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Susceptibility of Tethered Round Gobies (*Neogobius melanostomus*) to Predation in Habitats With and Without Shelters

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ABSTRACT. *We determined the susceptibility of the nonindigenous round goby* (Neogobius melanostomus) *to predation in sandy habitats with and without shelters in Lake St. Clair. Six round gobies were tethered in a 1* m^2 *area and videotaped in three habitat types: sand without shelters, sand with shelters (flowerpots), and sand without shelters within an enclosure (control). Daytime trials lasted 90 min; there were 20 replicates per treatment. More round gobies were missing from sand habitats without shelters (17/120) than from sand habitats with shelters (7/120) or control (0/120) habitats* ($X^2 = 18.25$, $P < 0.005$)*, indicating that there is a greater potential risk of predation in open habitats than in habitats with cover. Round gobies that were missing from tethers versus those that remained differed significantly in mean (± SE) total length (72 ± 4 mm versus 89 ± 1 mm) and weight (5.2 ± 0.8 g versus 9.1 ± 0.3 g). Round gobies removed from tethers were smaller than those that remained. Smallmouth bass* (Micropterus dolomieu) *were videotaped in the habitats where tethered fish were missing. Seven yellow perch* (Perca flavescens) *were retrieved that were entwined in tethers and in each case a perch had a round goby in its mouth. Predation risk to a small round goby is high in sandy habitats without shelters.*

INDEX WORDS: Neogobius melanostomus, *round goby, predation, habitat, shelters, tethering, Lake St. Clair.*

INTRODUCTION

An invading species may proliferate in new regions because of the absence of predators and altered habitat (Moyle 1986). With unlimited food resources, an invader may undergo a population explosion before potential predators adapt to its presence and use it as a food source. The round goby (*Neogobius melanostomus*), a bottom-dwelling fish native to the Black, Caspian, Marmara, Azov, and Aral seas, was first discovered in June 1990 in both the Gulf of Gdansk of the Baltic Sea (Skora and Stolarski 1993) and the Laurentian Great Lakes (Jude *et al.* 1992). Concerns about the round goby in new regions include their ability to transfer contaminants from benthic invertebrates through the food web (Morrison *et al.* 2000), their negative effects on native species (Dubs and Corkum 1996, Janssen and Jude 2001), and their reproductive success owing to their multiple spawning habits and parental care (Charlebois *et al.* 1997, MacInnis and Corkum 2000).

In Lake Erie, round gobies contribute significantly to the diet of obligate benthivores (e.g., stonecat, *Noturus flavus*), facultative benthivores (e.g., smallmouth bass, *Micropterus dolomieu*) and occasionally meropelagic fishes (yellow perch, *Perca flavescens*; walleye, *Sander vitrea* (formerly *Stizostedion vitreum*, N.E. Mandrak, Fisheries and Oceans Canada, personal communication) (T. Johnson, Ontario Ministry of Natural Resources, Wheatley, Ontario; C. Knight, Ohio Division of Wildlife, personal communication). Fishes in the native Black Sea representing the same feeding guilds, obligate benthivores (e.g., Atlantic sturgeon, *Acipenser sturio*; European flounder, *Platichthys flesus luscus*) and pelagic fishes (e.g., European

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perch, *Perca fluviatilis*; Atlantic salmon, *Salmo salar*; European pike-perch, *Sander lucioperca*), feed on round gobies (V. Zamorov, Odessa National University, personal communication; Charlebois *et al.* 1997). In contrast, birds rather than fish feed on round gobies in the Gulf of Gdansk, a habitat characterized by shallow, slightly saline waters with sand substrates. In the Gulf of Gdansk, the round goby represents 72% of the diets of great cormorants (*Phalacrocorax carbo*) (Bzoma and Stempniewicz 2001).

The threat of predation affects habitat selection in several freshwater fish assemblages (Mittelbach 1981). Round gobies prefer rock substrates, but also are found in fine gravel and sand substrates in which they are known to burrow. Ray and Corkum (2001) showed that round gobies occur in crevices and under rocks, and to a lesser extent on sandy substrates. In the Great Lakes, shipwrecks and rubble areas are commonly used as nurseries by gobies (Wickett and Corkum 1998), presumably because nest defense by males is more cost effective in complex than in simple habitats. Because round gobies are day active in the field (Ray and Corkum 2001), occupancy of shelters or refuges by gobies may be a useful strategy to avoid visual predators.

In this study, we determine the susceptibility of the round goby to predation by monitoring tethered round gobies placed in sand habitats with and without shelters and in a sandy area lacking shelters within an enclosure (control). We videotaped trials in an attempt to identify likely predators. We also determined if there were differences in mean size of round gobies between those that were missing from tethers (assumed to be removed by predators) and those that remained.

METHODS

Round gobies were collected in summer months (July-August) of 1999 and 2002 using hook and line or minnow traps from several shoreline areas near the study site on Lake St. Clair at the town of Belle River, Ontario (42°18′N; 82°45′W). Fish were maintained in a laboratory (8L:16D) and fed Nutrafin fish flakes and zebra mussels (*Dreissena polymorpha*) under ambient water temperatures (> 15°C) for 3 d prior to field trials.

Results of a pilot study to determine manageable prey density and appropriate tethering devices showed that six round gobies/m^2, each secured with a 25-cm, 10-pound test line, enabled fish to move freely without lines becoming entangled. Round gobies were tethered by inserting a threaded small hook just below the dorsal fin of each fish. The other end of the line was attached to a swivel on a coded tethering device that had an open ring bolt with a light-weight key chain, enabling the fish to move freely. Prior to being tethered, fish were measured (1 mm) and weighed (0.1 g). Tethering units containing random sizes of round gobies were secured to the sediment by inserting the long end of the open ring bolt into the lake bottom in a 1-m^2 grid delineated by PVC pipes filled with cement. This grid was placed on the lake bottom in water 75 cm deep and 40 m from shore in an area where common piscivores such as smallmouth bass and yellow perch were often observed. Both round gobies and their predators are frequently encountered in shallow nearshore waters of Lake St. Clair (Corkum, personal observation). Trials were run on days when the water temperature was above 15°C and when there was little to no overcast.

To assess differences in susceptibility of the round goby to predation, we conducted 20 trials where gobies were tethered in sand habitats with and without shelters (clay flowerpots) in Lake St. Clair. Two randomized trials were conducted simultaneously (i.e., two sandy areas both without shelters; one sandy area with and one without shelters; **or** two sandy areas both with shelters) in daylight hours (between 0800 and 1800 h). We conducted our field experiment during the day because a laboratory study showed no differences in round goby activity over 24 h (Krausse and Corkum, unpublished data), field observations revealed round gobies are day-active (Ray and Corkum 2001), and potential round goby predators are active during the day (ODNR 2000).

Six round gobies were tethered in sand habitats with **or** without shelters within a metre grid. Each shelter consisted of a flowerpot (open diameter: 10 cm, length: 10.5 cm, diameter at closed end: 7 cm) that was cut in half lengthwise. These shelters enabled us to set up treatments easily by manipulating one known variable of constant size to compare potential predation between habitats. Forsgren *et al.* (1996) also used flowerpots cut in half to serve as substrates in their study on sand gobies. Flowerpots, PVC pipe, and clay tiles are used routinely for studying predation on fishes in field and laboratory experiments (e.g., Mattila 1992, Nemeth 1998, MacInnis and Corkum 2000, Mirza and Chivers 2002).

The tethering units with fish were placed in a meter grid far enough away from one another so that the units did not tangle during the trial, i.e., some fish were placed close to the corners of the square grid and others were placed close to the center. Within these constraints, the placement of tethered round gobies was random. In trials with shelters, a half flowerpot was placed near the tethering unit, enabling the fish to use it for shelter. Each trial was videotaped for 90 minutes (the battery life of the video camera) using a Hi 8 Sony® camcorder in an Amphibico® waterproof housing unit and viewed later to identify potential predators. The housing unit was secured to cement blocks and set up so that the entire grid could be viewed on videotape. We set the camera to record and left the water for the duration of each trial. After 90 min, tethering devices were retrieved and round gobies were recorded as either present or missing.

Controls for this study were conducted in a laboratory and in Lake St. Clair in July and August 2002. In the laboratory, ten trials each with six tethered round gobies per m^2 were conducted for 90 min in a flow through fiberglass tank to determine if tethered fish exhibited typical swimming behavior, and if fish escaped from tethers or suffered mortality. The tethered fish were secured by burying the end of the tether in aquarium sand. In the field controls, six round gobies/m^2 (20 replicates) were tethered for 90 minutes in a sandy habitat within a screened enclosure. Plastic mesh (1 cm opening) screen was secured to a metal frame that extended 25 cm above the cement filled PVC pipes that delineated a 1 meter grid. The enclosure excluded predators and contained round gobies that may have escaped from tethers.

RESULTS

We assumed that predators removed round gobies that were missing from tethering units in Lake St. Clair. Control studies performed in both the laboratory and field helped to confirm this assumption. In both control studies, all tethered round gobies were recovered and remained attached to tethering units. All round gobies tethered in the laboratory remained active. There was no round goby mortality in either of these control studies.

In the field trials, 17 of 120 round gobies were missing from sand habitats without shelters compared with 7 of 120 gobies that were missing from sand habitats with shelters and 0 of 120 gobies missing from the enclosures (sand habitats without shelters). Over 90% of the remaining tethered round gobies from all treatments were still active after 90 min and those that had shelters provided were typically found within the shelter when retrieved. Results of a chi-squared analysis showed that round goby were not equally removed from the three habitat treatments ($X^2 = 18.250$, $P < 0.005$, df = 2). Specifically, there was more presumed predation (on the basis of missing round gobies) from sandy habitats without shelters than from sandy habitats with shelters.

The 420 round gobies used in our experiments (360 goby in the field; 60 goby in the laboratory) varied in mean (± SE) total length, TL (86 ± 1 mm), and weight, WT (8.5 ± 0.3 g). Size of round gobies missing from tethers versus those remaining was significantly different in TL (± S.E.) (72 ± 4 mm vs. 89 ± 1 mm; $t = 4.663$, $P < 0.001$, df = 358) and weight (5.2 ± 0.7 g vs. 9.4 ± 0.3 g; $t = 3.584$, $P = 0.004$, df = 358). Fish that were missing were significantly smaller than fish that remained (Fig. 1).

We were unable to record predation events because turbid water impaired visibility. However, juvenile smallmouth bass were observed three times on the videotape in trials where round gobies were recorded as missing. In seven (six in sand habitats without shelters and one in a sand habitat with shelters) cases, yellow perch (*Perca flavescens*) were found hooked to the tethering units. Each time, a round goby was contained within the mouth of the yellow perch.

DISCUSSION

Fish predation is often estimated by sampling potential predators and examining their stomach contents (Salini *et al.* 1990, Brewer *et al.* 1995). This approach may be unsuitable if the study objective is to compare predation in different habitats. Because fish predators are mobile, their stomach contents may contain items caught in more than one habitat type (Haywood and Pendrey 1996). Tethering techniques cannot be used to determine absolute rates of predation because animal movement is constrained (McIvor and Odum 1988). For example, tethering may restrict the "normal" behavioral activity of the round goby during escape attempts or defensive postures, increasing their susceptibility to predation. Nevertheless, tethering can be used to assess relative predation at different locations and results are consistent across treatments (Post *et al.* 1998). In our study, predation on round gobies, recorded by tallying fish that were missing from tethers, varied with size of the round goby and habitat type (sandy habitats with and without shelters). More round gobies were missing from sand

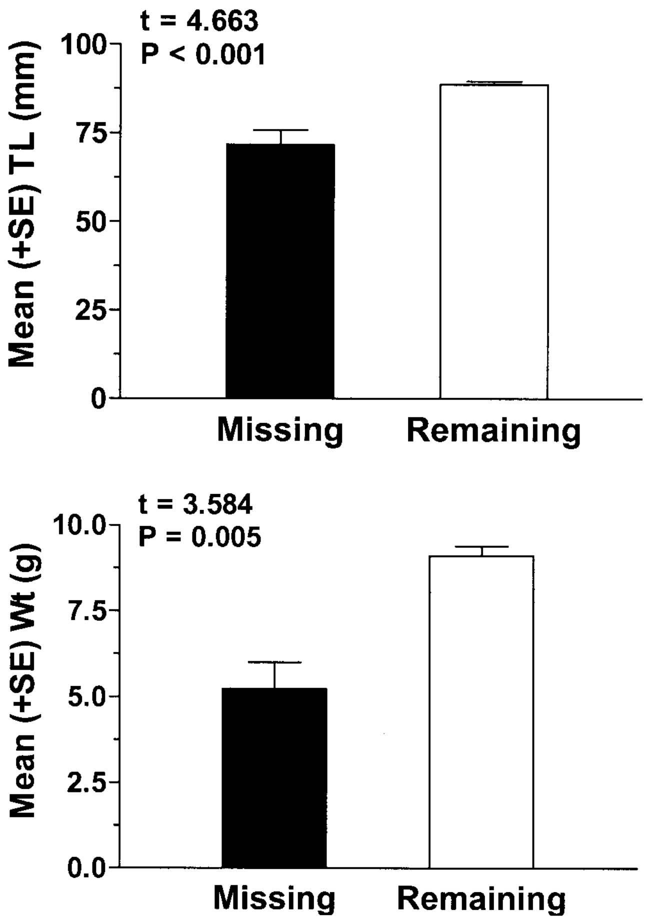

FIG. 1. Mean (+S.E.) total length, TL (upper panel), and weight, WT (lower panel), of round gobies that were missing (solid) and remaining (open) on tethers from all habitats after 90 min. Size of round gobies missing from tethers was significantly smaller in total length ($t = 4.663$, $P < 0.001$, $df = 358$) and weight ($t = 3.584$, $P = 0.004$, $df = 358$) than fish that remained.

habitats without shelters than with shelters and round gobies that were missing were smaller than those that remained.

Recently, Tomba *et al.* (2001) suggested that one of the most effective means of predator avoidance is refuge use. Our daytime study showed that more round gobies were removed from sand habitats without shelters than from sand habitats with shelters. Flowerpot shelters that mimicked complex habitat resulted in reduced susceptibility to predation. Other researchers also have shown the importance of complex vs. simple habitats in reducing predation of tethered fish. For example, Shulman (1985) reported that more tethered larval fishes were removed near a reef, where there was less shelter, than in areas where complex habitat (seagrasses and algae) provided shelter from predation. Haywood and Pendrey (1996) also reported that predation on juvenile tiger prawns (*Penaeus monodon*) was greater in areas where vegetation cover was minimal.

On the basis of our findings, we reject the null hypothesis that there was no difference in the size of round gobies removed from tethers between sand habitats with and without shelters. Round gobies removed (i.e., missing) from tethers were significantly smaller (total length and weight) than those that remained. Post *et al.* (1998) described smaller, juvenile fish as being highly vulnerable to size-selective, gape-limited fish predators. Posey and Hines (1991) observed a similar pattern of predation on small clams with no detectable predation risk for large clams. Thus, vulnerability to predators is strongly size-dependant with the smallest individuals being the most susceptible (Mittelbach and Chesson 1987). Accordingly, small fish are often found in the most protected habitats (Mittelbach and Chesson 1987, Post *et al.* 1998).

Many fishes including smallmouth bass (*Micropterus dolomieu*), rock bass (*Ambloplites rupestris*), tubenose goby (*Proterorhinus marmoratus*), and stonecat (*Noturus flavus*) feed on the round goby (Jude *et al.* 1995). Round gobies also are present in the diet of mudpuppies (R. Haas, MDNR Mt. Clemens, MI, personal communication) and the Lake Erie water snake, *Nerodia sipedon insularum* (King *et al.* 1999). However, the most common predator of the round goby appears to be smallmouth bass. In June and July, round goby represented 60 to 100% of the smallmouth bass diet in Lake Erie (ODNR 2000).

Forage fish may reduce predation risk by occupying refuges and displaying various defensive behaviors (Walters and Juanes 1993). When habitats are complex, the absolute abundance of individual structural components may affect behaviors of both predators and prey by altering foraging modes and encounter rates among organisms (Savino and Stein 1982, 1989). An increase in habitat complexity results in a decrease in foraging efficiency of predators because of decreased visual or tactile cues among predators (Savino and Stein 1982).

In our study, we show that sandy habitats with shelters were effective in reducing round goby predation from yellow perch (and likely smallmouth bass) during daylight hours. Ray and Corkum

(2001) suggested that large adult round gobies likely induce smaller juveniles to leave preferred rocky habitats and disperse to sandy habitats. Clearly, predation risk to small round goby is high in sandy habitats without shelters.

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