

NOTES

Changes in Mottled Sculpin and Johnny Darter Trawl Catches after the Appearance of Round Gobies in the Indiana Waters of Lake Michigan

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Abstract.—We investigated the response of the mottled sculpin *Cottus bairdi* and the johnny darter *Etheostoma nigrum* to the invasion and proliferation of the round goby *Neogobius melanostomus* at three near-shore locations in southern Lake Michigan. Fish were collected by trawling from June through August, 1984–2002. Mean annual catches of mottled sculpin in trawl samples ranged from 0 to 4.4 fish/h from 1984 to 1998, whereas mean annual johnny darter catches ranged from 0 to 29 fish/h in the same period. Round gobies were first sampled in 1998, and the relative population abundance increased in the following years, ranging up to 371 fish/h at one site by 2001. From 1999 to 2002, only a single mottled sculpin and only 12 johnny darters were collected in 72 h of trawling. This study documents the rapid decline of the mottled sculpin and johnny darter following the round goby invasion to this portion of the lake.

The round goby *Neogobius melanostomus* was first observed in southern Lake Michigan in Calumet Harbor, Illinois, in 1993; round gobies then spread east to Hammond Harbor in 1994, to East Chicago and Burns Harbor in 1995, and to near Michigan City in 1998 (Charlebois et al. 1997; Camp et al. 1999). Establishment of the round goby in this portion of the lake, as well as the rest of the Laurentian Great Lakes (Crossman et al. 1992; Jude et al. 1992), and its subsequent effects on native fishes and ecosystem function is causing concern to resource managers (Charlebois et al. 2001).

Although effects of the recent invasion of the round goby have not been fully determined, it has been suggested that increases in population density most heavily influence other benthic fish species, such as sculpin *Cottus* spp., darters *Etheostoma* spp. and logperch *Percina caprodes* (Jude et al. 1992). The round goby has been successful in outcompeting mottled sculpin *Cottus bairdi* and logperch and in preying upon lake trout eggs (Chotkowski and Marsden 1999; French and Jude 2001; Janssen

and Jude 2001) and may be influencing community structure. This hypothesis has been supported by both laboratory and experimental field data, particularly on the recruitment failure of mottled sculpin in Calumet Harbor (Janssen and Jude 2001). However, this phenomenon has not been broadly observed in Lake Michigan. Moreover, no studies have delineated and compared demographic trends in native benthic fish populations in the nearshore or open waters of Lake Michigan before and after the invasion. Therefore, the objective of this study was to determine the response of populations of mottled sculpin and johnny darters *E. nigrum* to the round goby invasion in southern Lake Michigan. In addition, this study chronicles the timing of round goby invasion and population expansion to this region of Lake Michigan.

Study Area

Three sample stations were located in the southern basin of Lake Michigan at the 5-m depth contour (Figure 1). Station K (center of station: 41°42'26"N, 86°56'48"W) was approximately 2.8 km southwest (227° compass bearing) from the Michigan City, Indiana harbor entrance. Station M (center of station: 41°37'45"N, 86°53'12"W) was approximately 1 km east of Washington Park Michigan City (compass bearing of 68°), and station G (center of station: 41°44'7"N, 87°15'07"W) was located approximately 5.7 km from the Burns Ditch harbor entrance (compass bearing of 259°) near the city of Gary. The bottom from Michigan City west to Gary is generally flat and sandy, but station K additionally has intermittent clay depressions of up to 1 m or more in depth, creating an irregular bottom structure that is quite different from the surrounding flat, sandy areas in this portion of the lake (McComish et al. 2000). Visual observations during scuba dives on the sampling zone confirmed the heterogeneous bottom. All areas were generally free of large rocks, boulders, debris, and allochthonous material.

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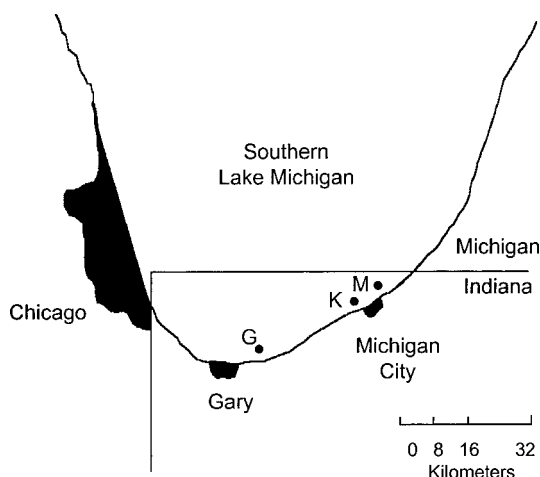


FIGURE 1.—Location of the three semiballoon trawl sites—M, K, and G—in the southern basin of Lake Michigan, where effects of round goby on mottled sculpin and johnny darters were investigated between 1984 and 2002. All sites were located along the 5-m depth contour and were approximately 0.75 km in length.

Methods

In a given calendar year, fish were collected with a semiballoon bottom trawl between sunset and 2400 hours once in each of six periods: June 1–15, June 16–30, July 1–15, July 16–31, August 1–15, and August 16–31. Each sample consisted of six trawl tows of 10 min, for a total sample effort of 1 h. All fish captured in a given tow were placed in a separate plastic bag and held on ice in portable coolers until they could be sorted dockside the next day. Collections were made annually from 1984 through 2002 for stations M and K and from 1989 through 2002 for station G. More detail on the site location and trawling methods can be found in Shroyer and McComish (1998).

Individual trawl tows on a particular night were not statistically independent of each other and were combined into a single value. Thus, six samples (one per period) were obtained annually at both stations M and K for 19 years and six samples were collected at station G for 14 years, for a total of 312 samples. A failure to meet normality assumptions precluded the use of several statistical tests to determine changes in the mottled sculpin and johnny darter populations after the goby invasion. This resulted principally from the large number of zero values found in the data set for all three species. A Kruskal–Wallis test was used to evaluate differences in johnny darter, mottled sculpin, and round goby catches among stations M, K, and G for the years 1989–1998 and 1999–2002. Additionally, a chi-

square test for association was used to determine changes in the mottled sculpin and johnny darter frequency of occurrence (between periods before (1984–1998) and after (1999–2002) the goby invasion. This analysis was based on presence or absence of mottled sculpin and johnny darters in a particular sample, rather than actual trawl catches. For all statistical tests (as described by Zar 1999) significance was set at $\alpha = 0.05$.

Results

Johnny darters were captured in just over half of all samples (165/312) and annual mean catches ranged up to 29.50 individuals per trawl sample (six 10-min tows totaling 1 h; Table 1). Differences in annual mean catch among stations M, K, and G were not significant within sample periods 1989–1998 (Kruskal–Wallis: $P = 0.46$) and 1999–2002 (Kruskal–Wallis: $P = 0.35$). The frequency of occurrence of johnny darters from 1984 to 1998 for all stations combined was 64% ($N = 240$); this frequency dropped to 15% ($N = 72$) in 1999–2002 (Table 2). Individual stations M, K, and G each followed a similar trend (Table 2), although station G declined more rapidly (Table 1).

From 1984 to 2002, mottled sculpin capture frequency and annual mean catches were highest at station K (southern basin of Lake Michigan), albeit catches in some years were restricted to one or only a few fish, and no fish were captured in 1985, 1986, 1988 or in the three most recent sampling years, 2000–2002 (Table 1). The mean annual numbers of mottled sculpin caught during 1989–1998 at stations G and M were significantly lower than K (Kruskal–Wallis: $P < 0.01$), ranging up to 0.50 individuals per 1-h sample during the period of record (Table 1). Frequency of occurrence at station K (37%) was also significantly greater than at stations M (9%) and G (2%; $\chi^2 = 33.3$, $P < 0.01$; Table 1). Frequency of occurrence values changed at station K after the appearance of the round goby, declining significantly to 4% for the period 1999–2002 (Table 2). The frequency of occurrence dropped to zero for 1999–2002 for both stations M and G (Table 2). However, statistical differences could not be determined because chi-square computation assumptions could not be met (see Zar 1999).

Round goby were first collected in 1998 at stations M and G, where they were at relatively low abundance levels and occurrence frequencies (Table 1). In the following 4 years both catches and frequency of occurrence increased, station K hav-

TABLE 1.—Benthic fish species frequency of occurrence (FO; number of samples in which the species was captured, where the maximum number of samples possible = 6 in a given year) and mean catch (number per 1-h sample) and standard deviation at sites M, K, and G in the extreme southern basin of Lake Michigan from 1984 to 2002. The six annual samples represent one sample per each of six sample periods per station per year.

Year	Johnny darter		Mottled sculpin		Round goby	
	FO	Mean catch	FO	Mean catch	FO	Mean catch
Station M						
1984	2	1.67±3.21	2	0.33±0.51	0	0.00
1985	2	1.83±3.60	0	0.00	0	0.00
1986	0	0.00	0	0.00	0	0.00
1987	1	0.17±0.42	3	0.50±0.51	0	0.00
1988	0	0.00	0	0.00	0	0.00
1989	4	1.00±0.88	0	0.00	0	0.00
1990	4	2.67±3.87	1	0.17±0.42	0	0.00
1991	4	4.17±7.42	2	0.33±0.51	0	0.00
1992	5	3.33±2.65	0	0.00	0	0.00
1993	5	19.17±41.15	0	0.00	0	0.00
1994	4	3.67±5.39	0	0.00	0	0.00
1995	5	10.00±17.15	0	0.00	0	0.00
1996	4	10.33±13.72	1	0.33±0.81	0	0.00
1997	3	5.67±9.33	1	0.17±0.42	0	0.00
1998	3	2.33±3.63	0	0.00	1	0.17±0.42
1999	4	2.50±2.74	0	0.00	4	2.80±2.87
2000	1	0.17±0.42	0	0.00	6	29.30±37.48
2001	0	0.00	0	0.00	5	11.80±12.15
2002	0	0.00	0	0.00	6	43.00±64.27
Station K						
1984	5	1.67±1.37	1	0.17±0.42	0	0.00
1985	3	0.50±0.54	0	0.00	0	0.00
1986	0	0.00	0	0.00	0	0.00
1987	2	0.83±1.59	4	5.67±10.09	0	0.00
1988	2	0.33±0.51	0	0.00	0	0.00
1989	6	4.17±3.60	2	1.00±1.76	0	0.00
1990	4	1.50±1.52	2	0.33±0.51	0	0.00
1991	5	5.17±6.17	3	1.50±1.76	0	0.00
1992	4	2.83±3.77	2	1.17±2.03	0	0.00
1993	6	18.83±12.15	2	2.17±3.48	0	0.00
1994	6	19.17±20.31	6	7.17±6.56	0	0.00
1995	5	9.33±13.33	5	9.50±12.00	0	0.00
1996	5	29.50±29.39	6	12.6±14.26	0	0.00
1997	4	5.83±12.35	3	1.83±3.14	0	0.00
1998	6	7.00±7.54	5	5.83±7.13	0	0.00
1999	3	3.00±3.53	1	0.17±0.42	6	88.33±40.17
2000	1	0.17±0.42	0	0.00	6	254.17±99.94
2001	1	0.17±0.42	0	0.00	6	371.30±230.74
2002	0	0.00	0	0.00	6	288.30±239.49
Station G (not sampled from 1984 to 1988)						
1989	2	2.50±3.89	0	0.00	0	0.00
1990	4	2.33±2.74	0	0.00	0	0.00
1991	5	6.17±4.70	0	0.00	0	0.00
1992	4	4.83±3.65	0	0.00	0	0.00
1993	6	10.67±18.35	0	0.00	0	0.00
1994	6	17.00±10.63	0	0.00	0	0.00
1995	4	7.33±10.36	1	0.33±0.81	0	0.00
1996	5	28.50±45.32	1	0.17±0.42	0	0.00
1997	6	6.67±9.14	0	0.00	0	0.00
1998	3	2.00±2.77	0	0.00	3	1.00±1.37
1999	1	0.17±0.42	0	0.00	4	2.00±1.91
2000	0	0.00	0	0.00	5	5.33±4.97
2001	0	0.00	0	0.00	4	8.80±17.81
2002	0	0.00	0	0.00	3	8.17±12.00

TABLE 2.—Comparison of mottled sculpin and johnny darter frequency of occurrence (FO; as explained in Table 1) for years before (1984–1998) and after (1999–2002) the invasion of round goby in the extreme southern basin of Lake Michigan. Values designated as NM indicate that test assumptions could not be met, so the chi-square test ($\alpha = 0.05$) was not calculated.

Station and period	Number of sample periods	Johnny darter				Mottled sculpin			
		FO		χ^2	<i>P</i>	FO		χ^2	<i>P</i>
		<i>N</i>	%			<i>N</i>	%		
Station M									
1984–1998	90	46	51	3.1	0.079	10	11	NM	NM
1999–2002	24	5	21			0	0		
Station K									
1984–1998	90	63	70	6.0	0.015	41	46	7.9	<0.01
1999–2002	24	5	21			1	4		
Station G									
1989–1998	60	45	75	13.3	<0.01	2	3	NM	NM
1999–2002	24	1	4			0	0		
All									
Before 1998	240	154	64	20.2	<0.01	53	22	13.0	<0.01
1999–2002	72	11	15			1	1		

ing the highest mean annual catches, ranging up to 371.3 individuals per 1-h sample (Table 1).

Discussion

Reduction of mottled sculpin and johnny darter catches to near zero in 2000, 2001, and 2002 concomitant with round goby expansion cannot be viewed as coincidental. Although the mottled sculpin and johnny darter populations between 1984 and 1999 were present in low amounts (Table 1), they were consistent in occurrence until the round goby invasion.

Round gobies have been suggested to negatively influence the mottled sculpin, among other benthic fish species, when they coexist (Jude et al. 1995; Jude and DeBoe 1996; Janssen and Jude 2001). Jude et al. (1995) hypothesized that the demise of the mottled sculpin may be due to the round goby out-competing the mottled sculpin for food, shelter, and spawning sites. The latter hypothesis was supported by Janssen and Jude (2001), who found that round gobies interfered with nesting mottled sculpin, thereby causing recruitment failure. In addition, Dubs and Corkum (1996) suggested the aggressive behavioral interactions of the round goby toward the mottled sculpin would likely result in its demise in the wild. It seems likely these same negative influences are affecting the johnny darter in a similar manner in southern Lake Michigan.

The index trawl sampling of this study not only documented the time of round goby invasion in the extreme southern basin, but it also provided quantitative measures that revealed the decline in the

mottled sculpin and johnny darter populations in the latter part of that 19-year period. Other capture methodologies could be used for such an assessment (e.g., small-mesh traps, diver or angler surveys) but in the southern basin of Lake Michigan this may be logistically more difficult. Although 51-mm stretch-mesh gill nets are easily deployed, they capture only the largest gobies in the nearshore fish community (McComish et al. 2000). Thus, qualitative observations of establishment of fish species and quantitative density measures in Lake Michigan have been difficult to document.

The larger catch of round gobies at station K suggests this station has environmental features that are different than stations M and G. Shroyer and McComish (1998) described station K as having a heterogeneous bottom with deep (1 m or more) clay depressions, which contrasts to the flat, sandy bottom at stations M and G. This variation in habitat along the 5 m trawl depth may provide an explanation for the differences in trawl catch observed among stations K, M, and G.

The decline of johnny darter frequency of occurrence was greatest at station G, but parallel declines occurred at stations M and K, lagging behind by a year. This lag could have easily been due to a differing invasion rate by the round goby or to environmental differences among these stations. The round goby in southern Lake Michigan probably originated from a Calumet City, Illinois, invasion (Charlebois et al. 1997) and moved east, explaining this temporal inconsistency.

The recent population depression of mottled

sculpin and johnny darters in the extreme southern nearshore waters of Lake Michigan is almost certainly occurring because of biological interaction with the round goby. This follows a pattern that has been observed with other exotic species in the Great Lakes, such as sea lampreys *Petromyzon marinus* effects on lake trout *Salvelinus namaycush*; alewives *Alosa pseudoharengus* effects on lake whitefish *Coregonus clupeaformis*, bloater *Coregonus hoyi*, yellow perch *Perca flavescens*, and white perch *Morone americana*; and Eurasian ruffe *Gymnocephalus cernuus* effects on a variety of native fish species (Lawrie 1970; Mills et al. 1993, 1994; Shroyer and McComish 2000; Madenjian et al. 2002). Although the round goby's effects on native fishes are ongoing and developing, the effects are probably understated at present and may not be fully understood for some time.

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