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Habitat and Site Affinity of the Round Goby

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ABSTRACT. *A study was conducted in 1996 to compare densities of the round goby (*Neogobius melanostomus*) in rock and sand habitats in day and night at three sites (Sarnia, St. Clair River; town of Belle River, Lake St. Clair; Peche Island, Detroit River). The sites represent an expansion in round goby distribution from Sarnia where gobies were first reported in 1990 downstream to Peche Island where gobies appeared in 1993. Site affinity at Peche Island was estimated using mark-recapture and observations of individual fish. Mean density of round gobies differed among sites ($p < 0.001$), light regime ($p < 0.001$), habitat ($p < 0.001$), and the interaction of light regime and site ($p = 0.007$). Mean densities of the round goby were 0.3 to 3 fish/m^2 (Peche Island), 0.5 to 3 fish/m^2 (town of Belle River), and 5 to 9 fish/m^2 (Sarnia). Overall, highest densities of the round goby occurred in the day and on rocks. Small (≤ 5 cm) round gobies were most common at Peche Island, the most recently colonized site, indicating that juveniles may disperse more rapidly than adults. Of 200 fish that were marked, 58% were recaptured, indicating high site fidelity among round gobies. The estimated mean (± SE) home range of the round goby determined using SCUBA (5 ± 1.2 m^2) was likely underestimated because few fish were observed. Larger round gobies may induce smaller fish to leave preferred rock habitats and move to sand habitats from which they disperse.*

INDEX WORDS: *Round goby,* Neogobius melanostomus, *habitat, site affinity, nonindigenous species, Great Lakes.*

INTRODUCTION

One of the many reasons for the success of the introduced round goby (*Neogobius melanostomus*) in colonizing new areas is its wide tolerance range for various environmental factors including habitats (Charlebois *et al.* 1997). In its native range in the Black and Caspian seas and surrounding waters, the bottom-dwelling round goby occupies a variety of habitat types including coarse gravel as well as shell and sandy inshore areas (Charlebois *et al.* 1997). In Europe, adult round gobies that invaded the Gulf of Gdansk (and were first reported in 1990) occupy sandy-stony substrates, mussel beds, and piers (Skora 1996); juveniles occur on "muddy-sandy humus-containing bottom overgrown with benthic flora" (Skora 1996). In the St. Clair River of the Laurentian Great Lakes, round gobies occur in cobble, riprap, and vegetation in nearshore areas where substrates provide large interstices for refuge and spawning (Jude and Deboe 1996). In Lake Michigan, round gobies are abundant on cobble and sand substrates, although juveniles appear to be more abundant on sand than the adults (Charlebois *et al.* 1997).

Initial sightings of round gobies in the Great Lakes were in harbor locations, suggesting that the distribution of the fish within the basin resulted from ballast water discharged from ships. Alternatively, abandoned eggs in round goby nests that may have been deposited initially in crevices on the bottom of ships could have been maintained (i.e., aerated) without parental care and dispersed by ships moving from port to port. Once round gobies colonized an area and reproduced, the fish likely began to disperse naturally.

One goal in studying an invading species is to determine its potential population density in new environments. If substrate preference of round gobies is known and if substrate maps of rivers and lakes are available, prediction of round goby densities in waterbodies is possible. This study was conducted to determine the substrate preference of the round goby by comparing densities of the round goby on

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different substrate types (rock vs. sand) in the night and day at three different sites along the St. Clair River-Lake St. Clair–Detroit River corridor. These sites represent an expansion in the distribution of the round goby downstream from Sarnia, where the round goby was first reported in 1990 (Jude *et al.* 1992, Crossman *et al.* 1992) to Peche Island, where gobies were reported in October 1993 (Dubs and Corkum 1996). In this study SCUBA was used to census fish and to compare their densities at each location. At the downstream Peche Island site, site fidelity was examined using mark-recapture and observed fish movement to estimate home range size. It was expected that densities of round goby would be highest at Sarnia, where fish were first introduced, and lowest at the most downstream site, Peche Island. It was also anticipated that if juveniles dispersed more readily than adults, more small fish would be found at Peche Island.

METHODS

Density Estimates

Round goby density was estimated at three sites [St. Clair River (Sarnia), Lake St. Clair (town of Belle River), and the Detroit River (Peche Island)]. These sites were selected using the following criteria: 1) the presence of round gobies at the site for a minimum of 2 y; 2) the presence of rock and sand habitats; 3) accessibility to the site; and 4) similar water depth (3 to 5 m) among sites.

The most common fish census procedure, replicate strip transects (Sale 1997), was used to determine habitat preference of round gobies. Using SCUBA, three transects in each habitat (sand and rock) were surveyed during the day and night at the three sites (Peche Island, 12 to 13 June; Sarnia, 28 to 29 June; town of Belle River, 8 and 9 July 1996). At the Peche Island and Belle River sites, the rock and sand habitats were 600 m apart; replicate transects within each habitat were 100 m apart. By chance, rock and sand habitats at Sarnia were more closely spaced (separated by 200 m and parallel transects within each habitat were separated by 7 to 10 m). For each transect, a 50-m tape measure was placed on the substrate. Fish returned to the area within a few minutes of setting out the tape. After 10 minutes, one diver (WJR) swam along the 50-m transect holding a 1-m pole perpendicular to the tape measure so that fish were tallied within an area 50 m^2. Ruled marks along the pole were used to estimate the size of the gobies observed. Size rather than reproductive status of the round goby was recorded. Other taxa observed also were recorded.

Accuracy of estimating fish density is notoriously difficult. Observations are affected by visual capabilities of the diver, both diver and fish movement, fish species, and the relationship between the spatial scale of the sampling unit in relation to fish movements (Sale 1997). Underwater lights were used at night to enhance observations. Two small dive lights were attached to the air tank and angled downward while the diver held a third larger light. Observations indicated that underwater lights at night did not appear to attract or repel round gobies.

A three–way analysis of variance (ANOVA) test was used to determine if there were significant differences in mean densities of round gobies among the three sites, two habitats (rock vs. sand), two light conditions (day vs. night), and their interactions. Three replicate transects in rock and sand habitats were monitored at each site. Additional ANOVA tests were conducted for small ($\leq$ 5 cm) and large (> 5 cm) round gobies separately.

Site Affinity

Mark-recapture Study

A mark-recapture study was conducted to determine site affinity of the round goby on the Windsor, Ontario, shoreline of the Detroit River within view of Peche Island. Water depth was about 1.7 m and the substrate consisted of large rocks encrusted with zebra mussels. Round gobies were caught in a 1 m $\times$ 2 m area during the day using a hook and line baited with worms. After fish were sexed (using genital papilla; Miller 1984) and measured, they were marked by injecting non-lethal acrylic paint into their cheeks using a 3-cc needle and syringe. Wolfe and Marsden (1998) showed that fish marked with paint retained their marks for about 11 months in the laboratory and one field-marked fish retained a paint tag for > 7 months.

Fish were marked either on the left or right cheek with one of four colors of acrylic paint (blue, red, green, or white) to indicate the day of capture. Once all fish for a given day were marked, they were released together into the river. All marked fish that were caught after the first day were measured, sexed, and preserved. Two hundred fish were marked from 3 to 29 September. Fishing continued for 2 weeks (30 Sept. to 15 Oct.) to recapture as many marked fish as possible.

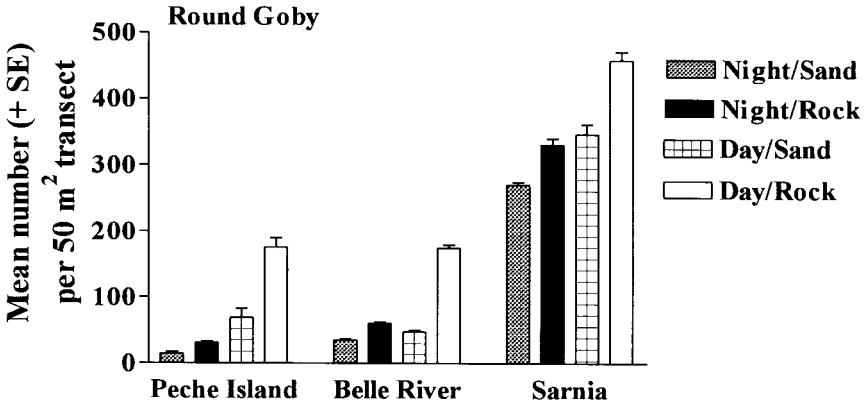

FIG. 1. Mean (+S.E.) number of round gobies observed along 50 m² transects (n = 3) in sand and rock substrates in the day and night.

Home Range

A home range study was conducted 100 m off the south shore of Peche Island at a depth of 3 to 4 m with a substrate type of rock (65%) and sand (35%). Using SCUBA, the distance traveled by 8 individual round gobies was tracked for 1 h each during daylight in mid-summer (29 July to 12 August). Keeping well away from the fish, the diver dropped a 1-cm colored bolt as the fish moved from one area to another. Different colored bolts were used over time. After 1 h, the area traveled by the designated goby was measured by multiplying the furthest two distances in an x, y co-ordinate plane.

RESULTS

Density Estimates

Round gobies were found in both rock and sand habitats at all three sites. Densities of round gobies observed within the 50 m^2 transects ranged from 0.3 to 3 fish/m^2 at Peche Island, from 0.5 to 3 fish/m^2 at the town of Belle River, and from 5 to 9 fish/m^2 at Sarnia. Results of the 3-way ANOVA indicated that mean density of the round goby differed significantly among sites ($df = 2, 24$; $F = 1293$; $p < 0.001$), light regime ($df = 1, 24$; $F = 297$; $p < 0.001$), habitat ($df = 1, 24$; $F = 212$; $p < 0.001$), and the interaction of light regime × site ($df = 2, 24$; $F = 6.09$; $p = 0.007$). Overall, more round gobies were observed in the day than at night and on rocks than on sand (Fig. 1). The highest densities of round gobies were recorded at Sarnia in the St. Clair River where round gobies were first reported in 1990. The round goby density recorded on sand substrates at Sarnia was apparently higher than goby densities observed on rock at the other sites (Fig. 1).

Fewer small (≤ 5 cm) round gobies were observed than large (> 5 cm) ones (Fig. 2). ANOVA results revealed significant differences in mean density of small round gobies for all main effects including site location ($df = 2, 24$; $F = 47.83$; $p < 0.001$), light regime ($df = 1,24$; $F = 34.07$; $p < 0.001$), and habitat ($df = 1.24$, $F = 32.03$; $p < 0.001$) as well as one interaction term (light × site: $df = 2, 24$; $F = 29.61$; $p < 0.001$). Small round gobies appeared to be most common at Peche Island (10 to 70 fish per 50 m^2 transect) and these fish were observed most often in the day on rock substrates.

There were significant differences among mean density of large round gobies (> 5 cm) among light regime ($df = 1,24$; $F = 274.55$; $p < 0.001$), habitat ($df = 1,24$; $F = 185.22$; $p < 0.001$), site location ($df = 2, 24$; $F = 1846.59$; $p < 0.001$), and two interaction terms (light x habitat: $df = 1, 24$; $F = 72.96$; $p < 0.001$; and light x site: $df = 2, 24$; $F = 10.12$; $p < 0.001$). Large round gobies were most abundant at Sarnia. Mean number of large round gobies at Sarnia ranged from 250 (sand habitats at night) to 425 (rock habitats in the day)/50 m^2 (Fig. 2). Apparently, large round gobies occur most often in the day on rocks (Fig. 2).

Species other than round gobies also were recorded during the transect survey (Table 1). Emerald shiners (*Notropis atherinoides*), logperch (*Percina caprodes*), crayfish (*Orconectes* spp.), darters (*Etheostoma* spp.), yellow perch (*Perca flavescens*), smallmouth bass (*Micropterus*

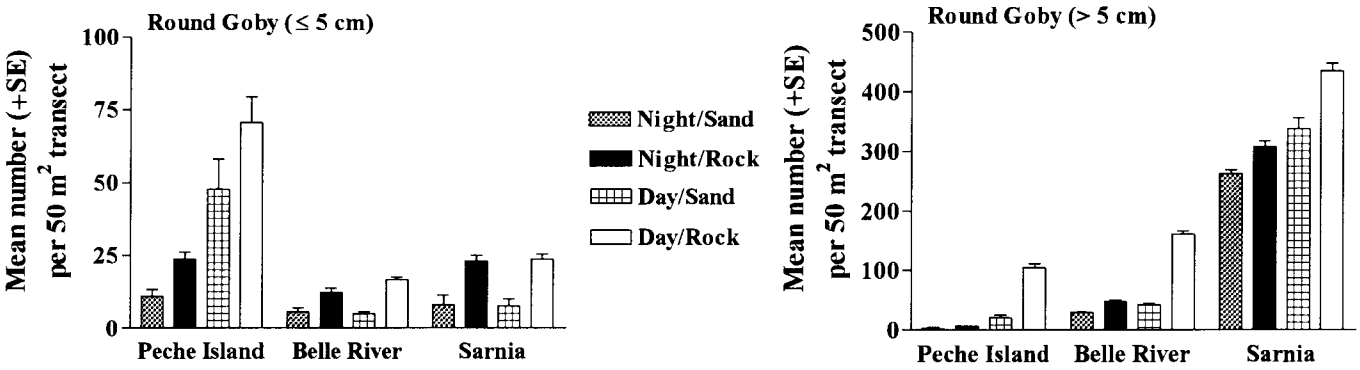

FIG. 2. Mean (+S.E.) number of small (TL ≤ 5 cm) and large (> 5 cm) round gobies observed along 50 m² transects (n = 3) in sand and rock substrates in the day and night.

dolomieu), and channel catfish (*Ictalurus punctatus*) were common. Emerald shiners and logperch occurred most often during the day and on rock substrates. Night-active crayfish and smallmouth bass were recorded more often on rock than sand substrates. Darters, seen in day and night, and the predominately diurnal yellow perch were common on sand substrates. Four other fishes (spottail shiner, *Notropis hudsonius*; freshwater drum, *Aplodinotus grunniens*; white sucker, *Catostomus commersoni*; and tubenose goby, *Proterorhinus marmoratus*) were observed infrequently (Table 1).

Site Affinity

Mark-recapture

Of the 200 gobies that were marked, 108 (54%) were male and 92 (46%) were female. Most fish (58%) were recaptured between 5 September to 15 October, indicating high site affinity (Fig. 3). Round gobies that were marked on day 1 (3 September) were still being recaptured 42 days later on 15 October. Of the 115 round gobies that were recaptured, 66 fish were male and 49 fish were female. Because the paint marks were still clearly

TABLE 1. Occurrence of other taxa (listed in decreasing order of abundance) observed along transects in day and night and on sand and rock substrates.

		% observed		% observed	
Taxa	n	Day	Night	Rock	Sand
emerald shiners	16	81	19	75	25
logperch	15	73	27	67	33
crayfish	12	0	100	100	0
darters	12	42	58	25	75
yellow perch	11	73	27	27	73
smallmouth bass	7	29	71	100	0
channel catfish	6	0	100	100	0
spottail shiner	4	0	100	100	0
freshwater drum	3	0	100	67	33
white sucker	2	100	0	100	0
tubenose goby	2	100	0	0	100

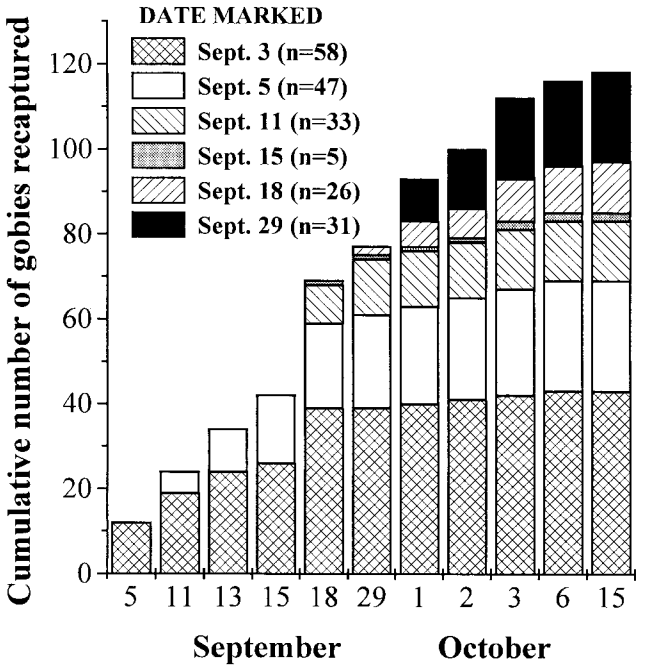

FIG. 3. Cumulative number of round gobies recaptured at a site in the Detroit River during 1996. The legend indicates date when fish were first captured and marked (n = 200).

visible on other fish after 6 weeks, it is reasonable that the 110 unmarked round gobies caught during the first two weeks of October were not previously captured.

Home Range

Eight round gobies (TL: 7–10 cm) were observed using SCUBA for 1-h each in the Detroit River near Peche Island. Mean (± SE) home range was estimated to be 5 (± 1.2) m^2. During the observation period, round gobies fed and moved towards and away from other gobies. No other fishes were seen during the observation periods. The earliest mean time that gobies reached their maximum distance traveled (home range) in the study was 30 minutes.

DISCUSSION

Density Estimates

There was a significant difference in the number of gobies observed among the three study sites (Fig. 1). Because round gobies were first recorded in the St. Clair River in 1990 (Jude *et al.* 1992), three years before they were reported in the Detroit River, it was anticipated that the original site of colonization would have the highest population densities of round gobies. As expected, mean density of round gobies at the St. Clair River site (Sarnia) was significantly higher than at the other sites (Fig. 1). Also, small (≤ 5 cm) round gobies were most common at Peche Island (the most recently colonized site), suggesting that juveniles may disperse more rapidly than adults.

Transect studies underestimate densities of round gobies because fish that are hidden among rocks or buried in sand are not counted. At Peche Island, density estimates of round gobies, determined by uncovering rocks within a quadrat, were 19 fish/m^2 (W. Ray, personal observation) versus 0.3 to 3/m^2 fish along a transect. Even "complete" enumeration, however, is still only an estimate of occurrence (Sale 1997). Nevertheless, the densities reported here for round gobies corresponded to 1996 Lake Erie estimates near Fairport, Ohio (1.8 to 6.3 gobies/m^2 ; K. Baker, Heidelberg College, personal communication), where similar census techniques were used.

Round gobies were more abundant in rock than in sand habitats and more abundant in the day than night. Angling experience also confirms these observations. The habitat complexity of rock substrates corresponds to an increase in refuges, which accounts for higher densities of gobies on rocks than on sand. Although Jude *et al.* (1995) suggested that round gobies were not expected to become abundant in nearshore sandy areas of the Great Lakes, gobies were common in sand habitats at all three study sites.

Fish activity may be related to differences in many factors including predation, competition, food resources, light level, and time of day (Helfman 1986, MacLennan and Simmonds 1992). In this study, there were no apparent differences in density of small round gobies between day and night at two (town of Belle River and Sarnia) of three sites (Fig. 2). Therefore, the predation rate may be higher on small gobies at night when the piscivorous species such as crayfish, channel catfish, freshwater drum, and smallmouth bass were active. Jude *et al.* (1992) reported that round gobies moved onto sand beaches to feed at night. In this study, large round gobies were not seen as often at night, suggesting that the fish may be occupying refuges at this time. Because large round gobies feed predominately on sessile zebra mussels (Ghedotti *et al*. 1995, Ray and Corkum 1997), a resource that is always available, large gobies could opt to feed whenever predation is low.

Site Affinity

The relatively high (58%) percentage of round gobies that were recaptured indicates that round gobies have a high tendency for site fidelity in rock habitats. The longest time between which a round goby was marked and recaptured was 42 days. Most fish (58%) that were marked were recaptured within 7 to 14 days (Fig. 3). Although males (66 of 108) were recaptured more often than females (49 of 92), both sexes exhibited site fidelity. Wolfe and Marsden (1998), who conducted a round goby tagging study in Lake Michigan, also found that the round goby exhibited site fidelity. They reported that all recaptured fish were retrieved within 67 m of the tagging site with the exception of one fish tagged on 23 October 1996 and recaptured 29 June 1997 by an angler 2 km from the original tagging site. Despite possible on- or offshore movement during the winter months, round gobies demonstrate high site affinity.

Diet, predation, intraspecific interactions, and familiarity with an area influence home ranges of fish (Helfman 1986, MacLennan and Simmonds 1992). In temperate climates, home range sizes of fishes, which are about 20 times larger in lakes than in

rivers (Minns 1995), may be attributed to lower productivity in lakes (Randall *et al.* 1995) and differences in refuge sites (Hill and Grossman 1987). Also, fish home ranges increase with increasing body size. Mottled sculpin (*Cottus bairdi*) and the round goby, with similar body morphology, size, and habits, have relatively small home ranges. Hill and Grossman (1987) studied home range size of mottled sculpins in a stream for 18 months using acrylic paint to mark mottled sculpin. They found that mean (± SE) home range size of mottled sculpin in a North Carolina stream was 12.9 (± 2.4) m; stream width ranged from 2 to 11 m. This home range was considered to be high owing to three storms that increased flow five-fold (Hill and Grossman 1987). The home range size of round gobies [5 ± 1.2 m^2 (SE)] estimated in this study likely is an underestimate because few fish (n = 8) were observed in one season, mid-summer. However preliminary, these observations of a small home range are consistent with the high site fidelity of round gobies in habitats that were predominantly rock. Additional research is needed to identify the home range of round gobies and to determine if certain size classes are more prone to disperse than others. Larger round gobies may induce juveniles to leave preferred rock habitats and move to sand habitats from which they disperse.

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