perch spawns in shallow water over a variety of bottom types and often increases in numbers despite the presence of other established species (Scott and Crossman, 1973). In addition, the presence of juvenile specimens in moderately disturbed habitats in Indiana, such as the East Branch of the Grand Calumet River, suggests that these individuals may be transients, opportunistically moving into new areas. Marcy and Richards (1974) have shown that young-of-the-year reach lengths of 70 mm by the end of their first year of growth.

***Morone saxatilis***. The striped bass was originally a marine and estuarine native of the Atlantic Coast drainage (Burgess, 1980b). The species has been introduced widely throughout the United States, sometimes as an artificial hybrid with *Morone chrysops* (Hardy, 1978), and is now common in the Ohio River and its interior tributaries, especially the lower Wabash River (Simon, pers. obs.). The species was first introduced into the Pacific Coast in San Francisco estuary in 1879 and 1882 and has since spread to Vancouver Island, British Columbia, and northern Baja California, Mexico (Scofield, 1931; Shebley, 1917, 1927). The early life history stages have been collected from Lake Ontario and from Chesapeake Bay near Havre de Grace, Maryland (Jordan and Eigenmann, 1890; U.S. Commission of Fish and Fisheries, 1889). The species was not previously known from Lake Michigan.

The first record from Indiana waters was two specimens about 75 mm in length which were collected near the breakwall from Bethlehem Steel's discharge into Lake Michigan at the Port of Indiana during June 1998. Two additional specimens, between 800 and 900 mm in length, were collected from the same location in August 1998. Angler reports during the summer suggest that the species has been observed in Lake Michigan as far east as the Bailey Generating Station in Porter County (J. Exl, pers. comm.).

The species spawns in fresh, turbid, shallow (0.3 to 6.1 m) rivers over a wide variety of bottom types with strong currents (Mansueti and Hardy, 1967; Hardy, 1978). Egg survival often depends on currents at least 30 cm/sec so that the eggs remain in suspension and often drift at speeds up to 2.06 km/hr (Neal, 1964). Hybrid striped bass have been stocked into the Calumet River by the State of Illinois (S. Pescatelli, pers. comm.) and are presumably the source of the fish that entered Lake Michigan. Clark (1968) and Raney (1952) suggest that females reach maturity at 432 mm TL and males at 174 mm TL around the end of their third year of life.

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## LITERATURE CITED

Becker, G.C. 1983. Fishes of Wisconsin. Univ. Wisconsin Press, Madison, Wisconsin, 1054 pp.

Brazo, D. 1989. Lake Michigan salmon management study. Indiana Dept. Natur. Res., Div. Fish Wildl., Indianapolis, Indiana, 23 pp.

_____. 1990. Salmon management study. Indiana Dept. Natur. Res., Div. Fish Wildl., Indianapolis, Indiana, 19 pp.

Burgess, G.H. 1980a. *Morone americana* (Gmelin), white perch. *In:* D.S. Lee, C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. (Eds.), *Atlas of North American Freshwater Fishes*, p. 573, North Carolina State Mus. Natur. Hist. Publ. 1980-12, Raleigh, North Carolina, 836 pp.

_____. 1980b. *Morone saxatilis* (Walbaum), striped bass. *In:* D.S. Lee, C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. (Eds.), *Atlas of North American Freshwater Fishes*, p. 576, North Carolina State Mus. Natur. Hist. Publ. 1980-12, Raleigh, North Carolina, 836 pp.

_____ and D.S. Lee. 1980. *Gasterosteus aculeatus* Linnaeus, three-spine stickleback. *In:* D.S. Lee, C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. (Eds.), *Atlas of North American Freshwater Fishes*, p. 563, North Carolina State Mus. Natur. Hist. Publ. 1980-12, Raleigh, North Carolina, 836 pp.

Burkhead, N.M. and J.D. Williams. 1991. An intergeneric hybrid of a native minnow, the golden shiner, and an exotic minnow, the rudd. Trans. Amer. Fish. Soc. 120: 781-795.

Burr, B.M., D.J. Eisenhour, K.M. Cook, C.A. Taylor, G.L. Seegert, R.W. Sauer, and E.R. Atwood. 1996. Nonnative fishes in Illinois waters: What do the records reveal. Trans. Illinois State Acad. Sci. 89: 73-91.

_____ and M.L. Warren, Jr. 1993. Fishes in the Big Muddy River drainage with emphasis on historical changes. *In:* L.W. Hesse, C.B. Stalnaker, N.G. Benson, and J.R. Zuboy (Eds.), *Proceedings of the Symposium on Restoration Planning for the Rivers of the Mississippi River Ecosystem*, pp. 186-209, Nat. Biol. Surv. Biol. Rep. 19, 284 pp.

Busch, W.D.N., D.H. Davies, and S.J. Nepszy. 1977. Establishment of white perch, *Morone americana*, in Lake Erie. J. Fish. Res. Board Can. 34: 1039-1041.

Clark, J. 1968. Seasonal movements of striped bass contingents of Long Island Sound and the New York bight. Trans. Amer. Fish. Soc. 97: 320-343.

Conner, J.V., R.P. Gallagher, and M.F. Chatry. 1980. Larval evidence for natural reproduction of the grass carp (*Ctenopharyngodon idella*) in the lower Mississippi River. U.S. Fish Wildl. Serv., Biol. Serv. Prog. FWS/OBS-80/43: 1-19.

Crossman, E.J., E. Holm, R. Cholmondeley, and K. Tuininga. 1992. First records for Canada of the rudd, *Scardinius erythrophthalmus*, and the round goby, *Neogobius melanostomus*. Can. Field-Natur. 106: 206-209.

Francis, J.T., S.R. Robillard, and J.E. Marsden. 1996. Yellow perch management in Lake Michigan: A multijurisdictional challenge. Fisheries 21(2): 18-20.

Gerking, S.D. 1945. The distribution of fishes in Indiana. Invest. Indiana Lakes Streams 3: 1-137.

_____. 1955. Key to the fishes of Indiana. Invest. Indiana Lakes Streams 4: 49-86.

Hardy, J.D., Jr. 1978. Development of fishes of the mid-Atlantic bight: An atlas of egg, larval, and juvenile stages. Vol. III. Aphredoderidae through Rachycentridae. U.S. Fish Wildl. Serv., Biol Serv. Progr. FWS/OBS-78/12, 394 pp.

Johnston, C.E. 1991. Discovery of the three-spine stickleback (*Gasterosteus aculeatus*) (Pisces: Gasteroskidae) in the Lake Michigan drainage, Illinois. Trans Illinois Acad. Sci. 84: 173-174.

Jordan, D.S. and C.H. Eigenmann. 1890. A review of the genera and species of Serranidae found in the waters of America and Europe. U.S. Comm. Fish. Bull. 8: 329-441.

Jude, D.J., J. Janssen, and G. Crawford. 1995. Ecology, distribution, and impacts of the newly introduced round and tubenose gobies in the biota of the St. Clair and Detroit Rivers. *In:* M. Munawor, T.A. Edsall, and J. Leach (Eds.), *The Lake Huron Ecosystem: Ecology, Fisheries, and Management*, pp. 447-460, SPB Acad. Publ., Ecovision World Monogr. Ser., Amsterdam, The Netherlands, 888 pp.

_____, R.H. Reider, and G.R. Smith. 1992. Establishment of Gobiidae in the Great Lakes Basin. Can. J. Fish. Aquat. Sci. 49: 416-421.

Lin, S.Y. 1935. Life history of the Waan Ue, *Ctenopharyngodon idella* (Cuv. and Val.). Lingnan Sci. J. 14: 129-135, 271-274.

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 I. Natur. Res. Inst., Univ. Maryland, 202 pp.

Marcy, B.C. and F.P. Richards. 1974. Age and growth of the white perch *Morone americana* in the lower Connecticut River. Trans. Amer. Fish. Soc. 103: 117-120.

McComish, T.S., S.M. Shroyer, K.J. Hanauer, and S.W. Shuler. 1994. Characteristics of the near-shore nonsalmonine fish community in Indiana waters of Lake Michigan with emphasis on yellow perch. Indiana Dept. Natur. Res., Div. Fish Wildl., Indianapolis, Indiana, 212 pp.

Meek, S.E. and S.F. Hildebrand. 1910. A synoptic list of the fishes known to occur within fifty miles of Chicago. Field Mus. Natur. Hist. No. 142, Zool. Ser. Publ. 7(9): 223-338.

Miller, P.J. 1986. Gobiidae. *In:* P.J.P. Whitehead, M.L. Bauchot, J.C. Hureau, J. Nielsen, and E. Tortonese (Eds.), *Fishes of the Northeast Atlantic and Mediterranean*, pp. 1019-1095, UNESCO, Paris, France.

Mills, E.L., J.H. Leach, J.T. Carlton, and C.L. Secor. 1993. Exotic species in the Great Lakes: A history of biotic crises and anthropogenic introduction. J. Great Lakes Res. 19: 1-54.

Neal, W.E. 1964. Striped bass study. Virginia's Dingell-Johnson Proj., Job Completion Rep., Fed. Aid Proj.-5-R-9, Warmwater Fish Manage. Invest., Job 8, Comm. Game Inland Fish, Richmond, Virginia, 14 pp.

Page, L.M. and C. Laird. 1993. Exotic fishes in Illinois. Illinois Natur. Hist. Surv. Rep. 324: 3-5.

Pflieger, W.L. 1978. Distribution and status of the grass carp (*Ctenopharyngodon idella*) in Missouri streams. Trans. Amer. Fish. Soc. 107: 113-118.

Raibley, P.T., D. Blodgett, and R.E. Sparks. 1995. Evidence of grass carp (*Ctenopharyngodon idella*) reproduction in the Illinois and Mississippi Rivers. J. Freshwater Ecol. 10: 65-74.

Raney, E.C. 1952. The life history of the striped bass, *Roccus saxatilis* (Walbaum). *In:* E.C. Raney, E.F. Tresselt, E.F. Hollis, V.D. Vladykov, and D.H. Wallace (Eds.), *The Striped Bass, Roccus saxatilis*, pp. 5-97, Bull. Bingham Oceanogr. Collect. Yale Univ. 14, 347 pp.

Robinson, H.W. and T.M. Buchanan. 1988. Fishes of Arkansas. Univ. Arkansas Pr., Fayetteville, Arkansas, 536 pp.

Savitz, J., C. Aiello, and L.G. Bardygula. 1989. The first record of the white perch (*Morone americana*) in Illinois waters of Lake Michigan. Trans. Illinois State Acad. Sci. 82: 57-58.

Scofield, E.C. 1931. The general ecology of *Roccus lineatus*. M.S. Thesis, Leland Stanford Junior Univ., Stanford, California, 73 pp.

Scott, W.B. and W.J. Christie. 1963. The invasion of the lower Great Lakes by the white perch, *Roccus americanus* (Gmelin). J. Fish. Res. Board Can. 20: 1189-1195.

_____ and E.J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184, 966 pp.

Shebley, W.H. 1917. History of the introduction of food and game fishes into the waters of California. Calif. Fish Game 3: 3-12.

_____. 1927. History of fish planting in California. Calif. Fish Game 13: 163-174.

Simon, T.P. 1992. New ichthyofaunal records for the Calumet, Kankakee, and Iroquois drainages of Indiana. Proc. Indiana Acad. Sci. 101: 279-291.

_____ and P.B. Moy. 1996. Status, trends, and potential of fish communities in the Grand Calumet River and Indiana Harbor Canal. U.S. Army Corps Eng., Central Dist., Chicago, Illinois, 32 pp.

_____ and P.M. Stewart. 1999. Structure and function of fish communities in the southern Lake Michigan basin with emphasis on the restoration of native fish communities. Natur. Area J. 19: 142-154.

_____, J.O. Whitaker, Jr., J.S. Castrale, and S.A. Minton. 1992. Checklist of the vertebrates of Indiana. Proc. Indiana Acad. Sci. 101: 95-126.

Smith, C.L. 1985. The inland fishes of New York State. New York State Dept. Environ. Conserv., Albany, New York, 522 pp.

Trautman, M.B. 1982. The fishes of Ohio. Ohio State Univ. Pr., Columbus, Ohio, 782 pp.

U.S. Commission of Fish and Fisheries. 1889. Report of the Commissioner. U.S. Fish Comm. Rep. 14(1889): *ix-lvii.*

Vladimirov, V.I. 1975. Critical periods in the development of fishes. J. Ichthyology 15: 851-868.
Wooton, R.J. 1976. The biology of sticklebacks. Academic Pr., New York, 387 pp.
Zimpfer, S.P., C.F. Bryan, and C.H. Pennington. 1987. Factors associated with the dynamics of grass carp larvae in the lower Mississippi River Valley. Amer. Fish. Soc. Symp. 2: 102-108.