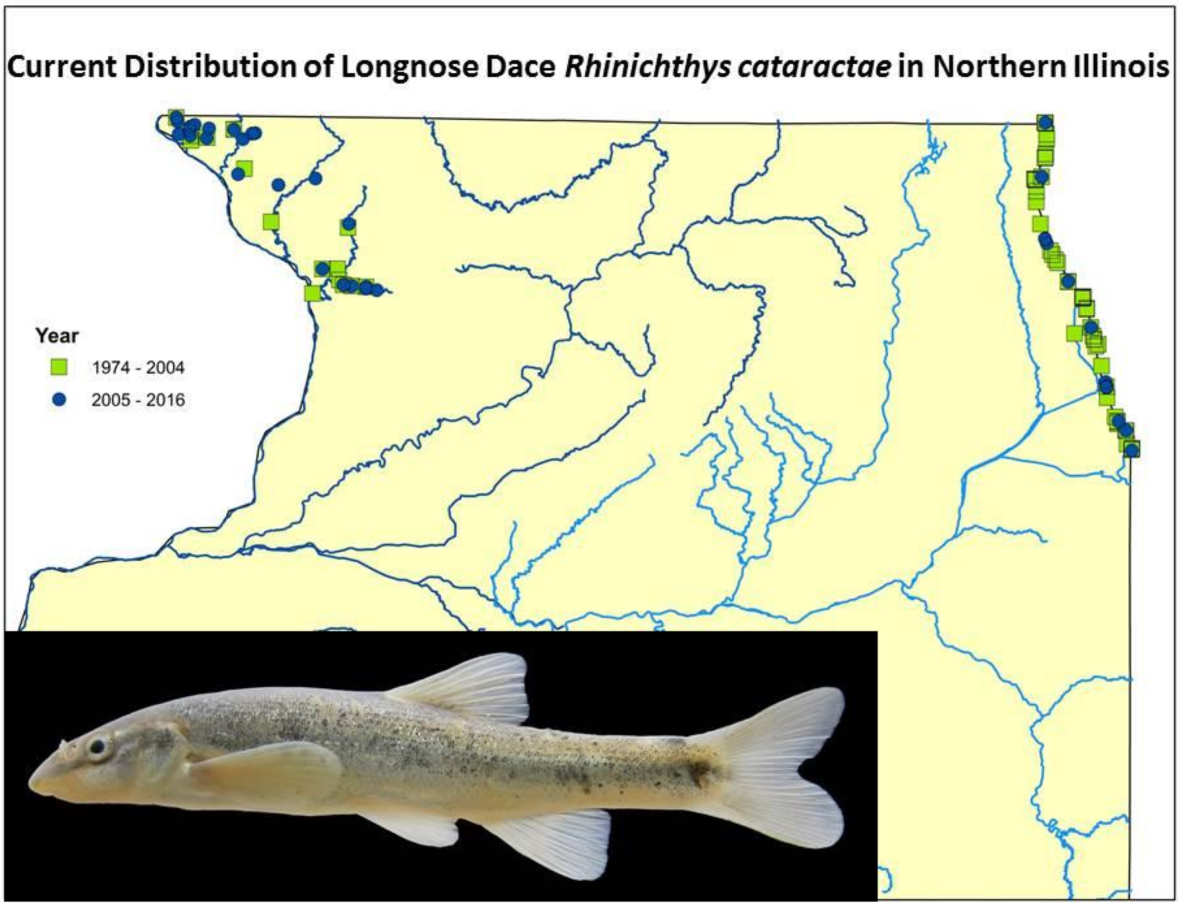
Assessing the Status of Potential Illinois Endangered and Threatened Fish Species

Philip W. Willink
Daniel P. Haerther Center for Conservation and Research
John G. Shedd Aquarium
Chicago, Illinois
March, 2017



Report for United States Fish and Wildlife Service and Illinois Department of Natural Resources
State Wildlife Grant # T-106-R-1
United States Fish and Wildlife Service Grant # F15AF01082

Table of Contents

Overview

The following is an assessment of the status of a dozen species of fishes distributed across northern Illinois. The initial focus was on determining the distribution of the species, followed by attempts to determine the long-term population trends. Sources of data included historical fish reports, museum records, state and federal agency databases, and fieldwork. Because of the variety of sources that are based on a variety of fieldwork methods spread out over 150+ years, there are many caveats and qualifications associated with the results. Regardless of the data sources, compiling this information into one place is one of the first steps in developing any conservation or management plans.

The species were chosen because they were considered data deficient and/or are on the cusp of being considered Threatened or Endangered in the state of Illinois. An emphasis was placed on Lake Michigan, which is arguably the part of Illinois we know the least about from a natural history perspective. But some other fish species distributed across northern Illinois were taken into consideration as well in order to examine the larger biogeographic context of the region.

One anticipated output of this project is to use these results to inform decisions regarding which fish species should be listed as Threatened, Endangered, or neither in the state of Illinois. The Illinois Endangered Species Protection Board is in the process of reviewing current listings. The review of fishes is scheduled to start during the spring of 2017, so the completion of this project is timely and the results will be put to use almost immediately.

Another future output is to use these assessments as the foundation for a series of Species Guidance Documents. These documents are of a particular format being designed by the Illinois Department of Natural Resources to consolidate biological information, analyze threats, and suggest management actions for natural resource professionals (and amateurs). Writing comprehensive Species Guidance Documents from scratch for a dozen species was not possible within the one-year timeframe of this project. This is primarily because of the extensive time it takes to review the natural history literature and develop a comprehensive management plan. Five draft examples are provided to give the readers an idea of how the outputs of this project will be used in the future.

This report is divided into two sections. The first part is a series of distribution maps with text describing the distribution and status of the fishes. The second part includes five examples of draft Species Guidance Documents for select species.

Part I

Distribution and Status of a Dozen Fish Species across Northern Illinois

Banded Killifish

Fundulus diaphanus

In Illinois, Banded Killifish are found in the glacial lakes region of northeastern Illinois, the shoreline of Lake Michigan and associated tributaries, the Calumet Region, the Chicago Area Waterway System, the lower Des Plaines River, the upper Illinois River, and along the northern / central portions of the Mississippi River and lower Rock River (Fig. 1).

In the late 1800s, Banded Killifish were reported in the scientific literature to be most abundant in Lake Michigan, more specifically, at tributary mouths (Nelson 1876, Jordan 1878). But it was also known to be found in smaller numbers from inland lakes and streams across northern Illinois (Nelson 1876, Jordan 1878, Forbes 1884). Most of these localities were found in the Fox, Des Plaines, and Calumet watersheds (Forbes and Richardson 1920). Specific localities included Calumet River (Jordan 1878), Lake Calumet (Forbes and Richardson 1920), Des Plaines River at Libertyville (Meek and Hildebrand 1910), and Wolf Lake (Meek and Hildebrand 1910, Forbes and Richardson 1920).

Jordan (1878) gives one location for *Fundulus menona*, an old name for *Fundulus diaphanus*, as “Rock River; Crystal Lake, McHenry Co.”. Forbes and Richardson (1920) describe this location as “headwaters of the Rock River”. Technically this would be the headwaters of the Kishwaukee watershed that is part of the Rock River. However, Crystal Lake sits on top of the watershed divide between the Kishwaukee River and the Fox River. Without evidence to the contrary, we will assume the single historical record for the Rock basin is accurate. But there is always the possibility the record is off by a couple miles, which would put the record in the headwaters of the Fox River where Banded Killifish are well known.

Forbes and Richardson (1920) also include two records from ponds near Bloomington – Normal. These are the only records from the Sangamon system.

Through most of the 20^{th} Century, Banded Killifish were restricted to two areas. One was the glacial lakes near the Wisconsin border (Retzer and Batten 2005), the Fox Chain-O-Lakes, and a few Field Museum records from 1930s and 1940s for the Dead River. The other area was the Calumet Region, including Wolf Lake and Powder Horn Lake (Greenberg 2002, Retzer and Batten 2005, Willink 2009). Retzer (2005) listed them as extirpated from the Kishwaukee and Salt Creek (Sangamon) watersheds. He also claimed they were extirpated from the Des Plaines watershed, although they were probably still present in some of the glacial lakes within the basin.

Around 2001, Banded Killifish were stable in the glacial lakes region, but also started to become common along the shoreline of Lake Michigan (Table 1, Fig. 2). From 2006-2009, they appeared in the Illinois River near the mouth of the Fox River. It is unclear if this population can trace its origins to Lake Michigan or the headwaters of the Fox River.

From 2010-2011, there was a population increase in the Calumet Region. Banded Killifish were already known from the area, but not in large numbers. Greenfield and Rogner (1984) did not find them in Lake Calumet in 1981-1982, but there were consistent records from Wolf Lake and Powder Horn Lake over the years (Greenberg 2002, Retzer and Batten 2005, Willink 2009). The population in the Illinois River near the mouth of the Fox River was maintaining itself and even spreading downstream. There was also a translocation experiment by the Forest Preserve District of DuPage County into the DuPage River that does not appear to have succeeded.

By 2012-2013, Banded Killifish were in the glacial lakes, common along the shoreline of Lake Michigan, and had spread through the Calumet Region into the Chicago Area Waterway System all the way to the upper Illinois River. Many of these new records were a byproduct of increased sampling to monitor Asian Carp (e.g., Illinois Department of Natural Resources – Aquatic Nuisance Species Program). The increase in distribution is not solely an artifact of increased sampling. The fishes of Will County, including the portion of the Des Plaines River within the county, were recently assessed using historical records and fieldwork (Willink and Veraldi 2009). As of 2007, there was not a single Banded Killifish record within Will County. It is possible they were present in low numbers, and surveys missed them. But when the identical sites are visited today, Banded Killifish are common (personal observation, P.W. Willink 2017).

Banded Killifish were recorded for the first time in the Illinois portion of the Mississippi in 2007. (First record was technically Davenport, Iowa. Personal communication John Olson, Ben Hucka, and Jerad Stricker (Iowa Department of Natural Resources)). From 2012-2015, they continued their spread south down the Mississippi and moderately up the Rock River (Rivera et al. 2013, Tiemann et al. 2015, Hrabik 2016, Lamer et al. 2016, Schmidt 2016).

In summary, Banded Killifish are stable in the glacial lakes region, although they may be declining in the Fox Chain-O-Lakes proper. Over the past couple decades, they have become much more common along the shoreline of Lake Michigan, spread into the Calumet watershed (where they have been known to exist in low numbers for the past century), down the Chicago Area Waterway System, along the lower Des Plaines River, and then into the upper Illinois River. More recently they have also been spreading south along the Mississippi.

Globally, Banded Killifish are distributed from the Dakotas east through the Great Lakes and down the St. Lawrence Seaway. Along the east coast, they range from North Carolina northward to Nova Scotia (Page and Burr 2011).

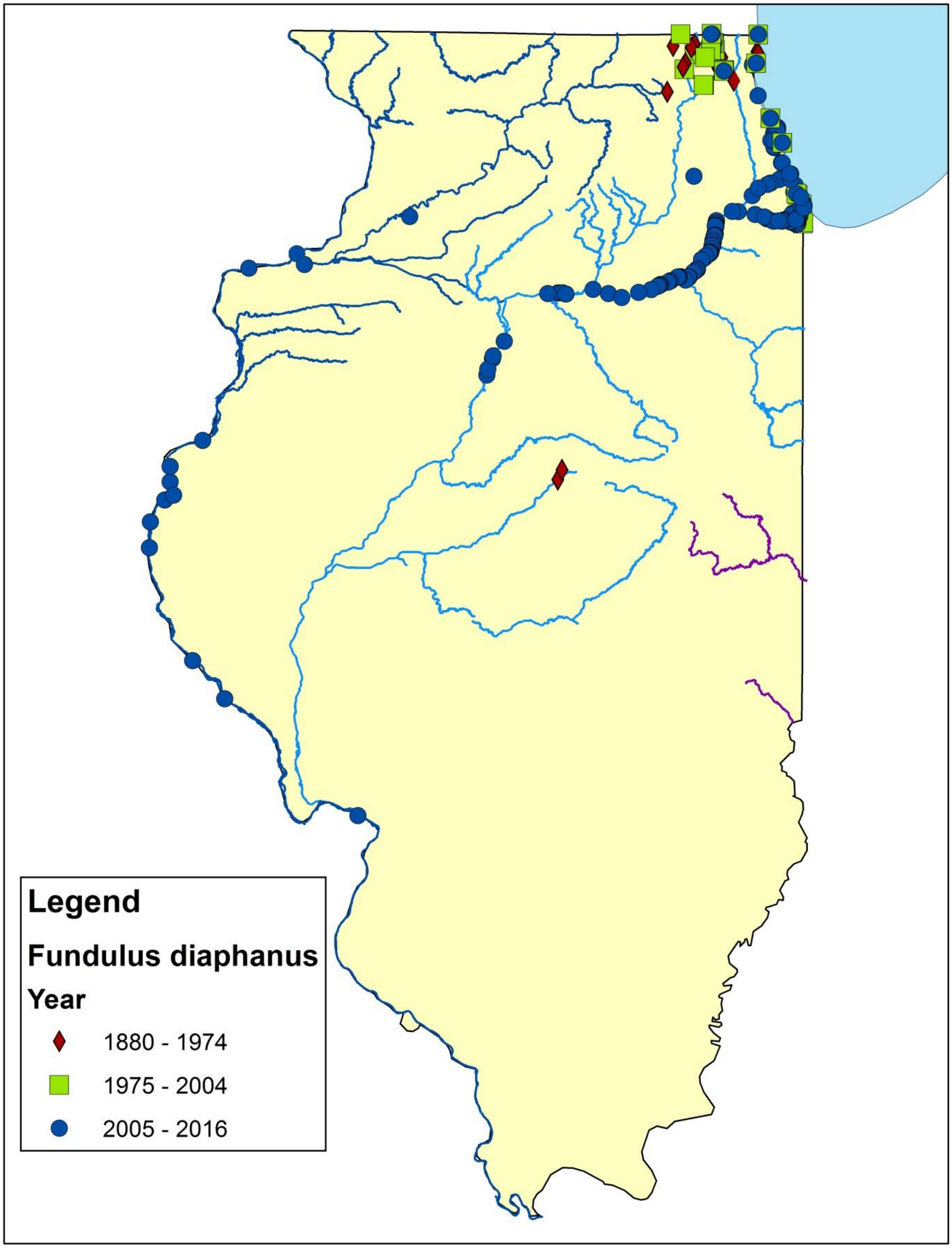


Figure 1. Historical and current distribution of Banded Killifish *Fundulus diaphanus* in Illinois.

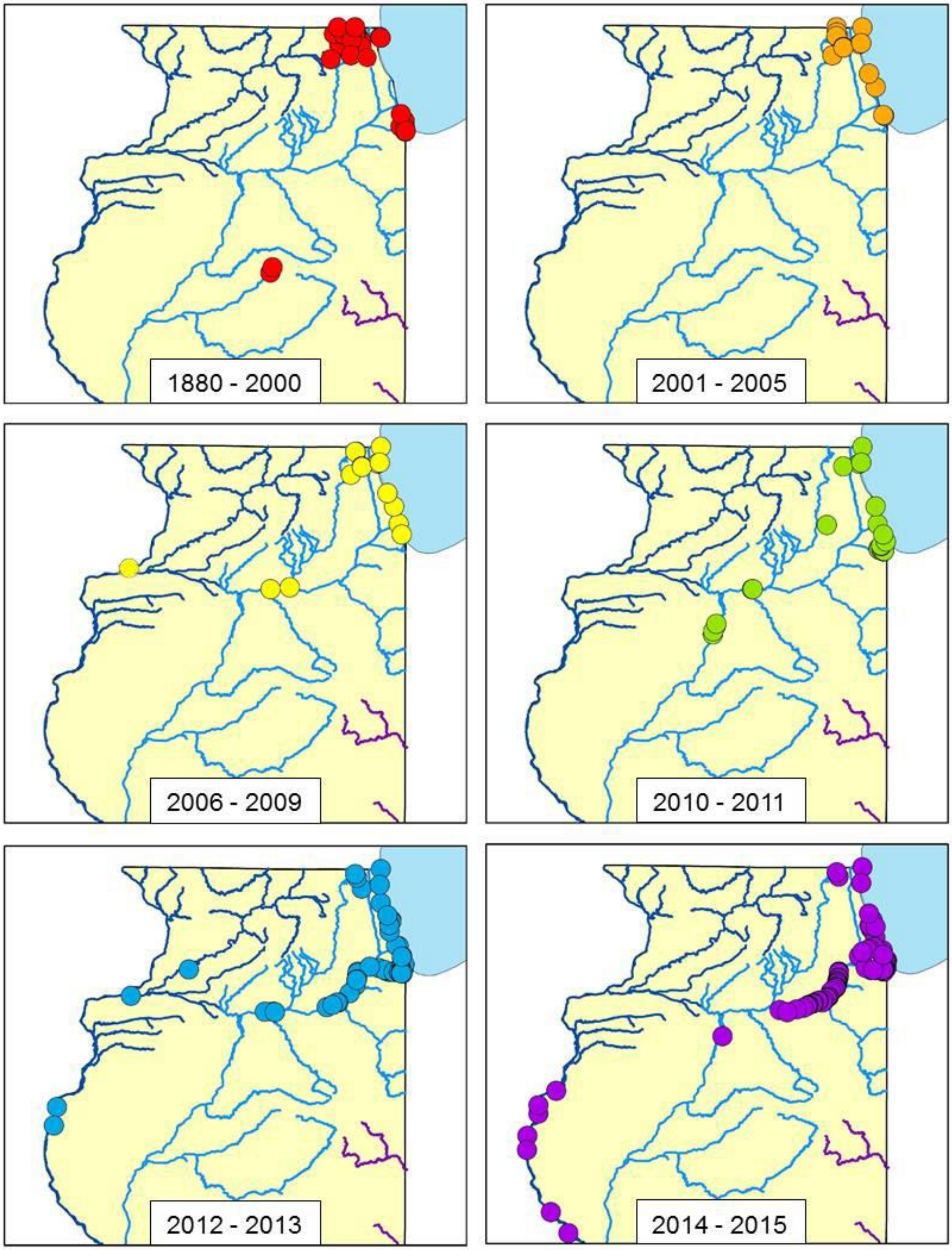


Figure 2. Distribution of Banded Killifish *Fundulus diaphanus* in Illinois divided into six time periods. The intent of the different periods is to show the changes in distribution over time.

Table 1. Relative abundance (mean number of fish/seine haul) of **Banded Killifish** *Fundulus diaphanus* over 37 years of beach seine sampling at five locations along the Lake Michigan shoreline in Illinois, 1979-2016. The number of seine hauls is in parentheses. NS indicates no sample. IDNR unpublished data.

	Location					
Year	Farwell Ave (205)	Jackson Outer (220)	North Point (179)	Tower Road (206)	Waukegan (224)	All Locations (1,034)
1979	NS	0	NS	NS	NS	0
1980	NS	NS	NS	NS	NS	NS
1981	0	0	NS	NS	NS	0
1982	0	0	NS	NS	NS	0
1983	0	0	NS	NS	NS	0
1984	0	0	NS	NS	NS	0
1985	NS	NS	NS	NS	0	0
1986	0	0	NS	0	0	0
1987	0	0	NS	0	0	0
1988	0	0	NS	0	0	0
1989	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1992	NS	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	0	0	0	0	0	0
1999	0	0	0	0	0	0
2000	0	0	0	0	0	0
2001	0.3	0	0	0.1	0.5	0.2
2002	0.6	0.3	0.9	0.1	0.9	0.5
2003	1.0	0	0	0.7	0	0.3
2004	0.2	0.6	0	0	0.1	0.2
2005	1.0	0.4	0.4	2.0	4.3	1.7
2006	0.1	1.4	0.3	0	0.3	0.4
2007	0.1	0.1	1.4	0.1	1.4	0.6
2008	0	0.5	0.7	0.3	0	0.3
2009	0.1	1.7	0	0	0.6	0.4
2010	1.5	0.5	0	0	2.5	0.9
2011	0	0	1.8	0	0.3	0.4
2012	0	0	0.8	0.2	5.4	1.3
2013	0	0.7	0	0	3.3	0.8
2014	0.1	2.8	0	0	14.9	3.6
2015	0.1	4.5	1.4	0.3	3.4	1.8
2016	2.7	3.1	0.5	0.2	7.1	2.8
All Years	0.3	0.6	0.3	0.1	1.7	0.6

Bloater
Coregonus hoyi

In Illinois, Bloater are only found in Lake Michigan, from the shoreline to the deepest portions of the lake. They tend to be concentrated between depths of 15 to 120 meters. The Illinois distribution map (Fig. 3) shows them clustered along the northern state line, but this is an artifact of where deep water sampling has been done effectively. They are probably more widespread than what is indicated, with their distribution following the Lake Michigan depth contours.

Sometimes they are seined up in waters less than waist deep (Table 2, P.W. Willink personal observation). These occurrences are sporadic, and probably have more to do with upwellings and storms, or random movements of stray individuals.

Historically, catching Bloater in deep water was not unusual in the late 1800s (Nelson 1876, Jordan 1878, Meek and Hildebrand 1910). But because very few people made the effort to do this, they only occasionally made their way to fish markets (Jordan 1878), and very little was known about them. In time a significant commercial fishery was developed, but exact catch locations were not recorded. Very few specimens were vouchered in museum collections. It was not until the late 1960s when the United States Geological Survey began annual bottom trawls that scientific data on Bloater started to be routinely recorded (Bunnell et al. 2015).

At this time, their range is assumed to be comparable to what it was in the past.

It is possible to get an indirect indication of population abundances over time. As the fishery for the larger Lake Whitefish *Coregonus clupeaformis* and Lake Herring *Coregonus artedi* declined in southern Lake Michigan in the late 1800s and early 1900s (Milner 1874, Eshenroder et al. 1995), attention shifted to the smaller but relatively more abundant Bloater. Exact statistics are difficult to determine because Bloater and a couple other less common coregonid species were lumped together as ‘deepwater ciscoes’ or ‘chubs’ in catch data. But in general the commercial Bloater fishery increased until the 1950s, at which point it declined to zero in 2001 (Baldwin et al. 2009). Part of this increase in bloater numbers was probably due to the overfishing of other coregonids, but another aspect is the collapse of the Lake Trout fishery and a shifting of effort to whatever was left in Lake Michigan (Smith 1968). Technically there is still a commercial fishery for Bloater in Illinois, but no one is actively fishing at this time.

There has been an effort by the United States Geological Survey to evaluate the density of Bloater throughout all of Lake Michigan since 1973. According to their bottom trawl results, adult Bloater numbers were low in the 1970s, but rose significantly during the 1980s and 1990s. Population numbers plummeted around 1999 and have continued to decline ever since (Bunnell et al. 2015). Midwater trawl and acoustic surveys since the 1990s found similar results (Warner et al. 2015).

Along the Illinois shoreline over the past decade, they have been caught more frequently in beach seines (e.g., Table 2). But it is still uncommon to find them that close to shore. It is unclear if this increased frequency is a meaningful trend.

Globally, the distribution of Bloater is restricted to the Great Lakes (Page and Burr 2011).

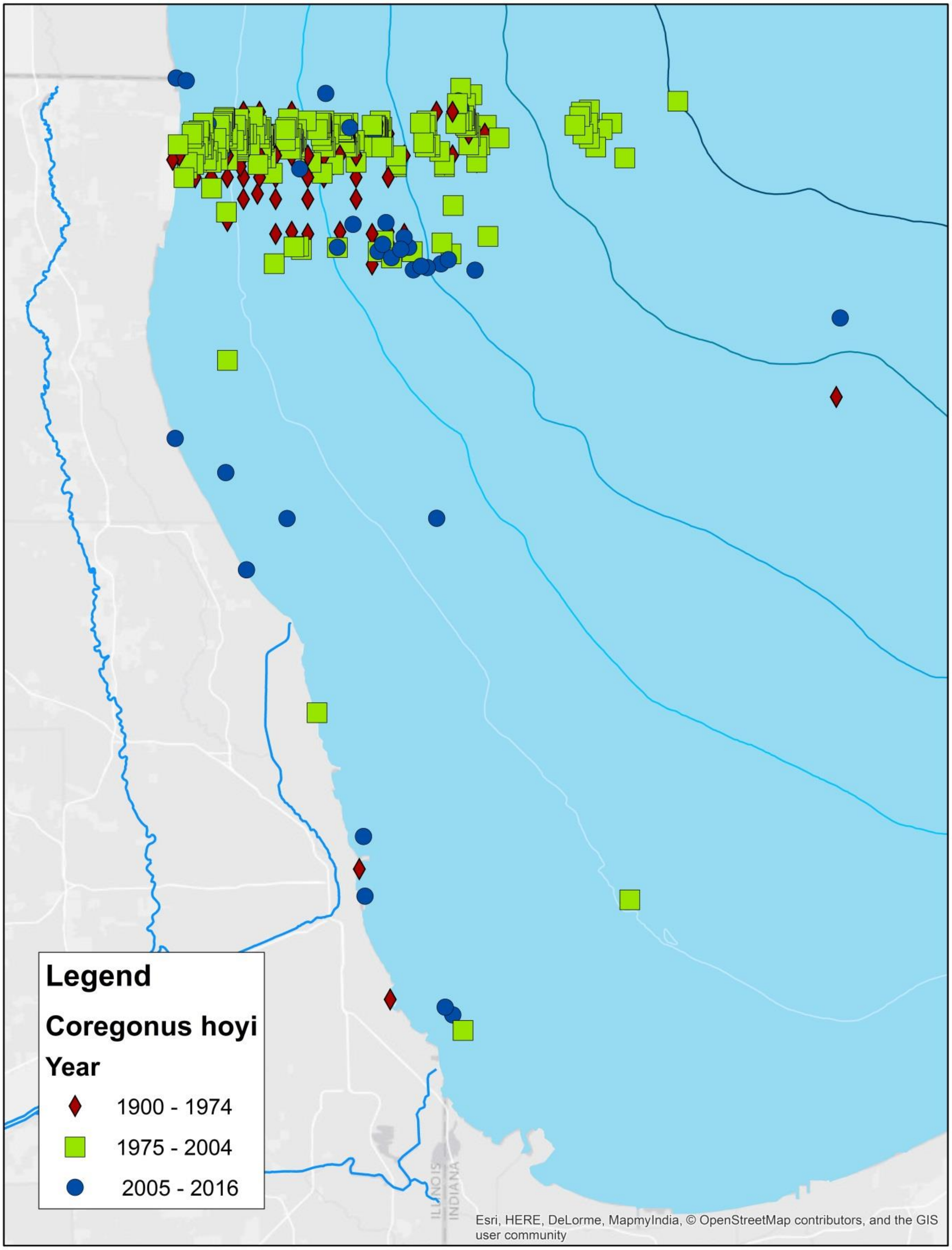


Figure 3. Historical and current distribution of Bloater *Coregonus hoyi* in Illinois. Lake Michigan contour lines are 25 meters.

Table 2. Relative abundance (mean number of fish/seine haul) of **Bloater** *Coregonus hoyi* over 37 years of beach seine sampling at five locations along the Lake Michigan shoreline in Illinois, 1979-2016. The number of seine hauls is in parentheses. NS indicates no sample. IDNR unpublished data.

	Location					
Year	Farwell Ave (205)	Jackson Outer (220)	North Point (179)	Tower Road (206)	Waukegan (224)	All Locations (1,034)
1979	NS	0.0	NS	NS	NS	0
1980	NS	NS	NS	NS	NS	NS
1981	0	0	NS	NS	NS	0
1982	1.0	0	NS	NS	NS	0.7
1983	0	0	NS	NS	NS	0
1984	0	0	NS	NS	NS	0
1985	NS	NS	NS	NS	0	0
1986	0	0	NS	0	0	0
1987	0	0	NS	0	0	0
1988	0	0	NS	0	0	0
1989	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1992	NS	0	0	NS	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	0	0	0	0	0	0
1999	0.1	0	0	0	0	<0.1
2000	0	0	0	0	0	0
2001	0	0	0	0	0	0
2002	0	0	0	0	0	0
2003	0	0	0	0	0	0
2004	0	0	0	0	0	0
2005	0	0	0.1	0	0	<0.1
2006	0	0	0	0	0	0
2007	0	0	0	0.3	0	0.1
2008	0	0	0	0	0	0
2009	0	0	0.1	0	0	<0.1
2010	0	0	0.2	0	0	<0.1
2011	0	0	0	0	0	0
2012	0	0	0	0	0	0
2013	0	0	0	0	0	0
2014	0	0	0.9	0.1	0	0.2
2015	0	0	0.1	0	0	<0.1
2016	0	0	0	0	0	0
All Years	<0.1	0	0.1	<0.1	0	<0.1

Deepwater Sculpin
Myoxocephalus thompsonii

In Illinois, Deepwater Sculpin are only found in the deep waters of Lake Michigan. Locality records have depths ranging from 15 to 128 meters. The Illinois distribution map (Fig. 4) shows them clustered along the northern state line, but this is an artifact of where deep water sampling has been done effectively. They are probably more widespread than what is indicated, with their distribution following the Lake Michigan depth contours.

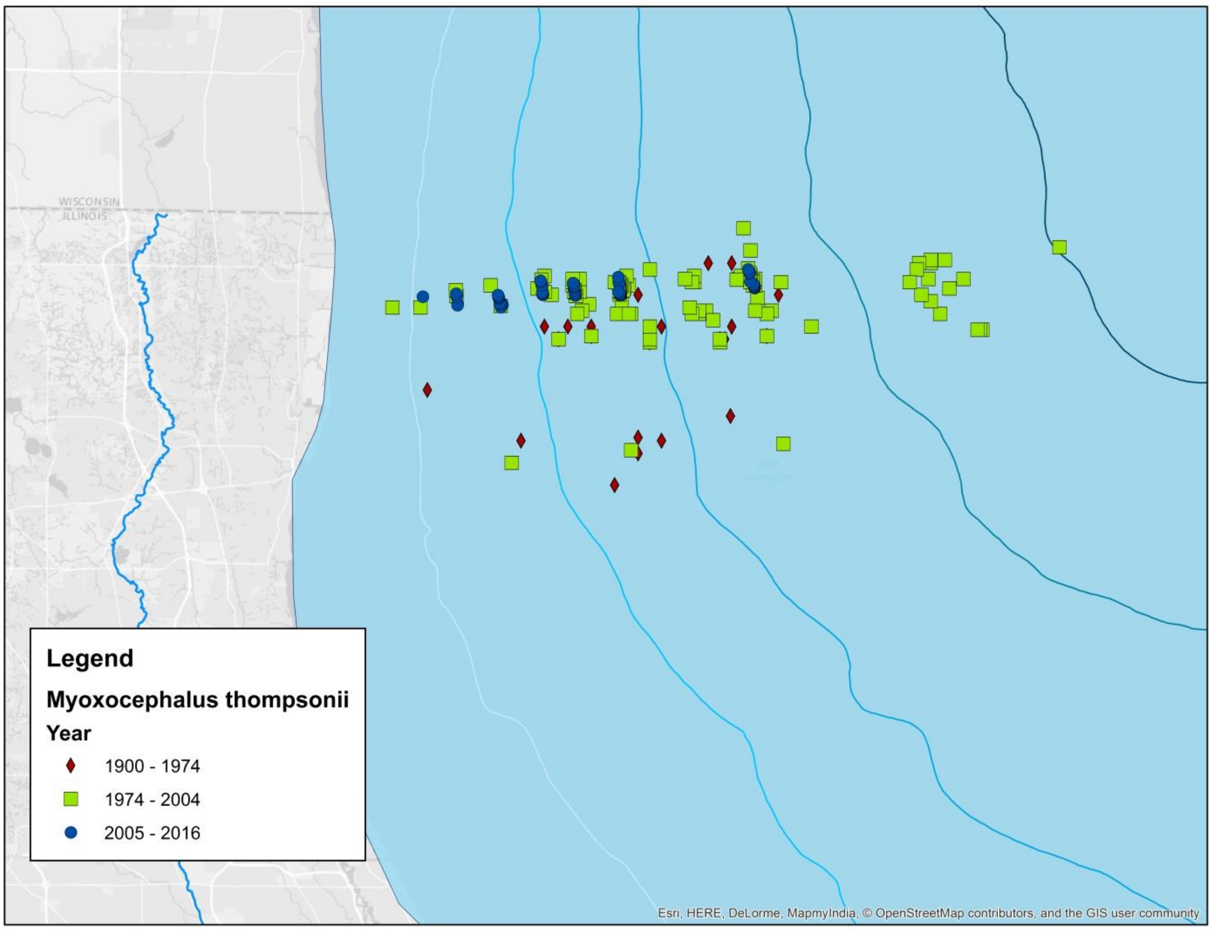


Figure 4. Historical and current distribution of Deepwater Sculpin *Myoxocephalus thompsonii* in Illinois. Lake Michigan contour lines are 25 meters.

Historically, people have known since the 1800s that Deepwater Sculpin were living along the bottom of the deepest parts of Lake Michigan (Hoy 1872, Milner 1874, Nelson 1876, Jordan 1878). Initial records were based almost completely on finding them in the guts of predatory fishes, like Lake Trout and Burbot, which were caught in deep waters (Hoy 1872, Milner 1874, Van Oosten and Deason 1938, Deason 1939). Over time, a handful of specimens were collected in nets and vouchered in museum collections. This paucity of records is largely due to the difficulty of surveying deep water habitats. It was not until the late 1960s when the United States Geological Survey began annual bottom trawls that Deepwater Sculpin started to be found routinely.

At this time, their range is assumed to be comparable to what it was in the past.

It is difficult to assess population abundances over time due to the paucity of historical data. But there has been an effort by the United States Geological Survey to evaluate the density of Deepwater Sculpin throughout all of Lake Michigan since 1973. According to their results, Deepwater Sculpin numbers were low in the early 1970s, but increased significantly until the 1980s. Population numbers dropped around 1989, but remained moderate until around 2007. Since then, the population has continually declined (Bunnell et al. 2015). These results are based on standardized bottom trawls at set locations and depths. It is possible that Deepwater Sculpin are moving to even deeper water, hence the standard surveys may be missing many of them, and the apparent population decline is not as dramatic as initially thought (Bunnell et al. 2015).

Globally, Deepwater Sculpin are found throughout the Great Lakes, as well as some deeper lakes in Quebec, Ontario, Manitoba, Saskatchewan, and Northwest Territories (Scott and Crossman 1973, Page and Burr 2011).

Lake Chub
Couesius plumbeus

In Illinois, Lake Chub are only known from the nearshore zone of Lake Michigan (Fig. 5). Most records are close to shore in less than a few feet of water, but they have been found several miles offshore at depths of around 50 feet (INHS 87576).

Historically, there are about a dozen museum records since the late 1800s. There are mentions of them in the literature (e.g., Jordan 1878, Forbes 1884), but these references usually just say they live in Lake Michigan, and little else. Forbes and Richardson (1920) do not even include Lake Chub in their account of Illinois fishes. This species was certainly present over the past couple centuries, but in modest numbers, and was probably overlooked as well (Smith 1979).

Standardized beach seine surveys by Illinois Department of Natural Resources – Lake Michigan Program from 1979 to 2016 did not record Lake Chub until 1994 (Table 3, Figure 6). Present day, they are never found in large numbers, but are consistently found from year-to-year. Over the long term, it appears that their numbers may have actually increased slightly since we are now finding them consistently. Figure 6 may show a recent decrease in abundance over the past decade, but more data are needed to clarify any trends. For now, their status is considered stable.

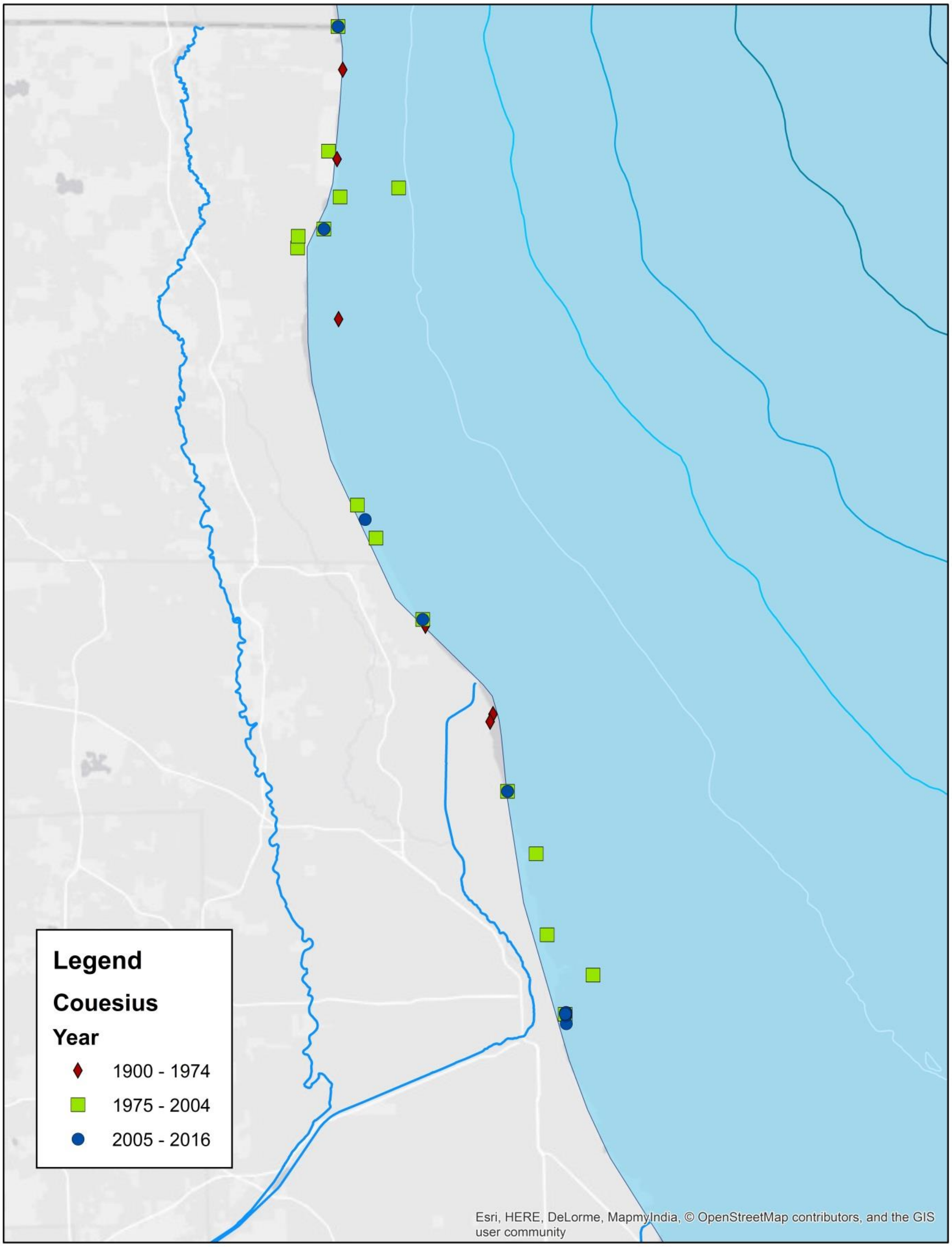
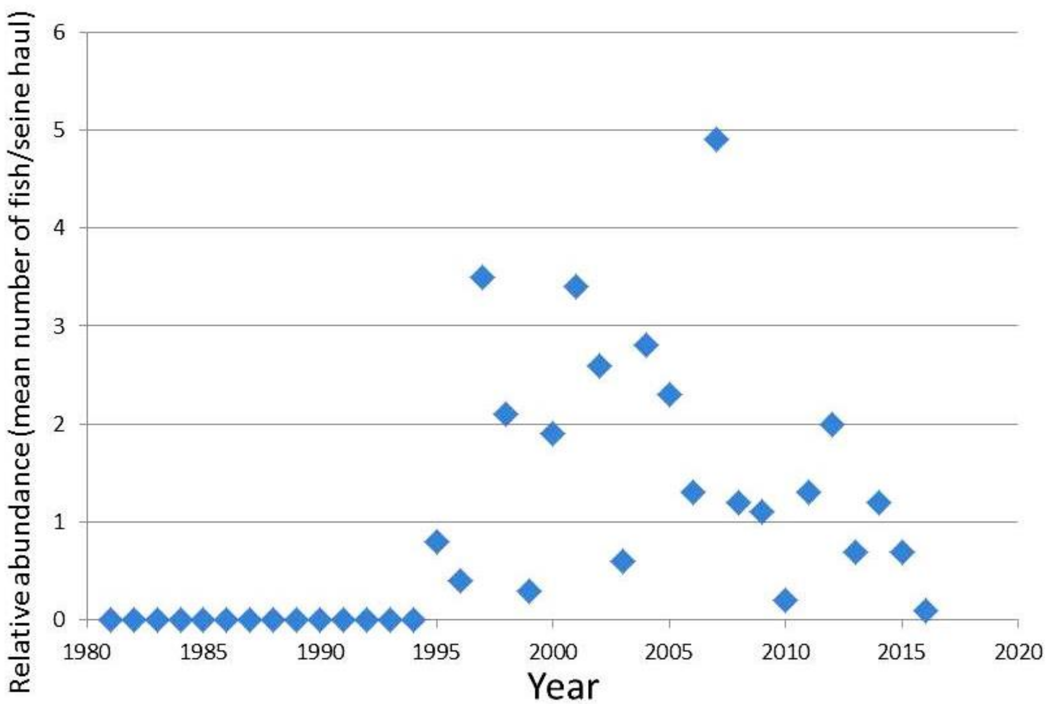


Figure 5. Historical and current distribution of Lake Chub *Couesius plumbeus* in Illinois. Lake Michigan contour lines are 25 meters.

Table 3. Relative abundance (mean number of fish/seine haul) of **Lake Chub** *Couesius plumbeus* over 38 years of beach seine sampling at five locations along the Lake Michigan shoreline in Illinois, 1979-2016. The number of seine hauls is in parentheses. NS indicates no sample. IDNR unpublished data.

	Location					
Year	Farwell Ave (205)	Jackson Outer (220)	North Point (179)	Tower Road (206)	Waukegan (224)	All Locations (1,034)
1979	NS	0	NS	NS	NS	0
1980	NS	NS	NS	NS	NS	NS
1981	0	0	NS	NS	NS	0
1982	0	0	NS	NS	NS	0
1983	0	0	NS	NS	NS	0
1984	0	0	NS	NS	NS	0
1985	NS	NS	NS	NS	0	0
1986	0	0	NS	0	0	0
1987	0	0	NS	0	0	0
1988	0	0	NS	0	0	0
1989	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1992	NS	0	0	NS	0	0
1993	0.0	0	0	0	0	0
1994	0.0	0	0	0	0	0
1995	3.7	0	0	0.7	0.2	0.8
1996	0.8	0	0	1.3	0	0.4
1997	12.1	0	0	4.6	0.7	3.5
1998	10.3	0	0.3	0.6	0.1	2.1
1999	1.1	0	0	0.3	0	0.3
2000	8.4	0	0	0	0.1	1.9
2001	6.7	0	4.5	5.1	2.0	3.4
2002	8.0	0	0.7	1.3	2.8	2.6
2003	3.5	0	0	0	0	0.6
2004	7.4	0	0	1.3	7.9	2.8
2005	10.6	0	0.3	2.4	0	2.3
2006	4.4	0	0.1	1.8	0.2	1.3
2007	19.7	0	0	1.1	0	4.9
2008	5.3	0	0	0	0	1.2
2009	5.0	0	0	0	0	1.1
2010	0.7	0	0	0.2	0	0.2
2011	0	0	0	1.4	5.3	1.3
2012	0	0	0	0	9.6	2.0
2013	3.2	0	0	0.1	0	0.7
2014	5.0	0	0	0.6	0.1	1.2
2015	2.9	0	0	0	0	0.7
2016	0.1	0	0.3	0	0	0.1
All Years	4.8	0	0.1	1.0	0.9	1.3

Figure 6. Relative abundance of Lake Chub from 1981 to 2016. Combined data from Lake Michigan beach seine surveys at Farwell Avenue, Jackson Outer Harbor, North Point, Tower Road, and Waukegan. IDNR unpublished data.



Globally, Lake Chub are distributed from eastern Alaska, across almost all of Canada excluding the far northern islands, the Great Lakes, much of New England and northern New York, and dipping down into parts of Montana, Wyoming, and other nearby states. It is the northernmost distributed minnow (family Cyprinidae) in North America (Page and Burr 2011).
The southernmost populations in the western United States are disjunct and considered to be glacial relicts (Bestgen et al. 1991, Stasiak 2006).

Lake Sturgeon (Lake Michigan population only)
Acipenser fulvescens

There are no known museum voucher specimens for Lake Sturgeon from the Illinois portion of Lake Michigan. This is mostly because it is difficult to preserve and maintain large specimens, so people rarely make the effort to do so. But because they are so large and distinctive, they are prominently mentioned in published reports whenever they are present.

Lake Sturgeon are included in the first published list of animals from the Chicago Region, where it is noted that they live in Lake Michigan at Chicago (Kennicott 1855). Other naturalists subsequently reported the same results (Forbes 1884), adding that they are numerous in Lake Michigan (Nelson 1876, Jordan 1878, Meek and Hildebrand 1910) (Fig. 7). Milner (1874) went on to say the population of Lake Sturgeon in southern Lake Michigan was on par with populations in Green Bay (Lake Michigan), the western end of Lake Erie, and Chaquamegon Bay (Lake Superior). In other words, he considered it one of the most significant populations in the Great Lakes.

Lake Sturgeon were also known to leave Lake Michigan and swim up the Calumet River, some as far as 18 miles (Nelson 1876, 1878). They were also found in Lake Calumet, where they were said to be "quite common" (Nelson 1878).

For many years, Lake Sturgeon were unpopular. They were not considered a valuable food fish. When they did get tangled in nets, fishermen often just killed them and threw them away (Forbes and Richardson 1920) or buried them in the sand (Meek and Hildebrand 1910). But opinions changed over time, and a fishery developed. In 1872, active fishing was reported in Waukegan and Calumet in Illinois with at least 25,147 pounds being handled in Chicago (Milner 1874). One Chicago retailer, and possibly more, was interested in smoked sturgeon, and was willing to pay well for the product because they had more requests for this meat than they could supply. Despite this interest in smoked sturgeon, most fishermen simply sold their catch fresh because it is a fair bit of work to smoke a large sturgeon (Milner 1874).

Pound nets were set in Chicago Harbor at a depth of 20-24 feet, but sturgeon were not numerous here. For example, only a dozen were caught in the spring of 1875. Several miles north of downtown Chicago, in the Lakeview neighborhood, many were caught while seining in the spring and fall. In South Chicago, sturgeon were considered "very abundant", with 8,000 pounds of dressed fish taken (Nelson 1878). In general, sturgeon were more common away from river mouths, instead being found along uninterrupted lengths of shore (Nelson 1878).

In Indiana, heading east from the Calumet River for a dozen miles or so, Lake Sturgeon were common in 26-31 feet of water (Nelson 1878). Meek and Hildebrand (1910) indirectly commented on the relative abundance of sturgeon in nearshore Indiana by citing only one sturgeon locality in Illinois (Lake Michigan, Chicago), but three different localities in Indiana.

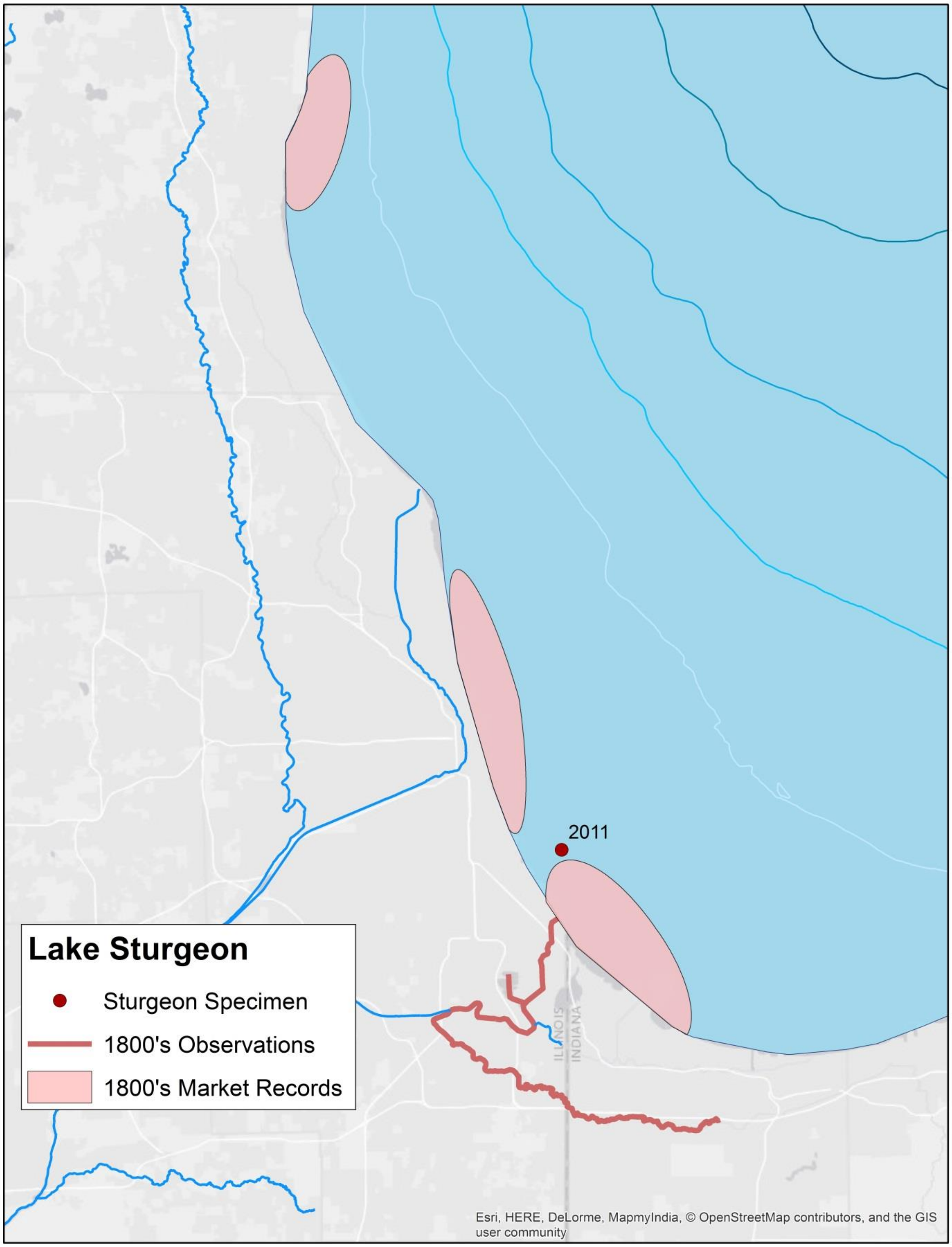


Figure 7. Historical and current distribution of Lake Sturgeon *Acipenser fulvescens* in the Illinois portion of Lake Michigan and tributaries. Lake Michigan contour lines are 25 meters.

In 1885, the combined catch of Waukegan, Chicago, and South Chicago was 101,362 pounds. But by now the fishery was being overexploited. In 1899, no sturgeon were reported in the fishery data (Forbes and Richardson 1920). Sturgeon were still around during the first decade of the 1900s, but very rare. When one was caught, it could fetch a price twice that of any other fish in Lake Michigan (Meek and Hildebrand 1910).

For many decades, there were no apparent records for Lake Sturgeon in the Lake Michigan portion of Illinois in the scientific literature. A fisherman did catch one in 2000 on the Illinois side of Wolf Lake (Tetra Tech 2002, Bowman 2011). However, the specimen was previously tagged in central Wisconsin, and there are doubts regarding the likelihood that it swam all the way to Wolf Lake on its own (Willink 2009). So this record is usually considered invalid.

There is an authenticated record from a water intake pipe in Chicago in the fall of 2011. And every year or so one is reported from Indiana (Bowman 2011).

Lake Sturgeon are still present in the Illinois portion of Lake Michigan, but are very rare. There is no evidence for spawning. Individuals that are found may simply be passing through from one section of Lake Michigan to another.

Longnose Dace
Rhinichthys cataractae

In Illinois, Longnose Dace are currently restricted to Lake Michigan in the northeastern corner of the state and several Mississippi tributaries in the northwestern corner of the state, notably the Menominee, Little Menominee, Sinsinawa, Plum, and Galena watersheds (Fig. 8). The largest population is in Lake Michigan, where they are common (Smith 1979) and can be found during just about every beach survey. Populations in the Mississippi tributaries are smaller and more localized (Tiemann et al. 2009).

There are three records from southern Illinois, all dating to 1873 to 1900, and all based on Illinois Natural History Survey specimens (INHS 84234, 84998, and 86432). Forbes and Richardson (1920) stated that they only had specimens from two localities in Illinois, Big Creek near the town of Anna in Union County (INHS 86432) and Waukegan (which is along Lake Michigan). They went on to say that the species prefers clear, cold streams, and that was the reason it was rare in Illinois. It is unclear why they overlooked the other two localities. Smith (1979) also stated that Longnose Dace were present in southern Illinois, citing the INHS Forbes and Richardson record, but is now extirpated.

To further confuse matters, there have been reported records for Longnose Dace in the Cumberland drainage of Tennessee and Kentucky (e.g., Gilbert (1980) in Atlas of North American Freshwater Fishes). However, oftentimes there are no voucher specimens. There is also a form of Blacknose Dace with long snouts in the region, so misidentifications are common

(Etnier and Starnes 1993). Etnier and Starnes (1993) only recognize Longnose Dace from eastern Tennessee. Clay (1975) did not recognize Longnose Dace from Kentucky.

Examination of specimen INHS 84234 collected in 1873 from the Ohio River near Cairo verified that it is a Longnose Dace based on length of snout, pale spot at base of dorsal fin just posterior of dorsal fin origin, and pale spot at dorsal junction of caudal peduncle and tail (P.W. Willink, personal observation). The identification of the two specimens in jar INHS 86432 collected in 1892 from Big Creek near the town of Anna in Union County is questionable, and these may very well be Blacknose Dace with long 'noses'.

The Longnose Dace record from the Ohio River near Cairo is interesting because the next nearest populations (that we are currently aware of) are over 300 miles away in any direction. It could be a remnant of a relict population dating back to the last glacial period. Or it could be a stray washed down the Ohio River from populations in West Virginia or Pennsylvania. We will probably never know with certainty. Regardless, Longnose Dace do not appear to be present in southern Illinois at this time.

Historically, Longnose Dace have been reported from Lake Michigan since the late 1800s (Nelson 1876, Jordan 1878). For whatever reason, these references highlight their living in clear water tributaries of Lake Michigan, but make no mention of them being found along beaches or other shoreline habitats. Meek and Hildebrand (1910) include them in their list of Chicago Region fishes, but do not give any specific localities. Forbes and Richardson (1920) were only aware of one record in Lake Michigan, and continued the story that Longnose Dace prefer clear, cold streams, and that is why it was rare in Illinois.

The oldest museum records are 1931 and 1939 in Lake Michigan. The oldest museum record for the Mississippi tributaries is 1960. From the 1960s on there is a semi-consistent series of records from both regions.

Data from the Illinois Department of Natural Resources – Lake Michigan Program shows a lot of up and down in regards to Longnose Dace numbers in standardized beach seine sampling from 1979-2016. More often than not, Longnose Dace are present if the appropriate habitat is available (Table 4). Numbers are relatively stable, with a few years where they are particularly abundant (Figure 9). These years with higher abundances could be due to randomly catching large schools of fish.

Excluding the extirpated southern Illinois population, Longnose Dace appear to be stable at this time in Illinois.

Globally, Longnose Dace have a massive distribution. In Canada, they extend from the border between Yukon and Northwest Territory along almost the entirety of the southern provinces to western Newfoundland. In the western United States, they are found in Washington, Oregon, Idaho, Montana, both Dakotas, Nebraska, Colorado, New Mexico, and along the Texas-Mexico border. They are also in the upper Mississippi drainage, throughout the Great Lakes and along the Appalachian Mountain chain from New Hampshire to Georgia (Page and Burr 2011).

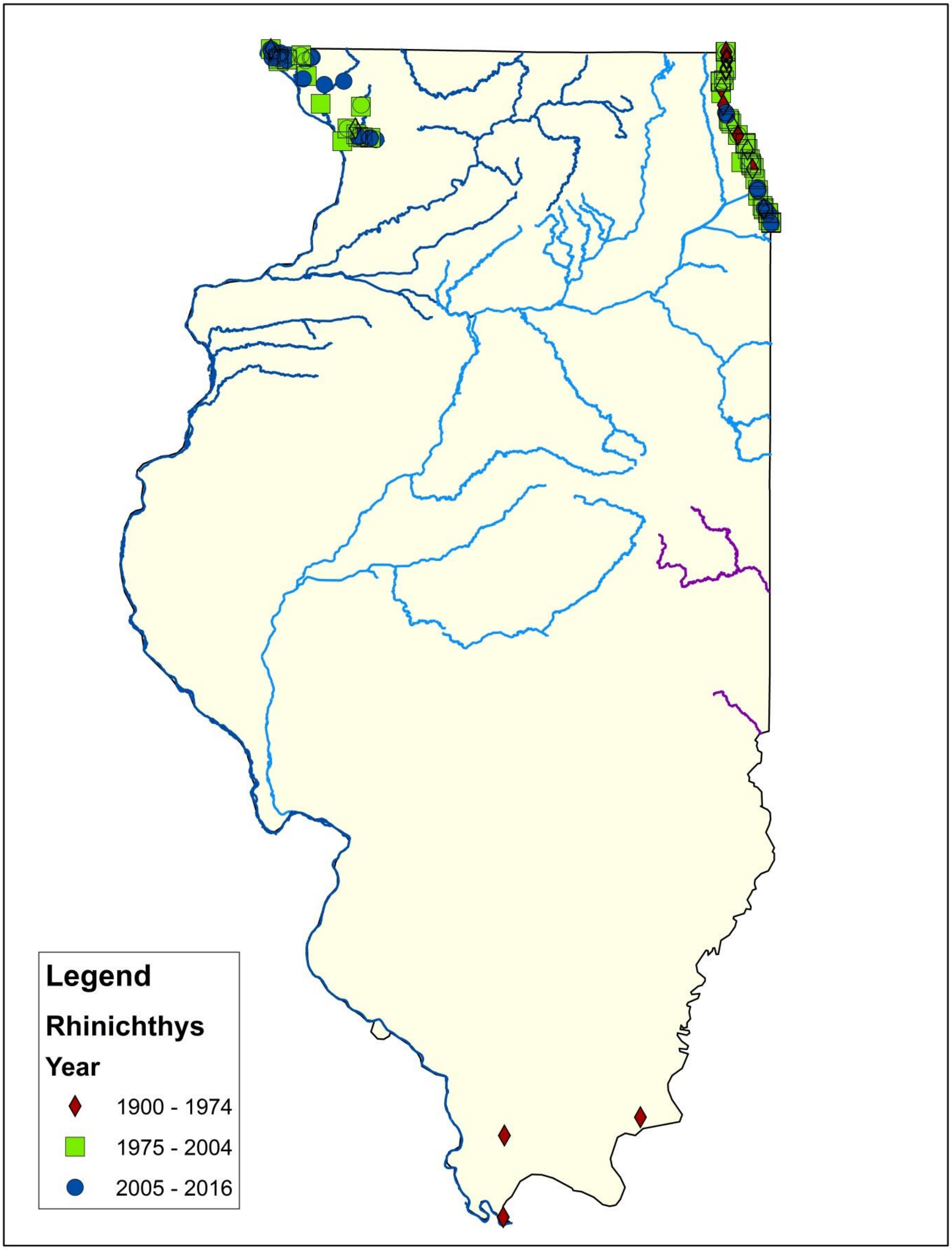
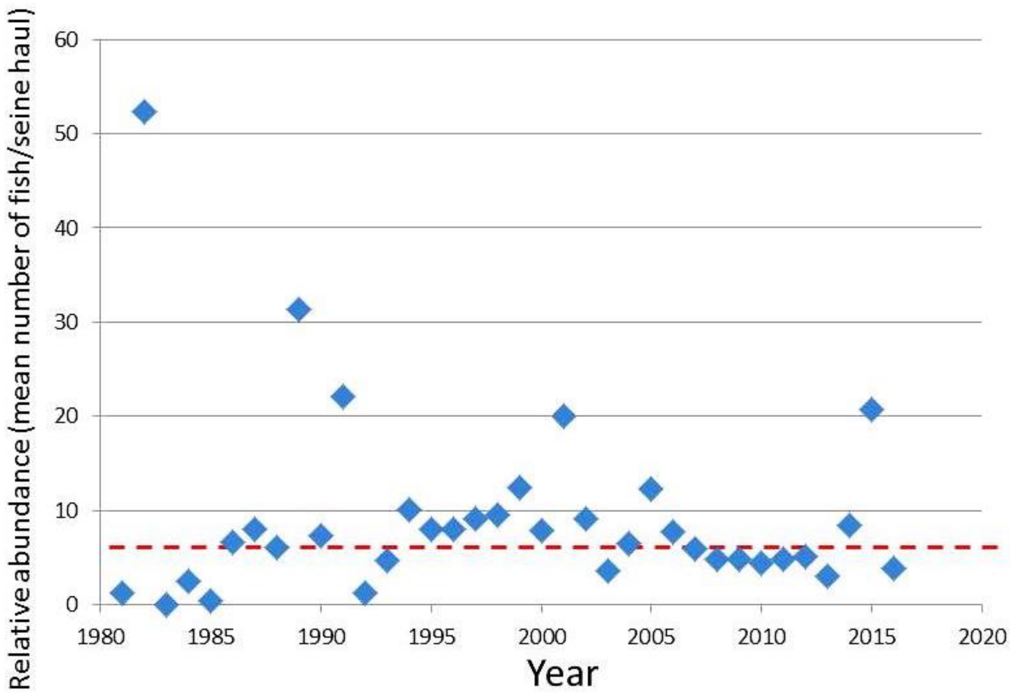


Figure 8. Historical and current distribution of Longnose Dace *Rhinichthys cataractae* in Illinois.

Table 4. Relative abundance (mean number of fish/seine haul) of **Longnose Dace** *Rhinichthys cataractae* over 38 years of beach seine sampling at five locations along the Lake Michigan shoreline in Illinois, 1979-2016. The number of seine hauls is in parentheses. NS indicates no sample. IDNR unpublished data.

	Location					
Year	Farwell Ave (205)	Jackson Outer (220)	North Point (179)	Tower Road (206)	Waukegan (224)	All Locations (1,034)
1979	NS	0	NS	NS	NS	0
1980	NS	NS	NS	NS	NS	NS
1981	2.5	0	NS	NS	NS	1.3
1982	78.5	0	NS	NS	NS	52.3
1983	0	0	NS	NS	NS	0
1984	5.0	0	NS	NS	NS	2.5
1985	NS	NS	NS	NS	0.5	0.5
1986	66.0	0	NS	5.0	0	6.6
1987	14.0	0.2	NS	5.0	18.0	8.1
1988	5.4	0	NS	17.6	0	6.1
1989	61.0	0	41.3	12.0	38.0	31.4
1990	44.0	0	1.5	1.8	8.3	7.4
1991	44.5	0	46.0	0	3.5	22.1
1992	NS	0	1.0	NS	0.5	1.3
1993	8.5	0	6.0	6.0	6.5	4.7
1994	20.5	0	8.3	14.5	12.3	10.1
1995	22.1	0.1	10.7	6.6	1.8	8.0
1996	23.7	0.1	2.3	18.5	0	8.1
1997	26.1	0	9.8	8.9	0.9	9.2
1998	27.2	0	10.2	10.8	0.8	9.5
1999	54.5	0.2	1.1	4.4	0.2	12.5
2000	33.3	0	0.5	1.3	0	7.9
2001	57.7	0	1.5	27.6	4.0	20.0
2002	20.8	0	7.1	4.4	13.1	9.2
2003	19.0	0	0	0	1.6	3.6
2004	26.6	0	7.3	0.8	5.1	6.5
2005	27.8	0	17.0	16.4	1.0	12.3
2006	26.4	0	12.1	0.6	1.0	7.7
2007	18.8	0	10.2	1.0	0.1	6.0
2008	14.0	0	8.5	0	0.3	4.9
2009	18.1	0	3.6	0	0	4.8
2010	20.7	0	0.8	0.2	0	4.5
2011	1.6	0	5.7	0.4	17.5	4.8
2012	9.2	0	2.0	13.8	0.2	5.2
2013	12.6	0	1.0	1.6	0	3.1
2014	26.8	0	11.6	1.9	0	8.4
2015	78.3	0	14.3	0.3	0.2	20.7
2016	6.6	0	13.5	1.1	0	3.9
All Years	27.5	<0.1	8.9	6.0	3.2	8.9

Figure 9. Relative abundance of Longnose Dace from 1981 to 2016. Combined data from Lake Michigan beach seine surveys at Farwell Avenue, Jackson Outer Harbor, North Point, Tower Road, and Waukegan. IDNR unpublished data. Red line is long-term average, but excludes years with unusually high abundances.



Mottled Sculpin
Cottus bairdii
(both subspecies, *Cottus bairdii bairdii* and *Cottus bairdii kumlieni*)

In Illinois, the Great Lakes Mottled Sculpin *Cottus bairdii kumlieni* is restricted to Lake Michigan and the Rock River watershed (Fig. 10). It is found along the entire shoreline of Lake Michigan. The most recent record in Lake Michigan was off of Lake Bluff in 2014 (S. Robillard and D. Makauskas). Prior to that, no Mottled Sculpins were seen since another one was found off of Lake Bluff in 2005. The next most recent records are off Jackson Park and another in Chicago Harbor in 1999. Various parts of this area are annually surveyed by Shedd Aquarium, Field Museum, IDNR, INHS, USACoE, and USF&WS.

In the Rock River basin, the sculpin is currently abundant in South Kinnikinnick Creek (P. Willink and T. Anton personal observation 2016, K. Rivera routine IDNR basin survey). There are historical records from the Leaf River (1969), Spring Branch of Stillman Creek (1948), and McFadyen Branch of Kent Creek (1948). All three areas were visited by P. Willink and T. Anton (D. Miller and others from Severson Dells Nature Center / Winnebago County Forest Preserve District collaborated with the Kent Creek surveys, and K. Rivera, R. O'Neil (both

IDNR) and J. Belcik (UofI) collaborated with Stillman Creek surveys) in 2016, but no sculpins were found. The exact locations of Spring Branch and McFadyen Branch are uncertain, but attempts were made to find cold streams flowing out of springs. IDNR and INHS have recently surveyed sites either at or close to these locations, and have not found sculpins.

There are sculpins in the Rock River watershed in Wisconsin, including just a few miles north of the Illinois-Wisconsin border. No sculpins have been found in nearby streams within Illinois (J. Tiemann, personal communication 2016).

The Northern Mottled Sculpin *Cottus bairdii bairdii* is restricted to the Illinois River and Vermilion (Wabash) watersheds (Fig. 10). Within the Vermilion watershed, it is found near the Indiana border in Grape Creek, Willow Creek, and Whippoorwill Branch, and is generally common at these sites (P. Willink, T. Anton, and J. Belcik personal observation 2016; IDNR and INHS records).

In the Illinois basin it is most abundant in the Fox watershed, found in many tributaries along its length downstream of the Fox Chain-of-Lakes. Current numbers appear to be comparable to historical abundances.

There is only one record from the Kankakee, and that was from Tower Creek in 2001 (F. Veraldi). The site was revisited in 2016 by P. Willink, F. Veraldi, and N. Barkowski, but no sculpins were found. It is unclear if this record is from an isolated population or stray individuals. Mottled Sculpins are found in the Kankakee headwaters in Indiana (Simon 2011), so there is always the possibility that some may be washed downstream into Illinois.

There are historical records from Pecumsaugan Creek (1962), but none have been found since then.

Northern Mottled Sculpin were historically found in three streams in the Des Plaines watershed (Willink and Veraldi 2009), but there are no records from Hickory Creek since 1997 or Long Run since 1955. Hickory Creek was surveyed multiple times by P. Willink and J. Bland in 2015-2016, and it is part of the routine IDNR basin survey. Portions of Long Run were surveyed in 2005 by P. Willink. There is still an isolated population in Black Partridge Creek (Steinmetz and Soluk 2001, Steinmetz et al. 2002), but it is essentially an 'island'.

Most of the above information is based on presence – 'absence' surveys that may incorporate number of specimens, and possibly the amount of effort it took to collect them. A more detailed analysis of the population in Black Partridge Creek was conducted by Steinmetz and Soluk (2001) and Steinmetz et al. (2002). The sculpins are found in a 1,200 foot (518 meters) stretch of stream. After extensive sampling, they used one method to estimate the population size to be 2,109 individuals in 2000 and 1,968 individuals in 2001, which translates to 0.075 sculpin/ft2 (0.81m2) in 2000 and 0.076 sculpin/ft2 (0.82/m2) in 2001. A different method estimated the population to be 1,200 individuals in 2000 and 1463 individuals in 2001, which translates to 0.044 sculpin/ft2 (0.47m2) in 2000 and 0.054 sculpin/ft2 (0.57m2) in 2001. These are probably underestimates, but they are about average according to the literature. Significant number of young-of-year were found. Four age classes were recognized based on sizes reported in the literature (Steinmetz and Soluk 2001, Steinmetz et al. 2002).

Steinmetz et al. (2002) conducted a Population Viability Analysis to simulate the status of the Black Partridge Creek population over the next 50 years (1000 replications). Their results indicate that the population is currently healthy and stable, and assuming no major environmental changes over the next 50 years, should continue to be healthy and stable. However, large-scale changes that could lower the carrying capacity of the population or increase the frequency of catastrophes could have disastrous consequences. Because the sculpins are dependent upon the stable cool water temperatures and flow at the site, anything that disrupts these conditions, such as a lowering of the water table, could drive the population to extinction. Increased sedimentation runs the risk of smothering their cobble habitat (Steinmetz et al. 2002).

In summary, the Great Lakes Mottled Sculpin is currently only known to be present in one stream in the Rock River watershed and rare in Lake Michigan, with only three records in the last couple decades. The Northern Mottled Sculpin appears to be stable throughout much of the Fox River watershed, stable in a small area of the Vermilion-Wabash watershed, rare to potentially extirpated from Pecumsaugan Creek, currently present in one stream in the Des Plaines watershed, and may have occasional individuals from the Kankakee River headwaters enter from Indiana.

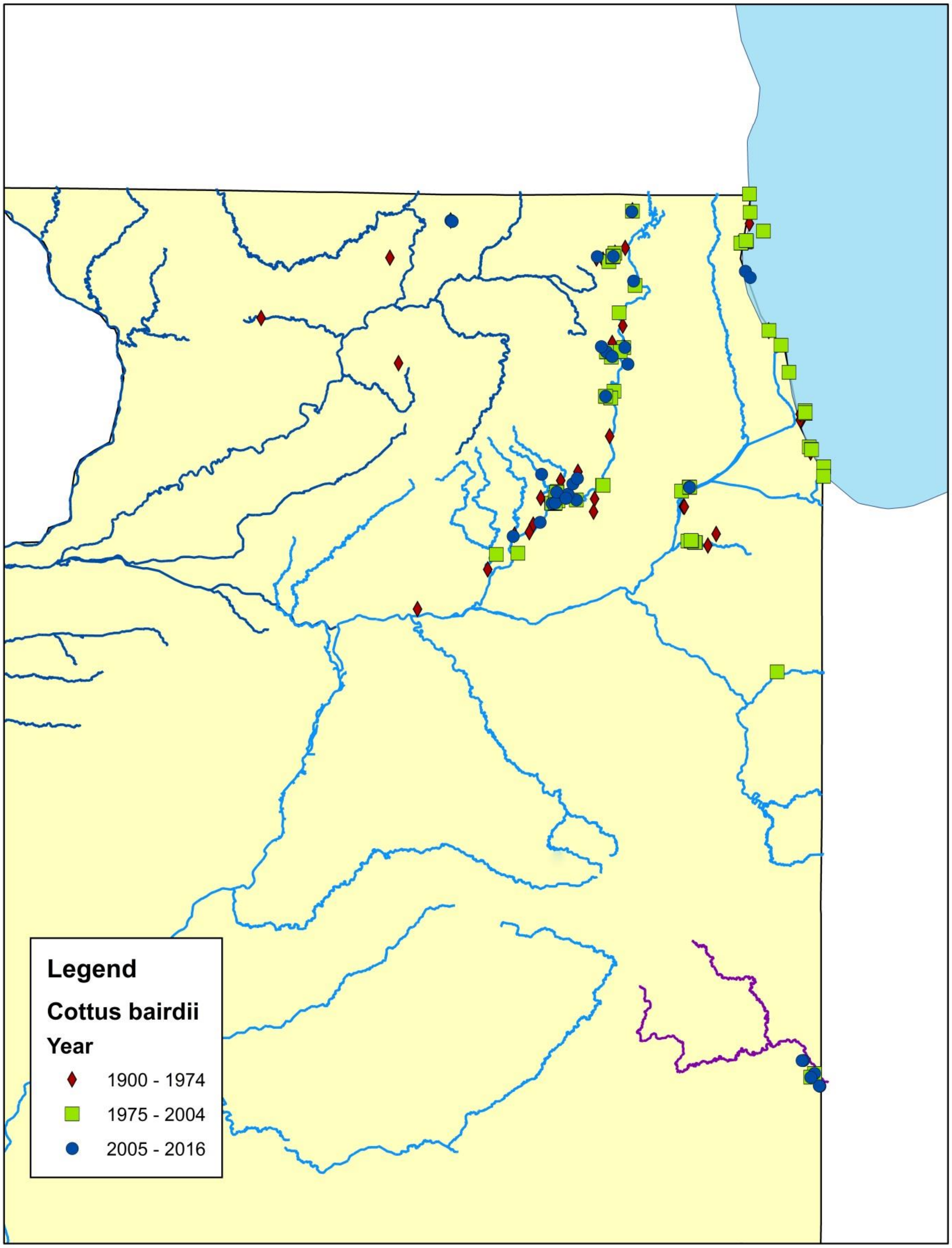


Figure 10. Historical and current distribution of Mottled Sculpin *Cottus bairdii* in Illinois.

Ozark Minnow
Notropis nubilus

In Illinois, Ozark Minnow is generally distributed in the northwestern portion of the state. Most records are from the Rock drainage. This is where the species was originally described from, and for many years it was only known from this region (Jordan 1878, Forbes 1884). Over time, additional populations were discovered in a couple tributaries of the Mississippi in the far northwestern corner of Illinois. There is also a population in Somonauk Creek of the Fox River watershed (Fig. 11).

There are scattered records along the Mississsppi in southwestern Illinois. To the west, Ozark Minnows are common in the Ozarks of Missouri and Arkansas. The Illinois records are considered transient individuals from these larger populations (Smith 1979).

Metzke and Holtrop (2014) developed a model of where Ozark Minnows could potentially be found in northern Illinois based on several stream habitat characteristics (e.g., gradient, size, catchment land use, flow, and temperature) of sites where there are historical records. Subsequent fieldwork was unable to discover any new populations of Ozark Minnows, and it was concluded the species is spatially declining within its range.

This same pattern was noticed in recent fieldwork. Although their overall range has not changed significantly in Illinois, their numbers appear to be decreasing. There have been no recent records in the Kishwaukee watershed, and it has been suggested that they are extirpated from the basin (Retzer 2005). They have not been seen in the Rock River near the type locality for many years. There are recent records in Franklin Creek, Stillman Creek, North Kinnikinnick Creek, and the upper Pecatonica, but fewer records than in the past. The remaining populations are becoming more and more isolated over time.

This general decline is also evident in the Catch Per Unit Effort data combined over several watersheds from 1995 to 2015 (Fig. 12). There was a distinct increase from 2000 to 2005, followed by a sudden drop from 2005 to 2010. All sorts of stochastic factors can cause this type of data to fluctuate up and down, but the dramatic reduction in numbers over two successive basin surveys is starting to look like a trend.

A fair number of Ozark Minnows were found at one site in the Apple River in 2016, but it is unclear what their status is throughout the watershed (personal observation 2016, P.W. Willink and K. Rivera).

In regards to the species entire distribution, Ozark Minnows are most common in the Ozarks, which include southern Missouri, northern Arkansas, and northeastern Oklahoma. Another population is found in northwestern Illinois, southwestern Wisconsin, northeastern Iowa, and extending up into Minnesota. A third isolated group is found in northwestern Wisconsin (Page and Burr 2011).

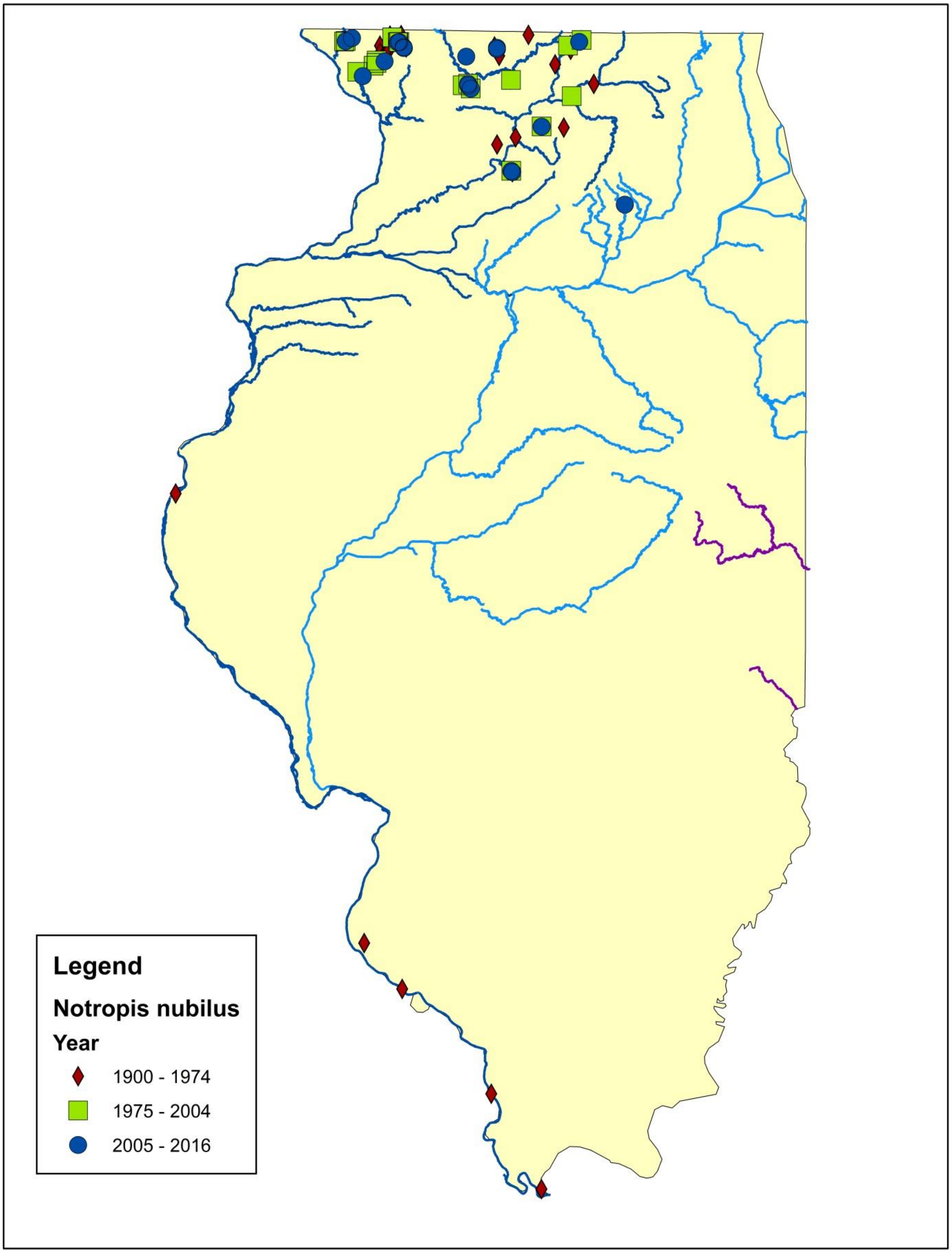


Figure 11. Historical and current distribution of Ozark Minnow *Notropis nubilus* in Illinois.

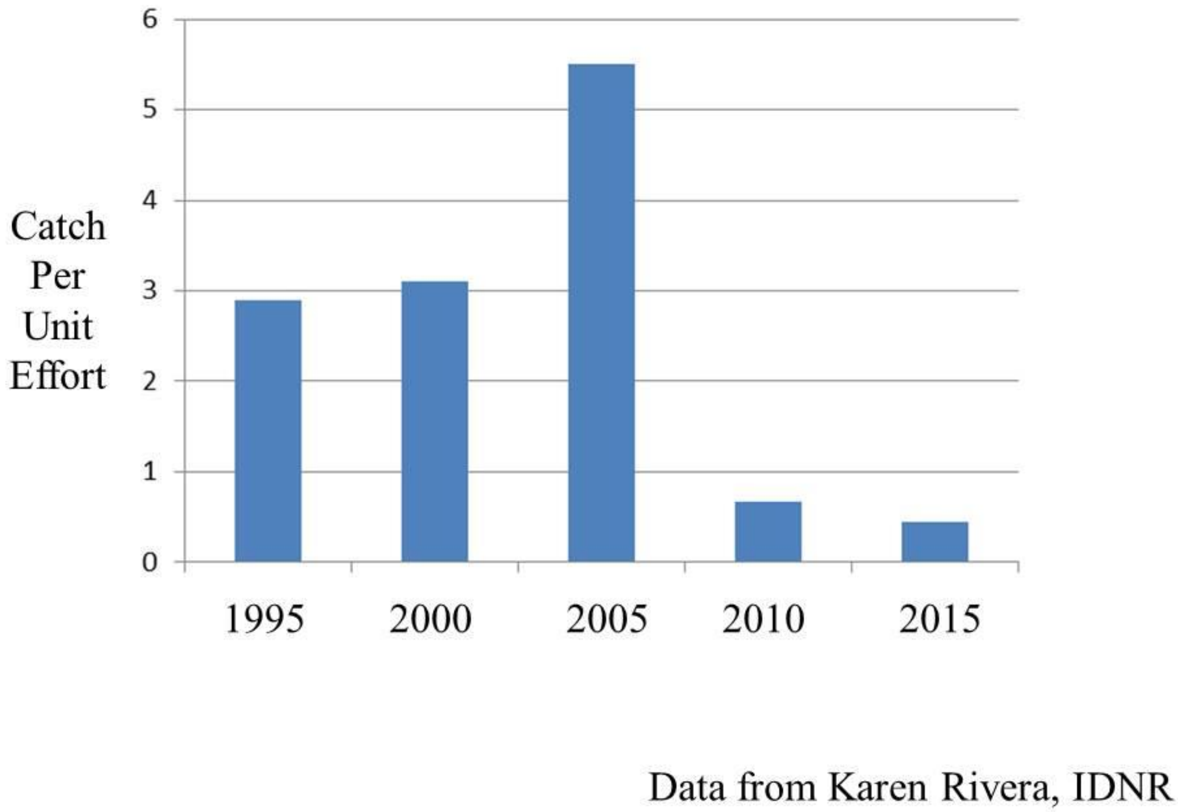


Figure 12. Catch Per Unit Effort for Ozark Minnow *Notropis nubilus* combined over several watersheds in northwestern Illinois.

Rosyface Shiner
Notropis rubellus

Rosyface Shiner is found in the Vermilion-Wabash basin as well as tributaries of the upper Illinois River, notably the Mackinaw, Big Bureau, West Bureau, Vermilion-Illinois, Fox, Aux Sable, Des Plaines, Kankakee and other watersheds in the central and northeastern portion of the state (Fig. 13). Discrimination between Rosyface Shiner and Carmine Shiner requires genetic analysis (Scott et al., unpublished data). Overall, their status appears to be stable.

The populations in the Des Plaines River are relatively recent, and their numbers appear to be increasing. Although there is an older record in the Des Plaines near the Wisconsin border, it is possible that colonization occurred from populations in the Kankakee, Aux Sable, and/or Hickory Creek watersheds. This would involve movement through the Brandon Lock and Dam complex on the Des Plaines River in Joliet as well as colonization of the area once occupied by the recently removed Hoffman Dam in Riverside.

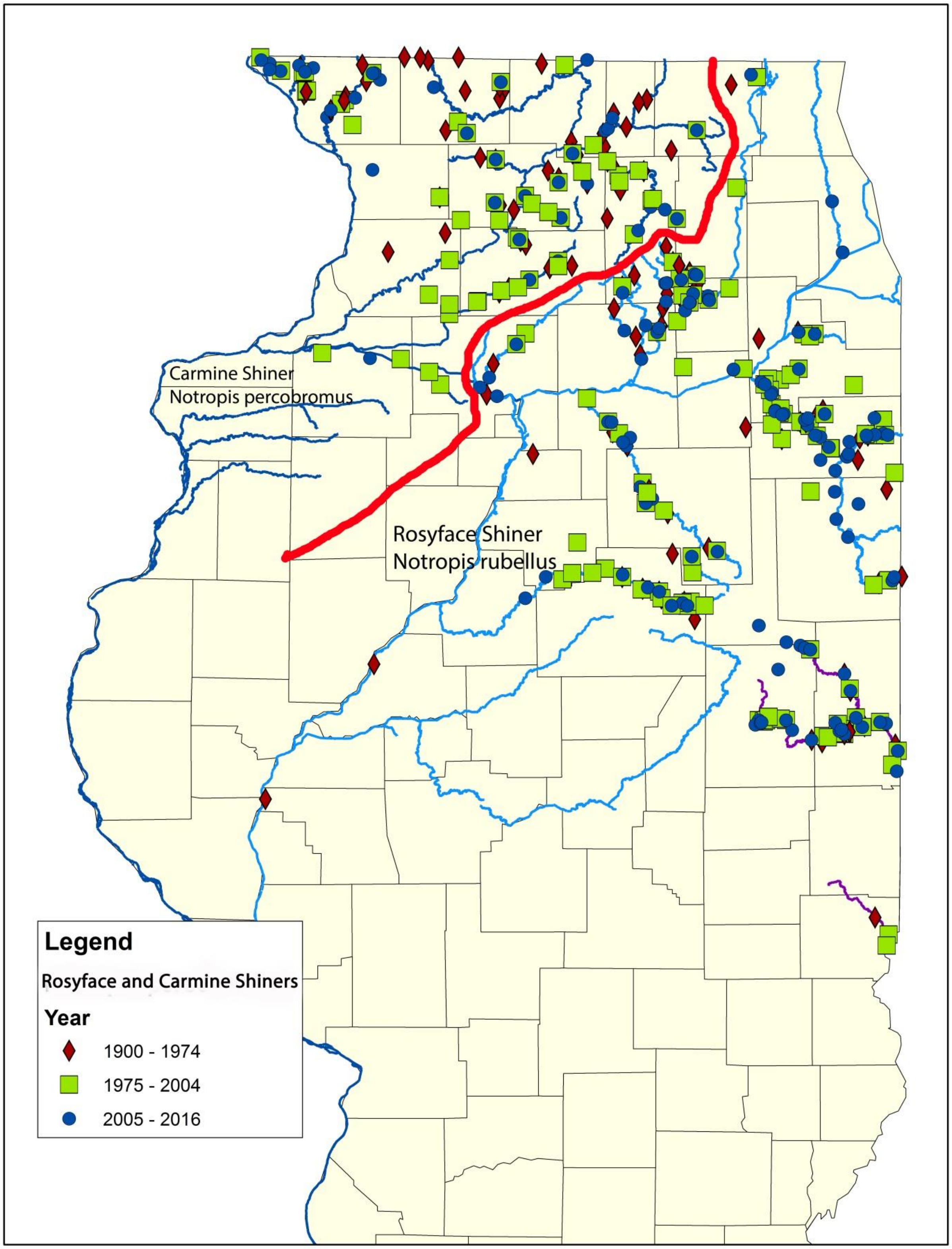


Figure 13. Historical and current distribution of Rosyface Shiner *Notropis rubellus* to the east of the red line, and Carmine Shiner *Notropis percobromus* to the west of the red line.

Carmine Shiner
Notropis percobromus

Carmine Shiner is found in tributaries of the upper Mississippi River in the northwestern portion of the state, notably the Rock, Green, Kishwaukee, Apple and other watersheds (Fig. 13). Discrimination between Carmine Shiner and Rosyface Shiner requires genetic analysis (Scott et al., unpublished data). Their status appears to be stable.

Slimy Sculpin
Cottus cognatus

In Illinois, the Slimy Sculpin is only found in Lake Michigan. Records are from the shoreline to depths of 110 meters, but they are generally in depths ranging from 9 to 91 meters. The Illinois distribution map (Fig. 14) shows them clustered along the northern state line, but this is an artifact of where deep water sampling has been done effectively. They are probably more widespread than what is indicated, with their distribution following the Lake Michigan depth contours.

Historically, there are very few mentions of them in the literature. One explanation may be their similarity to Mottled Sculpin caused confusion and misidentifications. Jordan (1878) does say that they live in the deep waters of Lake Michigan. Forbes and Richardson (1920) and Meek and Hildebrand (1910) make no mention of them at all. Deason (1939) was next to mention their presence in Illinois.

There are only a dozen vouchered museum specimens, with the first one deposited in the University of Michigan Museum of Zoology in 1931. This paucity of records is largely due to the difficulty of surveying deep water habitats. It was not until the late 1960s when the United States Geological Survey began annual bottom trawls that Slimy Sculpin started to be found routinely.

At this time, their range is assumed to be comparable to what it was in the past.

Since they were never common closer to shore, it is difficult to determine trends. But there has been an effort by the United States Geological Survey to evaluate the density of Slimy Sculpin throughout all of Lake Michigan since 1973. According to their results, Slimy Sculpin numbers were at a peak in the mid-1970s, dropped to low levels throughout the 1980s and early 1990s, before peaking again around 2006. Since then, Slimy Sculpin abundances have generally declined to low numbers (Bunnell et al. 2015).

Globally, Slimy Sculpin are found in Alaska, almost all of Canada, Washington, Idaho, Montana, north and eastern Minnesota, northeastern Iowa, Great Lakes, Pennsylvania, New York, and New England. Illinois is along the southern edge of its range.

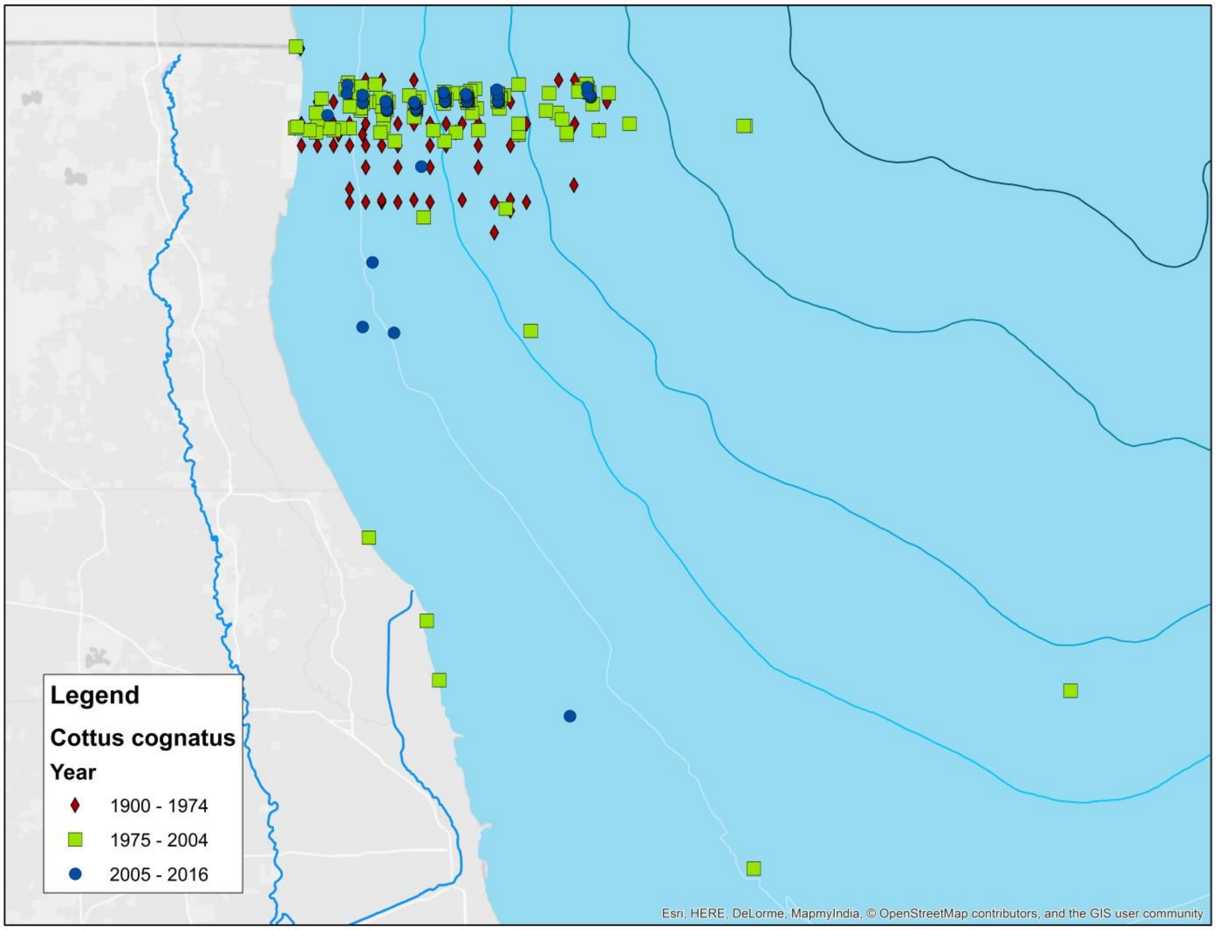


Figure 14. Historical and current distribution of Slimy Sculpin *Cottus cognatus* in Illinois. Lake Michigan contour lines are 25 meters.

Spoonhead Sculpin
Cottus ricei

In Illinois, the Spoonhead Sculpin is restricted to Lake Michigan. There are only seven records of Spoonhead Sculpin, making it one of the state's rarest, or at least little-known, species. What is even more surprising is the species was first discovered by Northwestern University zoology student Frank Leon Rice on the shore of Lake Michigan near Evanston (Becker 1983). The exact circumstances are unknown, but apparently there was a severe storm over Lake Michigan from January 1-5, 1876. At first the wind blew from the slightly west of south, then west, then switched to the east, then back from the southwest. At times the wind measured 44 miles per hour. On January 5, Rice and fellow classmate Nathan Smith Davis Jr. collected specimens on the beach. There were a great many algae, crayfishes, fishes, mudpuppies, and molluscs (Davis 1876, Resetar and Resetar 2015). As to whether a Spoonhead Sculpin was mixed in with these fishes or not is unknown, but the circumstances and timing fit. What we do know is that at some time around then Rice delivered the Spoonhead Sculpin specimen to E.W. Nelson who wrote the official description published in December, 1876. Nelson named the new species *Cottopsis ricei*, or Rice's Cottus, after his friend.

This single specimen was designated as the type. Unfortunately, it has disappeared. In a letter dated February 4, 1876, Davis wrote about the storm and commented that "Mr. Rice collected a number of different species of the smaller fishes, but by accident they were destroyed and I am not able to give a list of them." Once again, we do not know if a Spoonhead Sculpin was one of these smaller fishes from this particular storm, but at some time Rice was able to present the specimen to Nelson. Forbes and Richardson commented that they were "lacking access to Mr. Nelson's type" as they were writing the species account for The Fishes of Illinois (1909, 1920). Sabaj et al. (1997) question whether the specimen was ever deposited in the collections of the Illinois State Laboratory of Natural History (the forerunner of the current Illinois Natural History Survey). The whereabouts of this specimen remain a mystery to this day.

Although the specimen may have disappeared, regional ichthyologists were well aware of its discovery. Both Jordan (1878) and Meek and Hildebrand (1910) commented that it could be found in the deep waters of Lake Michigan.

The second occurrence of Spoonhead Sculpin in Illinois was roughly 33 years later when E.W. Youngren collected a specimen at the mouth of the Chicago River on March 1, 1909. The preserved specimen was originally housed at the Chicago Academy of Sciences when it was examined by C.L. Hubbs (1919a). The specimen has since been transferred to The Field Museum (FMNH catalog #42905 (previously #9539), where it resides to this day.

The next record is from Lake Michigan near Chicago in 1911 when a Spoonhead Sculpin was apparently sucked "through the city water system, from the intake about two miles out in the lake" (Hubbs 1919a). This specimen is now housed in The Field Museum (FMNH 5845).

A few years later, C.L. Hubbs added to our knowledge by collecting a specimen that "was found on the shore of Lake Michigan, near Winnetka, Illinois, where it had been driven with numerous other fishes by a storm, on July 8, 1919" (Hubbs 1920). Specimen is now housed in The Field Museum (FMNH catalog #9703).

No Spoonhead Sculpins were collected in the 1920s, but then three were in the 1930s. The first "was obtained by means of a minnow seine by Deason and F.W. Jobes on June 7, 1931, in 12 feet of water near the shore at a point approximately abreast the Wisconsin-Illinois state line" (Deason 1939). The specimen was deposited into the fish collection at the University of Michigan Museum of Zoology (UMMZ catalog #66275), with the locality information as "Lake Michigan, 9.5 mi N of Waukegan, breakwater, approximately abreast Wisconsin-Illinois line." Illinois is listed as the state, so the locality was apparently just south of the Wisconsin-Illinois state line.

Deason's (1939) review of Lake Michigan sculpins includes a map of Spoonhead Sculpin records. This distribution map shows a record off Waukegan. Presumably this record is from his fishery study in which they examined the gut contents of Lake Trout *Salvelinus namaycush* and Burbot *Lota lota* from southern Lake Michigan caught during the years 1930 and 1931 (Van

Oosten and Deason 1938). There is no known voucher specimen for this locality. It is unclear if the Spoonhead Sculpin(s) was eaten by Lake Trout or Burbot, as both ate Spoonhead Sculpins. However, Burbot tended to eat more Spoonhead Sculpins in the study.

The last time a Spoonhead Sculpin was found in Illinois was on September 3, 1939 when L.P. Woods caught one in Lake Michigan at Evanston. Specimen is now housed in The Field Museum (FMNH catalog #37335).

Deason (1939) also states that Hubbs (unpublished report) "took one near shore at Jackson Park, Chicago, in the summer of 1918 or 1919." This record has been subsequently re-reported in other publications, such as Fishes of Wisconsin by Becker (1983). However, there is no voucher specimen, which is odd because Hubbs preserved in a museum almost every fish he ever caught. But he did publish a manuscript about a Mottled Sculpin *Cottus bairdii* that Charles Brandler caught on May 29, 1919 "on the bottom of Lake Michigan near shore, from a pier in Jackson Park, Chicago" (Hubbs 1919b). This Mottled Sculpin specimen is currently in The Field Museum (catalog #9695). It is possible there has been confusion between the Jackson Park Mottled Sculpin record (Hubbs 1919b) and the Winnetka Spoonhead Sculpin record (Hubbs 1920). Until more information becomes available, the Jackson Park Spoonhead Sculpin record should be considered unreliable.

Meek and Hildebrand (1910) report Spoonhead Sculpin as one of the species living within 50 miles of Chicago, saying it is found in "deep waters of Lake Michigan." Most of their species accounts are based on Field Museum specimens, and they have specific locality information. Their Spoonhead Sculpin species account has rather vague locality information. Also, the account gives a range of values for certain morphological features, but it is not clear if they obtained the values from specimens or the literature, since they did both in their publication. In short, Meek and Hildebrand (1910) were aware of Spoonhead Sculpin in Illinois, but it is unclear where they received the information.

Smith (1979) also includes Spoonhead Sculpin in his The Fishes of Illinois. He clearly states that he is only aware of the species description by Nelson (1876) and the four specimens in The Field Museum fish collection.

In the region, the Spoonhead Sculpin has never been recorded from Indiana (Simon 2011). It was probably never too common in southern Lake Michigan, being relatively more common in northern Lake Michigan (Van Oosten and Deason 1938, Deason 1939, Potter and Fleischer 1992).

In southern Lake Michigan, the Great Lakes Fishery Laboratory found several Spoonhead Sculpins in trawls made in 1954. Subsequent trawling in 1960, 1964-1971, and 1973-1989 did not find any (Wells and McLain 1973; Potter and Fleischer 1992). The last documented appearance of Spoonhead Sculpin in southern Lake Michigan was in 1990 near Saugatuck, Michigan at a depth of 91 meters (Potter and Fleischer 1992).

Spoonhead Sculpin are found throughout the Great Lakes, north into Ontario and Quebec, then northwest through Canada all the way to the Yukon Territory (Scott and Crossman 1973). Illinois is essentially the southernmost extent of its range (Page and Burr 2011).

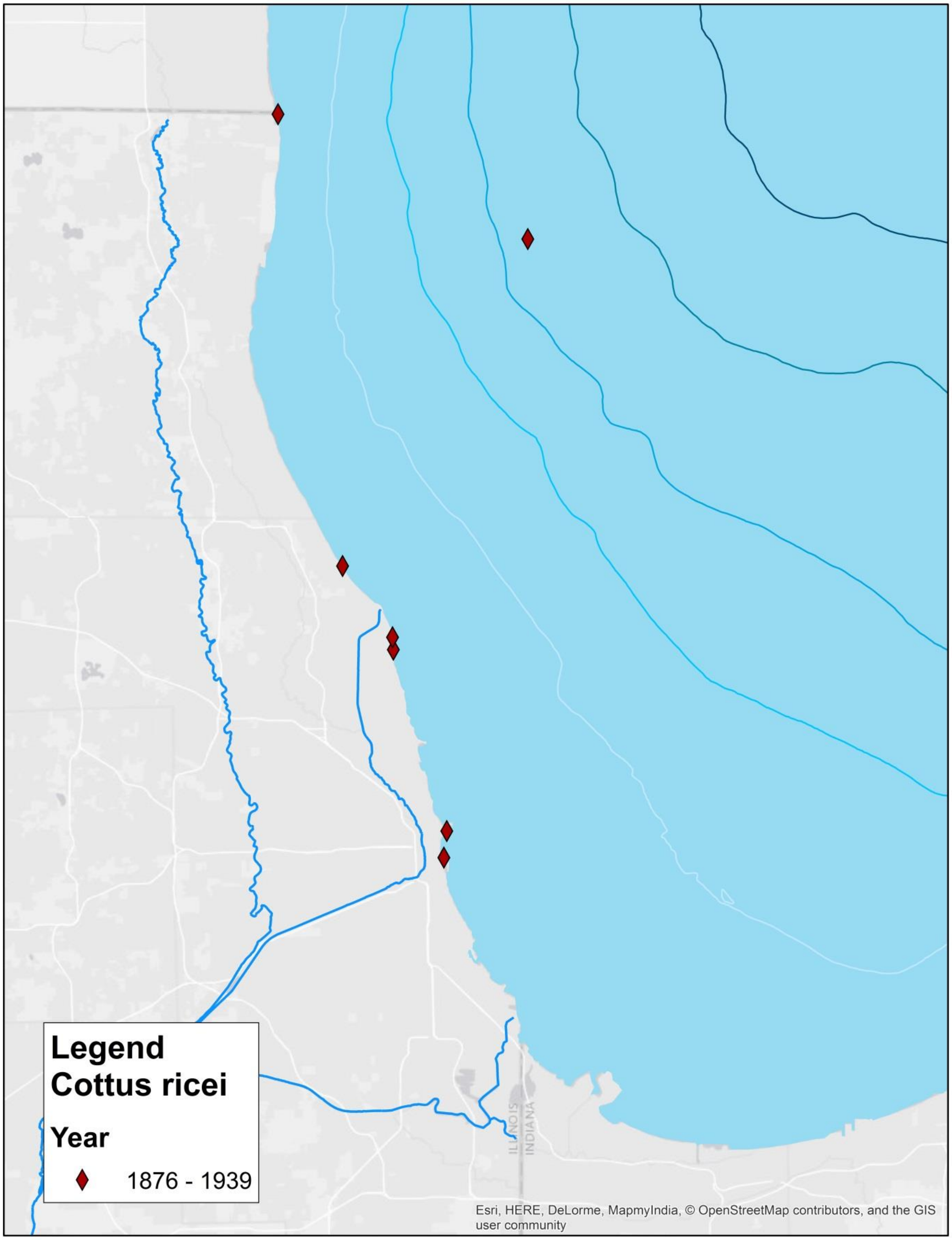


Figure 15. Historical and current distribution of Spoonhead Sculpin *Cottus ricei* in Illinois. Lake Michigan contour lines are 25 meters.

Literature Cited for Part I

Baldwin, N. A., R. W. Saalfeld, M. R. Dochoda, H. J. Buettner, and R.L. Eshenroder. 2009. Commercial Fish Production in the Great Lakes 1867-2006 [online]. Available from http://www.glfc.org/databases/commercial/commerc.php

Bowman, D. 2011. Sturgeons find operating room. Chicago Sun-Times, November 29.

Bunnell, D.B., C.P. Madenjian, T.J. Desorcie, M.J. Kostich, W. Woelmer, and J.V. Adams. 2015. Status and trends of prey fish populations in Lake Michigan, 2014. Pages 33-48 *In* Compiled Reports to the Great Lakes Fishery Commission of the Annual Bottom Trawl and Acoustics Surveys, 2014. United States Geological Survey, Great Lake Science Center, Ann Arbor, MI.

Clay, W.M. 1975. The fishes of Kentucky. Kentucky Department of Fish and Wildlife Resources Frankfort, KY. 416 pages.

Davis, N.S. Jr. 1876. Vegetable and animal substances thrown upon the shore of Lake Michigan at Evanston during a storm. Engineering News 3:55.

Deason, H.J. 1939. The distribution of cottid fishes in Lake Michigan. Papers of the Michigan Academy of Science, Arts, and Letters 24:105-115.

Eshenroder, R.L., M.E. Holey, T.K. Gorenflo, and R.D. Clark Jr. 1995. Fish-community objectives for Lake Michigan. Great Lakes Fishery Commission Special Publication 95-3, 56 pages.

Etnier, D.A. and W.C. Starnes. 1993. The fishes of Tennessee. The University of Tennessee Press, Knoxville. 689 pages.

Hoy, P.R. 1872. Deep-water fauna of Lake Michigan. Transactions of the Wisconsin Academy of Sciences, Arts, and Letters 1870-1872:98-101.

Forbes, S.A. 1884. A catalogue of the native fishes of Illinois. Report of the Illinois State Fish Commissioner for 1884:60-89.

Forbes, S.A. and R.E. Richardson. 1920. The fishes of Illinois. Illinois Natural History Survey. Second Edition. 357 pp.

Greenberg, J. 2002. A natural history of the Chicago Region. The University of Chicago Press, Chicago.

Greenfield, D.W. and J.D. Rogner. 1984. An assessment of the fish fauna of Lake Calumet and its adjacent wetlands, Chicago, Illinois: past, present, and future. Transactions of the Illinois State Academy of Science 77:77-93

Hrabik, R.A. 2016. Fish species found along Missouri's border new to state. Missouri Conservationist 77(3):7.

Jordan, D.S. 1878. A catalogue of the fishes of Illinois. Bulletin of the Illinois State Laboratory of Natural History 1:37-70.

Kennicott, R. 1855. Catalogue of animals observed in Cook County, Illinois. Illinois State Agricultural Society Transactions 1:577-595.

Lamer, J., E. Ratcliff, and K. Rivera. 2016. Banded Killifish in the Upper Mississippi River. The Upper Mississippi River Conservation Committee Newsletter Summer:2.

Meek, S.E. and S.F. Hildebrand. 1910. A syntopic list of the fishes known to occur within fifty miles of Chicago. Publication of the Field Museum of Natural History, Zoological Series 142:223-338.

Metzke, B.A. and A.M. Holtrop. 2014. Survey of Spring Cavefish (*Forbesichthys agassizii*), Ozark Minnow (*Notropis nubilus*) and Largescale Stoneroller (*Campostoma oligolepis*) status in Illinois. Illinois Natural History Survey Technical Report 2014(04), 42 pages.

Milner, J.W. 1874. The fisheries of the Great Lakes and the species of *Coregonus* or white fish, I.- report on the fisheries of the Great lakes; the result of inquiries prosecuted in 1871 and 1872. United States Commission of Fish and Fisheries, Report of the Commissioner for 1872 and 1873, Appendix A:1-75.

Nelson, E.W. 1876. A partial catalogue of the fishes of Illinois. Bulletin of the Illinois Museum of Natural History 1:33-52.

Page, L.M. and B.M. Burr. 2011. Peterson field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Harcourt, Boston. 663 pp.

Resetar, D.R.R. and A.R. Resetar. 2015. Doctor Elias Francis Shipman and the Hoosier frog. Proceedings of the Indiana Academy of Science 124:89-105.

Retzer, M.E. 2005. Changes in the diversity of native fishes in seven basins in Illinois, USA. American Midland Naturalist 153:121-134.

Retzer, M.E. and B. Batten. 2005. Fishes of the Chicago Region: a review of the Dennison and Illinois Natural History Survey collections. Transactions of the Illinois State Academy of Science 98:63-73.

Rivera, K.D., R.L. Haun, C.A. Anderson, and S.P. Romano. 2013. New distribution record for *Fundulus diaphanous* (LeSueur), family Fundulidae in Illinois. Transactions of the Illinois State Academy of Science 106:57.

Schmidt, K. 2016. Iowa's Longear Sunfish mystery solved…maybe - Addendum. American Currents 41(3):17-18.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184:1-966.

Smith, G.R. 1963. A late Illinoian fish fauna from southwestern Kansas and its climatic significance. Copeia 1963:278-285.

Smith, P.W. 1979. The fishes of Illinois. University of Illinois Press, Urbana. 314 pp.

Smith, S.H. 1968. Species succession and fishery exploitation in the Great Lakes. Journal of the Fisheries Research Board of Canada 25:667-693.

Tetra Tech 2002. Environmental assessment for ecosystem restoration project (section 206). Wolf Lake, Hammond, Indiana. Tetra Tech EM Inc., Chicago.

Tiemann, J.S., C.A. Taylor, J.H. Knouft, and J.L. Sherwood. 2009. Status, distribution, and resource requirements of the longnose dace *Rhinichthys cataractae* (Valenciennes) in the Wisconsin Driftless region of Illinois. Illinois Natural History Survey Technical Report 2009 (33):1-23.

Tiemann, J.S., C.A. Taylor, D. Wylie, J. Lamer, P.W. Willink, F.M. Veraldi, S.M. Pescitelli, B. Lubinski, T. Thomas, R. Sauer, and B. Cantrell. 2015. Range expansions and new drainage records for select Illinois Fishes. Transactions of the Illinois State Academy of Science 108:47-52.

Van Oosten, J. and H.J. Deason 1938. The food of the lake trout (*Cristivomer namaycush namaycush*) and of the lawyer (*Lota maculosa*) of Lake Michigan. Transactions of the American Fisheries Society 67:155-177.

Warner, D.M., S.A. Farha, R.M. Claramunt, D. Hanson, and T.P. O'Brien. 2015. Status of pelagic prey fishes in Lake Michigan, 2014. Pages 47-58 *In* Compiled Reports to the Great Lakes Fishery Commission of the Annual Bottom Trawl and Acoustics Surveys, 2014. United States Geological Survey, Great Lake Science Center, Ann Arbor, MI.

Wells, L. 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. Fishery Bulletin 67:1-15.

Willink, P.W. 2009. A century of shifting fish assemblages in Wolf Lake, Illinois-Indiana. Proceedings of the Indiana Academy of Science 118:187-195.

Willink, P.W. and F.M. Veraldi. 2009. The fishes of Will County, Illinois. Fieldiana, Zoology, New Series 115:1-61.

Part II

Draft Species Guidance Documents for Five Select Species

Conservation Guidance for

Lake Chub

Couesius plumbeus (Agassiz)

IL Status: Species in Greatest Conservation Need, NatureServe - SU

US Status: NatureServe – N5

Global Rank: NatureServe - G5

Trend: Stable

Family: Cyprinidae

Habitat: Nearshore Lake Michigan

Similar Species:
Creek chub *Semotilus atromaculatus*
Longnose Dace *Rhinichthys cataractae*
Sand Shiner *Notropis stramineus*
Spottail Shiner *Notropis hudsonius*

Species Information

Characteristics

Stout bodied minnow with generally cylindrical body. Eyes relatively large and lateral. Mouth slightly subterminal, moderately downturned, and extends to front of eye. Small threadlike barbel in rear corner of mouth. Pectoral fin with 13-19 rays. Pelvic fin with 7-9 rays and slightly anterior to dorsal fin. Dorsal fin rounded with 7-9 rays. Anal fin slightly emarginate with 8 rays. Caudal fin forked. Complete lateral line with 53-70 scales. Coloration is beige to green on back, lead (from which the scientific name *plumbeus* is derived) or silver along sides, grading to a cream-colored to white belly. With some dark gray scattered scales on back and sides. May also have a dark stripe above or along lateral line. Males have dorsal fin more anterior than in females (Hubbs 1942). Males have pectoral fin extending over 2/3 the distance from base of pectoral fin to base of pelvic fin, whereas females have pectoral fin extending over ½ this distance (McPhail and Lindsey 1970, Becker 1983). Breeding male with red/orange at base of pectoral fin, base of pelvic fin, corner of mouth (Richardson 1944), upper lip, upper end of opercular opening, as well as a generally reddish belly (Smith 2010). Small breeding tubercles cover top and side of head, breast, upper body, and rays of pectoral fin and pelvic fin. Females can be red/orange at base of pectoral fin and corner of the mouth. Breeding tubercles also present on head in females, but smaller and less densely distributed (Brown et al. 1970). Can reach 9 inches / 23 cm in total length. (Scott and Crossman 1973, Becker 1983, Bailey et al. 2004, Hubbs and Lagler (and Smith) 2004, Page and Burr 2011).

Fuiman and Baker (1981) described the larvae in great detail, including comparisons and hints on how to distinguish them from the larvae of other species, especially Longnose Dace *Rhinichthys cataractae*. Hubbs (1942) described a variety of adult characters in great detail, mostly in the context in distinguishing this species from Northern Pearl Dace *Margariscus nachtriebi* from Glacier National Park.

Can be distinguished from similar species by lacking a dark spot at the anterior base of the dorsal fin (versus having a dark spot at the anterior base of the dorsal fin in Creek Chub *Semotilus atromaculatus*), relatively smaller scales with 53-70 in the lateral line (versus relatively larger and more obvious scales with 31-38 in the lateral line of Sand Shiner *Notropis stramineus* and 36-42 in the lateral line of Spottail Shiner *Notropis hudsonius*), and a slightly subterminal mouth (versus an elongated snout producing a distinctly subterminal mouth in Longnose Dace *Rhinichthys cataractae*).

Taxonomy

Agassiz (1850) described Lake Chub as *Gobio plumbeus* based on specimens from Lake Superior and Lake Huron. At times, it was placed in the genus *Hybopsis*.

As is often the case with species with large distributions, various subspecies have been recognized. The anatomical differences among the subspecies have always been subtle, so there was little agreement on how to definitively recognize them. In a very general sense and based on morphology, the subspecies Northern Lake Chub *C. p. plumbeus* occupies the Great Lakes / St. Lawrence watershed, eastern Canada, then along northern Canada to the Yukon and Mackenzie watershed. The subspecies Prairie Lake Cub *C. p. dissimilis* is restricted to some streams of the Keweenaw Peninsula in Lake Superior and then is more common in eastern slope rivers of the Rocky Mountains. The third subspecies, *C. p. greeni*, occupies the western slope rivers of the Rocky Mountains. Characters used to distinguish among the subspecies include length and shape of dorsal fin, eye diameter relative to snout length, caudal peduncle scales, and vertebrae counts (McPhail and Lindsey 1970, Scott and Crossman 1973, Hubbs and Lagler 1964).

A genetic analysis of Cytochrome B found an Eastern clade and a Western Clade that were separated by 3.8% mean sequence divergence (2.5% net sequence divergence). The Eastern clade was composed of the Great Lakes / St. Lawrence watershed, eastern tributaries of Hudson Bay, and then all points to the east. This roughly matches the traditional distribution of *C. p. plumbeus*. The Western clade included western tributaries of Hudson Bay, upper Missouri watershed, then all points west. This roughly matches the traditional distribution *C. p. greeni* and *C. p. dissimilis*. The split between the clades was estimated to have occurred around 2.5-3 million years ago (Taylor et al. 2013).

If taxonomists decide that current subspecies should be elevated to the species level, and if the results from the genetic analysis in combination with historical morphological analyses remain unchanged, then the scientific name of Lake Chub in Illinois would remain *Couesius plumbeus* because the type locality is within the Great Lakes. Lake Chub elsewhere, particularly western North America, would instead receive a new scientific name.

Lake Chub are known to hybridize with Longnose Dace *Rhinichthys cataractae* (Hubbs and Lagler 1949) and Northern Pearl Dace *Margariscus nachtriebi* (Wells 1981).

Distribution and Status

In Illinois, Lake Chub are only known from the nearshore zone of Lake Michigan (Fig. 1). Most records are close to shore in less than a few feet of water, but they have been found several miles offshore at depths of around 50 feet (INHS 87576).

Historically, there are about a dozen museum records since the late 1800s. There are mentions of them in the literature (e.g., Jordan 1878, Forbes 1884), but these references usually just say they live in Lake Michigan, and little else. Forbes and Richardson (1920) do not even include Lake Chub in their account of Illinois fishes. This species was certainly present over the past couple centuries, but in modest numbers, and was probably overlooked as well (Smith 1979).

Standardized beach seine surveys by Illinois Department of Natural Resources – Lake Michigan Program from 1979 to 2016 did not record Lake Chub until 1994 (Table 1, Fig. 2). Present day, they are never found in large numbers, but are consistently found from year-to-year. Over the long term, it appears that their numbers may have actually increased slightly since we are now finding them consistently. Figure 1 may show a recent decrease in abundance over the past decade, but more data are needed to clarify any trends. For now, their status is considered stable.

Globally, Lake Chub are distributed from eastern Alaska, across almost all of Canada excluding the far northern islands, the Great Lakes, much of New England and northern New York, and dipping down into parts of Montana, Wyoming, and other nearby states. It is the northernmost distributed minnow (family Cyprinidae) in North America (Page and Burr 2011). The southernmost populations in the western United States are disjunct and considered to be glacial relicts (Bestgen et al. 1991, Stasiak 2006).

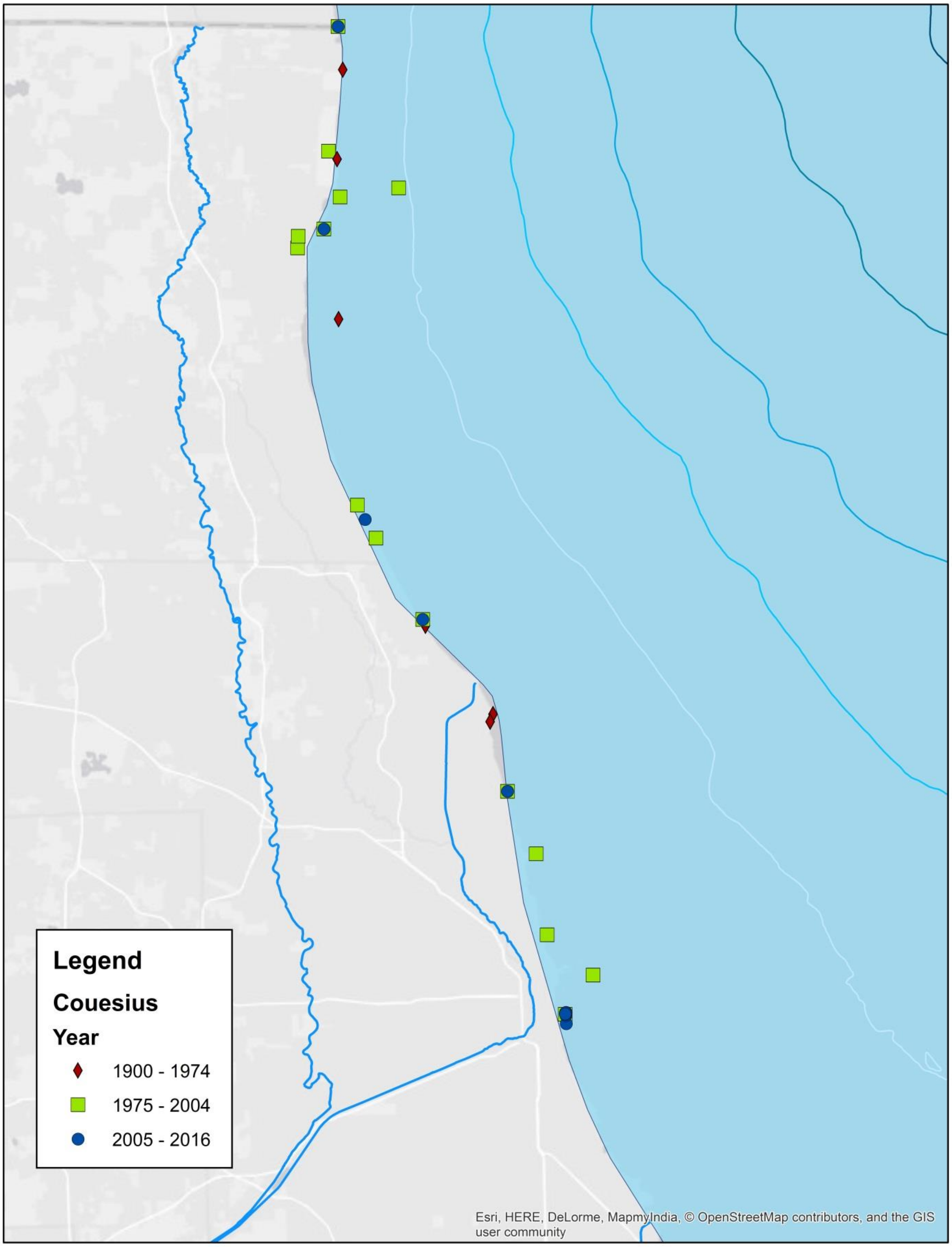
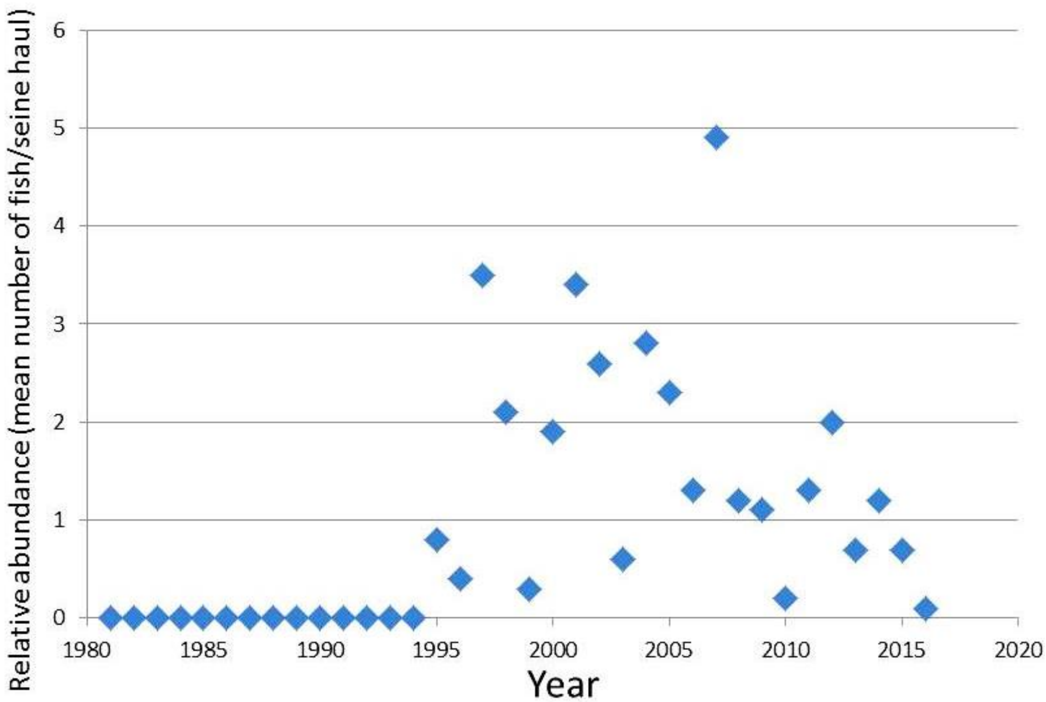


Figure 1. Historical and current distribution of Lake Chub *Couesius plumbeus* in Illinois. Lake Michigan contour lines are 25 meters.

Table 1. Relative abundance (mean number of fish/seine haul) of **Lake Chub** *Couesius plumbeus* over 38 years of beach seine sampling at five locations along the Lake Michigan shoreline in Illinois, 1979-2016. The number of seine hauls is in parentheses. NS indicates no sample. IDNR unpublished data.

	Location					
Year	Farwell Ave (205)	Jackson Outer (220)	North Point (179)	Tower Road (206)	Waukegan (224)	All Locations (1,034)
1979	NS	0	NS	NS	NS	0
1980	NS	NS	NS	NS	NS	NS
1981	0	0	NS	NS	NS	0
1982	0	0	NS	NS	NS	0
1983	0	0	NS	NS	NS	0
1984	0	0	NS	NS	NS	0
1985	NS	NS	NS	NS	0	0
1986	0	0	NS	0	0	0
1987	0	0	NS	0	0	0
1988	0	0	NS	0	0	0
1989	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1992	NS	0	0	NS	0	0
1993	0.0	0	0	0	0	0
1994	0.0	0	0	0	0	0
1995	3.7	0	0	0.7	0.2	0.8
1996	0.8	0	0	1.3	0	0.4
1997	12.1	0	0	4.6	0.7	3.5
1998	10.3	0	0.3	0.6	0.1	2.1
1999	1.1	0	0	0.3	0	0.3
2000	8.4	0	0	0	0.1	1.9
2001	6.7	0	4.5	5.1	2.0	3.4
2002	8.0	0	0.7	1.3	2.8	2.6
2003	3.5	0	0	0	0	0.6
2004	7.4	0	0	1.3	7.9	2.8
2005	10.6	0	0.3	2.4	0	2.3
2006	4.4	0	0.1	1.8	0.2	1.3
2007	19.7	0	0	1.1	0	4.9
2008	5.3	0	0	0	0	1.2
2009	5.0	0	0	0	0	1.1
2010	0.7	0	0	0.2	0	0.2
2011	0	0	0	1.4	5.3	1.3
2012	0	0	0	0	9.6	2.0
2013	3.2	0	0	0.1	0	0.7
2014	5.0	0	0	0.6	0.1	1.2
2015	2.9	0	0	0	0	0.7
2016	0.1	0	0.3	0	0	0.1
All Years	4.8	0	0.1	1.0	0.9	1.3

Figure 2. Relative abundance of Lake Chub from 1981 to 2016. Combined data from Lake Michigan beach seine surveys at Farwell Avenue, Jackson Outer Harbor, North Point, Tower Road, and Waukegan. IDNR unpublished data.



Habitat

Lake Chub appear to prefer cobble or gravel substrate, but can also be found over sand. They are generally not found over mud or within vegetation. They will enter tributaries of Lake Michigan, but are typically only found at or near the mouths of the creek or river. They are most often found in the exposed portions of the shoreline, instead of within protected bays or harbors. When in streams, they are found in areas with significant current, like riffles, as opposed to pools with little to no moving water.

During a survey of Isle Royal in Lake Superior, Hubbs and Lagler (1949) found Lake Chub out in the lake in 20-35 feet of water, immediately along the shore, and in portions of the streams close to Lake Superior. A similar pattern was displayed in Michigan's upper peninsula, the Lake Superior and Lake Michigan shores of Wisconsin, as well as the Canadian portions of lakes Superior, Huron, and Ontario, with Lake Chub being found along the shore or near the mouths of tributaries, especially during spring spawning (Hubbs and Brown 1929, Taylor 1954, Becker 1983). In Wisconin, they were found over sand with scattered boulders (Becker 1983). They utilize Lake Michigan tributaries for spawning, but some Lake Superior tributaries have year-round residents (Becker 1983, Willink personal observation). Dymond (1926) also found them near the mouths of tributaries, as well as in bays of Lake Nipigon with sand bottom and sparse vegetation. In Lake Abitibi in Ontario, they were found over sand or gravel along exposed shorelines instead of in sheltered bays with vegetation. When found in a nearby river, they were in a section with a fast current (Dymond and Hart 1927). They are most abundant in less than 1 meter of water (Becker 1983). In Lake Ontario, they have been found at depths of 36 feet and 100 feet (Dymond et al. 1929). In Lake Huron and nearby lakes, they have been found at night at depths of 5-8 meters and 18-25 meters (Emery 1973).

Species Biology

The most detailed description of Lake Chub spawning is by Brown et al. (1970) for a Saskatchewan river connected to a lake. Lake Chub spend the entire or most of the year in the lake. Many migrated from the lake into the river in May when water temperatures were 4^{o} C. The ice cover was in the process of melting at this time. Some migrated at least 3 kilometers through the lake to reach the river, but the exact minimum and maximum migration distances are unknown. Fish initially staged in the deeper parts of the river. By late May when water temperatures were 8^{o} C, the Lake Chubs moved into shallower waters to spawn. Fish returned to the lake by early June when water temperatures were 16^{o} C. As Lake Chub were leaving the river, Longnose Dace *Rhinichthys cataractae* were migrating into the river. No Lake Chubs were found in the river at any other time of the year (Brown et al. 1970). In an upstate New York stream, Lake Chub spawned in gravel riffles within 20 meters of the lake. Eggs were present in mid- to late-June one year and mid-May the next year, when water temperature was 12 to 13^{o} C (Fuiman and Baker 1981).

In the Saskatchewan lake, Lake Chub appeared in the shallows in mid-June when water temperatures were 10^{o} C. Spawning occurred in shallow water over rocky shoals or along rocky shores in late June. It is assumed that the reason for the later spawning in the lake is because the lake was colder. Gravid females were found until mid-September. There did not appear to be any mixing of the 'river-breeding' population and the 'lake-breeding' population (Brown et al. 1970).

It has been demonstrated that temperature is the primary factor controlling spermatogenesis, although photoperiod may play a slight role. This would help explain why Lake Chub in British Columbia spawn in June or July (Ahsan 1966). They migrated into tributaries in mid-June, as the ice was finished melting, in Western Labrador (Bruce and Parsons 1976). And they were reported in breeding colors in August in central Quebec (Richardson

1944), although there were no actual spawning observations. Lake Chub spawn in June in Lake Nipigon (Dymond 1926). Females with eggs were found in Lake Ontario on June 6 and July 21 (Dymond et al. 1929). In the Great Lakes, they spawn from April to May (Scott and Crossman 1973, Becker 1983). In Lake Michigan tributaries in Wisconsin, spawning migrations up streams could be 1 mile, but were usually less than ½ mile (Becker 1983).

In Saskatchewan, fish entered shallows in the morning, congregating over rocks in just a few inches of water along the shore. No territories were defended, and no nests were built. However, males were aggressive towards each other during spawning, chasing each other, and although they may not set up rigorous territories, they will try to defend space around themselves. Males were more numerous than females in the spawning area, but this may because females enter spawn, then leave, while males remain looking for additional opportunities (Brown et al. 1970). Bruce and Parsons (1976) also found males to be more common.

Spawning took place in the afternoon through the evening. When a female is present, males chase the female, bumping her from below or swimming alongside, each male trying to be the closest. Colors become more intense. Eventually, a male pushes a female near rocks, the male rubs up against female and vibrates until eggs are released. This pattern is repeated several times (Brown et al. 1970).

Non-adhesive eggs were spread over rocks or, less frequently, gravel. Eggs are rarely dispersed over mud or leaves. There is no parental care. The number of eggs per female ranged from roughly 700 eggs at 90 mm total length to 2400 eggs at 130 mm total length. Fry were first observed in the river in early June. In the laboratory, eggs hatched after 10 days at 8 to 19^{o} C (Brown et al. 1970). In western Labrador, the number of eggs from fish ranging from 90 to 119 mm fork length was 214-1540 (Bruce and Parsons 1976).

In spawning groups in a Saskatchewan river and lake, age-group III females averaged 95.1 mm total length, and age-group IV were 110.5 mm on average. Age-group V and older accounted for 6% of the females. Females appeared to be larger and live longer than males (Brown et al. 1970). During spawning in a western Labrador stream, most fish were age-group III, with some in age-group IV, and none in age-group V. Age-group II males were present and mature, but no females were seen in this age-group. Most age-group III were females mature, and they averaged 86 mm fork length. Like in Saskatchewan, females tended to be longer than males (Bruce and Parsons 1976). Females were also larger than males at a Lake Michigan (Wisconsin) spawning population. All males were age class III, except for one age class IV. All females were age class IV or older, with some potentially being VI or VII (Becker 1983).

In Lake Michigan of Wisconsin, in April age class III fish averaged 155.1 mmTL, age class IV fish were 168.6 mmTL, and age class V fish were 177.8 mmTL. In July, age class I fish averaged 71 mmTL, age class II fish were 109.6 mmTL, age class III fish were 130.6 mmTL, and age class IV fish were 165.5 mmTL. Young-of-year were 44-70 mmTL in September (Becker 1983).

In the laboratory, Lake Chub are most active during the day. However, field studies in a stream in New Brunswick from late June to late August found them to be most active in the morning and evening. It was possible to capture them in baited traps during the day, so it was inferred that there must be some level of activity throughout the daylight hours. They seemed to move mostly at night during spawning migrations (Reebs et al. 1995). They exhibited a similar pattern in Lake Huron and nearby lakes, being more active during the day and twilight hours, but also partially active at night (Emery 1973). Lake Chub will form large schools or aggregations at times (McPhail and Lindsey 1970, Becker 1983).

This crepuscular or diurnal activity pattern is consistent with their neuroanatomy. The relatively large optic lobes of their brain and an almost complete lack of external taste buds is an indication that the Lake Chub uses almost exclusively sight to forage for prey. Taste buds are also relatively low in number in the mouth, so the fish apparently does not sort food in the mouth (Davis and Miller 1967).

The diet of Lake Chub from the Wisconsin portion of Lake Michigan was composed of cladocerans and copepods in smaller fish. Larger fish had eaten Ephemeroptera, Diptera, and Odonata (Becker 1983). In western Lake Superior, they primarily ate crustaceans (e.g., *Mysis*, copepods, and cladocerans) as well as the insects Chironomidae and other Diptera. In the fall, molluscs and fish eggs were present in the diet, and unidentified fish in the spring (Anderson and Smith 1971). Ontario populations foraged on chironomid larvae and other insect larvae, as well as cladocerans and algae (Scott and Crossman 1973). Northwestern Canada populations incorporated both terrestrial and aquatic insects, zooplankton, algae, and small fish into their diet (McPhail and Lindsey 1970).

Some work has been done on the thermal physiology of the species, taking advantage of some Lake Chub populations in British Columbia that are found in hot springs (Darveau et al. 2012). When comparing a stable hot spring population to a variable temperature hot spring population to a typical lake population with large temperature fluctuations throughout the year, the fish from the stable temperature conditions were the least tolerant to large temperature changes. But, when given a chance to acclimate, it was possible to raise the critical thermal maximum for all populations. A similar result was found for the lowering of critical thermal minimum, but fish from hot springs acclimated to warm temperatures did poorly in cold temperatures.

Lake Chub circadian periods (length of activity during one day) changed throughout the year. Temperature did not play a role, but photoperiod appeared to (Kavaliers 1978). The pineal organ plays a role in controlling the circadian rhythm (Kavaliers 1980), but there is also a nonpineal extraretinal photoresponse that appears to be able to act independently of the pineal organ (Kavaliers 1981). The photo cues influencing the circadian rhythm are twilight and day-length (Kavaliers and Ross 1981). The end result is a complex series of factors controlling the daily activity patterns of a species in an area that experiences dramatic seasonal changes every year.

Conservation / Management

Threats

No clearly defined threats have been identified for Lake Chub in Lake Michigan in Illinois. Invasive species and habitat loss are possibilities, but not documented at this time. Because they prefer cooler water temperatures, it is realistic to presume that climate change will influence their distribution, but this has not been demonstrated either.

Regulations

Lake Chub are not listed as Endangered or Threatened in Illinois. They are not considered game fish. The only regulations for Lake Chub would be general fishing regulations covering non-game fish and regulations covering the movement or sale of fishes potentially infected with the disease Viral Hemorrhagic Septicemia.

Conservation Efforts

There are no specific conservation efforts in Illinois or other Great Lakes states.

There are conservation efforts in Wyoming, Nebraska, South Dakota, and Colorado, where Lake Chub are found in rivers and reservoirs (Isaak et al. 2003, Stasiak 2006). These populations are fragmented and declining. Conservation recommendations are general or stream-oriented. For example, invasive species control, reducing numbers of predators, reducing erosion and sedimentation, preventing habitat loss, improving water quality, managing water quantity during droughts and floods, increase connectivity so recolonization is possible, and chemical reductions (e.g., fertilizer, pesticides, etc.) (Isaak et al. 2003, Stasiak 2006).

Survey Guidelines

In wadable areas along the shores of Lake Michigan, Lake Chub can be caught with a beach seine over sand. These seines should be relatively long, such as 25 feet or longer, but not so long that it is impossible for individuals to actually maneuver and pull the net. It also helps to have a bag in the center of the seine to concentrate the fishes in one spot and help prevent them from escaping.

Seining over cobble is problematic, so the best method under these conditions is to use either a backpack electrofisher or an electrofishing boat, depending upon the depth of the water. This is a productive method when the water is clear and waves are minimal. Otherwise, there is very little chance of finding Lake Chub while electrofishing.

Fish traps (e.g., minnow traps, crab traps, etc.), fine-mesh gill nets, and trawls should be able to collect Lake Chub in deeper water. However, very few have actually been found to date with these methods in Illinois.

When surveying tributaries of Lake Michigan, it is best to conduct the work in the spring to try and coincide with potential spawning behavior. During the rest of the year, Lake Chub may be in tributary mouths, but it is unlikely to find them upstream.

Stewardship Recommendations

Lake Chub appear to have an affinity for cobble and other irregular substrates along the bottom. In Lake Michigan, sand is always moving along the shoreline, sometimes smothering rocky areas. This movement of sand is a natural process, but Lake Chub could benefit from initiatives that shelter areas along the lakefront, deflecting sand from cobble and other stone structures. These methods could be incorporated into harbor designs, breakwaters, etc.

Although Lake Chub spend most or all of the year in Lake Michigan, it is possible that some may enter suitable Lake Michigan tributaries in the spring to spawn. A suitable tributary would be one with stretches of water running over cobble and gravel, preferably close to the lake. The mouths of some suitable tributaries are blocked by rubble, garbage, debris, etc. Restoring tributary mouths in such a way that streams are reconnected with Lake Michigan would expand the amount of potential habitat for the Lake Chub, especially spawning habitat.

Avoidance Measures

Any construction activities that permanently cover cobble or gravel along the Lake Michigan lakefront should be discouraged. These are potential spawning and foraging sites. Lake Chub also live over sand, but sand is very common.

It is possible that Lake Chub enter Lake Michigan tributaries. These tributaries are often small and located in ravines. They can be susceptible to groundwater perturbations that run the risk of drying the stream out completely. The hydrology of these small watersheds needs to be protected.

Minimization Measures

Because Lake Chub spawn over cobble and gravel in the spring, it is important to avoid disturbing these sites in the spring, even if the disturbance is only temporary.

Mitigation and Conservation Opportunities

<u>Restoration/Habitat Creation</u>

There is a considerable amount of interest in protecting and restoring Lake Michigan tributary ravines by Illinois Department of Natural Resources, Openlands, Park District of Highland Park, Forest Preserve District of Lake County, US Army Corps of Engineers, the Field Museum, and others. It is unclear if Lake Chub in the context of ravine tributaries have been specifically considered by any of these groups, but it is a possibility.

Research Needs

Several species of fishes, including Lake Chub, are at or near the southern extent of their global range in southern Lake Michigan. These species are also distributed throughout Canada and the northern United States, and are generally found in cool or cold water systems. The impacts of climate change on these species in Lake Michigan need to be examined in greater detail. Will a given species shift its distribution northward? Or will a given species shift its habitat to deeper, colder waters? Or will Lake Michigan buffer the impacts of climate change such that there are no perceptible changes in a species' distribution or habitat?

Nothing is known about Lake Chub spawning in Illinois. Presumably they do so over cobble and gravel along the Lake Michigan shoreline. Perhaps they spawn in some of the Lake Michigan tributaries. More information is required about regional Lake Chub spawning.

References

Agassiz, L. 1850. Lake Superior: its physical character, vegetation, and animals, compared with those of other and similar regions. Gould, Kendall, and Lincoln, Boston. 428 pages.

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

Anderson, E.D. and L.L. Smith Jr. 1971. A synoptic study of food habits of 30 fish species from western Lake Superior. Minnesota Agricultural Experiment Station Technical Bulletin 279, 199 pages.

Bailey, R.M., W.C. Latta, and G.R. Smith. 2004. An atlas of Michigan fishes with keys and illustrations for their identification. Miscellaneous Publications Museum of Zoology, University of Michigan 192:1-215.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison. 1,052 pp.

Bestgen, K.R., K.D. Fausch, and S.C. Riley. 1991. Rediscovery of a relict southern population of Lake Chub, *Couesius plumbeus*, in Colorado. Southwestern Naturalist 36:125-126.

Brown, J.H., U.T. Hammer, and G.D. Koshinsky. 1970. Breeding biology of the lake chub, *Couesius plumbeus*, at Lac la Ronge, Saskatchewan. Journal of the Fisheries Research Board of Canada 27:1005-1015.

Bruce, W.J. and R.F. Parsons. 1976. Age, growth and maturity of lake chub (Couesius plumbeus) in Mile 66 Brook, Ten Mile Lake, western Labrador. Fisheries and Marine Service Research and Development Technical Report 683:1-13.

Darveau, C.-A., E.B. Taylor, and P.M. Schulte. 2012. Thermal physiology of warm-spring colonists: variation among lake chub (Cyprinidae: *Couesius plumbeus*) populations. Physiological and Biochemical Zoology 85:607-617.

Davis, B.J. and R.J. Miller. 1967. Brain patterns in minnows of the genus Hybopsis in relation to feeding habits and habitat. Copeia 1967:1-39.

Dymond, J.R. 1926. The fishes of Lake Nipigon. University of Toronto Studies, Biological Series, Publications of the Ontario Fisheries Research Laboratory 27:1-108.

Dymond, J.R. and J.L. Hart. 1927. The fishes of Lake Abitibi (Ontario) and adjacent waters. University of Toronto Studies, Biological Series, Publications of the Ontario Fisheries Research Laboratory 28:1-19.

Dymond, J.R., J.L. Hart, and A.L. Pritchard. 1929. The fishes of the Canadian waters of Lake Ontario. University of Toronto Studies, Biological Series, Publications of the Ontario Fisheries Research Laboratory 37:1-35.

Emery, A.R. 1973. Preliminary comparisons of day and night habits of freshwater fish in Ontario lakes. Journal of the Fisheries Research Board of Canada 30:761-774.

Forbes, S.A. 1884. A catalogue of the native fishes of Illinois. Report of the Illinois State Fish Commissioner for 1884:60-89.

Forbes, S.A. and R.E. Richardson. 1920. The fishes of Illinois. Illinois Natural History Survey. Second Edition. 357 pp.

Fuiman, L.A. and J.P. Baker. 1981. Larval stages of the lake chub, *Couesius plumbeus*. Canadian Journal of Zoology 59:218-224.

Hubbs, C.L. 1942. Sexual dimorphism in the cyprinid fishes, *Margariscus* and *Couesius*, and alleged hybridization between these genera. Occasional Papers of the Museum of Zoology, University of Michigan 468:1-6.

Hubbs, C.L. and D.E.S. Brown. 1929. Materials for a distributional study of Ontario fishes. Transactions of the Royal Canadian Institute 17:1-56.

Hubbs, C.L. and K.F. Lagler. 1949. Fishes of Isle Royale, Lake Superior, Michigan. Papers of the Michigan Academy of Science, Arts, and Letters 33:73-133.

Hubbs, C.L. and K.F. Lagler 1964. Fishes of the Great Lakes region. University of Michigan Press, Ann Arbor. 213 pages.

Hubbs, C.L. and K.F. Lagler (and G.R. Smith). 2004. Fishes of the Great Lakes region. Revised Edition. The University of Michigan Press, Ann Arbor. 276 pp.

Isaak, D.J., W.A. Hubert, and C.R. Berry Jr. 2003. Conservation assessment for lake chub (*Couesius plumbeus*), mountain sucker (*Catostomus platyrhynchus*), and finescale dace (*Phoxinus neogaeus*) in the Black Hills National Forest of South Dakota and Wyoming. U.S. Geological Survey, 94 pages.

Jordan, D.S. 1878. A catalogue of the fishes of Illinois. Bulletin of the Illinois State Laboratory of Natural History 1:37-70.

Kavaliers, M. 1978. Seasonal changes in the circadian period of the lake chub, *Couesius plumbeus*. Canadian Journal of Zoology 56:2591-2596.

Kavaliers, M. 1980. Retinal and extra-retinal entrainment action spectra for the activity rhythms of the lake chub, *Couesius plumbeus.* Behavioral and Neural Biology 30:56-67.

Kavaliers, M. 1981. Circadian rhythm of nonpineal extraretinal photosensitivity in a teleost fish, the lake chub, Couesius plumbeus. Journal of Experimental Zoology 216:7-11.

Kavaliers, M. and D.M. Ross. 1981. Twilight and day length affects the seasonality of entrainment and endogenous circadian rhythms in a fish, *Couesius plumbeus*. Canadian Journal of Zoology 59:1326-1334.

McPhail, J.D. and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Bulletin of the Fisheries Research Board of Canada 173:1-381.

Page, L.M. and B.M. Burr. 2011. Peterson field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Harcourt, Boston. 663 pp.

Reebs, S.G., L. Boudreau, P. Hardie, and R.A. Cunjak. 1995. Diel activity patterns of lake chubs and other fishes in a temperate stream. Canadian Journal of Zoology 73:1221-1227.

Richardson, L.R. 1944. Brief records of fishes from central Quebec. Copeia 1944:205-208.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184:1-966.

Smith, P.W. 1979. The fishes of Illinois. University of Illinois Press, Urbana. 314 pp.

Smith, G.R. 2010. Guide to Great Lakes fishes. University of Michigan Press, Ann Arbor. 126 pp.

Stasiak, R. 2006. Lake chub (*Couesius plumbeus*): a technical conservation assessment. USDA Forest Service, Rocky Mountain Region, 49 pages.

Taylor, E.B., C.-A. Darveau, and P.M. Schulte. 2013. Setting conservation priorities in a widespread species: phylogeographic and physiological variation in the lake chub, *Couesius plumbeus* (Pisces: Cyprinidae). Diversity 5:149-165.

Taylor, W.R. 1954. Records of fishes in the John N. Lowe collection from the Upper Peninsula of Michigan. Miscellaneous Publication University of Michigan Museum of Zoology 87:1-50.

Wells, A.W. 1981. Occurrence of hybridization between *Couesius plumbeus* and *Semotilus margarita*. Copeia 1981:487-489.

Conservation Guidance for

Mottled Sculpin

Cottus bairdii Girard

IL Status: NatureServe – S2

US Status: NatureServe – N5

Global Rank: NatureServe - G5

Trend: Stable in Fox and Vermilion (Wabash) watersheds, declining elsewhere

Family: Cottidae

Habitat: Coolwater streams and nearshore Lake Michigan

Similar Species:
Banded Sculpin *Cottus carolinae*
Slimy Sculpin *Cottus cognatus*
Spoonhead Sculpin *Cottus ricei*
Deepwater Sculpin *Myoxocephalus thompsonii*
Round Goby *Neogobius melanostomus*

Species Information

Characteristics

Large, moderately flattened head and body tapering to a laterally compressed caudal peduncle, giving it a 'tadpole-like' appearance. Moderately upturned eyes. Wide terminal mouth with numerous tiny teeth in bands on the upper and lower jaws. Two midline chin pores. Gill membranes broadly connected to isthmus. Three spines on preopercle covered by skin, except possibly the upper spine that may be exposed. Upper spine length typically 1/2 of eye diameter and straight or only moderately curved. Large pectoral fins with 13-17 rays. Pelvic fins beneath pectoral fins, with 1 spine and 4 rays, the spine and first ray closely connected and difficult to distinguish. Two dorsal fins barely connected at base. First dorsal 6-9 spines, second dorsal 15-19 rays. Anal fin 10-14 rays. Rounded caudal fin. Body largely scaleless, but sometimes with patch of prickles, usually beneath pectoral fins. Incomplete lateral line extending to approximately 2/3 the length of the second dorsal fin, with 14-27 pores. Gas bladder is absent. Coloration a mottled brown or cream with three or four indistinct black or dark brown vertical bars. Darker on back and lighter belly. First dorsal fin has a dark blotch along front margin, and another dark blotch at the posterior end that may be confluent with dark bar on body. Other fins may have diffuse dark spots that sometimes form indistinct bands. Breeding males have reddish band near dorsal edge of first dorsal fin, with dark band beneath it. Adult males with genital papilla, whereas it is absent or reduced in females (Hann 1927, Ludwig and Norden 1969). Can reach 6 inches / 15 cm in length (Scott and Crossman 1973, Becker 1983, Bailey et al. 2004, Hubbs and Lagler (and Smith) 2004, Page and Burr 2011).

Can be distinguished from similar species by having an incomplete lateral line (versus complete lateral line in Deepwater Sculpin *Myoxocephalus thompsonii*, Spoonhead Sculpin *Cottus ricei*, and Banded Sculpin *Cottus carolinae*), pelvic fins with 1 spine and 4 rays (versus pelvic fin with 1 spine and 3 rays in Slimy Sculpin *Cottus cognatus*), and two separate pelvic fins (versus pelvic fins fused to form disk in Round Goby *Neogobius melanostomus*).

Taxonomy

Illinois has two subspecies of Mottled Sculpin, the Great Lakes Mottled Sculpin *Cottus bairdii kumlieni* and the Northern Mottled Sculpin *Cottus bairdii bairdii*.

Strauss (1986) documented hybridization between Mottled Sculpin and Slimy Sculpin in the upper Susquehanna drainage. Hybrids have not been observed in Illinois, but it is a possibility. (See also Hubbs 1955:17 and Robins 1954:161 and Godkin et al. 1982). Furthermore, sculpins have the ability to adapt to micro-habitats, as evidenced by a specialized cave population within the Mottled Sculpin – Slimy Sculpin complex in Pennsylvania (Espinasa and Jeffery 2003). This type of specialization, or adaptation to another form of micro-habitat, has not been documented in Illinois, but it is also a possibility

Because of the confusing taxonomy, many older papers in the literature that refer to Mottled Sculpin *Cottus bairdii* are now either considered different species or are probably different species. Since they are closely related, their ecologies are probably similar to the Mottled Sculpins found in Illinois. But in case there are differences, their life-history information is not included in this synopsis. If one is curious in reading these publications, a partial list is found in the Addendum.

Distribution and Status

In Illinois, the Great Lakes Mottled Sculpin *Cottus bairdii kumlieni* is restricted to Lake Michigan and the Rock River watershed (Fig. l). It is found along the entire shoreline of Lake Michigan. The most recent record in Lake Michigan was off of Lake Bluff in 2014 (S. Robillard and D. Makauskas). Prior to that, no Mottled Sculpins were seen since another one was found off of Lake Bluff in 2005. The next most recent records are off Jackson Park and another in Chicago

Harbor in 1999. Various parts of this area are annually surveyed by Shedd Aquarium, Field Museum, IDNR, INHS, USACoE, and USF&WS.

In the Rock River basin, the sculpin is currently abundant in South Kinnikinnick Creek (P. Willink and T. Anton personal observation 2016, K. Rivera routine IDNR basin survey). There are historical records from the Leaf River (1969), Spring Branch of Stillman Creek (1948), and McFadyen Branch of Kent Creek (1948). All three areas were visited by P. Willink and T. Anton (D. Miller and others from Severson Dells Nature Center / Winnebago County Forest Preserve District collaborated with the Kent Creek surveys, and K. Rivera, R. O'Neil (both IDNR) and J. Belcik (UofI) collaborated with Stillman Creek surveys) in 2016, but no sculpins were found. The exact locations of Spring Branch and McFadyen Branch are uncertain, but attempts were made to find cold streams flowing out of springs. IDNR and INHS have recently surveyed sites either at or close to these locations, and have not found sculpins.

There are sculpins in the Rock River watershed in Wisconsin, including just a few miles north of the Illinois-Wisconsin border. No sculpins have been found in nearby streams within Illinois (J. Tiemann, personal communication 2016).

The Northern Mottled Sculpin *Cottus bairdii bairdii* is restricted to the Illinois River and Vermilion (Wabash) watersheds (Fig. 1). Within the Vermilion watershed, it is found near the Indiana border in Grape Creek, Willow Creek, and Whippoorwill Branch, and is generally common at these sites (P. Willink, T. Anton, and J. Belcik personal observation 2016; IDNR and INHS records).

In the Illinois basin it is most abundant in the Fox watershed, found in many tributaries along its length downstream of the Fox Chain-of-Lakes. Current numbers appear to be comparable to historical abundances.

There is only one record from the Kankakee, and that was from Tower Creek in 2001 (F. Veraldi). The site was revisited in 2016 by P. Willink, F. Veraldi, and N. Barkowski, but no sculpins were found. It is unclear if this record is from an isolated population or stray individuals. Mottled Sculpins are found in the Kankakee headwaters in Indiana (Simon 2011), so there is always the possibility that some may be washed downstream into Illinois.

There are historical records from Pecumsaugan Creek (1962), but none have been found since then.

Northern Mottled Sculpin were historically found in three streams in the Des Plaines watershed (Willink and Veraldi 2009), but there are no records from Hickory Creek since 1997 or Long Run since 1955. Hickory Creek was surveyed multiple times by P. Willink and J. Bland in 2015-2016, and it is part of the routine IDNR basin survey. Portions of Long Run were surveyed in 2005 by P. Willink. There is still an isolated population in Black Partridge Creek (Steinmetz and Soluk 2001, Steinmetz et al. 2002, and P. Willink personal observation), but it is essentially an 'island'.

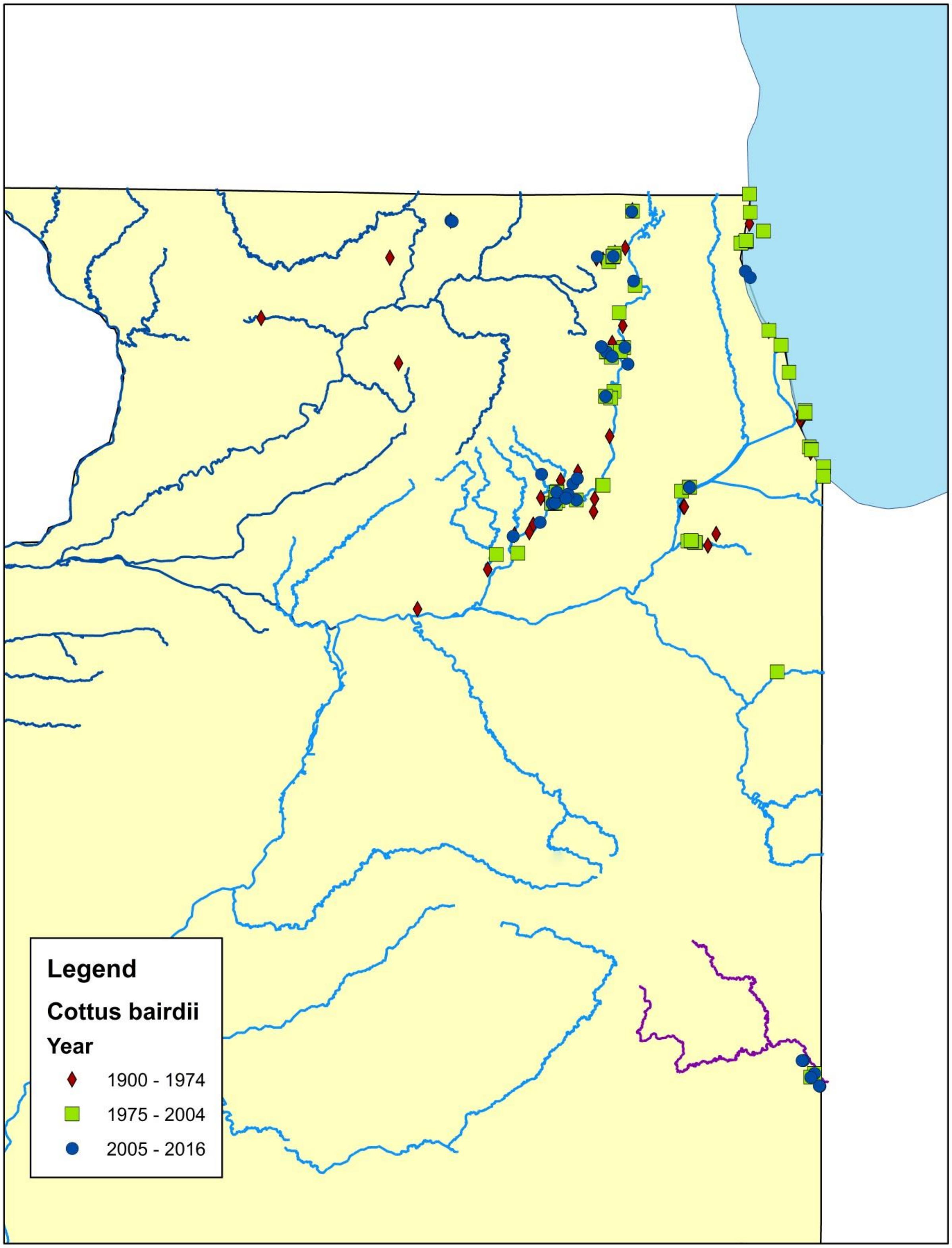


Figure 1. Historical and current distribution of Mottled Sculpin *Cottus bairdii* in Illinois.

Most of the above information is based on presence – ‘absence’ surveys that may incorporate number of specimens, and possibly the amount of effort it took to collect them. A more detailed analysis of the population in Black Partridge Creek was conducted by Steinmetz and Soluk (2001) and Steinmetz et al. (2002). The sculpins are found in a 1,200 foot (518 meters) stretch of stream. After extensive sampling, they used one method to estimate the population size to be 2,109 individuals in 2000 and 1,968 individuals in 2001, which translates to 0.075 sculpin/ft2 (0.81m2) in 2000 and 0.076 sculpin/ft2 (0.82/m2) in 2001. A different method estimated the population to be 1,200 individuals in 2000 and 1463 individuals in 2001, which translates to 0.044 sculpin/ft2 (0.47m2) in 2000 and 0.054 sculpin/ft2 (0.57m2) in 2001. These are probably underestimates, but they are about average according to the literature. Significant number of young-of-year were found. Four age classes were recognized based on sizes reported in the literature (Steinmetz and Soluk 2001, Steinmetz et al. 2002).

Steinmetz et al. (2002) conducted a Population Viability Analysis to simulate the status of the Black Partridge Creek population over the next 50 years (1000 replications). Their results indicate that the population is currently healthy and stable, and assuming no major environmental changes over the next 50 years, should continue to be healthy and stable. However, large-scale changes that could lower the carrying capacity of the population or increase the frequency of catastrophes could have disastrous consequences. Because the sculpins are dependent upon the stable cool water temperatures and flow at the site, anything that disrupts these conditions, such as a lowering of the water table, could drive the population to extinction. Increased sedimentation runs the risk of smothering their cobble habitat (Steinmetz et al. 2002).

In summary, the Great Lakes Mottled Sculpin is currently only known to be present in one stream in the Rock River watershed and rare in Lake Michigan, with only three records in the last couple decades. The Northern Mottled Sculpin appears to be stable throughout much of the Fox River watershed, stable in a small area of the Vermilion-Wabash watershed, rare to potentially extirpated from Pecumsaugan Creek, currently present in one stream in the Des Plaines watershed, and may have occasional individuals from the Kankakee River headwaters enter from Indiana.

Habitat

Mottled Sculpin are found in both streams and nearshore Lake Michigan. In streams, the bottom is usually cobble or gravel. Sometimes they are found over sand, but almost never over mud. When sand is the dominant substrate, the sculpins are usually associated with sticks, logs, etc. or some other type of protective cover. Stream gradient is moderate to high.

Water temperatures are cool, and the water source is typically groundwater, oftentimes with springs and seeps nearby. In Black Partridge Creek in Illinois, Steinmetz et al. (2002) measured annual temperatures in a stream reach containing sculpins, as well as upstream and downstream of the sculpin population. Average temperatures over two years ranged from roughly 2-23C. The middle section with the sculpins had the most stable temperature readings, with relatively colder summer temperatures and relatively warmer winter temperatures. This was also where most of the springs and seeps are located. The warmest summer temperatures were upstream, and were at times 10C above the temperatures in the section of stream with sculpins (Steinmetz et al. 2002). In a southern Michigan stream, water temperature was 18.67^{o}+/-0.21^{o}C in the summer (July-August 1999-2005), and 2.08^{o}+/-0.32^{o}C in the winter (December-January 1998-2005) (Breen et al. 2009). Water flow was stable because of groundwater input (Breen et al. 2009).

Small to medium-sized streams with cool water and a moderate to high gradient often fall into the category of headwater streams. As multiple streams continue to merge farther down the watershed, the primary stream grows in size and tends to warm. Sculpins are far less common to absent in this portion of the watershed. Zorn et al. (2002) found a similar pattern when conducting a cluster analysis of stream fishes in Michigan's Lower Peninsula. Their results indicated that Mottled Sculpin are typically found in streams with smaller catchment areas, medium flow, and some groundwater input. C.L. Hubbs felt that Mottled Sculpins were more common among vegetation in colder northern Michigan streams, whereas they were more common among cobble in relatively warmer southern streams (Hann 1927).

In Lake Michigan, Mottled Sculpin are associated with bedrock outcrops, cobble deposits, etc.

Species Biology

Mottled Sculpin live on the bottom where they are well camouflaged among the rocks. They use their large pectoral fins to hold their place in the current, darting out from time-to-time to catch prey (personal observation, PWW, Pearse 1918, Cahn 1927). They will swim away when threatened, but rarely go more than a few feet at a time (Hann 1927).

In Illinois, Mottled Sculpin spawn in or around April (Smith 1979). Gravid females were seen in South Kinnikinnick Creek on March 29, 2016, and sculpin eggs along with recently spawned adults were seen in Rob Roy Creek on May 2, 2013 (personal observation, PWW). In Lake Michigan – Calumet Harbor, gravid females were seen May 5 and 12, 1995 and May 15, 1996. Spent females were seen May 13 and 19, 1995 and May 22, 1996 (Janssen and Jude 2001).

Ludwig and Norden (1969) published a detailed account of Northern Mottled Sculpin spawning in Mt. Vernon Creek, southern Wisconsin, from April 1 to May 3. Water temperatures were 8.9-13.9^{o} C (48-57^{o} F). Nests were usually in riffles free of sediment, typically in spaces beneath cobble. The ceiling of these spaces is often flat. Sometimes nests were in crevices, on Elodea, or in excavated tunnels 4 cm across and 15+ cm deep. There was only one mature male per nest, but there could be multiple females and immature individuals.

After a gravid female enters the nest, the male and female rotate until they are upside-down. The pale orange-yellow adhesive eggs are attached to the roof of the nest in a clump. The female leaves shortly thereafter. It is possible for another gravid female to enter the same nest at a later time and deposit more eggs with the same mature male. Nests averaged 1,205 eggs, and within a nest there was an average of 3.3 clumps of eggs per nest. Eggs hatched in roughly 17 days at 11.1-12.8^{o} C (52-55^{o} F). Larvae absorbed their yolk sacs in 14 days, at which time they left the nest. Males remained in the nests until the fry were able to leave (Ludwig and Norden 1969).

Smith (1922) recorded very similar observations from a small stream in southeastern Michigan. Eggs were found attached to the undersides of rocks in a riffle in April and May. Any given nest could have two to three clumps of eggs, with about 200 eggs per clump. Different clumps could be different shades of white to orange-yellow, and are presumed to be from different females. An adult sculpin was always found in the nest with the eggs, and each time this adult was a male.

Hann (1927) also made similar observations in a southeastern Michigan stream in regards to nests under stones and males guarding nests. Nests were in water 15-35 cm deep. The first eggs of the season were noticed on April 19, newly hatched fry as well as eggs were present on May 26, and then no eggs were located on May 28. Water temperature ranged from 5-16 C during this time period. It was not uncommon for multiple females to visit a single nest, and one nest had five groups of eggs. Nest sites were well oxygenated.

In an aquarium, Hann (1927) observed a female upside down in a nest with the male next to her but right-side up. He appeared to be holding her in place. Initially they were facing the same direction, but then he turned around. The female spun right-side up and left eggs attached to the ceiling of the nest. The male remained near the eggs and even turned upside down at one point. It is unclear if he fertilized the eggs at this time or some other time. The eggs hatched in 20 days at 13-15 C.

C.L. Hubbs postulated that sculpins in colder northern Michigan streams may spread their eggs over plants (Hann 1927), but this does not seem to have been verified.

In west-central Ohio, spawning occurred mid-April to mid-May, with males guarding nests until late June (Downhower and Brown 1979). Adult males were generally solitary during the spring and summer, sometimes acting aggressively towards each other. This appears to lead to a uniform distribution among spawning sites, with males around 0.1 meters from each other. Smaller sculpins were distributed throughout the area, but not usually in the exact same place as adult males. Since a large sculpin can eat another sculpin that is 40 millimeters less in length than itself, it is assumed larger sculpins either chase off or eat smaller individuals (Downhower and Brown 1979). Males defended their nests, but did not defend the area around their nests (Downhower et al. 1983).

Males are generally larger than females (Downhower et al. 1983). All males, regardless of size, seem to prefer larger nests. However, larger males were able to defend the larger nests from smaller individuals. If there was an abundance of nesting sites, the smaller sites were unutilized.

Females were more likely to be found at nests where other females had already spawned. Apparently some nests and/or males are more desirable than others (Downhower and Brown 1979). Females appear to prefer larger males, with male size correlated with female reproductive success. But the smallest females tended to stay away from the largest males because of the cannibalistic nature of the species (Downhower et al. 1983). Consequently, roughly the same sized males and females spawned with each other, with larger females spawning earlier (Downhower et al. 1987).

Hence larger males tended to have larger nests, spawned more times, and spawned earlier in the season. Still, even smaller males in smaller nests were usually able to obtain at least one spawning opportunity, and this tended to be later in the season (Downhower et al. 1983, 1987).

In Black Partridge Creek in Illinois, there were two peaks in the size distribution of the stream population in August, with one peak a little less than 40 mm and the other a little less than 80 mm. Steinmetz and Soluk (2001) thought the second peak represented two age classes based on what has been reported in the literature. In a southeastern Michigan stream, sculpins were mature at two years with a standard length of 45-70 millimeters. Average size of Year 1 individuals was 34 mmSL. Average size of adult males was 73 mmSL, and the average size of adult females was 69.4 mmSL. The largest individual was a male at 113 mmSL (Hann 1927). In Calumet Harbor, the largest individual was approximately 115 mm Total Length (Janssen and Jude 2001).

A comparison between Slimy Sculpin and Mottled Sculpin in northeastern Wisconsin streams discovered that Slimy Sculpin weighed more than Mottled Sculpin at a given length, although they were close in size. Furthermore, a comparison between Mottled Sculpin measured in August versus October revealed that at a given length August individuals weighed more than October individuals. October individuals were larger, but August individuals had a higher condition factor (Kinziger 1998).

Mottled Sculpin in Rob Roy Creek (Fox drainage) predominantly ate the isopod *Asellus militaris*, along with a considerable amount of algae (Anderson 1975). The isopod was not common at the site, indicating the sculpins were intentionally seeking it out. Furthermore, the isopods were mostly embedded in algae which helps explain the significant amount of algae found in the sculpin guts. Some individual sculpins ate mostly chironomids (*Procladius*, *Ablabesmyia*, and *Chironomus*), and these individuals usually had few to no isopods in their gut. Smaller sculpins were more likely to have fed upon chironomids or trichopterans (*Orchrotrichia unio*, *Cheumtopsyche aphanta*, *Hydropsyche bifida*, and *Hydropsyche betteni*). Other items in the guts were *Agabus*, *Gammarus limnaeus*, *Planorbula*, *Physa*, Naididae, and fish (Anderson 1975).

Mottled Sculpin in Calumet Harbor that ranged from 37-52 millimeters Total Length ate amphipods (Gammarus), isopods (Caecidotea), and some cladocera and diptera. Individuals 82-123 millimeters Total Length ate amphipods, isopods, and some crayfish (Janssen and Jude 2001).

Pearse (1918) examined the diet of Mottled Sculpins in southern Wisconsin, and found that they ate (in descending order) Amphipods, May-fly nymphs, Chironomid larvae, leeches, copepods, adult midges, algae, oligochaetes, ostracods, caddis-fly larvae, cladocerans, and plant remains, with Amphipods and May-fly nymphs accounting for over half. Cahn (1927) found comparable results in southeastern Wisconsin, with entomostracans and small crustaceans most common, insects, stonefly larvae, dragonfly nymphs, mayfly nymphs, Chironomus larvae, and Simulium larvae present, and the occasional small mollusk.

In lab experiments on sculpins from southwest Michigan, increased turbidity decreased foraging ability, but not significantly (Steinmetz et al. 2002).

Sculpins are generally nocturnal, spending much of the day hiding under cover. Because they are more active at night, they are easier to find and are more likely to be away from cover, like over sand (Emery 1973, Dubs and Corkum 1996, Breen et al. 2009). Peak feeding is at dusk, but they will forage throughout the night as well (Emery 1973).

In a southern Michigan stream, most sculpins only moved a few meters during the course of a year. One individual moved 511 meters in 207 days, but 84% of the individuals moved less than 100 meters. Sculpins were more likely to swim longer distances upstream than downstream (Breen et al. 2009). A western Michigan stream exhibited a very similar pattern. One individual moved 839 meters over one year, but 77% of the individuals moved less than 100 meters. Fish moved upstream and downstream, but were more likely to move upstream. However, there was more woody debris (i.e., better habitat) upstream. There was no relationship between total length and movement, but fish less than 60 millimeters were not monitored (Deboer et al. 2015)

They were active throughout the winter, with no significant seasonality differences, although some did move their home range between seasons (Breen et al. 2009).

A cluster analysis of stream fishes in Michigan's Lower Peninsula grouped Mottled Sculpin and Blacknose Dace *Rhinichthys atratulus* together (Zorn et al. 2002).

Conservation / Management

Threats

The primary threats to Mottled Sculpin are habitat loss, invasive species, climate change, and lack of connectivity among populations. The intensity of the particular threat varies from watershed to watershed.

The primary threat to Great Lakes Mottled Sculpin in Lake Michigan is invasive species, more specifically, the Round Goby *Neogobius melanostomus*. The first goby in southern Lake Michigan appeared in the Calumet River in 1993 (Charlebois et al. 1997). Since then, their population has spread and dramatically increased in number. According to SCUBA surveys in Calumet Harbor, Mottled Sculpin were common prior to the goby arrival, but were almost completely absent by 1998 (Janssen and Jude 2001). In the Illinois waters of Lake Michigan, two sculpins were collected in 1999, and then not another one until 2014. Indiana has reported a similar pattern.

There have been a number of hypotheses put forward to explain the displacement of sculpins by gobies. There does not appear to be significant predation between the two species. Juveniles of the two species may compete for food, since their diets are similar, but adult diets are not. Adult Round Gobies eat a high percentage of dreissenid mussels, whereas adult sculpins tend to forage on amphipods, isopods, and crayfish (Janssen and Jude 2001). A more telling clue was the absence of sculpin nests and young, leading to a lack of recruitment (Janssen and Jude 2001).

Experiments demonstrated that Round Gobies are simply more aggressive than Mottled Sculpins, especially in the context of defending potential nesting sites (i.e., cavities under rocks). In general, gobies were more likely to approach, chase, or bite a sculpin than vice versa. Sculpins would act to defend a nest, but were rarely aggressive in trying to displace a goby from a nest. Gobies, on the other hand, would attack sculpins in nests and actively defend their own nests. In time, gobies occupied the majority of nesting sites and there was essentially no successful sculpin spawning (Dubs and Corkum 1996, Janssen and Jude 2001).

The population of Great Lakes Mottled Sculpin in the Rock watershed was in a tenuous position to begin with because the sub-populations were widely separated. Dams and habitat degradation enhanced this fragmentation. Even minor barriers, such as the typical raised culverts under roads that are only a foot or two above the water level, can be insurmountable to a small, benthic fish that rarely, if ever, jumps. Only during floods would a sculpin be able to bypass such structures, and even then the fish would have to deal with extreme flows.

The end consequence is if something happened to one sub-population, there were limited to no colonization opportunities from the other sub-populations. Changes in surrounding land use, such as forest to agriculture, could increase erosion and sedimentation as well as alter hydrology, resulting in the extirpation of local populations.

It is not known what happened to the Leaf River population. In regards to the populations in Spring Branch of Stillman Creek and McFadyen Branch of Kent Creek, there appears to have been disruptions to the springs. In Stillman Creek, it is unclear where Spring Branch is located, but there is now a reservoir where the spring could have been according to the description of the site from 1948. It is also unclear where McFadyen Branch of Kent Creek is located, but there was a famous spring in the watershed that is now chocked with vegetation and much of the bottom is softer sediment due to reduced flow. Sculpins may still be present at these sites, but as of 2016, none have been found.

Today, there appears to be just one remaining significant population of sculpins in the Rock watershed, and that is South Kinnikinnick Creek. Its persistence appears to be due to a spring(s) and stable groundwater input as well as being located in a Boone County Conservation District nature preserve and an Illinois Nature Preserve. Climate change is a long-term concern, but habitat degradation is the most immediate and serious threat.

The population of Northern Mottled Sculpin in the Des Plaines watershed is in a similar situation. There were very few sub-populations to begin with, and they were separated from each other. Dams and habitat degradation enhanced this fragmentation. The end consequence is if something happened to one sub-population, there were limited to no colonization opportunities from the other sub-populations. The sub-populations in Hickory Creek and Long Run appear to be extirpated (Willink and Veraldi 2009), with no sculpins collected in the last nineteen years. The nearby municipality of Joliet draws its water from underground aquifers. The depth of this groundwater has been increasing over the years, so much so that Joliet is looking for alternative sources of drinking water. A possible consequence of this water drawdown may be an altered hydrology that has eliminated or warmed the local springs and groundwater inputs. Combine this with changes in land use, draining of wetlands, and several wastewater treatment plants located along Hickory Creek (Dorkin 1980, Willink and Veraldi 2009), and it appears to have been too much for the sculpins.

Northern Mottled Sculpin are still present in Black Partridge Creek (Willink and Veraldi 2009, personal observation PWW), but they are an ‘island’. Its persistence appears to be due to springs and stable groundwater input as well as being located in a Cook County Forest Preserve and an Illinois Nature Preserve. The next nearest populations are in the headwaters of the Kankakee River in Indiana or the Fox River. This population is stable, barring any catastrophes or changes in springs / seeps / groundwater input (Steinmetz and Soluk 2001, Steinmetz et al. 2002). Round Gobies are in the nearby Des Plaines River, but have not seemed to have crossed the extensive wetlands between the outlet of Black Partridge Creek and the main channel of the Des Plaines River. Even if gobies do invade Black Partridge Creek, it is unclear if they would unleash the same devastation as in Lake Michigan. Adult Round Gobies feed primarily on Zebra and Quagga Mussels(Janssen and Jude 2001). When these mussels are not present, the impact of the gobies is usually greatly reduced.

The population of Northern Mottled Sculpin in the Fox watershed is the healthiest in Illinois. Some sub-populations are isolated from each other by dams and degraded habitat, increasing the risk of local extirpation. Changes in land use could impact hydrology, and this needs to be monitored. If connectivity can be enhanced and the aquifers are protected, then the primary threat to sculpins in the Fox would be climate change.

The FishVis project (Stewart et al. 2016) modelled the impact of climate change on the distribution of Mottled Sculpin across Minnesota, Wisconsin, Michigan, New York, and portions of Indiana, Ohio, and Pennsylvania. According to their particular parameters, streams in southern Wisconsin will be generally unsuitable for the existence of Mottled Sculpin by the years 2081-2100. The Great Lakes proper were not included in the analysis. Some of the headwaters of the Rock, Fox, and Des Plaines watersheds are in Wisconsin, so it is possible to extrapolate that streams in northern Illinois face a similar future as southern Wisconsin. Mottled Sculpin is a coldwater species at the southern edge of its range. As the world warms up, and streams warm up, temperatures are expected to increase above that which sculpins currently live.

Regulations

Mottled Sculpin are not listed as Endangered or Threatened in Illinois. They are not considered game fish. The only regulations for Mottled Sculpin would be general fishing regulations covering non-game fish and regulations covering the movement or sale of fishes potentially infected with the disease Viral Hemorrhagic Septicemia.

Conservation Efforts

Mottled Sculpin was chosen by Chicago Wilderness as one of its twelve priority species in 2015. It is being used as a representative of imperiled coolwater headwater habitats. Openlands is leading the conservation efforts, collaborating with Shedd Aquarium, Illinois Department of Natural Resources, and Indiana Department of Natural Resources. The first step was developing a 5-year work plan. Key elements of the plan include assessing and potentially re-introducing Mottled Sculpin into sites in the Des Plaines and/or Nippersink watersheds, enhancing habitat in a Fox River tributary to see if the effort results in a population increase, remove barriers to increase connectivity among populations, and work with local government agencies and conservation groups to implement these changes.

Survey Guidelines

Mottled Sculpins are small, cryptically colored fish that live on the bottom within the cracks and crevices among rubble or other objects. They are negatively buoyant because they lack a swim bladder, hence they remain on the bottom when stunned or incapacitated, often drifting into the spaces among the rubble when in this state. Water is usually clear (but not always). In streams, current is moderate to swift.

The most effective method for surveying streams with this type of fish under these conditions is to set a seine in a fixed spot, usually a riffle. Then an individual(s) positions themselves several feet upstream, vigorously shuffling their feet, moving the rubble around, disturbing the substrate, etc. in an attempt to dislodge any sculpins from their hiding places. The individual(s) move slowly towards the seine, using the commotion from their shuffling feet to force any dislodged fish into the seine. Once the individual(s) reach the seine, it is picked up to see if any fish are present. It is possible to measure the length of the seine and the distance the individual(s) shuffled downstream into the seine, hence measuring the amount of area surveyed.

A similar method is to use a dipnet, either one typically used for electrofishing or an invertebrate D-net. The net is set in place on the bottom, and then the cobble upstream is shuffled and disturbed. The advantage to this method is it can be done by one person, with that individual holding the handle of the net to keep it in place, and the moving a couple feet upstream to shuffle into the net. (Setting a seine in a riffle can be done by one person, but is usually done with three or more people.) The disadvantage with this method is it covers a relatively small area.

Pulling a seine through the water is also possible. This tends to be less effective because the net has to go over the rubble, and the fish are usually in the cracks between the rubble. Also, the seine routinely gets snagged on rubble and debris, allowing any fish in the seine to escape.

Backpack electrofishing and electric seines can work well when the water is clear and individuals can see the bottom. Sculpins are benthic fish that remain on the bottom when incapacitated, often drifting into the spaces between objects. Biologists often have to use their dipnets to dig the sculpins out of these places. Measuring distance travelled, area covered, or time the survey took place can be used to quantify effort.

Turbid water is problematic when electrofishing. The sculpins may dart to the surface at times, but this is usually very brief, requiring quick reflexes from whoever is trying to net them. If the fish drift into the cracks between objects, they are usually unseen and passed over. One method to help mitigate this is to closely follow the probe with a dipnet in the hope of blindly catching a fish before it settles on the bottom.

In lakes, electrofishing or pulling a seine is possible in shallow water. In deeper water, one must set traps or nets. Traps can be standard minnow traps or other types of fish traps. Baiting with dead fish, dog food or cat food, etc. can work well. Lights, such as glow-sticks, can also work. It is believed that these lights attract aquatic invertebrates, which in turn attract the sculpins (Schmidt 2013). Nets (such as gillnets or trammel nets) need to be small mesh, typically ½” square or smaller. These nets do not need to be tall because sculpins are benthic. Since sculpins are more active at night, it is best to set traps and nets in the evening and then retrieve them in the morning.

Stewardship Recommendations

The primary environmental factor determining the distribution of Mottled Sculpin in Illinois is cold water. They are almost exclusively tied to aquatic systems with cooler water temperatures, whether this is nearshore Lake Michigan or sections of streams with significant input from springs, seeps, or groundwater in general. Strategies that promote the input of precipitation into the ground that will recharge aquifers will help maintain or enhance Mottled Sculpin habitat. One example is planting native vegetation, either forests or prairies. Another example in urban areas would be permeable pavement. Disconnecting drain tiles will also facilitate the movement of water deeper underground to where it can cool in the aquifers before flowing back into the stream. These activities do not necessarily have to be adjacent to the stream, but can have benefits anywhere within the watershed since groundwater can travel extended distances.

Maintaining or planting trees and native vegetation in the riparian zone has the added benefit of shading the stream. Shading generally does not impact minimum or average water temperatures in a stream, but can reduce maximum temperature (Johnson 2004). Riparian vegetation also helps to lock soils in place, minimizing erosion. Excessive erosion leads to excessive sedimentation in the stream. Sculpins generally live over ‘cleaner’ substrates, like cobble, gravel, or sand, often hiding beneath rocks or sticks. Excessive sedimentation runs the risk of covering these substrates, essentially smothering the sculpin's habitat. Their hiding places will be filled in with silt.

Coolwater streams in Illinois have a tendency to be headwater streams. Headwaters streams are often separate from each other, resulting in a series of discontinuous populations. Mottled Sculpins have the ability to swim from one unaltered headwater to the next, but all too often there are structures impeding their movement and fragmenting the sculpins into isolated populations. It is important to maintain and enhance connectivity among populations in order to facilitate gene flow and increase re-colonization opportunities.

Increasing, or at least maintaining, connectivity among populations is critical. Sculpins are small fish that live along the bottom, tend to not swim far, and rarely, if ever, jump. Hence even minor obstacles can fragment a population or prevent them from colonizing new stream reaches. One common barrier is a culvert under a road. If these are a few inches or more from the downstream water level, then it is not possible for a sculpin to move upstream except during floods. But when these raised culverts are removed and replaced with a structure that is even with the stream bottom, then sculpins are able to move freely (Deboer et al. 2015). Replacement of raised culverts and avoiding installing them in the first place is critical to maintaining connectivity of upstream and downstream populations.

Dams, even low-head dams, are much larger impediments to sculpin movement. Some type of fish passage structure (e.g., fish ladder) would be needed for sculpins to freely move up- and downstream. Many fish passage structures are designed with something like a salmon in mind. Salmon are large, powerful swimmers with impressive jumping abilities. These structures would not be suitable for promoting the movement of sculpins. The best option would be to remove the dam, if possible. If not possible, then a 'sculpin-friendly' fish passage structure would be required to bypass the dam.

At this time, the primary stewardship challenge for Mottled Sculpin in Lake Michigan is invasive species control, more specifically, the Round Goby. Unfortunately there are no known solutions for reducing their numbers. Various ideas have been discussed, such as releasing sterile males or using underwater sound 'canons', but to date none of these options are realistically feasible or effective.

Many native fishes (e.g., Largemouth Bass, Smallmouth Bass, Lake Trout, Walleye, etc.) will eat Round Gobies (Taraborelli et al. 2010, Creque and Czesny 2013), but there have been no noticeable drops in the goby population to date. Perhaps in time goby numbers will be reduced to a level where sculpins and gobies can co-exist.

Gobies and sculpins may be able to co-exist in situations where dreissenid mussels (Zebra Mussels and Quagga Mussels) are absent. The majority of the diet of adult gobies is dreissenid mussels, and they tend to do less well when this food source is absent. And there are ways to control dreissenid mussels in the open environment, most notably the dead form of the bacteria *Pseudomonas flourescens* that is marketed under the trade name Zequanox. But once again, large scale applications in a great lake are unrealistic at this time.

Avoidance Measures

Because the primary environmental factor determining the distribution of Mottled Sculpin in Illinois is cold water, it is critical to avoid activities that increase water temperatures. These warmwater discharges could be either at the site where Mottled Sculpin are present or upstream. Typical warmwater discharges are from wastewater treatment plants, factories, power plants, etc. Other sources of warm water are impoundments and possibly drain tiles. Construction of any of these would be detrimental to sculpin populations.

A less obvious factor leading to warmer water is groundwater drawdowns, such as from wells. Average groundwater temperatures tend to approximate the average annual air temperature. This means a stream with significant groundwater input will receive relatively cooler water in the summer and relatively warmer water in the winter, resulting is a stable temperature regime and flows. During the summer, surface runoff or shallow groundwater near the surface tends to be warmer than deeper groundwater (Summers 1961, Steinmetz et al. 2002). Wells will drop the level of the groundwater. This can potentially stop springs and seeps from flowing. More often, the cooler groundwater is replaced by warmer surface runoff, potentially leading to temperatures above those suitable for sculpins. Any parties that utilize groundwater, whether private homes or agriculture or industry, run the risk of over-utilizing aquifers, leading to the disruption of the hydrology necessary for sculpins to survive.

Excess erosion can lead to the siltation of stream beds, covering the cobble, gravel, and sand where sculpins forage on aquatic insects and take cover under rocks and sticks. Erosion is a common issue at many construction sites, such as at bridges, roads running along streams, homes and businesses adjacent to streams, etc. Erosion control measures, such as siltation screens, would be beneficial.

A more dramatic example would be completely filling in a stream or redirecting / rechanneling a stream. Sculpins can live in tiny streams that are only a few inches deep, such as headwaters or outflows from springs or seeps. It is very easy to completely fill in a stream this size at a housing development, mall construction site, etc. A more common example would be the digging of a drainage ditch someplace else nearby that is more convenient for the developers. However, the recently created ditch may not have the same hydrology, resulting in a warmwater stream dominated by runoff instead of the naturally occurring coldwater stream driven by groundwater. Destruction of natural streams should be avoided, even if an ‘artificial’ stream is created nearby to replace it.

Introduction of invasive species, especially the Round Goby, should be avoided. There are populations of Mottled Sculpin that are separated from the goby invasion by barriers or distance. The most likely vectors of introduction into these places in the near future are accidental stocking or bait bucket transfers. Accidental stocking is when a stream is stocked with a desired species (like bass), but gobies are accidentally transferred as well. Bait bucket transfer is when someone is using fish as bait, then at the end of the day the person still has some live bait left over, so the angler releases the live bait into the stream or lake. There have been many public campaigns to spread awareness of these issues and to try and avoid them.

Minimization Measures

Mottled Sculpin spawn from April to May, depending upon water temperature. During this time, males are defending nests and eggs, hence are reluctant to leave spawning sites. Eggs are attached to the ceiling of the nest, so are not mobile. Even the fry do not swim around much, and the males remain with the nests until the fry disperse. Any activities that could potentially disturb spawning and the protection of eggs and fry (e.g., construction equipment in the stream, erosion upstream, etc.) should be shifted to a different time of year.

Research Needs

Mottled Sculpin are not known from the driftless area of Illinois, despite the habitat appearing to be suitable. There is also a lack of records immediately to the north across the Wisconsin state line. Conduct surveys of streams near the Illinois-Wisconsin state line in the driftless area to ascertain whether sculpin are present.

Assess sensitivity to salts, specifically potential impacts from road salt runoff. (Sculpins are a marine group that invaded freshwater, so maybe they are not overly impacted.)

Mottled Sculpin are often found in coolwater streams. These streams are usually cool during the summer because of significant groundwater inputs. If something happens that causes the regional water table to drop, these streams may warm to a point where they no longer sustain Mottled Sculpin. Urban development sometimes utilizes significant amounts of groundwater for drinking, industry, etc. More information is needed on the future of groundwater, especially in areas experiencing urban growth, such as the Fox River watershed and areas near Rockford.

References

Anderson, R.V. 1975. Selective feeding of the sculpin, *Cottus bairdi* Girard, in Illinois. Transactions of the Illinois State Academy of Science 68:118-121.

Bailey, R.M., W.C. Latta, and G.R. Smith. 2004. An atlas of Michigan fishes with keys and illustrations for their identification. Miscellaneous Publications Museum of Zoology, University of Michigan 192:1-215.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison. 1,052 pp.

Breen, M.J., C.R. Ruetz III, K.J. Thompson, and S.L. Kohler. 2009. Movements of mottled sculpins (*Cottus baridii*) in a Michigan stream: how restricted are they? Canadian Journal of Fisheries and Aquatic Science 66:31-41.

Cahn, A.R. 1927. An ecological study of southern Wisconsin fishes. Illinois Biological Monographs 11:1-151.

Charlebois, P.M., J.E. Marsden, R.G. Goettel, R.K. Wolfe, D.J. Jude, S. Rudnika. 1997. The round goby, *Neogobius melanostomus* (Pallas), a review of European and North American literature. Illinois-Indiana Sea Grant Program and Illinois Natural History Survey INHS Special Publication 20:1-76.

Creque, S.M. and S.J. Czesny. 2013. Growth and survival rate of nearshore fishes in Lake Michigan. Illinois Natural History Survey Technical Report 2013(24):1-32.

Deboer, J.A., J.M. Holtgren, S.A. Ogren, and E.B. Snyder. 2015 Movement and habitat use by mottled sculpin after restoration of a sand-dominated 1st-order stream. American Midland Naturalist 173:335-345.

Dorkin, J.L. Jr. 1980. The fishes of Hickory Creek. Master's thesis. University of Illinois at Chicago.

Downhower, J.F., L.S. Blumer, and L. Brown. 1987. Seasonal variation in sexual selection in the mottled sculpin. Evolution 41:1386-1394.

Downhower, J.F. and L. Brown. 1979. Seasonal changes in the social structure of a mottled sculpin (*Cottus bairdi*) population. Animal Behavior 27:451-458.

Downhower, J.F., L. Brown, R. Pederson, and G. Staples. 1983. Sexual selection and sexual dimorphism in mottled sculpins. Evolution 37:96-103.

Dubs, D.O.L. and L.D. Corkum. 1996. Behavioral interactions between round gobies (*Neogobius melanostomus*) and mottled sculpins (*Cottus bairdi*). Journal of Great Lakes Research 22:838-844.

Emery, A.R. 1973. Preliminary comparisons of day and night habits of freshwater fish in Ontario lakes. Journal of Fisheries Research Board of Canada 30:761-774.

Espinasa, L. and W.R. Jeffery. 2003. A troglomorphic sculpin (Pisces: Cottidae) population: geography, morphology and conservation status. Journal of Cave and Karst Studies 65:93-100.

Hann, H.W. 1927. The history of the germ cells of *Cottus bairdii* Girard. Journal of Morphology and Physiology 43:427-497.

Hubbs, C.L. and K.F. Lagler (and G.R. Smith). 2004. Fishes of the Great Lakes region. Revised Edition. The University of Michigan Press, Ann Arbor. 276 pp.

Janssen, J., M.B. Berg, and S.J. Lozano. 2005. Submerged terra incognita: Lake Michigan's abundant but unknown rocky zones. Pages 113-139 in State of Lake Michigan: Ecology, Health and Management. Edited by T. Edsall and M. Munawar. Ecovision World Monograph Series, Aquatic Ecosystem Health and Management Society.

Janssen, J. and D.J. Jude. 2001. Recruitment failure of mottled sculpin *Cottus bairdi* in Calumet Harbor, southern Lake Michigan, induced by the newly introduced round goby *Neogobius melanostomus*. Journal of Great Lakes Research 27:319-328.

Johnson, S.L. 2004. Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. Canadian Journal of Fisheries and Aquatic Science 61:913-923.

Kinziger, A.P. 1998. Comparison of weight-length regressions for slimy sculpin (*Cottus cognatus*) and mottled sculpin (*C. bairdi*) from the West Twin River drainage, Wisconsin. Bios 69:1-6.

Ludwig, G.M. and C.R. Norden. 1969. Age, growth and reproduction of the northern mottled sculpin (*Cottus bairdi bairdi*) in Mt. Vernon Creek, Wisconsin. Occasional Papers in Natural History by Milwaukee Public Museum 2:1-67.

Page, L.M. and B.M. Burr. 2011. Peterson field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Harcourt, Boston. 663 pp.

Pearse, A.S. 1918. The food of the shore fishes of certain Wisconsin lakes. Bulletin of the Bureau of Fisheries 35:146-292.

Savage, T. 1963. Reproductive behavior of the mottled sculpin, *Cottus bairdi* Girard. Copeia 1963:317-325.

Schmidt, K. 2013. Minnow trap surveys for deepwater (*Myoxocephalus thompsonii*) and slimy (*Cottus cognatus*) sculpin in northeastern Minnesota lakes. American Currents 38(2):19-22.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184:1-966.

Simon, T.P. 2011. Fishes of Indiana. Indiana University Press, Bloomington. 345 pp.

Smith, B.G. 1922. Notes on the nesting habits of *Cottus*. Papers of the Michigan Academy of Sciences 2:222-224.

Smith, P.W. 1979. The fishes of Illinois. University of Illinois Press, Urbana. 314 pp.

Steinmetz, J., J. Cashmore, and D. Soluk. 2002. Population viability of mottled sculpin (*Cottus bairdi*) in Black Partridge Creek. Illinois Natural History Survey Aquatic Ecology Report 02/03:1-20.

Steinmetz, J. and D. Soluk. 2001. Population viability of mottled sculpin (*Cottus bairdi*) in Black Partridge Creek. Illinois Natural History Survey Aquatic Ecology Report 01/01:1-11.

Stewart, J.S., S.A. Covert, N.J. Estes, S.M. Westenbroek, D. Krueger, D.J. Wieferich, M.T. Slattery, J.D. Lyons, J.E. McKenna Jr., D.M. Infante, and J.L. Bruce. 2016, FishVis, A regional decision support tool for identifying vulnerabilities of riverine habitat and fishes to climate change in the Great Lakes Region: U.S. Geological Survey Scientific Investigations Report 2016–5124, 15 p., with appendixes, http://dx.doi.org/10.3133/sir20165124.

Strauss, R.E. 1986. Natural hybrids of the freshwater sculpins *Cottus bairdi* and *Cottus cognatus* (Pisces: Cottidae): electrophoretic and morphometric evidence. American Midland Naturalist 115:87-105

Summers, W.K. 1961. Water temperatures in a well near Wild Rose, Wisconsin. Wisconsin Academy of Sciences, Arts and Letters 50:221-232.

Taraborelli, A.C., M.G. Fox, T.B. Johnson, and T. Schaner. 2010. Round goby (*Neogobius melanostomus*) population structure, biomass, prey consumption and mortality from predation in the Bay of Quinte, Lake Ontario. Journal of Great Lakes Research 36:625-632.

Willink, P.W. and F.M. Veraldi. 2009. The fishes of Will County, Illinois. Fieldiana, New Series 115:1-61.

Zorn, T.G., P.W. Seelbach, and M.J. Wiley. 2002. Distributions of stream fishes and their relationship to stream size and hydrology in Michigan's Lower Peninsula. Transactions of the American Fisheries Society 131:70-85.

Addendum

Because of the confusing taxonomy, many older papers in the literature that refer to Mottled Sculpin *Cottus bairdii* are now either considered different species or are probably different species. Since they are closely related, their ecologies are probably similar to the Mottled Sculpins found in Illinois. But in case there are differences, their life-history information is not included in this synopsis. If one is curious in reading these publications, here is a partial list:

Montana:
Bailey, J.E. 1952. Life history and ecology of the sculpin *Cottus bairdi punctulatus* in southwestern Montana. Copeia 1952:243-255.

McCleave, J.D. 1964. Movement and population of the Mottled Sculpin (*Cottus bairdii* Girard) in a small Montana stream. Copeia 1964:506–513.

Utah:
Zarbock, W.M. 1952. Life history of the Utah sculpin, *Cottus bairdi semiscaber* (Cope), in Logan River, Utah. Transactions of the American Fisheries Society 81:249-259.

North Carolina:
Grossman, G.D., K. McDaniel, and R.E. Ratajczak, Jr. 2002. Demographic characteristics of female mottled sculpin, *Cottus bairdi*, in the Coweeta Creek drainage, North Carolina. Environmental Biology of Fishes 63:299-308.

Hill, J. and G.D. Grossman. 1987. Home range estimates for three North American stream fishes. Copeia 1987:376-380.

Petty, J.T. and G.D. Grossman. 1996. Patch selection by mottled sculpin (Pisces: Cottidae) in a southern Appalachian stream. Freshwater Biology 35:261–276.

Petty, J.T. and G.D. Grossman. 2004. Restricted movement by mottled sculpin (Pisces: Cottidae) in a southern Appalachian stream. Freshwater Biology 49:631–645.

Petty, J.T. and G.D. Grossman. 2007. Size-dependent territoriality of mottled sculpin in a southern Appalachianstream. Transactions of the American Fisheries Society 136:1750–1761.

Virginia – probably Blue Ridge Sculpin *Cottus caeruleomentum*:
Matheson, Jr., R.E. and G.R. Brooks, Jr. 1983. Habitat segregation between *Cottus bairdi* and *Cottus girardi*: an example of complex inter- and intraspecific resource partitioning. American Midland Naturalist 110:165-176.

Resetarits, Jr. W.J. 1997. Interspecific competition and qualitative competitive asymmetry between two benthic stream fishes. Oikos 78:429-439.

Maryland – probably Blue Ridge Sculpin *Cottus caeruleomentum*

Savage, T. 1963. Reproductive behavior of the mottled sculpin, *Cottus bairdi* Girard. Copeia 1963:317-325.

Conservation Guidance for

Ozark Minnow

Notropis nubilus (Forbes)

IL Status: Species in Greatest Need of Conservation, NatureServe – S2

US Status: NatureServe – N5

Global Rank: NatureServe - G5

Trend: Decreasing

Family: Cyprinidae

Habitat: Streams with clear, running water over cobble and gravel

Similar Species:
Hornyhead Chub *Nocomis biguttatus* (especially juveniles)
Bluntnose Minnow *Pimephales notatus*
Brassy Minnow *Hybognathus hankinsoni*

Species Information

Characteristics

Generally cylindrical body. Mouth slightly subterminal and moderately-sized, not extending backward to eye. No barbel. Eye relatively large. Snout rounded. Pectoral fin with 13-15 rays, and on lower part of body. Pelvic fin with 8 rays, and closer to anal fin than to pectoral fin. Dorsal fin with 8 rays, tip broadly rounded, and directly above pelvic fin. Anal fin with 8 rays, rounded tip, and rear edge curved. Tail is forked. Complete lateral line with 33-38 scales. Long coiled gut (roughly twice the length of the body) with black peritoneum. Coloration is white across the lower half of the body. Diffuse black stripe extending from snout, through eye, all the way to base of tail. May be a dark blotch at base of tail and semi-continuous with the stripe. Pale stripe above the black stripe. Back is brownish yellow with a touch of green. Scales on the back outlined with dark pigment. Dark line along middle of back with gold specs. Fins clear. The width of the pectoral fin in males is the same as its length, whereas in females the width is less than the length. Another difference is the distance between the tip of the pectoral fin and the base of the pelvic fin is less than half the length of the pectoral fin length, but more than half in females (Becker 1983). Male breeding coloration includes orange around rear edge of opercular opening, and then extending back along lower half of the body varying distances (e.g., to base of pectoral fin or half of body length). Fins mostly orange, with edges either clear (pectoral, pelvic, and anal) or with black pigmentation (dorsal and tail). Large tubercles on top of head and back, as well as first several pectoral rays. Smaller tubercles on rest of head, over most scales, and the pelvic, anal, and dorsal fins. Female breeding coloration and tubercles similar, but less intense to almost absent. Can reach 4 inches / 9 cm in total length. (Branson 1962, Pflieger 1975, Smith 1979, Becker 1983, Robison and Buchanan 1988, Page and Burr 2011). Branson (1962) diagramed the nuptial tubercle patterns in detail.

Taxonomy

The Ozark Minnow was officially described as *Alburnops nubilus* in 1878 by S.A. Forbes based on twenty specimens from the Rock River in Oregon, Ogle County collected on June 5, 1877 (Jordan 1878, Forbes and Richardson 1920, Sabaj et al. 1997). An additional specimen was collected by E.W. Nelson on July 15, 1877 in nearby Pine Creek (Sabaj et al. 1997).

For a while, it was placed in the genus *Hybognathus*, and then was shifted into *Dionda* for many years based on its long coiled gut. It is now considered to be in the genus *Notropis*.

Cytochrome b genetic data indicates the individuals from the upper Mississippi (including northern Illinois) are part of the same species found in the northern Ozarks, even though there are no intervening Ozark Minnow records between the two regions. Apparently the Ozarks acted as a refugium during the glacial advances, and then Ozark Minnows colonized northward as the glaciers retreated. Populations between the upper Mississippi and Ozarks were extirpated over time to create the distribution gap (Berendzen et al. 2010).

Ozark Minnows will hybridize with Bleeding Shiner (Pflieger 1975).

Distribution and Status

In Illinois, Ozark Minnow is generally distributed in the northwestern portion of the state (Fig. 1). Most records are from the Rock drainage. This is where the species was originally described from, and for many years it was only known from this region (Jordan 1878, Forbes 1884). Over time, additional populations were discovered in a couple tributaries of the Mississippi in the far northwestern corner of Illinois. There is also a population in Somonauk Creek of the Fox River watershed.

There are scattered records along the Mississppi in southwestern Illinois. To the west, Ozark Minnows are common in the Ozarks of Missouri and Arkansas. The Illinois records are considered transient individuals from these larger populations (Smith 1979).

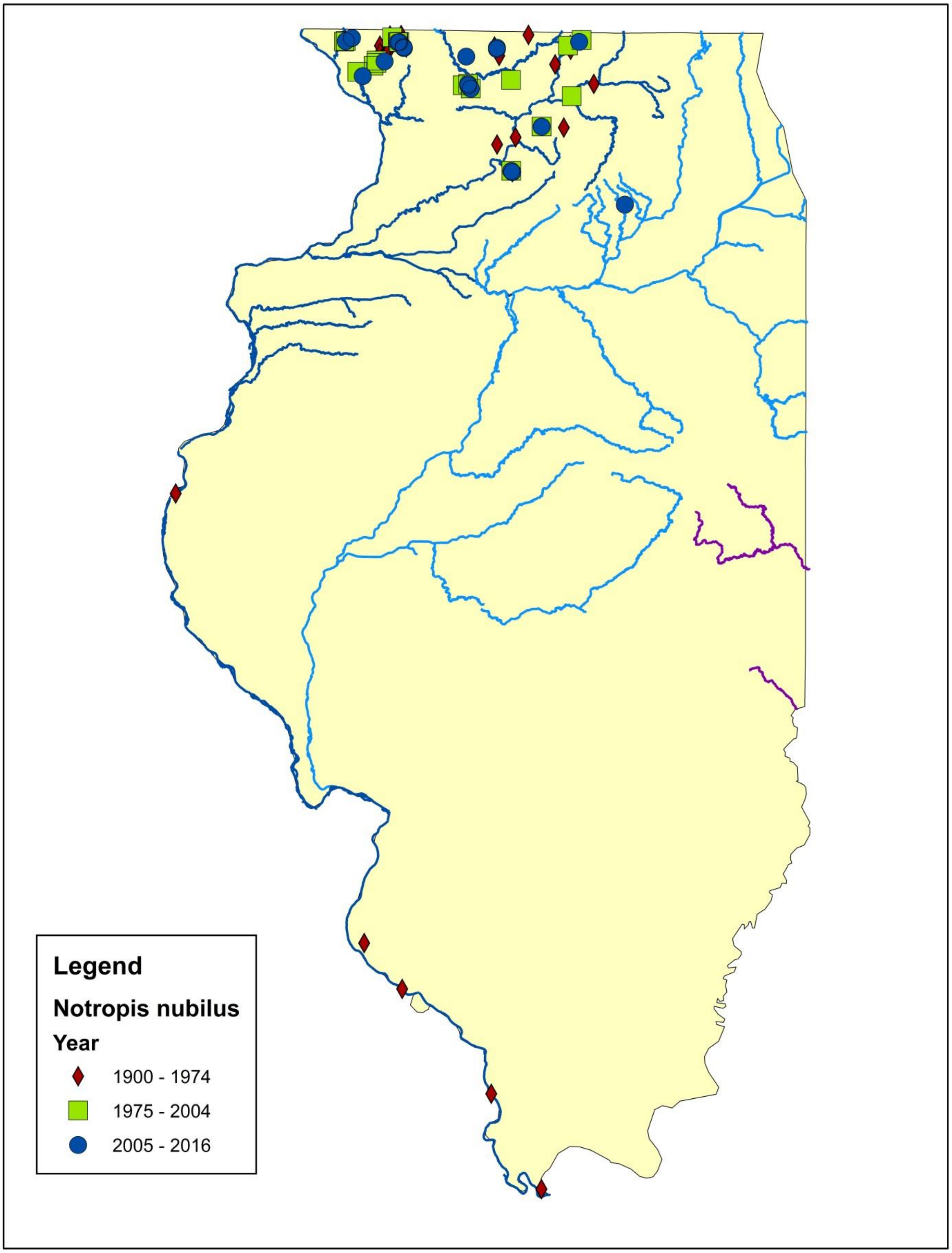


Figure 1. Historical and current distribution of Ozark Minnow *Notropis nubilus* in Illinois.

Metzke and Holtrop (2014) developed a model of where Ozark Minnows could potentially be found in northern Illinois based on several stream habitat characteristics (e.g., gradient, size, catchment land use, flow, and temperature) of sites where there are historical records. Subsequent fieldwork was unable to discover any new populations of Ozark Minnows, and it was concluded the species is spatially declining within its range.

This same pattern was noticed in recent fieldwork. Although their overall range has not changed significantly in Illinois, their numbers appear to be decreasing. There have been no recent records in the Kishwaukee watershed, and it has been suggested that they are extirpated from the basin (Retzer 2005). They have not been seen in the Rock River near the type locality for many years. There are recent records in Franklin Creek, Stillman Creek, North Kinnikinnick Creek, and the upper Pecatonica, but fewer records than in the past. The remaining populations are becoming more and more isolated over time.

This general decline is also evident in the Catch Per Unit Effort data combined over several watersheds from 1995 to 2015 (Fig. 2). There was a distinct increase from 2000 to 2005, followed by a sudden drop from 2005 to 2010. All sorts of stochastic factors can cause this type of data to fluctuate up and down, but the dramatic reduction in numbers over two successive basin surveys is starting to look like a trend.

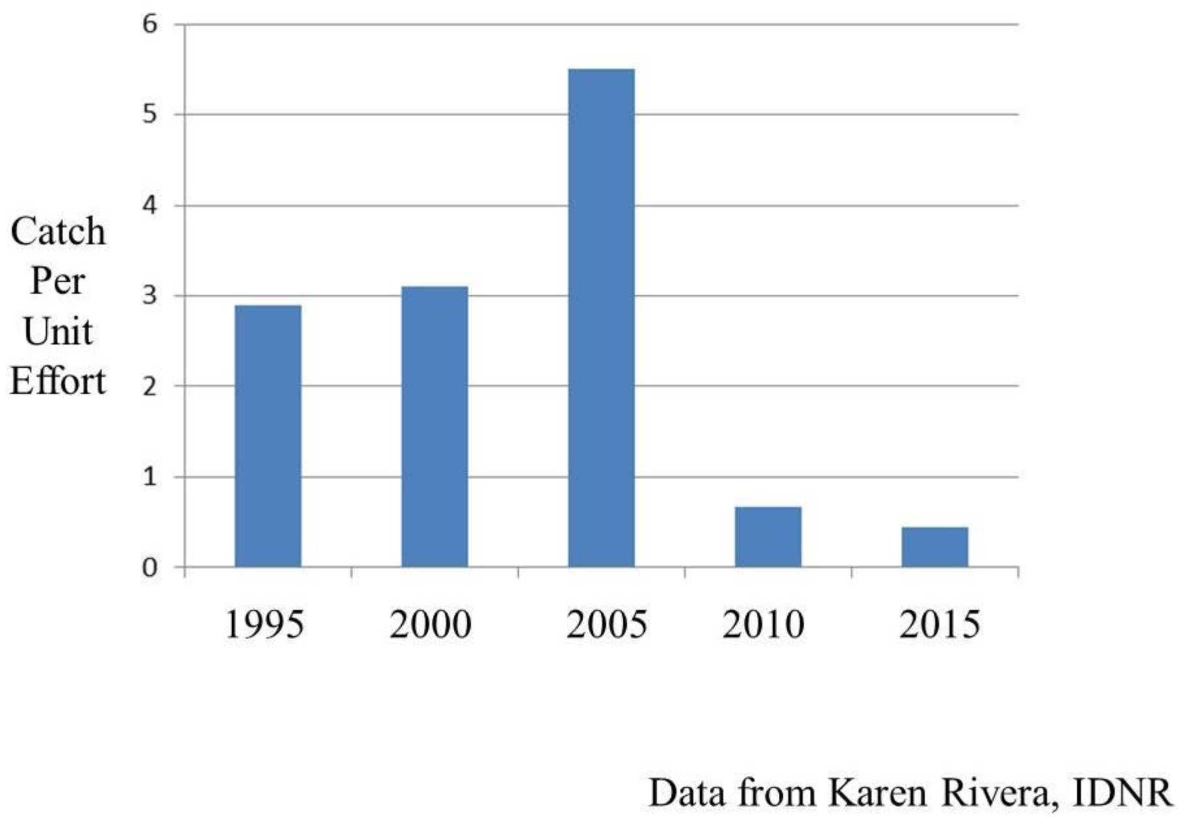


Figure 2. Catch per Unit Effort for Ozark Minnow based on Illinois Department of Natural Resources data combined over several watersheds from 1995 to 2015.

A fair number of Ozark Minnows were found at one site in the Apple River in 2016, but it is unclear what their status is throughout the watershed (personal observation 2016, P.W. Willink and K. Rivera).

In regards to the species entire distribution, Ozark Minnows are most common in the Ozarks, which include southern Missouri, northern Arkansas, and northeastern Oklahoma. Another population is found in northwestern Illinois, southwestern Wisconsin, northeastern Iowa, and extending up into Minnesota. A third isolated group is found in northwestern Wisconsin (Page and Burr 2011).

There is evidence that this range has changed over time. Fossil Ozark Minnows were discovered in southwestern Kansas, well outside their current distribution. The fossils dated to the late Illinoian of the Pleistocene. It was hypothesized that changes in climate during glacial periods caused the shifting distribution of the species (Smith 1963).

Habitat

Ozark Minnows live in medium-sized streams with a moderate current. Water is clear, shallow (less than a couple feet deep usually), and the bottom is typically gravel and cobble as well as sand or possibly bedrock. Siltation is minimal. Aquatic vegetation may be present, but is not abundant. They are most common right along the edges of the current, such as in a side pool or the upstream portion of the pool just downstream of a riffle, instead of directly in the current. Similar observations have been made in Missouri (Pflieger 1975, Glazier and Taber 1980), Oklahoma (McNeely 1987), Arkansas (Robison and Buchanan 1988), and Wisconsin (Becker 1983). This type of habitat is common in the Ozarks, where Ozark Minnows are described as abundant and habitat generalists (Moore and Paden 1950, McNeely 1987)

There are exceptions. Cahn (1927) reported finding Ozark Minnows at a site in southeastern Wisconsin characterized by little current, mud bottom, and turbid water. Ozark Minnows are no longer believed to be present in the area, and lack of suitable habitat may be the explanation (Becker 1983). Another site in southwestern Wisconsin was characterized as having moderately turbid water and the bottom was gravel (40%), sand (30%), and muck (30%), which is atypical. It was also in a pasture (D. Becker personal communication in Becker 1983).

Surrounding land cover in Illinois in the early 1800s was forest, and this is still somewhat the case today at sites where Ozark Minnows persist (Metzke and Holtrop 2014).

Ozark Minnows are typically swimming just above the bottom (Pflieger 1975, Becker 1983). Lab experiments verified this preference, and noted that they will move higher in the water column when Hornyhead Chub *Nocomis biguttatus* or Largescale Stoneroller *Campostoma oligolepis* are present. But will not move too far up the water column if Bleeding Shiner *Notropis zonatus* or Bigeye Shiner *Notropis boops* are present above them (Gorman 1988).

Species Biology

In northern Illinois, Forbes and Richardson (1920) found males in breeding condition and females with eggs in mid-May. Smith (1979) reported they spawn in May and June in Illinois. In southern Wisconsin, the spawning period is May to July, maybe into August (Becker 1983). In Missouri, Ozark Minnows spawn from late April to early July, but most observations are mid- to late May (Pflieger 1975, Glazier and Taber 1980, Fowler et al. 1984).

The most detailed observations on spawning were by Fowler et al. (1984) in Missouri where several hundred Ozark Minnow and Duskystripe Shiner *Notropis pilsbryi* gathered along the stream edge of a run between two riffles. Water temperature was 17-18 C, depth 1-20 cm, over a gravel bottom, with a moderately swift current (no current immediately along shore) (Branson 1962, Fowler et al. 1984). Fish spawned in shallow depression several inches across, but they did not make the depressions themselves. Most spawning occurred in 1-10 cm of water, but there was some in deeper areas as well. Spawning in the deeper areas was usually next to rocks several inches across. Spawning occurred mid-morning to late afternoon (Fowler et al. 1984).

Typical pawning behavior involved several fish swimming to the depression, waiting a few seconds, then a dozen or two additional fish joined them. Then all the minnows began shimmering and vibrating against one another in a mass right along the bottom. Sometimes an individual would jump out of the water. The whole affair lasted about a minute, and then the fish would swim off in different directions (Fowler et al. 1984).

In the context of discussing breeding tubercles, Branson (1962) commented on how Ozark Minnows are routinely running into one another and the bottom. Males hit the bottom and push off with their anal fin and caudal peduncle. The tubercles help the males grab the females with their fins and body. Tubercles along the belly may also help the fish maintain position along the stream bottom as they are spawning in the fast flowing water.

Ozark Minnows will also spawn over Hornyhead Chub nests (Pflieger 1975). These nests are constructed by the male chub picking up gravel from one spot and depositing the gravel close nearby. The end result is a depression in the stream bed next to a mound of gravel.

Sometimes other fishes are spawning nearby. In Missouri, this is often the Bleeding Shiner. The Bleeding Shiner spawning aggregations are usually a little farther upstream than the Ozark Minnow spawning aggregations. Because both species eject milt and eggs into the water column, there is a possibility of cross fertilization between the species (Pflieger 1975).

Individual females in Missouri carried 32 to 888 eggs in their ovaries (Glazier and Taber 1980). In Wisconsin the mature yellow eggs were about 1 mm in diameter in the ovaries. On May 19, July 20, and July 26, the number of mature eggs ranged from 282-557 (Becker 1983)

During spawning, Ozark Minnow eggs are non-adhesive, randomly dispersed over the bottom, and sink into the cracks among the gravel. Individual eggs in the environment were roughly 2.1 mm in diameter (Fowler et al. 1984). Eggs hatched after 36-48 hours at 23-24 C. Individuals were 4.6-6.8 mm Total Length as yolk-sac larvae and 6.8 mm Total Length as larvae (Fowler et al. 1984).

In a Missouri stream from May to July, there were three age classes present (0, I, II). Age class I were roughly 30 mmSL, and Age Class II were around 50 mmSL. By August, no Age class II individuals were found, indicating that this species usually only lives for about 30 months (Glazier and Taber 1980). In another Missouri study, Age Class II individuals averaged 53.8 mmSL (Fowler et al. 1984). In late July in Wisconsin, the total length of fish for Age Class I was mean 48.2 mm (range 41-52), Age Class II 62.5 mm (56-75), and a single Age Class III measuring 80 mm (Becker 1983). An average female is larger than an average male (Pflieger 1975, Glazier and Taber 1980, Becker 1983).

No individuals less than 45 mmSL were collected with eggs. Only Age Class II and older individuals were mature (Glazier and Taber 1980, Becker 1983, Fowler et al. 1984).

A Missouri spawning aggregation was 39% male and 61% female (Glazier and Taber 1980).

Ozark Minnows in Oklahoma ate (in decreasing importance) detritus, sand, non-filamentous algae, filamentous algae, and vascular plants. There were no seasonal diet patterns (McNeely 1987). In southeastern Wisconsin, the gut contents were primarily algae (Spirogyra, Zygnema, Closterium) and some entomostracan and small insect larvae (Cahn 1927). In southwestern Wisconsin, the gut contents were primarily diatoms as well as green algae, blue-green algae, vegetative material, and sand (Becker 1983). Their long intestine and grinding pharyngeal teeth are consistent with the vegetarian diet (Jordan 1878, Pflieger 1975, Becker 1983).

Gelwick et al. (1997) classified Ozark Minnows as algivores. They conducted an experiment in an Oklahoma stream where pens in pools were used to exclude Stonerollers *Campostoma* spp. and Ozark Minnows from grazing along the bottom. The substrate at un-penned sites remained relatively clean, whereas penned sites exhibited algal growth with silt collecting in the algae.

Among individuals taken from an Arkansas stream in June with a maximum water temperature of 30 C, females were significantly more tolerant of heat than males when exposed to temperatures ranging from 35-37.5 C (Baker et al. 1970).

When compared to sixteen other fish species in Oklahoma, Ozark Minnow was ranked average to sensitive to petroleum refinery effluents, depending upon the particular toxicology test (Bunting 1963).

Ozark Minnows are often in schools (Pflieger 1975, Becker 1983). These schools can be mixed-species, and in Missouri may include Bleeding Shiner, Duskystripe Shiner, Carmine Shiner, Telescope Shiner, Wedgespot Shiners, Largescale Stonerollers, and Central Stonerollers (Branson 1962, Pflieger 1975).

Conservation / Management

Threats

Metzke and Holtrop (2014) concluded that Ozark Minnows were losing habitat at specific sites, and that this decline could be due to changing land use. Historically, the range of Ozark Minnows was largely forested. But today, those forests are now agriculture, cattle pastures, or urban (Metzke and Holtrop 2014).

This is consistent with the species biology. Ozark Minnows have a preference for clear, running water, and are generally absent from streams that are turbid and the bottom is predominantly soft silt (Becker 1983). That would make turbidity and sedimentation the proximate threat.

Turbidity and sedimentation are most closely tied to land use in the watershed. Both urban and agricultural settings can enhance runoff, with this runoff carrying particulate matter into the streams. The particulate matter makes the water turbid. When the particulate matter settles out of the water column it covers the bottom with sediment, smothering whatever substrate was originally present.

Turbidity per se may not be a problem for Ozark Minnows. A more serious issue is sedimentation. These fish forage on algae, diatoms, small aquatic insects, etc. that grow and live on rocks on the bottom of the stream. If the bottom is covered with sediment, their food source disappears. Also, Ozark Minnows broadcast their eggs over the bottom. If the eggs are covered by sediment, they suffocate and die.

Related to this, dams, even small ones, change stream habitat from a flowing water system to impoundments where current is significantly reduced. This in turn facilitates sedimentation, and has a tendency to increase water temperatures. Fish assemblages shift from running water specialists to low flow, warmwater generalists (Winston et al. 1991, Kanehl et al. 1997, Tiemann et al. 2004, Santucci et al. 2005, Catalano et al. 2007, Slawski et al. 2008).

Dams also fragment populations, preventing movement of fish from one stream reach to another. Under natural conditions, if something happens to one population (e.g., drought extirpates fishes from a stream reach), then the impacted site is re-colonized at a later date by fishes from other parts of the stream (Larimore et al. 1959, Griswold et al. 1982). Dams can prevent this movement of fishes, re-colonization does not occur, and the fish(es) are lost from the impacted site (Griswold et al. 1982, Winston et al. 1991, Santucci et al. 2005, Catalano et al. 2007). In watersheds with multiple dams, the impacts can be cumulative (Slawski et al. 2008).

The increasing isolation of populations in Illinois is not due solely to dams. Degradation of intervening habitat is probably more important in decreasing the connectivity among populations, especially in the Rock River watershed. As population sizes in isolated groups decreases, the likelihood of genetic bottlenecks and the subsequent loss of genetic diversity increases.

The potential impacts of climate change have not been explicitly examined for Ozark Minnows. The impacts of road salts are unknown.

Regulations

Ozark Minnow is not listed as Endangered or Threatened in Illinois. They are not considered game fish. The only regulations for Ozark Minnow would be general fishing regulations covering non-game fish and regulations covering the movement or sale of fishes potentially infected with the disease Viral Hemorrhagic Septicemia.

Conservation Efforts

The status of Ozark Minnow in Illinois has been evaluated twice recently. The first concluded that the species may be increasing slightly when analyzing fishery data to determine population trends over the past four decades. Primary stressors were thought to be sedimentation (and its impact on habitat structure) and fragmentation (Metzke et al. 2012).

In a more focused follow-up study, the habitat preferences for Ozark Minnow were modeled, and then fieldwork was used to validate the model (Metze and Holtrop 2014). It was concluded that the species was declining, at least spatially. Historically, the area was largely forested. Recently land use has shifted to agriculture and urban, and this was postulated as a potential reason for the drop in occurrences.

Because of its preference for clearwater streams, and sensitivity to sedimentation, the Ozark Minnow was included as a Focal Species for Apple River Canyon State Park by the Streams Campaign of the Illinois Wildlife Action Plan (State of Illinois 2016).

Wisconsin lists Ozark Minnow as Threatened as well as a Species of Greatest Conservation Need. The Wisconsin Wildlife Action Plan recommends restoring habitat in Platte River watershed, which is immediately north of northwestern Illinois (Wisconsin Department of Natural Resources 2015).

Survey Guidelines

Ozark Minnows swim just above the bottom, and the bottom substrate is often cobble. This makes seining difficult, as the net tends to snag frequently. It can still be a productive method, and works better if the bottom is gravel or one is trying to catch a school of fish in a pool. Moderately sized seines, such as 15 or 20 feet in length, tend to be most effective under these circumstances. (Fish tend to swim around shorter seines, and longer seines tend to frequently get caught on rocks, sticks, etc.)

Backpack electrofishing works, but many of the Ozark Minnows will either see the individual carrying the backpack or feel the edge of the electric field and swim away. ‘Pinning’ the fish in an enclosed area, like a side channel or pool below a riffle, works well by closing off the escape routes. In a similar manner, an electric seine with a block net works well. Most of the Ozark Minnows are netted either at the block net or along some obstruction in the stream channel that hinders the fish from swimming away.

Another issue with electrofishing is when the stunned fish drifts to the bottom and disappear in the cracks among the cobble. They may be difficult to see under these circumstances, and it can be very difficult to get a net in the confined space to dip the fish.

Focusing on pools at the base of riffles increases ones chances of capturing fish.

Stewardship Recommendations

Ozark Minnows prefer clear water and minimal sedimentation of the stream bottom. Sedimentation is usually related to eroding landscapes, hence methods that minimize the amount of soil that is carried by runoff are critical. Land-use in the watershed, both where the Ozark Minnows live as well as upstream, typically drives this aspect of the system. Vegetation, both forests and prairies, locks soils in place, minimizing erosion. The more vegetation the better, but even narrow strips of vegetation along a stream (i.e., riparian buffer) can help. Other possibilities include a suite of agricultural best management practices, such as no-till farming (Montgomery 2007) or terrain modification.

Minimization Measures

Ozark Minnows spawn in May or June. They broadcast their eggs over the bottom substrate that is usually gravel or cobble. If the eggs are covered by silt, they will suffocate and die. Any activities at a spawning site or upstream that would increase sedimentation should be avoided during the spawning season. Silt curtains and other erosion control methods at streamside construction sites are sometimes effective at minimizing sedimentation, but this should be evaluated on a case-by-case basis.

Mitigation and Conservation Opportunities

Restoration/Habitat Creation

The preferred habitat of Ozark Minnows is running water over gravel or cobble in larger creeks and smaller rivers. One of the most effective methods at creating this habitat is dam removal. These smaller to moderately-sized aquatic systems often have smaller dams that appear to be insignificant. But even the removal of a small dam can have large impacts.

When the dam is present, the flow of water in the impoundment is slower and the rate of sedimentation is higher. After the removal of the dam, the flow of water is faster, and this increased current carries sediment farther downstream, reducing sedimentation at the dam site. Water clarity (sediments suspended in the water column) is more dependent upon conditions upstream. But softer sediments on the bottom, like mud, will be washed downstream, exposing the heavier sediments, like gravel and cobble when present. Ozark Minnows spawn over gravel and cobble, not mud.

Dams also fragment the aquatic habitat, preventing the movement of fish and associated gene flow among different parts of streams. If a catastrophe strikes part of stream (e.g., drought, oil spill, excess fertilizer, etc.), then dams may prevent the recolonization of the site after the catastrophe is over. Connectivity is critical in maintaining meta-population dynamics.

Research Needs

Assess the genetic metapopulation structure of Ozark Minnow in Illinois. Is there gene flow among populations? Is there a loss of genetic diversity in isolated populations?

Is it possible for Ozark Minnows to move from one 'population' to another? Can connectivity among at least some populations be maintained or increased?

References

Baker, C.D., W.H. Neill Jr., and K. Strawn. 1970. Sexual difference in heat resistance of the Ozark Minnow, *Dionda nubila* (Forbes). Transactions of the American Fisheries Society 99:588-591.

Berendzen, P.B., J.F. Dugan, and T. Gamble. 2010. Post-glacial expansion into the Paleozoic Plateau: evidence of an Ozarkian refugium for the Ozark minnow *Notropis nubilus* (Teleostei: Cypriniformes). Journal of Fish Biology 77:1114-1136.

Branson, B.A. 1962. Observations on the breeding tubercles of some Ozarkian minnows with notes on the barbels of *Hybopsis*. Copeia 1962:532-539.

Bunting II, D.L. 1963. The relative resistances of seventeen species of fish to petroleum refinery effluents and a comparison of some possible methods of ranking resistances. Ph.D. dissertation, Oklahoma State University.

Cahn, A.R. 1927. An ecological study of the southern Wisconsin fishes. The brook silverside (*Labidesthes sicculus*) and the cisco (*Leucichthys artedi*) in their relations to the region. Illinois Biological Monograph 11:1-151.

Catalano, M.J., M.A. Bozek, and T.D. Pellett. 2007. Effects of dam removal on fish assemblage structure and spatial distributions in the Baraboo River, Wisconsin. North American Journal of Fisheries Management 27:519-530.

Forbes, S.A. 1884. A catalogue of the native fishes of Illinois. Report of the Illinois State Fish Commissioner for 1884:60-89.

Forbes, S.A. and R.E. Richardson. 1920. The fishes of Illinois. Illinois Natural History Survey. Second Edition. 357 pp.

Fowler, J.F., P.W. James, and C.A. Taber. 1984. Spawning activity and eggs of the Ozark Minnow, *Notropis nubilus*. Copeia 1984:994-996.

Gelwick, F.P., M.S. Stock, and W.J. Matthews. 1997. Effects of fish, water depth, and predation risk on patch dynamics in a north-temperate river ecosystem. Oikos 80:382-398.

Glazier, J.R. and C.A. Taber. 1980. Reproductive biology and age and growth of the Ozark Minnow, *Dionda nubila*. Copeia 1980:547-550.

Gorman, O.T. 1988. An experimental study of habitat use in an assemblage of Ozark minnows. Ecology 69:1239-1250.

Griswold, B.L., C.J. Edwards, and C.L. Woods III. 1982. Recolonization of macroinvertebrates and fish in a channelized stream after a drought. Ohio Journal of Science 82:96-102.

Jordan, D.S. 1878. A catalogue of the fishes of Illinois. Bulletin of the Illinois State Laboratory of Natural History 1:37-70.

Kanehl, P. D., J. Lyons, and J. E. Nelson. 1997. Changes in the habitat and fish community of the Milwaukee River, Wisconsin, following removal of the woolen mills dam. North American Journal of Fisheries Management 17:387–400.

Larimore, R.W., W.F. Childers, and C. Heckrotte. 1959. Destruction and re-establishment of stream fish and invertebrates affected by drought. Transactions of the American Fisheries Society 88:261-265.

McNeely, D.L. 1987. Niche relations within an Ozark stream cyprinid assemblage. Environmental Biology of Fishes 18:195-208.

Metzke, B.A., L.C. Hinz. Jr., and A.C. Hulin. 2012. Status revision and update for Illinois' fish species in greatest need of conservation. Illinois Natural History Survey Technical Report 2012(19):1-173.

Metzke, B.A. and A.M. Holtrop. 2014. Survey of Spring Cavefish (*Forbesichthys agassizii*), Ozark Minnow (*Notropis nubilus*) and Largescale Stoneroller (*Campostoma oligolepis*) status in Illinois. Illinois Natural History Survey Technical Report 2014(04), 42 pages.

Moore, G.A. and J.M. Paden. 1950. The fishes of the Illinois River in Oklahoma and Arkansas. American Midland Naturalist 44:76-95.

Page, L.M. and B.M. Burr. 2011. Peterson field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Harcourt, Boston. 663 pp.

Pflieger, W.L. 1975. The fishes of Missouri. Missouri Department of Conservation. 343 pages.

Retzer, M.E. 2005. Changes in the diversity of native fishes in seven basins in Illinois, USA. American Midland Naturalist 153:121-134.

Robison, H.W. and T.M. Buchanan. 1988. Fishes of Arkansas. The University of Arkansas Press, Fayetteville. 536 pages.

Sabaj, M.H., K.S. Cummings, and L.M. Page. 1997. Annotated catalog of type specimens in the Illinois Natural History Survey Fish Collection. Illinois Natural History Survey Bulletin 35:253-300.

Santucci, V. J., S. R. Gephard, and S. M. Pescitelli. 2005. Effects of multiple low-head dams on fish, macroinvertebrates, habitat, and water quality in the Fox River, Illinois. North American Journal of Fisheries Management 25:975–992.

Slawski, T.M., F.M. Veraldi, S.M. Pescitelli, and M.J. Pauers. 2008. Effects of tributary spatial position, urbanization, and multiple low-head dams on warmwater fish community structure in a Midwestern stream. North American Journal of Fisheries Management 28:1020-1035.

Smith, G.R. 1963. A late Illinoian fish fauna from southwestern Kansas and its climatic significance. Copeia 1963:278-285.

State of Illinois. 2016. Illinois wildlife action plan, 2015 implementation guide. Illinois Department of Natural Resources, Springfield. 292 pages.

Tiemann, J. S., D. P. Gillette, M. L. Wildhaber, and D. R. Edds. 2004. Effects of low-head dams on riffle-dwelling fishes and macroinvertebrates in a midwestern river. Transactions of the American Fisheries Society 133:705–717.

Winston, M.R., C.M. Taylor, and J. Pigg. 1991. Upstream extirpation of four minnow species due to damming of a prairie stream. Transactions of the American Fisheries Society 120:98-105.

Wisconsin Department of Natural Resources. 2015. 2015-20205 Wisconsin Wildlife Action Plan. Madison, WI.

Conservation Guidance for

Rosyface Shiner

Notropis rubellus (Agassiz)

Note: Conservation Guidance Document for Carmine Shiner *Notropis percobromus* is almost identical.

IL Status: NatureServe – Does not occur in Illinois (according to NatureServe)

US Status: NatureServe – N5

Global Rank: NatureServe - G5

Family: Cyprinidae

Habitat: Medium-sized streams, usually with clear running water

Similar Species:
Carmine Shiner *Notropis percobromus*
Emerald Shiner *Notropis atherinoides*

Species Information

Characteristics

Elongate body that is laterally compressed. Terminal mouth extends just past front of eye. No barbel. Eye relatively large. Snout is pointed with a length (distance from front of eye to tip of chin) equal to or greater than eye diameter. Pectoral fin with 11-14 rays, and on lower part of body. Pelvic fin with 8 rays, and midway between pectoral fin and anal fin. Dorsal fin with7- 8 rays, tip broadly rounded, and well behind pelvic fin. Anal fin relatively long with 9-11 rays, rounded tip, and relatively straight rear edge. Tail is forked. Complete lateral line with 36-45 scales. The number of scales in a line between the head and dorsal fin is less than 25. Coloration is a shiny bluish-silver, hinting towards yellow-green on the back and white on the belly. Faint greenish stripe just above lateral line, and then just above that a faint dark stripe. Thin black line from head to dorsal fin. Black pigment around mouth, giving the appearance that it is wearing 'black lipstick'. Black pigment scattered around eye, over top of head, over scales on back, and along rays in the tail and pectoral and dorsal fins, but generally absent from lower half of head and body. Males have slightly longer pectoral fins than females. Male breeding coloration includes red over chin, snout, top half of head, lower half of body below lateral line (more intense towards the front of the fish), portions closest to the body of pectoral, pelvic, and anal fins, and band along base of dorsal fin. Tubercles cover snout, top of head, back, distinctly along pectoral fin rays, and less distinctly on other fins. Female breeding coloration similar but less intense to almost absent. Can reach 3 1/2 inches / 9 cm in total length. (Scott and Crossman 1973, Smith 1979, Becker 1983, Bailey et al. 2004, Hubbs and Lagler (and Smith) 2004, Page and Burr 2011).

Reed (1958) described in detail egg and larval development. Pfeiffer (1955) included anatomical description of fry. Miller (1963) provided detailed morphological descriptions of the parent species and hybrids, including information on meristic characters, morphometric characters, and gross internal morphology (including digestive tract, visceral organs, pigmentation of parietal peritoneum, Weberian ossicles, and brain).

Can be distinguished from similar species by rounded tip of dorsal fin and distance from front of eye to tip of chin greater than eye diameter (versus pointed tip of dorsal fin and distance from front of eye to tip of chin less than eye diameter in Emerald Shiner *Notropis atherinoides*).

Cannot be reliably distinguished morphologically from Carmine Shiner *Notropis percobromus*. These species can only be distinguished genetically at this time.

Taxonomy

Rosyface Shiner was described by Agassiz (1850) from Lake Superior near Sault St. Marie (Hubbs and Brown 1929). Other species that looked like Rosyface Shiner were also grouped together into what was eventually considered one species ranging from Oklahoma to Manitoba to New England to Tennessee. Genetic work split Rosyface Shiner into several groups, including Carmine Shiner *Notropis percobromus* (Wood et al. 2002, Berendzen et al. 2008), which is now used as the basis for recognizing these two species in Illinois.

Although genetics are currently used to distinguish Rosyface Shiner from Carmine Shiner, it is possible that an anatomical character(s) will be discovered in the future. Multivariate analyses based on 16 landmarks were able to distinguish Rosyface Shiner males from Carmine Shiner males, but there was still a fair bit of overlap when all individuals were analyzed (Berendzen et al. 2009). Rocky Shiner *Notropis suttkusi* from Oklahoma can be differentiated from Rosyface Shiner by differences in pigmentation, shape of lateral line, and a multivariate analysis of 25 distance measurements (Humphries and Cashner 1994). Highland Shiner *Notropis micropteryx* from Tennessee and adjacent states can be differentiated from Rosyface Shiner based on mean differences in counts of caudal peduncle scales, total vertebrae, lateral line scales, predorsal scales, circumferential scales, and scales below lateral line. But there is also a lot of overlap when using these counts. Furthermore, a multivariate analysis of 29 distance measurements discerned a slight difference between species, but also considerable overlap (Eisenhour and Eisenhour 2004). These species do appear to differ slightly in regards to body shape, and there are some potential morphological differences, but discovering an anatomical character that can be used to unambiguously distinguish Carmine Shiner from Rosyface Shiner in the field remains elusive.

Due to the tendency of Rosyface Shiners to spawn in specific areas where other species of cyprinid minnows are simultaneously spawning, combined with its behavior of expelling milt and eggs while in the water column (see Species Biology section below for more details), leads to extensive hybridization with other species.

The most common cyprinid minnow hybrid in North America is probably Rosyface Shiner crossing with either Common Shiner *Luxilus cornutus* or Striped Shiner *Luxilus chrysocephalus* (Hubbs and Brown 1929, Raney 1940, Gilbert 1964). This combination has been well documented and studied in regards to anatomy and behavior of both parent species (e.g., Miller 1962, 1963, Pfeiffer 1955, Tsai and Zeisel 1969). These hybrids have even been observed spawning, although it is unclear if offspring are fertile (Raney 1940).

The species *Notropis macdonaldi* was eventually identified as a hybrid between Rosyface Shiner and Common Shiner (Gilbert 1964)

Forbes and Richardson (1920) identified a species as *Notropis pilsbryi* based on three specimens from the East Fork of the Mazon River near Gardner. They even offered the following comments: "Fishes intermediate between those forms typified in Illinois by *N. cornutus* on the one hand and *N. atherinoides* and *rubrifrons* on the other and possessing resemblances to both" (page 149). These specimens were eventually identified as hybrids between Rosyface Shiner and Striped or Common Shiner, and not the true Duskystripe Shiner *Luxilus pilsbryi* (Hubbs and Brown 1929, Gilbert 1964).

The species *Notropis kanawha* from western Virginia was eventually identified as a hybrid between Rosyface Shiner and Mimic Shiner *Notropis volucellus* (Bailey and Gilbert 1960).

Other hybrid combinations include crosses with Rosyside Dace *Clinostomus funduloides* (Tsai and Zeisel 1969), White Shiner *Luxilus albeolus* (Gilbert 1964), and Saffron Shiner *Notropis rubricroceus* (Jenkins and Burkhead 1994).

Distribution and Status

Rosyface Shiner is found in the Vermilion-Wabash basin as well as tributaries of the upper Illinois River, notably the Mackinaw, Big Bureau, West Bureau, Vermilion-Illinois, Fox, Aux Sable, Des Plaines, Kankakee and other watersheds in the central and northeastern portion of the state (Fig. 1). Overall, their status appears to be stable.

The populations in the Des Plaines River are relatively recent, and their numbers appear to be increasing. Although there is an older record in the Des Plaines near the Wisconsin border, it is possible that colonization occurred from populations in the Kankakee, Aux Sable, and/or Hickory Creek watersheds. This would involve movement through the Brandon Lock and Dam complex on the Des Plaines River in Joliet as well as colonization of the area once occupied by the recently removed Hoffman Dam in Riverside.

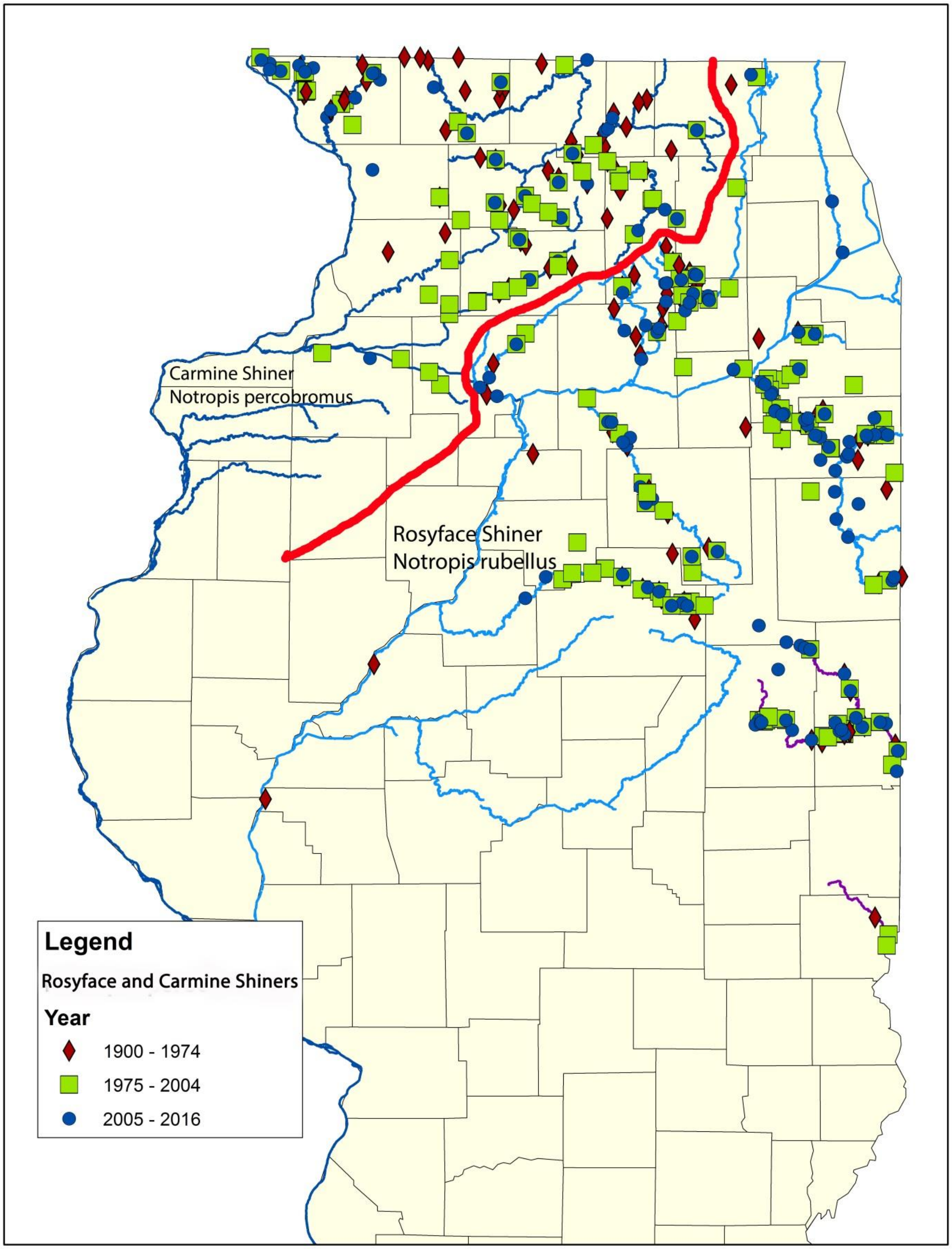


Figure 1. Historical and current distribution of Rosyface Shiner *Notropis rubellus* to the east of the red line, and Carmine Shiner *Notropis percobromus* to the west of the red line.

Habitat

Rosyface Shiners are almost exclusively found in moving water in medium-sized creeks up to smaller rivers. In large rivers and lakes, they seem to be replaced by Emerald Shiner *Notropis atherinoides*. Within streams, Rosyface Shiners live in both pools and riffles, but are most abundant at the junction of the two habitats where a riffle spills into a pool. Usually there is a drop-off at these places, and the fish are in the middle of the water column just off the drop-off. Within runs, they can be found in eddies, smaller pools, and side channels where the water is still moving, but the current may not be as swift as in the main channel.

Because they prefer moving water, bottom substrate is usually cobble, gravel, or sand. But in areas where the current slows considerably, silt can settle out and the bottom can be mud. They do not live amidst thick vegetation. Water temperatures are cooler, but it should not be considered a coldwater species.

The above observations were supported by a multivariate analysis of Rosyface Shiner in southwestern Ontario (Baldwin 1983). Adults appeared to prefer stream habitats with faster water, mean depth of 40-45 cm, very little vegetation, away from shore, and with a range of depths. They were found in a variety of habitat types, from riffles to pools, but almost never in pools that lacked current. Rosyface Shiner young-of-year appeared to prefer pools with very little vegetation, some turbidity, and a range of depths. Being a pool habitat, current was slower than where adults were found. Neither adults nor young-of-year appeared to prefer any type of bottom substrate. Both had a preference for slightly turbid water (Baldwin 1983).

Rosyface Shiners are usually associated with clear water. However, there are times when they can be found in turbid conditions. It is more likely that the streams are temporarily turbid due to a recent storm event, and will eventually clear up after time (personal observation). But there are always exceptions. Most of the literature claims that they are a clear water species (e.g., Forbes and Richardson 1920, Miller 1964, Smith 1979, Becker 1983), and that they do poorly when the water is turbid, leading to declining populations (Scott and Crossman 1973, Smith 1979, Trautman 1981). But at least some populations in Wisconsin (Becker 1983) and Ontario (Baldwin 1983) seem to do well in streams with increased turbidity.

Species Biology

There is less data on the natural history of Rosyface Shiners than one would think. Because of the ongoing taxonomic revisions, much of what is attributed to this species may actually be data associated with another within the closely related species group. For example, the following observations from New York, Pennsylvania, and Virginia populations are probably of an undescribed species. But they are included here because they are still considered Rosyface Shiners at this time, and it is assumed their natural histories are similar, or at least as similar as within other species with a large distribution. This seems justified given how similar the morphology is among populations/species.

In Illinois, Rosyface Shiner spawn in late May (Forbes and Richardson 1920) and maybe into early June (Smith 1979). In Wisconsin, spawning season seems to be delayed to May through June, and maybe later (Becker 1983), which fits with these populations being slightly north of Illinois.

Rosyface Shiners spawn over clean gravel (Raney 1940, Pfeiffer 1955, Reed 1957a, Baldwin 1983) or gravel nests constructed by other species (Hankinson 1932, Hubbs and Cooper 1936, Raney 1940, Reed 1957a, Miller 1964, Baldwin 1983, Tsai and Zeisel 1969). The most detailed description of spawning behavior over gravel is for a population in southwestern New York (Pfeiffer 1955). In early June, a school about four feet long and two and half feet wide consisting of approximately 100 individuals was observed. The front was mostly females, and the back mostly males, although there was some mixing. Individuals were generally a couple inches apart, but did bump into each other from time to time. The school moved quickly, generally in a circular pattern up and down a pool-riffle complex. Sometimes smaller groups of 15-20 individuals temporarily separated from the main school. This behavior continued for approximately ten days (Pfeiffer 1955).

Then for three days the school stopped moving around and remained at the bottom of a riffle. Actual spawning occurred the last week of June, continuing for roughly six days. Water temperature started at 76F and by the end of the period had reached 84F. Each day there were fewer and fewer fish until only ten remained (Pfeiffer 1955).

Spawning occurred at the base of the riffle in a couple inches of water over gravel, with around ten depressions several inches to a foot in diameter. The Rosyface Shiners started nearby in the pool, then suddenly swam to the spawning site. They broke up into groups of up to a dozen individuals each that settled into the depressions. All the individuals began to vibrate and wiggle against one another for several seconds. Then they relaxed for about half a minute. Then they all began to vibrate and wiggle again for several more seconds. Then they relaxed, and this pattern repeated itself for several minutes until the all the fish returned to the pool at the same time. The school remained in the pool for about ten minutes, and then the whole behavior pattern repeated itself. After several days of spawning, and when there were far fewer individuals remaining, the fish tended to stay in the depressions instead of rushing back and forth between pool and riffle. There was far less commotion at this time as well (Pfeiffer 1955).

For a Kentucky population, individuals were in breeding colors from mid-May to early July. Actual spawning aggregations were not observed until mid- to late-June, when water temperatures reached 21 to 25C. At this time, large schools of 400-800 individuals would concentrate in water less than a few inches deep and cover a small section of riffle 0.5-1 m2 (Eisenhour, D.J. and L.V. Eisenhour 2004).

Another type of behavior is spawning over the gravel nests of other species. In eastern New York, Rosyface Shiners did not approach the spawning site until late May when water temperatures were around 68F, and did not actually spawn until early June when temperatures were over 70F. Spawning lasted until late June (Miller 1964). Spawning occurred mostly over the nests of River Chub *Nocomis micropogon* and Cutlip Minnow *Exoglossum maxillingua*, but also Fallfish *Semotilus corporalis* and Creek Chub *Semotilus atromaculatus*. What these nests have in common is they are all constructed of clean gravel in flowing water and have some parts that are raised above the stream bed and other parts that are depressions. Most Rosyface Shiner spawning activity occurred while the nests were being made or right after they were finished. Older nests were not typically used (Miller 1964).

Groups of Rosyface Shiner over a given nest were typically 15-20. These schools seemed to be tied to certain nests, returning to the exact same spot a couple days in a row. Within a single school, individuals moved all over the place, but there did not seem to be any territoriality. Occasionally individuals would briefly bump each other. Normally they were a couple inches apart (Miller 1964).

Actual spawning occurred over nests in about one foot of water with a moderate to swift current. Rosyface Shiners were usually only a couple inches above the nests, with females being a bit higher than males, although both sexes moved around a lot. At times, two or three fishes (usually a female and one or two males) would quickly swim to the front of the depression, rapidly wiggle against each other for a few seconds, then swim or drift back to the school. There was also a lot of bumping and wiggling next to each other in the school proper, but it was difficult to tell if this was spawning, antagonistic encounters, or both. The school could be anywhere over the nest at these times (Miller 1964).

In Virginia, Rosyface Shiners spawned over Bluehead Chub *Nocomis leptocephalus* nests when the water temperature was 21.5-24C. Individuals in spawning condition were found from late May to mid-June (Jenkins and Burkhead 1994). In northwestern Pennsylvania, Rosyface Shiners spawned over River Chub *Nocomis micropogon* and Hornyhead Chub *Nocomis biguttatus* nests in late May. One year had a cold spring, and spawning did not commence until early June, and ended early July. Overall, the spawning period lasted approximately five weeks (Reed 1957a). Individuals started to group together over the nests ten days before spawning occurred. Water temperature was 68-72F when spawning started. Spawning activities continued for six days. The number of days is very similar to what was observed in southwestern New York (Pfeiffer 1955). Individuals did not return to the nests after spawning was completed. Initially, there were approximately 45 -60 individuals per chub nest, with males and females in equal numbers. By the end of the spawning season (i.e., late June), individuals were found spawning in nearby riffles in just a few inches of water. Group size was then 15-25 individuals, and males were more common (Reed 1957a).

Rosyface Shiners in southwestern Ontario exhibited both spawning behaviors, over *Nocomis* nests and over patches of clean gravel in or near riffles and in less than 40 cm of water (Baldwin 1983). They exhibited spawning colors from early May to mid-July, with actual spawning observed from mid-May to early June when water temperatures were 21.3-26.6C. For example, they also moved as a group of up to 50 individuals up and down the stream, returning to the same 30 cm square gravel patch. At times a couple of individuals would swim next to each other and wiggle.

Reed (1957a) conducted some experiments to test the spawning site fidelity of Rosyface Shiners. He found that they would not spawn over chub nests covered by gauze. If half a chub nest was covered by gauze, the shiners would spawn over the uncovered portion. If a chub nest was flattened, the Rosyface Shiners returned to the site of the nest and spawned over the gravel. Shiners continued to return to the same nest, disturbed or not, instead of moving to other nearby nests (Reed 1957a).

At times two Rosyface Shiners would swim away from the group at high speed, very close to each other and bumping into each other, the head of one just behind the head of the other, for a few feet and a few seconds at most. Then they would separate and rejoin the group. It was unclear if this was spawning or an antagonistic encounter (Pfeiffer 1955). Miller (1964) reported the same behavior, but added that sometimes the fishes moved more slowly, even drifting downstream as they came in contact with one another.

Other minnows also take advantage of the nests for spawning, especially Common Shiner *Luxilus cornutus* and Striped Shiner *Luxilus chrysocephalus*. At the eastern New York site, a little less than half of the Rosyface Shiner groups were mixed to some extent with Common Shiners (Miller 1964). In southwestern Ontario, three out of four were mixed groups (Baldwin 1983). When seen together, Common Shiners or Striped Shiners were usually slightly upstream of the Rosyface Shiners (Raney 1940, Miller 1964, Baldwin 1983). Pfeiffer (1955) repeatedly observed Common Shiner *Luxilus cornutus* and/or Striped Shiner *Luxilus chrysocephalus* dart into the middle of a spawning group of Rosyface Shiners and wiggle their bodies just like the Rosyface Shiners. Hubbs and Cooper (1936) characterized Rosyface Shiners as midwater spawners, and Hubbs and Brown (1929) actually observed Rosyface Shiners spawning just a few inches above Common Shiner. The Common Shiner spawning period starts before the Rosyface Shiner period, and extends longer (Miller 1964). These are all major factors for why these two species hybridize so frequently.

Blacknose Dace *Rhinichthys atratulus*-group, Stonerollers *Campostoma* spp., and Southern Redbelly Dace *Chrosomus erythrogaster* also spawn over *Nocomis* nests, hence are a potential source of hybrids as well (Hankinson 1932, Hubbs and Cooper 1936).

On average, age 1 females (50-57 mmSL) carried 600 eggs, age 2 females (52-67 mmSL) had 1090 eggs, and age 3 females (64-75 mmSL) had 1175 eggs (Pfeiffer 1955). Eggs in ovaries of some individuals about to spawn were in two forms; larger dark orange eggs and smaller white/yellow eggs (Baldwin 1983). The smaller white eggs were presumably immature. Eggs were reddish-orange after being released by the female (Pfeiffer 1955). Eggs sink (Becker 1983), but can float for at least 20 inches downstream depending upon how high up in the water column they are released (Reed 1957a). The eggs are adhesive (Reed 1958).

Rainbow Darter *Etheostoma caeruleum*, Northern Hog Sucker *Hypentelium nigricans*, and Central Stoneroller *Campostoma anomalum* have been observed feeding on Rosyface Shiner eggs (Reed 1957a).

Eggs hatched in roughly eight days. Fry then swam down and hid in the crevices among the sand and gravel (Pfeiffer 1955).

Of fish collected in May and June, 6% were immature, 42% were one year old (39-61 mmSL), 42% were two years old (56-70 mmSL), and 10% were three years old (61-75 mmSL). Males slightly outnumber the females for the one and two year olds, but there were twice as many females as males among 3 year olds. Maximum standard length for females was 75mm, and for males 71 mm (Pfeiffer 1955).

These results are very similar to a population in northwestern Pennsylvania. Over the course of an entire year, 70% were one year old (38-60 mmSL), 26% were two years old (50-68 mmSL), and 4% were three years old (58-78 mmSL). Males outnumber the females for the one and two year olds, but there were 50% more females than males among 3 year olds. Maximum female standard length was 78mm, and 76 mm for males (Reed 1957b).

In a Kentucky population from mid-May to early July, the mean male size was 47.9 mmSl, with a maximum of 56 mmSL. Females averaged 50.4 mmSL, with a maximum of 62.3 mmSL (Eisenhour and Eisenhour 2004).

In southwestern Ontario, adults measured in May and June were 2.9-9.2 cmTL, and this was a reflection of an unknown number of year classes. In July, adults were 5.1-7.8 cmTL, while YOY were 1.9-3.6 cmTL. By the end of August the YOY peak and adult peak(s) were blurred together and no longer possible to differentiate year classes. Individuals were not independently aged with scales or any other method. Prolonged spawning period may be reason year classes are difficult to distinguish by length (Baldwin 1983).

Three hermaphroditic individuals, each two years old, were found in northwest Pennsylvania. One individual was discovered during a project that sexed over 3,000 individuals, hence hermaphroditism is not a common occurrence (Reed 1954).

Rosyface Shiners are open water active swimmers (Hubbs and Cooper 1936) that sometimes can be found in schools (Jenkins and Burkhead 1994, Smith 1979). Rosyface Shiners were observed foraging along the bottom and at the surface. Some would hold station at the base of a riffle, dart to the surface to grab the prey item, then swim back down (Pfeiffer 1955). They have also been observed foraging in the middle of the water column while mixed with a school of Common Shiner *Luxilus cornutus* (Jenkins and Burkhead 1994). In general, they seem to spend most of their time swimming and foraging either in the middle of the water column or near the surface (Hubbs and Cooper 1936, Miller 1963, Baldwin 1983). Rosyface Shiners are mostly active during the day. At night they appear to move to areas out of the current, where they are less active (Baldwin 1983). They move to deeper water in pools during the winter (Trautman 1981, Baldwin 1983).

The population in northwestern Pennsylvania basically did not feed from November to March. During this time, Rosyface Shiners move from riffles to deeper pools to overwinter, then return to the riffles in the spring. There was a burst in foraging activity before spawning, then very little foraging during spawning (Reed 1957b). This lack of foraging during spawning was also noticed for the southwestern New York population (Pfeiffer 1955).

The diet of Rosyface Shiners collected in May and June in southwestern New York was 71% aquatic insects and 26% terrestrial insects. The dominant prey item was Plecoptera, followed by Ephemeroptera and Diptera. Odanata, Trichoptera, Coleoptera, Neuroptera, Hymenotptera, Hemiptera, Lepidoptera, Thysanoptera, and Arachnida each composed a couple percent of the diet. The rest was made up of vegetation, unidentified fish eggs, etc. (Pfeiffer 1955).

Reed (1957b) did not distinguish between aquatic and terrestrial insects in his northwestern Pennsylvania study. This population also appeared to have a more benthic focus. On average over the entire year, adults ate 72% insects and 18% algae and diatoms. Within insects, caddisflies were most common, followed by diptera, mayflies, and then other taxa. Juveniles ate 28% insects and 66% algae and diatoms, which presumably reflects their spending more time closer to the bottom.

Miller's (1963) anatomical observations discovered a relatively short gut that is consistent with the Rosyface Shiner's overwhelmingly carnivorous diet. The brain's medium-sized olfactory bulb and no olfactory lobe, large optic lobes, and small facial and vagal lobes indicates that the shiner is predominantly reliant upon eyesight and does little processing of prey once it is in the mouth.

Conservation / Management

Threats

Rosyface Shiners have a preference for clear, running water. They also tend to be absent from warmer streams. Dams and increased turbidity and sedimentation are the primary threats.

Turbidity and sedimentation are most closely tied to land use in the watershed. Both urban and agricultural settings can enhance runoff, with this runoff carrying particulate matter into the streams. The particulate matter makes the water turbid. When the particulate matter settles out of the water column it covers the bottom with sediment, smothering whatever substrate was originally present.

Turbidity is problematic for Rosyface Shiners because they are sight-feeders and cannot forage effectively in waters where they cannot see. But, there are instances where Rosyface Shiners appear to do fine with limited turbidity. A more serious issue is sedimentation because Rosyface Shiners broadcast their eggs over the bottom. If the eggs are covered by sediment, they suffocate and die.

Dams, even small ones, change stream habitat from a flowing water system to impoundments where current is significantly reduced. This in turn facilitates sedimentation, and has a tendency to increase water temperatures. Fish assemblages shift from running water specialists to low flow, warmwater generalists (Winston et al. 1991, Kanehl et al. 1997, Tiemann et al. 2004, Santucci et al. 2005, Catalano et al. 2007, Slawski et al. 2008).

Dams also fragment populations, preventing movement of fish from one stream reach to another. Under natural conditions, if something happens to one population (e.g., drought extirpates fishes from a stream reach), then the impacted site is re-colonized at a later date by fishes from other parts of the stream (Larimore et al. 1959, Griswold et al. 1982). Dams can prevent this movement of fishes, re-colonization does not occur, and the fish(es) are lost from the impacted site (Griswold et al. 1982, Winston et al. 1991, Santucci et al. 2005, Catalano et al. 2007). In watersheds with multiple dams, the impacts can be cumulative (Slawski et al. 2008).

The potential impacts of climate change have not been explicitly examined for Rosyface Shiner. But because Illinois is along the southern edge of the species range, and they do appear to have a tendency to be absent from warmer streams in the state, climate change is a possible concern in the future.

Excessive nutrient input, whether it is from agriculture, cattle, wastewater treatment plants, etc., can result in extensive algal and plant growth. Rosyface Shiners are active swimmers that prefer a significant amount of space to move around. They are almost never found in the middle of areas with dense aquatic vegetation. Copious algal and plant growth can force Rosyface Shiners out of a stream reach, regardless of water flow and bottom substrate.

The impacts of road salts are unknown.

Regulations

Rosyface Shiner is not listed as Endangered or Threatened in Illinois. They are not considered game fish. The only regulations for Rosyface Shiner would be general fishing regulations covering non-game fish and regulations covering the movement or sale of fishes potentially infected with the disease Viral Hemorrhagic Septicemia.

Conservation Efforts

There are no specific conservation efforts in Illinois.

Survey Guidelines

Rosyface Shiners are active swimmers in the middle of the water column. Bottom substrate is often cobble. The most effective method for catching them is a seine. Because these fish are typically in the middle of the water column or closer to the surface, it is not critical to have the lead line of the seine right on the bottom where it can get snagged. One can skim the lead line over the cobble and herd the fish in front of the seine. Once closer to shore, it is then necessary to have the lead line along the bottom as the fish try to escape by swimming below the net at the last moments.

Because Rosyface Shiners are active swimmers, they can swim around the edges of a seine. Larger seines minimize the number of fish that escape in this manner. It is possible to collect the fish in seines 10 feet or less in length, but seines 15 feet or longer are typically more productive.

Backpack electrofishing works, but many of the Rosyface Shiners will either see the individual carrying the backpack or feel the edge of the electric field and swim away. ‘Pinning’ the fish in an enclosed area, like a side channel or pool below a riffle, works well by closing off the escape routes. In a similar manner, an electric seine with a block net works well. Most of the Rosyface Shiners are netted either at the block net or along some obstruction in the stream channel that hinders the fish from swimming away.

Focusing on pools at the base of riffles increases ones chances of capturing fish.

Stewardship Recommendations

Rosyface Shiners prefer clear water and minimal sedimentation of the stream bottom. They can sometimes be found in moderately turbid streams, but are less common under these conditions. Turbidity is usually related to eroding landscapes, hence methods that minimize the amount of soil that is carried by runoff are critical. Land-use in the watershed, both where the Rosyface Shiners live as well as upstream, typically drives this aspect of the system. Vegetation, both forests and prairies, locks soils in place, minimizing erosion. The more vegetation the better, but even narrow strips of vegetation along a stream (i.e., riparian buffer) can help. Other possibilities include a suite of agricultural best management practices, such as no-till farming (Montgomery 2007) or terrain modification.

Riparian buffers have the added benefit of serving as a food source. Rosyface Shiner forage in mid-water and at the surface, eating a mixture of aquatic and terrestrial invertebrates. If terrestrial insects from the riparian buffer fall into the stream, they can serve as prey for the fish.

Minimization Measures

Rosyface Shiners spawn in May or June. They broadcast their eggs over the bottom substrate that is usually gravel or cobble. The eggs are adhesive and stick to whatever they land upon. If the eggs are covered by silt, they will suffocate and die. Any activities at a spawning site or upstream that would increase sedimentation should be avoided during the spawning season. Silt curtains and other erosion control methods at streamside construction sites are sometimes effective at minimizing sedimentation, but this should be evaluated on a case-by-case basis.

Mitigation and Conservation Opportunities

Restoration

The preferred habitat of Rosyface Shiners is running water over gravel or cobble in larger creeks and smaller rivers. One of the most effective methods at creating this habitat is dam removal.

These smaller to moderately-sized aquatic systems often have smaller dams that appear to be insignificant. But even the removal of a small dam can have large impacts.

When the dam is present, the flow of water in the impoundment is slower and the rate of sedimentation is higher. After the removal of the dam, the flow of water is faster, and this increased current carries sediment farther downstream, reducing sedimentation at the dam site. Water clarity (sediments suspended in the water column) is more dependent upon conditions upstream. But softer sediments on the bottom, like mud, will be washed downstream, exposing the heavier sediments, like gravel and cobble when present. Rosyface Shiners spawn over gravel and cobble, not mud.

Dams also fragment the aquatic habitat, preventing the movement of fish and associated gene flow among different parts of streams. If a catastrophe strikes part of stream (e.g., drought, oil spill, excess fertilizer, etc.), then dams may prevent the recolonization of the site after the catastrophe is over. Connectivity is critical in maintaining meta-population dynamics.

Research Needs

Assess potential impacts of climate change.

Find morphological characters that distinguish Rosyface Shiners from Carmine Shiners. (Species are currently recognized solely by genetic differences and geography.) This will facilitate field identifications, which are not possible at this time.

Develop monitoring methods for cryptic species, and determine the best way to incorporate these into conservation and management plans. See immediately above.

Assess potential impacts of road salts.

References

Agassiz, L. 1850. Lake Superior: its physical character, vegetation, and animals, compared with those of other and similar regions. Gould, Kendall and Lincoln, Boston. 428 pages.

Bailey, R.M. and C.R. Gilbert. 1960. The American cyprinid fish *Notropis kanawha* identified as an interspecific hybrid. Copeia 1960:354-357.

Bailey, R.M., W.C. Latta, and G.R. Smith. 2004. An atlas of Michigan fishes with keys and illustrations for their identification. Miscellaneous Publications Museum of Zoology, University of Michigan 192:1-215.

Baldwin, M.E. 1983. Habitat use, distribution, life history, and interspecific associations of *Notropis photogenis* (Silver Shiner; Osteichthyes: Cyprinidae) in Canada, with comparisons with *Notropis rubellus* (Rosyface Shiner). Master's Thesis, Carleton University, Ottawa. 189 pages.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison. 1,052 pp.

Berendzen, P.B., W.M. Olson, and S.M. Barron. 2009. The utility of molecular hypotheses for uncovering morphological diversity in the *Notropis rubellus* species complex (Cypriniformes: Cyprinidae). Copeia 2009:661-673.

Berendzen, P.B., A.M. Simons, R.M. Wood, T.E. Dowling, and C.L. Secor. 2008. Recovering cryptic diversity and ancient drainage patterns in eastern North America: historical biogeography of the *Notropis rubellus* species group (Teleostei: Cypriniformes). Molecular Phylogenetics and Evolution 46:721-737.

Catalano, M.J., M.A. Bozek, and T.D. Pellett. 2007. Effects of dam removal on fish assemblage structure and spatial distributions in the Baraboo River, Wisconsin. North American Journal of Fisheries Management 27:519-530.

Eisenhour, D.J. and L.V. Eisenhour. 2004. Morphological variation and systematics of the *Notropis rubellus* complex in Kentucky and Tennessee. Southeastern Naturalist 3:431-450.

Felley, J.D. and L.G. Hill. 1983. Multivariate assessment of environmental preferences of cyprinid fishes of the Illinois River, Oklahoma. American Midland Naturalist 109:209-221.

Forbes, S.A. and R.E. Richardson. 1920. The fishes of Illinois. Illinois Natural History Survey. Second Edition. 357 pp.

Gilbert, C.R. 1964 The American cyprinid fishes of the subgenus *Luxilus* (genus *Notropis*). Bulletin of the Florida State Museum, Biological Sciences 8:95-194.

Griswold, B.L., C.J. Edwards, and C.L. Woods III. 1982. Recolonization of macroinvertebrates and fish in a channelized stream after a drought. Ohio Journal of Science 82:96-102.

Hankinson, T.L. 1932. Observations on the breeding behavior and habitats of fishes in southern Michigan. Papers of the Michigan Academy of Science, Arts, and Letters 15:411-425.

Hubbs, C.L. and D.E.S. Brown. 1929. Materials for a distributional study of Ontario fishes. Transactions of the Royal Canadian Institute 17:1-56.

Hubbs, C. L., and G. P. Cooper. 1936. Minnows of Michigan. Cranbrook Institute of Science, Bulletin No. 8,, Bloomfield Hills, Michigan.84 pages.

Hubbs, C.L. and K.F. Lagler (and G.R. Smith). 2004. Fishes of the Great Lakes region. Revised Edition. The University of Michigan Press, Ann Arbor. 276 pp.

Humphries, J.M. and R.C. Cashner. 1994. *Notropis suttkusi*, a new cyprinid from the Ouachita uplands of Oklahoma and Arkansas, with comments on the status of the Ozarkian populations of *N. rubellus*. Copeia 1994:82-90.

Jenkins, R.E. and N.M. Burkhead. 1994. Freshwater Fishes of Virginia. American Fisheries Society, Bethesda, MD. 1079 pages.

Kanehl, P. D., J. Lyons, and J. E. Nelson. 1997. Changes in the habitat and fish community of the Milwaukee River, Wisconsin, following removal of the woolen mills dam. North American Journal of Fisheries Management 17:387–400.

Larimore, R.W., W.F. Childers, and C. Heckrotte. 1959. Destruction and re-establishment of stream fish and invertebrates affected by drought. Transactions of the American Fisheries Society 88:261-265.

Miller, R.J. 1963. Comparative morphology of three cyprinid fishes: *Notropis cornutus*, *Notropis rubellus*, and the hybrid, *Notropis cornutus* X *Notropis rubellus*. American Midland Naturalist 69:1-33.

Miller, R.J. 1964. Behavior and ecology of some North American cyprinid fishes. American Midland Naturalist 72:313-357.

Montgomery, D.R. 2007. Soil erosion and agricultural sustainability. Proceedings of the National Academy of Sciences 104:13268-13272.

Page, L.M. and B.M. Burr. 2011. Peterson field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Harcourt, Boston. 663 pp.

Pfeiffer, R.A. 1955. Studies on the life history of the rosyface shiner, *Notropis rubellus*. Copeia 1955:95-104.

Raney, E.C. 1940. Reproductive activities of the hybrid minnow, *Notropis cornutus* X *Notropis rubellus*. Zoologica., 25(3):361-367.

Reed, R.J. 1954. Hermaphroditism in the rosyface shiner, *Notropis rubellus*. Copeia 1954:293-294.

Reed, R.J. 1957a. The prolonged spawning of the rosyface shiner, *Notropis rubellus* (Agassiz), in northwestern Pennsylvania. Copeia 1957:250.

Reed, R.J. 1957b. Phases of the life history of the rosyface shiner, *Notropis rubellus*, in northwestern Pennsylvania. Copeia 1957:286-290.

Reed, R.J. 1958. The early life history of two cyprinids, *Notropis rubellus* and *Campostoma anomalum pullum*. Copeia 1958:325-327.

Santucci, V. J., S. R. Gephard, and S. M. Pescitelli. 2005. Effects of multiple low-head dams on fish, macroinvertebrates, habitat, and water quality in the Fox River, Illinois. North American Journal of Fisheries Management 25:975–992.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184:1-966.

Slawski, T.M., F.M. Veraldi, S.M. Pescitelli, and M.J. Pauers. 2008. Effects of tributary spatial position, urbanization, and multiple low-head dams on warmwater fish community structure in a Midwestern stream. North American Journal of Fisheries Management 28:1020-1035.

Smith, P.W. 1979. The fishes of Illinois. University of Illinois Press, Urbana. 314 pp.

Tiemann, J. S., D. P. Gillette, M. L. Wildhaber, and D. R. Edds. 2004. Effects of low-head dams on riffle-dwelling fishes and macroinvertebrates in a midwestern river. Transactions of the American Fisheries Society 133:705–717.

Trautman, M.B. 1981. The fishes of Ohio. Ohio State University Press. 782 pages.

Tsai, C.-f. and R.B. Zeisel. 1969. Natural hybridization of cyprinid fishes in Little Patuxent River, Maryland. Chesapeake Science 10:69-74.

Winston, M.R., C.M. Taylor, and J. Pigg. 1991. Upstream extirpation of four minnow species due to damming of a prairie stream. Transactions of the American Fisheries Society 120:98-105.

Wood, R.M., R.L. Mayden, R.H. Matson, B.R. Kuhajda, and S.R. Layman. 2002. Systematics and biogeography of the *Notropis rubellus* species group (Teleostei: Cyprinidae). Bulletin Alabama Museum of Natural History 22:37-80.

Conservation Guidance for

Spoonhead Sculpin

Cottus ricei (Nelson 1876)

IL Status: NatureServe – SH

US Status: NatureServe – N4

Global Rank: NatureServe – G5

Trend: Extremely rare

Family: Cottidae

Habitat: Deep waters of Lake Michigan

Similar Species:
Mottled Sculpin *Cottus bairdii*
Banded Sculpin *Cottus carolinae*
Slimy Sculpin *Cottus cognatus*
Deepwater Sculpin *Myoxocephalus thompsonii*
Round Goby *Neogobius melanostomus*

Species Information

Characteristics

Large head and tapering body, giving it a 'tadpole-like' appearance. Head flat, or 'spoon-shaped', relative to other sculpins. Moderately upturned eyes. Wide terminal mouth with numerous tiny teeth in bands on the upper and lower jaws. One midline chin pore. Gill membranes broadly joined to isthmus. Spines on preopercle covered by skin, except possibly the upper spine that may be exposed. Upper spine length typically 2/3 or more of eye diameter and curved upward and inward. Large pectoral fins with 14-16 rays. Pelvic fins beneath pectoral fins, with 1 spine and 4 rays, the spine and first ray closely connected and difficult to distinguish. Two dorsal fins barely connected at base. First dorsal 7-10 spines, second dorsal 16-18 rays. Anal fin 12-16 rays. Rounded caudal fin. Slender caudal peduncle, relative to other sculpins. Body scaleless, but sometimes with prickles especially dorsally. Lateral line complete, 33-36 pores. Coloration a mottled brown or cream, darker on the back and lighter belly. Sometimes juveniles with three or four indistinct saddles that become even less distinct with age. Faint vertical bar at end of caudal peduncle. Can reach 5.3 inches / 13.4 cm in total length (Delisle and Van Vliet 1968, Becker 1983, Bailey et al. 2004, Hubbs and Lagler (and Smith) 2004, Page and Burr 2011)

Fish (1932) described in detail an individual measuring 27.5 mm in length, as well as 12.5 mm and 16.2 mm specimens that were misidentified as *Triglopsis* (now *Myoxocephalus*) *thompsoni* and 6-11 mm specimens misidentified as *Cottus bairdi* (Snyder and Ochman 1985). Larvae and juveniles were described in detail, as well as compared them to other Great Lakes sculpin species, by Heufelder (1982) and Snyder and Ochman (1985).

Can be distinguished from similar species by having a complete lateral line (versus incomplete lateral line in Mottled Sculpin *Cottus bairdii* and Slimy Sculpin *Cottus cognatus*), dorsal fins barely connected at base (versus dorsal fins distinctly separate in Deepwater Sculpin *Myoxocephalus thompsonii* or barely separate in Banded Sculpin *Cottus carolinae*), and two separate pelvic fins (verus pelvic fins fused to form disk in Round Goby *Neogobius melanostomus*).

Taxonomy

Cottopsis ricei Nelson 1876
Uranidea pollicaris (Jordan and Gilbert 1883)
Cottus onychus (Eigenmann and Eigenmann 1892)
Cottus ricei (Nelson 1876)

Spoonhead Sculpin *Cottus ricei* was first discovered by Northwestern University zoology student F.L. Rice on the shore of Lake Michigan near Evanston, Illinois (Becker 1983). He delivered the specimen to E.W. Nelson who wrote the official description published in 1876. Nelson named the new species *Cottopsis ricei*, or Rice's Cottus, after his friend.

Several years later, Dr. P.R. Hoy collected a specimen in Lake Michigan off of Racine, Wisconsin. He donated the specimen to the United States National Museum (Smithsonian), where it was described as *Uranidea pollicaris* by Jordan and Gilbert (1883).

And then several years after that, Carl Eigenmann and his wife, Rosa Eigenmann (1892), described *Cottus onychus* from a single specimen collected near Calgary, Alberta. Both *U. pollicaris* and *C. onychus* were subsequently synonymized with *C. ricei*.

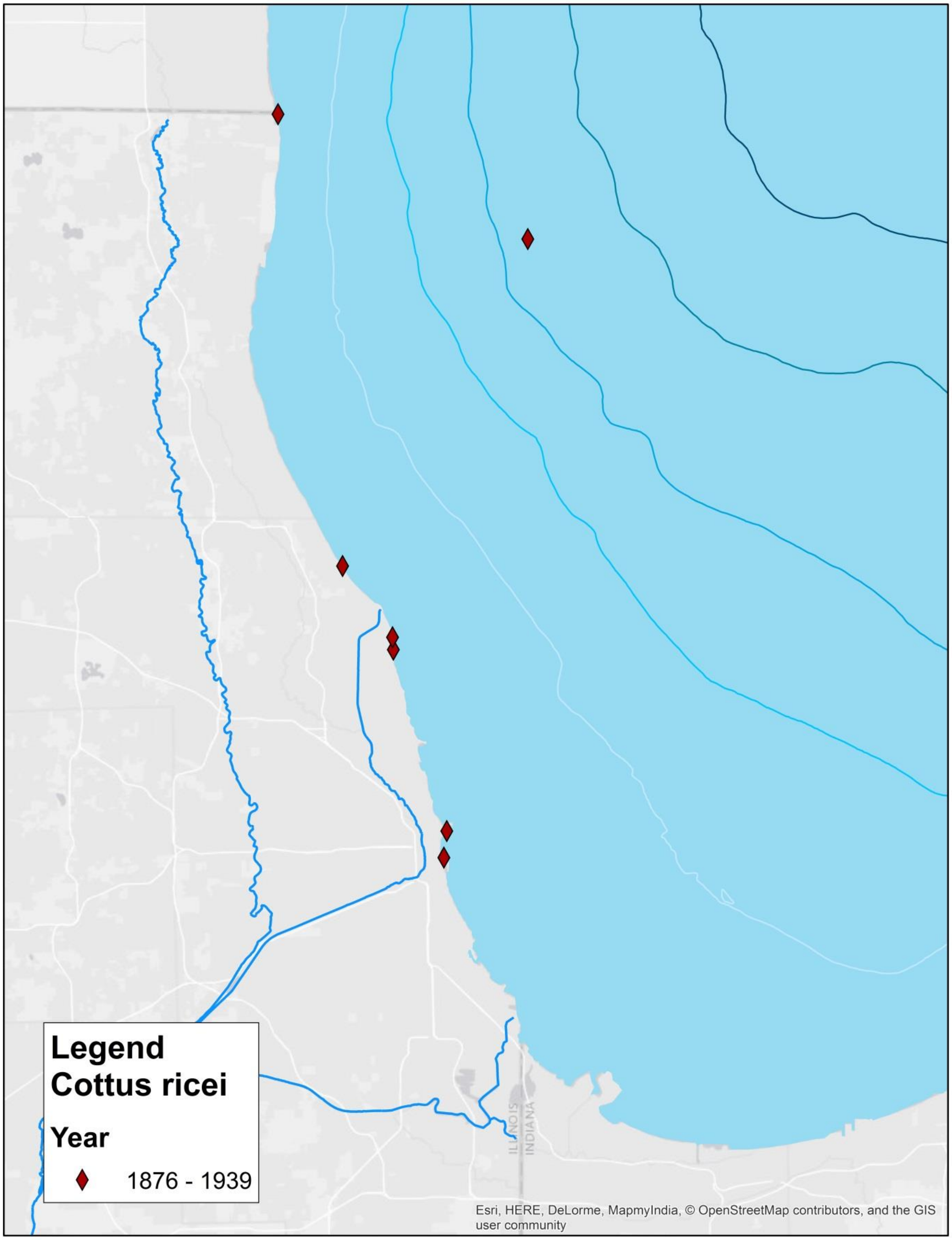


Figure 1. Historical and current distribution of Spoonhead Sculpin *Cottus ricei* in Illinois. Lake Michigan contour lines are 25 meters.

Distribution and Status

In Illinois, the Spoonhead Sculpin is restricted to Lake Michigan (Fig. 1). There are only seven records of Spoonhead Sculpin, making it one of the state's rarest, or at least little-known, species. What is even more surprising is the species was first discovered by Northwestern University zoology student Frank Leon Rice on the shore of Lake Michigan near Evanston (Becker 1983). The exact circumstances are unknown, but apparently there was a severe storm over Lake Michigan from January 1-5, 1876. At first the wind blew from the slightly west of south, then west, then switched to the east, then back from the southwest. At times the wind measured 44 miles per hour. On January 5, Rice and fellow classmate Nathan Smith Davis Jr. collected specimens on the beach. There were a great many algae, crayfishes, fishes, mudpuppies, and molluscs (Davis 1876, Resetar and Resetar 2015). As to whether a Spoonhead Sculpin was mixed in with these fishes or not is unknown, but the circumstances and timing fit. What we do know is that at some time around then Rice delivered the Spoonhead Sculpin specimen to E.W. Nelson who wrote the official description published in December, 1876. Nelson named the new species *Cottopsis ricei*, or Rice's Cottus, after his friend.

This single specimen was designated as the type. Unfortunately, it has disappeared. In a letter dated February 4, 1876, Davis wrote about the storm and commented that "Mr. Rice collected a number of different species of the smaller fishes, but by accident they were destroyed and I am not able to give a list of them." Once again, we do not know if a Spoonhead Sculpin was one of these smaller fishes from this particular storm, but at some time Rice was able to present the specimen to Nelson. Forbes and Richardson commented that they were "lacking access to Mr. Nelson's type" as they were writing the species account for The Fishes of Illinois (1909, 1920). Sabaj et al. (1997) question whether the specimen was ever deposited in the collections of the Illinois State Laboratory of Natural History (the forerunner of the current Illinois Natural History Survey). The whereabouts of this specimen remain a mystery to this day.

Although the specimen may have disappeared, regional ichthyologists were well aware of its discovery. Both Jordan (1878) and Meek and Hildebrand (1910) commented that it could be found in the deep waters of Lake Michigan.

The second occurrence of Spoonhead Sculpin in Illinois was roughly 33 years later when E.W. Youngren collected a specimen at the mouth of the Chicago River on March 1, 1909. The preserved specimen was originally housed at the Chicago Academy of Sciences when it was examined by C.L. Hubbs (1919a). The specimen has since been transferred to The Field Museum (FMNH catalog #42905 (previously #9539), where it resides to this day.

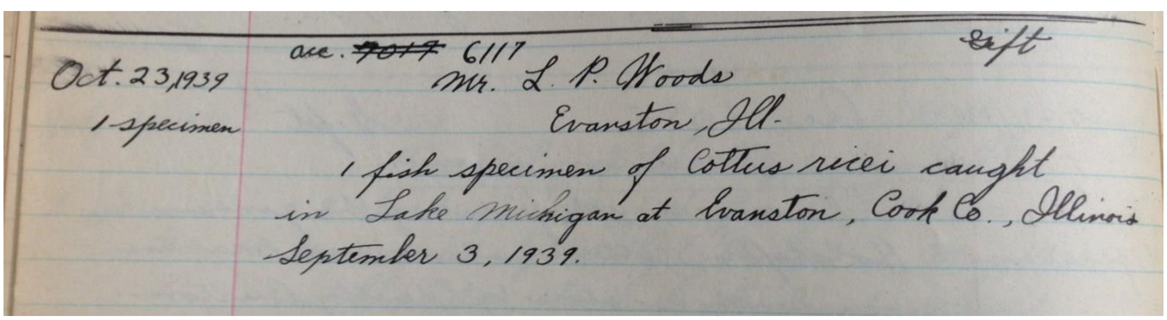
The next record is from Lake Michigan near Chicago in 1911 when a Spoonhead Sculpin was apparently sucked "through the city water system, from the intake about two miles out in the lake" (Hubbs 1919a). This specimen is now housed in The Field Museum (FMNH catalog #5845).

A few years later, C.L. Hubbs added to our knowledge by collecting a specimen that "was found on the shore of Lake Michigan, near Winnetka, Illinois, where it had been driven with numerous other fishes by a storm, on July 8, 1919" (Hubbs 1920). Specimen is now housed in The Field Museum (FMNH catalog #9703).

No Spoonhead Sculpins were collected in the 1920s, but then three were in the 1930s. The first "was obtained by means of a minnow seine by Deason and F.W. Jobes on June 7, 1931, in 12 feet of water near the shore at a point approximately abreast the Wisconsin-Illinois state line" (Deason 1939). The specimen was deposited into the fish collection at the University of Michigan Museum of Zoology (UMMZ catalog #66275), with the locality information as "Lake Michigan, 9.5 mi N of Waukegan, breakwater, approximately abreast Wisconsin-Illinois line." Illinois is listed as the state, so the locality was apparently just south of the Wisconsin-Illinois state line.

Deason's (1939) review of Lake Michigan sculpins includes a map of Spoonhead Sculpin records. This distribution map shows a record off Waukegan. Presumably this record is from his fishery study in which they examined the gut contents of Lake Trout *Salvelinus namaycush* and Burbot *Lota lota* from southern Lake Michigan caught during the years 1930 and 1931 (Van Oosten and Deason 1938). There is no known voucher specimen for this locality. It is unclear if the Spoonhead Sculpin(s) was eaten by Lake Trout or Burbot, as both ate Spoonhead Sculpins. However, Burbot tended to eat more Spoonhead Sculpins in the study.

The last time a Spoonhead Sculpin was found in Illinois was on September 3, 1939 when L.P. Woods caught one in Lake Michigan at Evanston. Specimen is now housed in The Field Museum (FMNH catalog #37335).


Oct. 23, 1939 — acc. ~~7017~~ 6117 — Gift
1 specimen
Mr. L. P. Woods
Evanston, Ill.
1 fish specimen of Cottus ricei caught in Lake Michigan at Evanston, Cook Co., Illinois September 3, 1939.

Field Museum ledger notes of *Cottus ricei* caught in 1939. Image by Kevin Swagel (Field Museum).

Deason (1939) also states that Hubbs (unpublished report) "took one near shore at Jackson Park, Chicago, in the summer of 1918 or 1919." This record has been subsequently re-reported in other publications, such as Fishes of Wisconsin by Becker (1983). However, there is no voucher specimen, which is odd because Hubbs preserved in a museum almost every fish he ever caught. But he did publish a manuscript about a Mottled Sculpin *Cottus bairdii* that Charles Brandler caught on May 29, 1919 "on the bottom of Lake Michigan near shore, from a pier in Jackson Park, Chicago" (Hubbs 1919b). This Mottled Sculpin specimen is currently in The Field

Museum (catalog #9695). It is possible there has been confusion between the Jackson Park Mottled Sculpin record (Hubbs 1919b) and the Winnetka Spoonhead Sculpin record (Hubbs 1920). Until more information becomes available, the Jackson Park Spoonhead Sculpin record should be considered unreliable.

Meek and Hildebrand (1910) report Spoonhead Sculpin as one of the species living within 50 miles of Chicago, saying it is found in "deep waters of Lake Michigan." Most of their species accounts are based on Field Museum specimens, and they have specific locality information. Their Spoonhead Sculpin species account has rather vague locality information. Also, the account gives a range of values for certain morphological features, but it is not clear if they obtained the values from specimens or the literature, since they did both in their publication. In short, Meek and Hildebrand (1910) were aware of Spoonhead Sculpin in Illinois, but it is unclear where they received the information.

Smith (1979) also includes Spoonhead Sculpin in his The Fishes of Illinois. He clearly states that he is only aware of the species description by Nelson (1876) and the four specimens in The Field Museum fish collection.

In the region, the Spoonhead Sculpin has never been recorded from Indiana (Simon 2011). It was probably never too common in southern Lake Michigan, being relatively more common in northern Lake Michigan (Van Oosten and Deason 1938, Deason 1939, Potter and Fleischer 1992).

In southern Lake Michigan, the Great Lakes Fishery Laboratory found several Spoonhead Sculpins in trawls made in 1954. Subsequent trawling in 1960, 1964-1971, and 1973-1989 did not find any (Wells and McLain 1973; Potter and Fleischer 1992). The last documented appearance of Spoonhead Sculpin in southern Lake Michigan was in 1990 near Saugatuck, Michigan at a depth of 91 meters (Potter and Fleischer 1992).

Spoonhead Sculpin are found throughout the Great Lakes, north into Ontario and Quebec, then northwest through Canada all the way to the Yukon Territory (Scott and Crossman 1973). Illinois is essentially the southernmost extent of its range (Page and Burr 2011).

Habitat

Very little is definitively known about the habitats of Spoonhead Sculpin in Illinois. Although most specimens were collected in shallow water near the shore or on the shore, it is presumed these are aberrations and that the primary population is in the deeper waters of Lake Michigan. Throughout Lake Michigan, they have been found in the stomachs of Lake Trout and Burbot caught from 81-438 feet (Deason 1939) and in bottom trawls from 9-91 meters (Potter and Fleischer 1992).

In Lake Superior, they have been found from 120-354 feet, being most common 240-294 feet (Dryer 1966), 10-210 meters, but usually in water deeper than 50 meters (Selgeby 1988), and up to 372 feet/114.4 meters, sometimes at depths of 72-150 feet/21.9-45.7 meters, but more common at 216 feet/65.8 m in July and August (Scott and Crossman 1973). At Isle Royale, they were in inland lakes, streams, and along the shore (Hubbs and Lagler 1949). In Lake Nipigon, one was found in a Burbot stomach caught at 105 feet, and others were seined up in June in 3 feet of water near shore (Dymond 1926). Lake Erie has a record at 22 meters (Fish 1932). Overall, they appear to be inhabiting a depth range between Slimy Sculpin *Cottus cognatus* and Deepwater Sculpin *Myoxocephalus thompsonii* (Scott and Crossman 1973, Brandt 1986), but with a greater overlap with the Slimy Sculpin.

Outside the Great Lakes, they have been caught in lakes at depths of 55 and 90 feet in June and 140 feet in August in Quebec (Delisle and Van Vliet 1968). In Ontario, they have been collected in swift streams (Dymond and Scott 1941). In northern Canada, they are most common in the shallow sections of large muddy rivers, although it is possible they may be in the deeper, unsurveyed portions of these same rivers (McPhail and Lindsey 1970). They have even been collected in slightly brackish waters in James Bay (Ryder et al. 1964). They never seem to be abundant in any of these regions (McPhail and Lindsey 1970).

Only inferences can be made in regards to substrate. Since they are collected in bottom trawls, Spoonhead Sculpin apparently spend some of their time over smooth lake bottoms. Spawning individuals are rare in trawls, and this is thought to mean they spawn in rocky areas where trawls are ineffective (Selgeby 1988).

Species Biology

There has been some confusion trying to determine when Spoonhead Sculpin spawn, and this is probably because of its large distribution and that it inhabits a variety of habitats. In Quebec, males were expressing milt in August when water temperatures were 4.5 C (Delisle and Van Vliet 1968). In Ontario, eggs in the ovaries were larger in August than in July or June, and much larger than eggs in December (Scott and Crossman 1973). But examining gonads from fish from Lake Superior indicated that Spoonhead Sculpin spawn early- to mid-May. Water temperature was not actually measured, but it was estimated to be a little above 4 C (Selgeby 1988). Based on the appearance of larvae, spawning appears to occur in mid- to late spring in both Quebec (Snyder and Ochman 1985) and Lake Erie (Fish 1932), and early May in Lake Superior (Heufelder 1982). Although the time of year of spawning may vary from place to place, it appears to occur at water temperatures around 4-5 C.

Spawning behavior has not been observed. Selgeby (1988) reported that relatively few spawning individuals were collected in bottom trawls, leading to the idea that spawning individuals must be among rocks where trawls are ineffective. This would be consistent with the spawning behavior of other sculpin species.

Eggs in the ovaries are relatively large and orange (Selgeby 1988). When the eggs hatch, the larvae are less developed than with other Great Lakes sculpins. The initial yolk sacs are relatively smaller than those in Mottled Sculpin or Slimy Sculpin, and there is little to no yolk left by the mesolarvae stage (Heufelder 1982, Snyder and Ochman. 1985). Larvae have been collected in plankton tows (Selgeby personal communication in Eck and Wells 1987), but it has not been definitively demonstrated that there is a pelagic larval period.

In regards to length, maximum growth in a Lake Superior population occurred during year 1, and then decreased throughout the life span of the fish, with growth during years 2 and 3 about 60% of year 1, and then only 35-40% of year 1 after that. The average length of year 1 sculpins was 36 mm, year 2 was 58 mm, year 3 was 73 mm, year 4 was 87 mm, year 5 was 102 mm, and year 6 was 112 mm (Selgeby 1988). Another study in the same area found the average length to be 3.0 inches, with a range of 1.7-4.2 inches (Dryer 1966). In regards to weight, growth was least during year 1, but then increased every year after that (Selgeby 1988). At a given length, Spoonhead Sculpins weighed less than Slimy Sculpins (Selgeby 1988).

After 1 ½ years, 80-90% of males were sexually mature, and 40% of females. Most were mature after 2 years, and all were mature after 2 ½ years. Most individuals were age III. No individuals over 6 years were observed (Selgeby 1988).

The diet of two western Lake Superior populations was predominantly benthic invertebrates. Amphipoda were most abundant by far, followed by Mysidacea. Other taxa present included Copepoda, Isopoda, Chironomidae, Ephemeroptera, Tricoptera, Coleoptera, Odonota, Hirudinea, and coregonid eggs (Anderson and Smith 1971). Another study in the same region documented burrowing amphipods (*Pontoporeia affinis*) making up 93% of the diet, followed by Opossum shrimp (*Mysis relicta*) with 5%. Opossum shrimp were more common in late summer and fall. Chironomids (larvae and pupae combined) accounted for 2%. Peak feeding was in July (Selgeby 1988).

Spoonhead Sculpin are eaten by Lake Trout (*Salvelinus namaycush*) and Burbot (*Lota lota*) (Dymond 1926, Fish 1932, Van Oosten and Deason 1938).

Potter and Fleischer (1992) reported only catching Spoonhead Sculpins at night while surveying Lake Michigan. They did not catch any while surveying the same sites during the day.

In Lake Superior, Spoonhead Sculpin were found in water temperatures ranging from 3.2 – 17.0 C. However, from May to June they appeared to prefer 4 C, in late August it was 5.3 C, and in late October it was 5.5 C (Selgeby 1988).

Conservation / Management

Threats

Because Spoonhead Sculpins are so rare and live in deep water, analyses of threats are based on indirect observations and hypothetical. With that in mind, the three primary threats are thought to be invasive species, loss of forage base, and increased predation pressure. These threats are not mutually exclusive of one another.

Spoonhead Sculpins have relatively less-developed larvae (in comparison to other Great Lakes sculpins) with tiny yolk sacs (Snyder and Ochman 1985), and have been collected in plankton tows (Selgeby personal communication in Eck and Wells 1987). This is consistent with other species that have a pelagic larval stage. If this is the case, then Spoonhead Sculpin larvae would be subject to pelagic predators, like the invasive Alewife *Alosa pseudoharengus* (Eck and Wells 1987, Potter and Fleischer 1992). Alewives are believed to have had significant negative impacts on many native fishes via direct predation on larvae/juveniles or competing with their young for food (Smith 1970, Wells and McLain 1973, Eck and Wells 1987). Alewife numbers increased significantly in Lake Michigan in the 1960s, and this is the same time lake-wide Spoonhead Sculpin numbers dropped (Potter and Fleischer 1992). Alewife numbers have been declining recently (Eck and Wells 1987), so it is possible that the intensity of this threat has also been decreasing (Potter and Fleischer 1992).

Another invasive species threat is the Round Goby *Neogobius melanostomus*. Because gobies are more common in nearshore areas, and Spoonhead Sculpin are in deeper waters, there is probably limited overlap between the two species. But because Round Gobies have had a devastating impact on Mottled Sculpin by outcompeting them for spawning sites (Dubs and Corkum 1996, Janssen and Jude 2001), there is a potential for negative interactions when they do meet.

Spoonhead Sculpins forage on amphipods (Anderson and Smith 1971, Selgeby 1988). One of the most common amphipods in the deeper portions of Lake Michigan, *Diporeia*, has experienced dramatic declines in the past couple decades. The exact reasons for the drop in numbers are unclear, but it is correlated with the expansion of the invasive dreissenid mussels (Nalepa et al. 2009). The end result is a potential decrease in the amount of food for Spoonhead Sculpins.

Lake Trout and Burbot, both native species, prey on Spoonhead Sculpin. Lake Trout numbers were low in southern Lake Michigan during the latter half of the 20th Century due to overfishing and Sea Lamprey *Petromyzon marinus* attacks (Eschmeyer 1957, Wells and McLain 1972, Holey et al. 1995, Eshenroder and Amatangelo 2002, Smith and Tibbles 1980). Recently, there has been a resurgence of Lake Trout numbers, and this may also result in increased predation pressure on Spoonhead Sculpin.

Regulations

Spoonhead Sculpin are not listed as Endangered or Threatened in Illinois. They are not considered game fish. The only regulations for Spoonhead Sculpin would be general fishing regulations covering non-game fish and regulations covering the movement or sale of fishes potentially infected with the disease Viral Hemorrhagic Septicemia.

Conservation Efforts

There are no specific conservation efforts in Illinois.

Survey Guidelines

Most Spoonhead Sculpin records in the Great Lakes are from bottom trawls (Dryer 1966, Selgeby 1988, Potter and Fleischer 1992). Bottom trawls have the advantage of being easy to standardize (i.e., set time and distance), so the amount of effort is easier to calculate. Disadvantages to bottom trawls are logistics (need a specialized boat and gear), costs, and they do not work well over rocks. Night trawling appear to be more productive than trawling during the day (Potter and Fleischer 1992).

Many historical records are based on gut content analyses. Lake Trout and Burbot both eat Spoonhead Sculpin (Dymond 1926, Fish 1932, Van Oosten and Deason 1938). Although one knows where the predator was caught, one does not know for certainty where the predator ate the sculpin.

Fine-mesh gill nets, 1 to 1 ½ inch mesh or less, can catch Spoonhead Sculpins (Delisle and Van Vliet 1968), although there are very few records based on this method. Other records are based on dead individuals washed up on beaches, trapped in intake pipes, or seined close to shore, but these seem to be more accidental than reliable population surveys in southern Lake Michigan.

Stewardship Recommendations

There are no known losses of habitat in the deep waters of Lake Michigan, hence habitat 'restoration' opportunities are limited, at best.

Reductions in invasive species, notably Alewife and Round Goby, would benefit the species. There are no known methods for reducing goby populations in the Great Lakes proper. Alewife numbers are declining, but it is unclear at what point this trend will stop. Part of the issue is salmon, especially Chinook Salmon *Oncorhynchus tshawytscha*, forage on Alewives. And salmon support a popular recreational fishery.

Increasing the forage base to counteract the decline in *Diporeia* numbers would benefit the species. Unfortunately, there are no feasible methods to achieve this goal at this time.

Increased predation pressure from Lake Trout and Burbot was listed as a threat, but Lake Trout and Burbot are both native predators and part of the original Lake Michigan food web. This is not a 'threat' that needs to be eliminated. Rather, it is one that needs to be brought into balance with the rest of the ecosystem.

All of these recommendations are assuming there is still a population of Spoonhead Sculpin remaining in Illinois. If there is no existing population, then the species would have to be re-introduced. The likelihood of success of a stocking a small fish on the bottom of a large lake seems low at this time.

Research Needs

More deepwater surveys are necessary in the Illinois portion of Lake Michigan. There is some effort at this time, but more attention needs to be focused on smaller fishes and rocky habitats in hundreds of feet of water. These are also logistically difficult surveys to conduct.

There have been no known studies of Spoonhead Sculpin spawning behavior. It is most feasible to conduct these studies in a northern Canada stream, but results from that type of habitat may not be applicable to the deep waters of the Great Lakes. Although it is assumed their behavior is similar to other sculpin species, this needs to be verified.

It has been hypothesized that Spoonhead Sculpin may have pelagic larvae (Eck and Wells 1987, Potter and Fleischer 1992), and there may be a pelagic dispersal stage. This basic life history characteristic needs to be verified. If true, then it would be important to model potential larval dispersal patterns in Lake Michigan. This information is critical in understanding the metapopulation dynamics of the species, as well as determining any colonization and recolonization opportunities.

The diet of Spoonhead Sculpin in southern Lake Michigan has never been determined. Any changes in diet correlating with the decline of *Diporeia* would be especially informative.

References

Anderson, E.D. and L.L. Smith Jr. 1971. A synoptic study of food habits of 30 fish species from western Lake Superior. Minnesota Agricultural Experiment Station Technical Bulletin 279, 199 pages.

Bailey, R.M., W.C. Latta, and G.R. Smith. 2004. An atlas of Michigan fishes with keys and illustrations for their identification. Miscellaneous Publications Museum of Zoology, University of Michigan 192:1-215.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison. 1,052 pp.

Brandt, S.B. 1986. Disappearance of the deepwater sculpin (*Myoxocephalus thompsoni*) from Lake Ontario: the keystone predator hypothesis. Journal of Great Lakes Research 12:18-24.

Davis, N.S. Jr. 1876. Vegetable and animal substances thrown upon the shore of Lake Michigan at Evanston during a storm. Engineering News 3:55.

Deason, H.J. 1939. The distribution of cottid fishes in Lake Michigan. Papers of the Michigan Academy of Science, Arts, and Letters 24:105-115.

Delisle, C. and W. Van Vliet. 1968. First records of the sculpins *Myoxocephalus thompsonii* and *Cottus ricei* from the Ottawa Valley, southwestern Quebec. Journal of the Fisheries Research Board of Canada 25:2733-2737.

Dryer, W. R. 1966. Bathymetric distribution of fish of the Apostle Islands Region, Lake Superior. Transactions of the American Fisheries Society 95:248-259.

Dubs, D.O.L. and L.D. Corkum. 1996. Behavioral interactions between round gobies (*Neogobius melanostomus*) and mottled sculpins (*Cottus bairdi*). Journal of Great Lakes Research 22:838-844.

Dymond, J.R. 1926. The fishes of Lake Nipigon. University of Toronto Studies, Biological Series, Publications of the Ontario Fisheries Research Laboratory 27:1-108.

Dymond, J.R. and W.B. Scott. 1941. Fishes of Patricia portion of the Kenora District, Ontario. Copeia 1941:243-245.

Eck, G.W. and L. Wells. 1987. Recent changes in Lake Michigan's fish community and their probably causes, with emphasis on the role of the alewife (*Alsoa pseudoharengus*). Canadian Journal of Fisheries and Aquatic Sciences 44(Supplement 2): 53-60.

Eigenmann, C.H. and R.S. Eigenmann. 1892. New fishes from western Canada. American Naturalist 26:961-964.

Eschmeyer, P.H. 1957. The near extinction of lake trout in Lake Michigan. Transactions of the American Fisheries Society 85:102-119.

Eshenroder, R.L. and K.L. Amatangelo. 2002. Reassessment of the lake trout population collapse in Lake Michigan during the 1940s. Great Lakes Fishery Commission Technical Report 65, 32 pages.

Fish, M.P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bulletin of the Bureau of Fisheries 47:293-398

Forbes, S.A. and R.E. Richardson. [1909]. The fishes of Illinois. Illinois State Laboratory of Natural History. 357 pp.

Forbes, S.A. and R.E. Richardson. 1920. The fishes of Illinois. Illinois Natural History Survey. Second Edition. 357 pp.

Heufelder, G.R. 1982. Cottidae. Pages 656-676 *In* Identification of larval fishes of the Great Lakes Basin with emphasis on the Lake Michigan Drainage. Ed. N.A. Auer. Great Lakes Fishery Commission, Special Publication 82-3.

Holey, M.E., R.W. Rybicki, G.W. Eck, E.H. Brown Jr., J.E. Marsden, D.S. Lavis, M.L. Toneys, T.N. Trudeau, and R.M. Horrall. 1995. Progress toward lake trout restoration in Lake Michigan. Journal of Great Lakes Research 21(supplement):128-151.

Hubbs, C.L. 1919a. Nomenclatural notes on the cottoid fishes of Michigan. Occasional Papers of the Museum of Zoology, University of Michigan 65:1-9.

Hubbs, C.L. 1919b. Notes on a specimen of *Cottus bairdii* from Lake Michigan. Copeia 73:69-70.

Hubbs, C.L. 1920. Further notes on the cottoid fishes of the Great Lakes. Copeia 77:1-3.

Hubbs, C.L. and K.F. Lagler. 1949. Fishes of Isle Royale, Lake Superior, Michigan. Papers of the Michigan Academy of Science, Arts, and Letters 33:73-133.

Hubbs, C.L. and K.F. Lagler (and G.R. Smith). 2004. Fishes of the Great Lakes region. Revised Edition. The University of Michigan Press, Ann Arbor. 276 pp.

Janssen, J. and D.J. Jude. 2001. Recruitment failure of mottled sculpin *Cottus bairdi* in Calumet Harbor, southern Lake Michigan, induced by the newly introduced round goby *Neogobius melanostomus*. Journal of Great Lakes Research 27:319-328.

Jordan, D.S. 1878. A catalogue of the fishes of Illinois. Bulletin of the Illinois State Laboratory of Natural History 1:37-70.

Jordan, D.S. and C.H. Gilbert. 1883. Description of a new species of Uranidea (*Uranidba* (sic) *pollicaris*) from Lake Michigan. Proceedings of the United States National Museum 5:222-223.

McPhail, J.D. and C.C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Bulletin of the Fisheries Research Board of Canada 173:1-381.

Meek, S.E. and S.F. Hildebrand. 1910. A synoptic list of the fishes known to occur within fifty miles of Chicago. Field Museum of Natural History, Zoological Series, Publication 142, 7:223-338.

Nalepa, T.F., D.L. Fanslow, and G.A. Lang. 2009. Transformation of the offshore benthic community in Lake Michigan: recent shift from the native amphipod *Diporeia* spp. to the invasive mussel *Dreissena rostriformis bugensis*. Freshwater Biology 54:466-479.

Nelson, E.W. 1876. A partial catalogue of the fishes of Illinois. Bulletin Illinois Museum of Natural History 1:33-52.

Page, L.M. and B.M. Burr. 2011. Peterson field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Harcourt, Boston. 663 pp.

Potter, R.L. and G.W. Fleischer. 1992. Reappearance of spoonhead sculpins (*Cottus ricei*) in Lake Michigan. Journal of Great Lakes Research 18:755-758.

Resetar, D.R.R. and A.R. Resetar. 2015. Doctor Elias Francis Shipman and the Hoosier frog. Proceedings of the Indiana Academy of Science 124:89-105.

Ryder, R.A., W.B. Scott, and E.J. Crossman. 1964. Fishes of northern Ontario, north of the Albany River. Royal Ontario Museum (Life Sciences) Contribution 60:1-30.

Sabaj, M.H., K.S. Cummings, and L.M. Page. 1997. Annotated catalog of type specimens in the Illinois Natural History Survey Fish Collection. Illinois Natural History Survey Bulletin 35:253-300.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184:1-966.

Selgeby, J.H. 1988. Comparative biology of the sculpins of Lake Superior. Journal of Great Lakes Research 14:44-51.

Simon, T.P. 2011. Fishes of Indiana. Indiana University Press, Bloomington. 345 pp.

Smith, B.R. and J.J. Tibbles. 1980. Sea lamprey (*Petromyzon marinus*) in lakes Huron, Michigan, and Superior: history of invasion and control, 1936-78. Canadian Journal of Fisheries and Aquatic Sciences 37:1780-1801.

Smith, P.W. 1979. The fishes of Illinois. University of Illinois Press, Urbana. 314 pp.

Smith, S.H. 1970. Species interactions of the alewife in the Great Lakes. Transactions of the American Fisheries Society 99:754-765.

Snyder, D. E. and S. Ochman. 1985. The larvae and juveniles of *Cottus ricei* and sympatric Cottidae. Pages 37-44 *In* Descriptions of Early Life History Stages of Selected Fishes: from the Third International Symposium on the Early Life History of Fishes and the Eighth Annual Larval Fish Conference. Eds. A. W. Kendall, Jr. and J. B. Marliave. Canadian Technical Report Fisheries and Aquatic Sciences No. 1359.

Van Oosten, J. and H.J. Deason 1938. The food of the lake trout (*Cristivomer namaycush namaycush*) and of the lawyer (*Lota maculosa*) of Lake Michigan. Transactions of the American Fisheries Society 67:155-177.

Wells, L. and A.L. McLain. 1972. Lake Michigan: effects of exploitation, introductions, and eutrophication on the salmonid community. Journal of the Fisheries Research Board of Canada 29:889-898.

Wells, L. and A.L. McLain. 1973. Lake Michigan – man's effects on native fish stocks and other biota. Great Lakes Fishery Commission, Technical Report No. 20, 56 pp.

Acknowledgments

This project would not have been possible without the assistance of Dan Makauskas (Illinois Department of Natural Resources), Steve Robillard (Illinois Department of Natural Resources), Vic Santucci (Illinois Department of Natural Resources), Trent Thomas (Illinois Department of Natural Resources), Steve Pescitelli (Illinois Department of Natural Resources), Tristan Widloe (Illinois Department of Natural Resources), Karen Rivera (Illinois Department of Natural Resources), Rick O'Neil (Illinois Department of Natural Resources), Jeremy Tiemann (Illinois Natural History Survey), Chris Taylor (Illinois Natural History Survey), Dan Wylie (Illinois Natural History Survey), Brian Metzke (Illinois Natural History Survey), Jodi Vandermyde (Illinois Natural History Survey), Tom Anton (Field Museum), David Bunnell (United States Geological Survey), Chuck Madenjian (United States Geological Survey), Sue Mochel (Field Museum), Kevin Swagel (Field Museum), Caleb McMahon (Field Museum), John Belcik (University of Illinois – Chicago), Samantha Hertel (Loyola University), Matt Bordeaux, Eve Barrs (Shedd Aquarium), Karen Murchie (Shedd Aquarium), James Torelli (Shedd Aquarium), William VanBonn (Shedd Aquarium), Jackie Grom (Shedd Aquarium), Garrett Johnson (Shedd Aquarium), Jaclyn Peterson (Shedd Aquarium), Aislinn Gauchay (Shedd Aquarium), Joy Dimitriou (Shedd Aquarium), Belle Archaphorn (Shedd Aquarium), Sharon Fuller (Shedd Aquarium), Sabrina Bainbridge (Shedd Aquarium), Kurt Hettiger (Shedd Aquarium), George Parsons (Shedd Aquarium), James Bland (Shedd Aquarium),Gregory Goldbogen (Cross Lake Association), Frank Veraldi (U.S. Army Corps of Engineers), Nicholas Barkowski (U.S. Army Corps of Engineers), Rodney Scott (Wheaton College), Benjamin Norton (Wheaton College), Michael Littmann, Jeff Lamars (Western Illinois University), Bob Hrabik (Missouri Department of Natural Resources), John Olson (Iowa Department of Natural Resources), Ben Hucka (Iowa Department of Natural Resources), Jerad Stricker (Iowa Department of Natural Resources), Don Miller (Winnebago County), Barbara Williams (Winnebago County), Matthew Vincent (Winnebago County), Rick Rudey (Winnebago County), Charles Johannsen (Winnebago County), Jamie Johannsen (Winnebago County), John Peterson (Winnebago County), Mike Grove (Winnebago County), John Nash Jr. (Winnebago County), John Nash Sr. (Winnebago County), Jo Nash (Winnebago County), Greg Keilback (Winnebago County), Kathy Martinez (Winnebago County), Greg Regnier (Great Lakes Expeditions), Damon Karras (Great Lakes Expeditions), Adam Karras (Great Lakes Expeditions), Richard Ong (Great Lakes Expeditions), Greer Bickley (Care Free Boat Club Chicago), Dan Kane (Boone County), Nick Huber (Lake County), Jessi DeMartini (DuPage County), and many members of the Asian Carp Monitoring Program. Boone County Conservation District, Forest Preserve District of Lake County, and Winnebego County kindly provided access to their preserves and helped with fieldwork.

This report was prepared by John G. Shedd Aquarium under award number F15AF01082 *from United States Fish and Wildlife Service, U.S. Department of the Interior. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of United States Fish and Wildlife Service or the U.S. Department of the Interior.*

Front cover image: Map prepared by Samantha Hertel. Longnose Dace image by Philip Willink.