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Competitive Interactions between Round Gobies and Logperch

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ABSTRACT. *We examined territorial defense and behavioural interactions between two species of fish resident in Hamilton Harbour: non-indigenous round gobies* (Neogobius melanostomus) *and native logperch* (Percina caprodes). *Trials consisted of placing one fish, "the resident" (either a round goby or a logperch), in a tank with a shelter for 24 hours before adding another fish, "the intruder" (either a round goby or a logperch), and recording aggressive incidents. Overall, gobies exhibited more aggressive behavior than logperch, and in general resident status had no effect on amount of aggression displayed. Also, gobies spent more time in shelters than logperch, and overall resident status did not affect the amount of time spent under shelter. We also compared abundance data for gobies and logperch using electrofishing transects in Hamilton Harbour that were conducted in 1995 and 2001 and found a dramatic increase in round goby numbers and a non-significant decrease in logperch numbers. Our data suggest that gobies are superior space competitors and hence the range expansion coupled with an increasing population size of the round gobies in Hamilton Harbour is likely to have deleterious consequences for logperch populations.*

INDEX WORDS: *Interspecies competition, Hamilton Harbour, Lake Ontario, Great Lakes exotic invasive species.*

INTRODUCTION

A number of researchers have suggested that the round goby, *Neogobius melanostomus,* a newly invasive species in the Great Lakes, has had deleterious effects on the populations of native fishes (de Kock and Bowmer 1993, Kuhns and Berg 1999, French and Jude 2001, Janssen and Jude 2001). In this study, we examined competitive interactions between one native species, logperch, and round gobies in the laboratory to determine if the outcome of such interactions might help explain the suggested demise of logperch populations (Jude *et al.* 1995, Chant 2002). We also examined the change in abundance of logperch and gobies in Hamilton Harbour from 1995 to 2001.

European and Asian aquatic species have been invading the Great Lakes since the settlement of North America (Charlebois *et al.* 2001). Some of the greatest ecological disasters in North America have resulted from such biological invaders (Mills *et al.* 1994), which have altered physical habitat, disrupted food webs, and caused local extinction of native species (Ricciardi and MacIsaac 2000). This threat intensified in the 1840s when ocean-going vessels began to traverse the Great Lakes. Transoceanic cargo ships can harbor European fish within their ballast tanks (Charlebois *et al.* 2001), regularly delivering them to new ecosystems. The most recent fish species to immigrate into the Great Lakes by ballast tank transfer is the round goby (Jude 1997).

The round goby, a benthic freshwater fish, is indigenous to the Caspian, Black, and Azov seas. In their first year males grow to 10–13 cm standard length (SL, the distance from the lower lip to the caudal peduncle), whereas females are limited to 8–11 cm SL (Berg 1949). Typically round gobies

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live for 4 years and can reach 25 cm in both native and invaded habitats (Charlebois *et al.* 1997). The round goby was first captured in North America on 28 June 1990, in the St. Clair River (North of Lake St. Clair) at Sarnia, Ontario, Canada (Jude *et al.* 1992). Between 1990 and 1992 only 14 round gobies were collected in the St. Clair River; however, by 1995 they were well established with over 3,000 round gobies collected from Lake Erie (Jude *et al.* 1992). The rate of the round goby's range expansion throughout the Great Lakes is considered to be very rapid relative to other invasive fish, such as the sea lamprey (*Petromyzon marinus*), which took almost 25 years to invade Lake Superior after first invading Lake Erie (Jude and Leach 1993).

At least one native fish species, the mottled sculpin (*Cottus bairdi*), has been negatively affected by round gobies (Janssen and Jude 2001). For a number of reasons, we believe that logperch (*Percina caprodes*), another species native to the Great Lakes, may also be deleteriously affected by competition with round gobies. Both species may inhabit similar habitats including sand, gravel, or rocky shallow beaches, spawn at the same time of year, and both species have benthic diets; juvenile round gobies in particular favor similar food items as logperch (such as chironomid larvae and cladocerans, Greenberg 1991, Jude *et al.* 1995, Charlebois *et al.* 1997, Thomas 1997, Scott and Crossman 1998). Although the size range of gobies and logperch overlap, on average Great Lake gobies are larger (mean round goby SL = 10.3 cm; Berg 1949) than logperch (mean logperch SL = 7.9 cm; Scott and Crossman 1998) providing them with a competitive advantage over logperch in terms of their ability to acquire and secure breeding habitat or shelter. In addition, round gobies are believed to directly prey on the eggs and young of logperch (Jude *et al.* 1992). Finally, three previous studies have documented the decrease of logperch in areas where gobies have increased in number (Lake St. Clair: Jude *et al.* 1995; Lake Ontario: Chant 2002; Christine Brousseau, Canada Centre for Inland Waters, personal communication, 2003). Direct evidence of competition between round gobies and logperch, however, has not yet been documented.

The aims of this study were twofold: 1) to investigate the interactions between round gobies and logperch in a shared space with a single resource (shelter) and 2) to monitor how round goby and logperch numbers had changed over time in Hamilton Harbour. To accomplish the first aim, we conducted four different types of trials, using round gobies and logperch as both residents and intruders. In general, in contests between territory holders (residents) and intruders, residents typically win (Maynard Smith and Parker 1976, Grafen 1987, Rosenberg and Enquist 1991, Tobias 1997). However, in competition experiments between mottled sculpins and round gobies, resident sculpins lost shelters to intruding round gobies (Dubs and Corkum 1996). Thus we predicted that 1) round gobies would display more aggressive behaviors than logperch; and that 2) round gobies would sequester the resource (spending more time in shelters) to the exclusion of logperch regardless of residence status. To tackle our second aim, we used data on the numbers and species of fish caught during 20 electrofishing transects conducted in Hamilton Harbour in 1995 and 2001. Transects compared were matched for location and date.

METHODS

Collection and Stock Tanks

Male round gobies were collected with baited minnow traps on 11 July 2002, from Lake Ontario, on the banks of La Salle Park, in Hamilton, Ontario. Round gobies collected ranged in length from 5.3 to 12.1 cm SL (average 8.7 ± 0.2 cm SL). They were housed in a 490 L stock tank in the Psychology Department of McMaster University, which was equipped with two Fluval 404 units and two air powered foam filters. Male logperch were collected with electrofishing gear on 20 August 2002 from the Royal Botanical Gardens Fishway, Hamilton, Ontario. Logperch ranged in length from 4.4 to 9.4 cm SL (average 6.6 ± 0.2 cm SL) and were housed in two 189 L stock tanks. These tanks were each filtered using two air powered foam filters. All tanks were maintained between 22–24°C. To control for differences in aggression between sexes, only males were used in this study. The fish were sexed by visually examining the urogenital papilla between the anus and the base of the anal fin. In females, the papilla is blunt and broad, shaped like a short cylinder with a slit across its top while in males it is more cone-like with a terminal slit (Miller 1984). Fish were used in experimental trials (see below) after an adjustment period of at least one week.

Opaque dividers were placed in the centre of the stock tanks to separate used and unused fish. This ensured that each fish was used only once in this experiment. Both round gobies and logperch were fed twice daily with Nutrafin Tropical® commercial flake food (morning 0900–1100 h; afternoon

1600–1800 h). In addition, twice a week the fish were fed a mixture of frozen bloodworm (*Chironomus* spp.) and brine shrimp (*Artemia* spp).

Experimental Tanks and Trials

Six 38 L tanks were used for this experiment. The sides and back of each tank were covered with blue adhesive paper, controlling for visual interference between fish in neighbouring tanks and minimizing light reflection. Each experimental tank was equipped with a central Aquaclear® Mini Cycle Guard Aquarium Power Filter, a thermometer, and a one-inch layer of coral sand as substrate. A half of a clay flowerpot was placed in the center of each tank to serve as a shelter. The light regime maintained was a 14/10-hour light/dark schedule and water temperature was maintained at 22°C. This photoperiod and temperature regime was chosen to reflect conditions likely experienced by round gobies and logperch in the shallow nearshore zone of Hamilton Harbour during the peak (July) of the breeding season (Barcia 1989).

All experimental trials (N = 49) were conducted between 22 August and 23 October 2002. First, one fish (resident) was placed in the tank, and then a second fish (intruder) was added 24 hours later. In 12 trials, both the resident and the intruder were round gobies, in 11 trials, the resident was a round goby, and the intruder was a logperch, in 15 trials the resident was a logperch, and the intruder was a round goby and in 11 trials, the resident and the intruder were both logperch (see Table 1).

Each trial took 3 days. On the first day of an experimental trial, between 0800 and 1000 h, a single fish was placed in a tank (the resident). Six hours later (between 1400 and 1600 h), once the fish had sufficient time to settle, explore the shelter and habituate to the tank, a 10-minute focal observation session was conducted on this lone resident fish. To habituate the fish to the observer, before any focal recordings were made, the observer would sit still for 10 minutes and recorded from a distance of 1 m from the tank. All behaviors as well as the location of each fish in each observational session were recorded. Eighteen hours later (between 0800 and 1000 h) on the second day of the trial, this resident fish was observed for another 10 minutes (second observation period), and the intruder fish was then added to the tank. Between 1400 and 1600 h of the second day, both fish were observed for a further 10 minutes (third observation period). The fourth and final observation took place between 0800 and 1000 h on the third day of the trial. In the third and fourth observation periods, both fish were observed simultaneously, using two separate stopwatches and two behavior checklists. It was possible to track and record all behaviors of the two fish concurrently. Thus the resident fish was observed four times for a total of 40 minutes, and the intruder was observed twice for a total of 20 minutes. After the fourth observation period, the standard lengths, total lengths, and wet weights of fish were recorded. These methods were based on a published study on competition between round gobies and mottled sculpins (Dubs and Corkum 1996).

Aggressive Interactions

During the third and fourth 10-minute observation periods (following the introduction of the intruder fish), all the behaviors displayed by both the resident and intruder fish were recorded. In particular, we used the recorded number of overt acts of aggression (the number of chases and the number of bites) by each fish (summed and averaged between the third and fourth observation periods) to compare the frequency of aggression between the species. A chase was defined as a quick movement toward the other fish, with the other fish moving quickly away in response, and a bite was defined as one fish vigorously closing its mouth on or near the

TABLE 1. Chi-squared goodness-of-fit tests were used to examine whether the number of times that the resident won differed from that expected by chance. The various types and the numbers of each trial conducted are provided.

Trial Type	Number of Trials	Number of Wins for Resident	χ^2	P
Round goby resident and round goby intruder	12	10	5.3	0.02
Round goby resident and logperch intruder	11	8	3.6	0.058
Logperch resident and round goby intruder	15	5	1.14	0.29
Logperch resident and logperch intruder	11	8	2.27	0.13

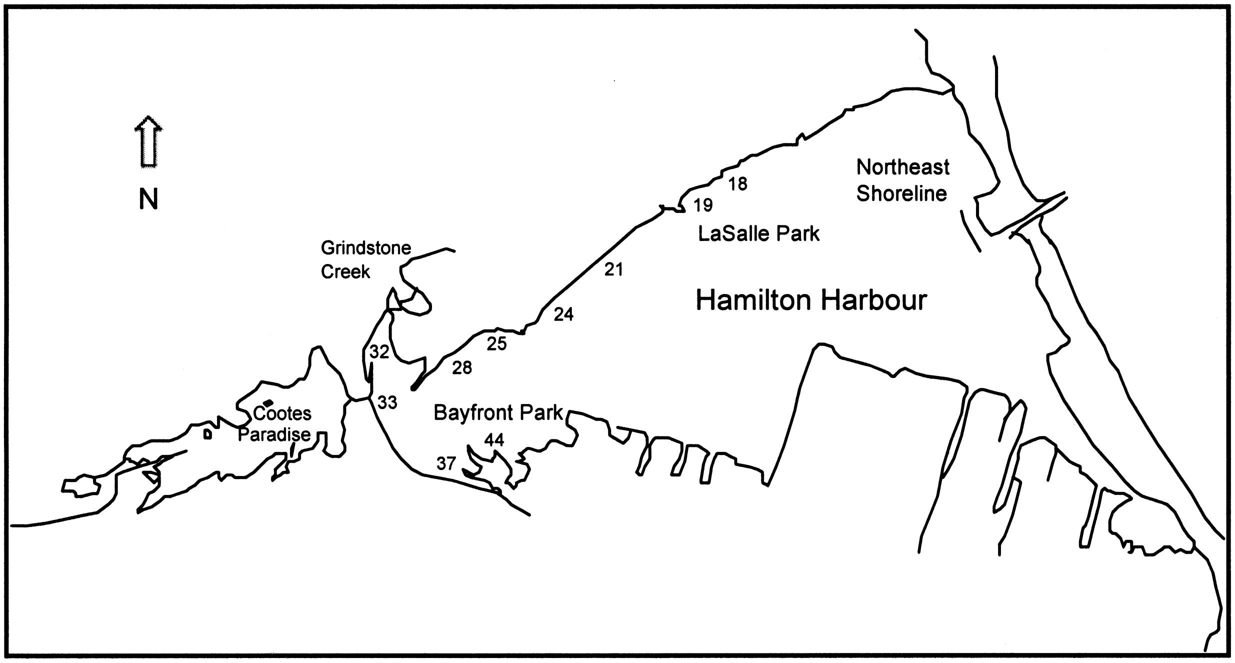

FIG. 1. A map of Hamilton Harbour showing the 10 matched electrofishing transects locations (matched for dates between 1995 and 2001). The transect numbers refer to particular known transect localities around the littoral zone and details can be found in Smokorowski **et al.** *1998.*

body of the other fish (as in Dubs and Corkum 1996). If a fish received serious injury during an observation period, the trial was immediately terminated and the fish were separated. Of 49 trials, four had to be prematurely terminated (see below).

Shelter Use

During each 10-minute observation period, we measured the amount of time each fish spent in the shelter to determine if one species spent more time in shelters than the other, and if residents spent more time in shelters than intruders. As with aggression, the time in the shelter was summed and averaged over the third and fourth observation periods. A fish was considered to be a "winner" if it spent more time in the shelter than the other fish in the same tank at the same time. As mentioned above, in contests between territory holders and intruders, residents normally win (Grafen 1987).

Body Size, Shelter Use, and Aggression

We also examined the effects of the difference in body size between the resident-intruder pair on both aggression and the amount of time spent in a shelter. We based the size difference on body weight differences (wet weight in grams) for each resident-intruder pair and compared this value to the average number of aggressive acts and the average time in spent in the shelter.

Electrofishing Transects—Goby Versus Logperch Abundance in Hamilton Harbour

To determine if the rise in round goby numbers was correlated with changes in logperch abundance, data on abundance of the two species were compared. The data came from fish counts made during 20 electrofishing transects of 100 m each in Hamilton Harbour (43°N, 79°W) conducted by the Royal Botanical Gardens Aquatic Research Team during July 1995 (n = 10 transects prior to the goby invasion) and July 2001 (n = 10 transects, post invasion). Overall 27 different fish species were caught in these electrofishing transects (Chant 2002). The location and dates of transects were matched between survey years and included transects at each of 10 sites known as 18, 19, 21, 24, 25, 28, 32, 33, 37, and 44 in Hamilton Harbour (see Fig.1 and Table 2). Fish were collected by using a Smith Root 5.0 GPP punt electrofisher from a motorized boat. The fish were collected in a dip net as they appeared near the surface and were held in an onboard

TABLE 2. The locations of the electrofishing transect sites around the littoral zone around Hamilton Harbour in 1995 and 2001. None of the locations sampled were industrial.

Location	Substrate Type	Number of round gobies caught in 2001	Number of logperch caught in 1995	Number of logperch caught in 2001
18	Sand	58	4	1
19	Sand	28	2	1
21	Sand	87	2	1
24	Sand	43	5	0
25	Mud	95	3	0
28	Mud	56	4	0
32	Mud	16	0	7
33	Mud	32	4	0
37	Cobble	73	0	16
44	Cobble	13	16	0

container filled with water until they could be identified by species and counted. All fish (apart from the round gobies) were returned to the site of collection following each transect. Round gobies captured were brought to the laboratory for further study. Note that although electrofishing may not be the best technique available to sample round gobies (or other bottom-dwelling fish that lack a swim bladder), the sampling technique was consistent between years and locations and the gear effectively caught large numbers of each species.

Statistical Analyses

Statistical tests were performed using the statistical program SPSS ©, version 10.1. Non-parametric statistics were used because the assumptions for parametric tests could not be met (transformations attempting to normalize the data were not successful). All tests were two tailed, and were considered significant at P-values ≤ 0.05. To determine whether on average round gobies were more aggressive than logperch, or whether residents were more aggressive than intruders, aggression frequency between groups were compared using Mann Whitney U tests. The sum of aggression observed in the third and fourth observational periods was calculated and then this sum was averaged across the two periods. In addition, the amount of time spent in the shelter was compared between species and fish of different resident status (again the amount of time in the third and fourth observational period were summed and averaged). The amount of time spent in the shelter was also compared between the third and fourth observational period combined and the first and second observational periods combined. To determine whether body size differences between resident and intruder or between a round goby and a logperch correlated to the difference in their frequency of aggression, Spearman rank correlation tests were performed. A chi-square goodness-of-fit test was used to examine whether round gobies or logperch won the resource (shelter) more often then expected by chance. To compare fish abundance in 1995 to 2001, Wilcoxon-signed ranks tests were performed on transects matched in date between years. A Spearman's correlation test was conducted to determine whether round goby abundance was related to logperch abundance.

We did not include the data from two round goby vs. logperch trials in the analysis because the round gobies strongly attacked the logperch directly before the observation period (observational period 3) and we immediately terminated these trials (see Table 1). Two trials with logperch as both residents and intruders were also excluded because one logperch in each trial jumped out of the tank before the first observation period.

RESULTS

Aggressive Interactions

Overall, round gobies exhibited more aggressive behavior than logperch (Mann-Whitney U test, $U = 696$, $N_{goby} = 48$, $N_{logperch} = 42$, $P = 0.001$, Fig. 2). All fish bit more often (mean ± S.E. = 1.0 + 0.33 per 10 minutes) and bites were more common than chases (mean ± S.E. = 0.50 + 0.18, Wilcoxon signed ranks test, $z = -1.967$, $p = 0.05$). While only mild aggression was observed during observation periods, in two trials where round gobies intruded on logperch, the logperch were found dead at the beginning of an observation period. The two logperch appeared to have been attacked. In a third trial, a round goby was observed to be consuming the logperch directly before the observation period, and so we immediately ended this trial.

Overall there was no effect of resident status on aggression, demonstrating that intruders were as aggressive as residents (Mann Whitney U test, $U = 895$, $N_{resident} = 45$, $N_{intruder} = 45$, $P = 0.11$, within trial comparisons: Wilcoxon signed ranks test, $z = -0.737$, $p = 0.46$). When the size difference

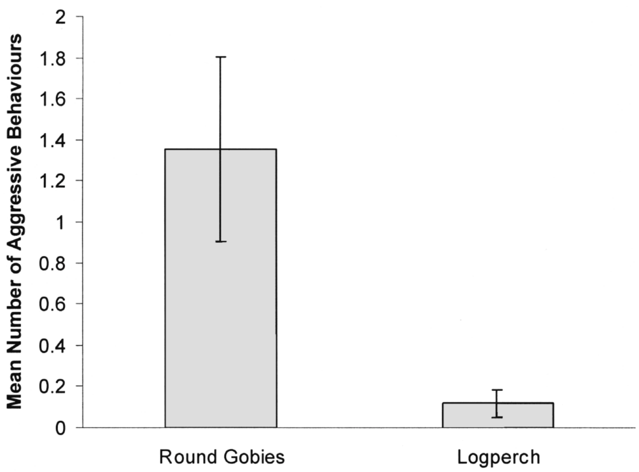

FIG. 2. The overall mean (±S.E.) number of aggressive behaviors exhibited by round gobies and logperch in all trials.

between resident-intruder pairs was small, significantly more aggressive acts were exhibited (by both fish combined) compared to when the size difference between the pair was large (U=88.5, $N_{\text{pairs with a large size difference}}$= 16, $N_{\text{pairs with a small size difference}}$ = 28, P=0.04, Fig 3.).

When the interaction between residency status and species was explored further (Fig. 4) we found

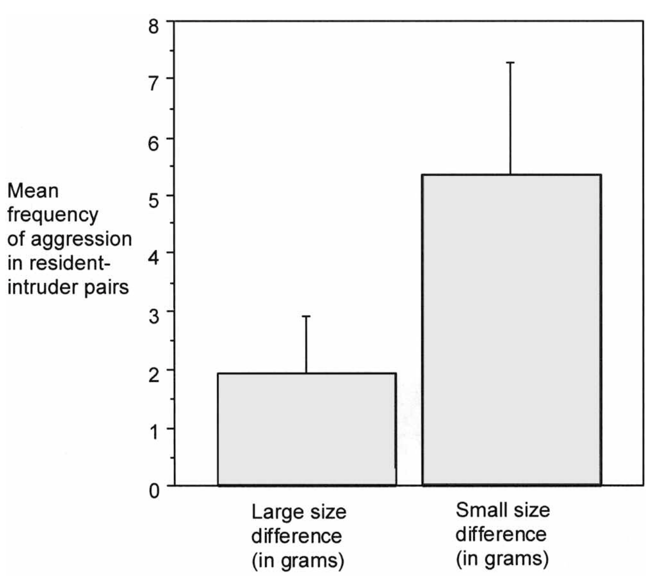

FIG 3. The overall mean (±S.E.) number of aggressive behaviors exhibited by resident and intruders when the size difference (in grams) between the pair was small (≤ 2.5 grams, N = 28) versus large > 2.5 grams, N = 16).

that, in the trials involving *both species*, aggression rates of resident round goby were in fact significantly higher than rates of resident logperch (Mann-Whitney U test, U = 97, $N_{\text{goby vs logperch trials}}$ = 9, $N_{\text{logperch vs goby trials}}$ = 15, P = 0.05, Fig. 4). In these trials involving *both species*, aggression rates of round goby intruders tended to be higher than the rates of logperch intruders but not significantly so (Mann-Whitney U test, U = 95, $N_{\text{goby vs logperch trials}}$ = 15, $N_{\text{logperch vs goby trials}}$ = 9, P = 0.07). When considering just the trials involving only *one species*, aggression rates of round goby residents did not significantly differ from aggression rates of logperch residents (Mann-Whitney U test, U = 75, $N_{\text{goby vs goby trials}}$ = 12, $N_{\text{logperch vs logperch trials}}$ = 9, P = 0.10). In these trials involving just *one species*, aggression rates of round goby intruders were also not significantly different than the aggression rates of logperch intruders (Mann-Whitney U test, U = 63, $N_{\text{goby vs goby trials}}$ = 12, $N_{\text{logperch vs logperch trials}}$ = 9, P = 0.21).

Shelter Use

Prior to the introduction of intruders, lone round gobies and lone logperch spent similar amounts of time in shelters (Mann-Whitney U test, U = 265, N_{goby} = 23, $N_{logperch}$ = 26, P = 0.49).

However, after the introductions, round gobies spent significantly more time in shelters than logperch (U = 692, N_{goby} = 48, $N_{logperch}$ = 42, P = 0.01, Fig. 5). Overall, round gobies won shelter more often during inter-specific competition than logperch (in the 24 trials in which a round goby interacted with a logperch, 17 round gobies won while only 7 logperch won shelter, chi-square test, χ^2 = 4.17, df = 1, P = 0.04, Table 1).

Residents tended to spend more time in a shelter (U = 101, $N_{resident}$ = 45, $N_{intruder}$ = 45, P = 0.06). When interaction between residency status and time each species spent under the shelter was explored further we found that round goby residents tended to spend more time in the shelter compared to logperch residents when considering only trials involving both species (Mann Whitney U test, U = 101, N_{goby} = 9, $N_{logperch}$ = 15, P = 0.07) but spent similar amounts of time in the shelter compared to logperch residents when considering only trials with single species (Mann Whitney U test, U = 73, N_{goby} = 12, $N_{logperch}$ = 9, P = 0.17). Round goby intruders spent significantly more time in the shelter than logperch intruders when considering multispecies trials (Mann Whitney U test, U = 121, $N_{logperch}$ = 9, N_{goby}

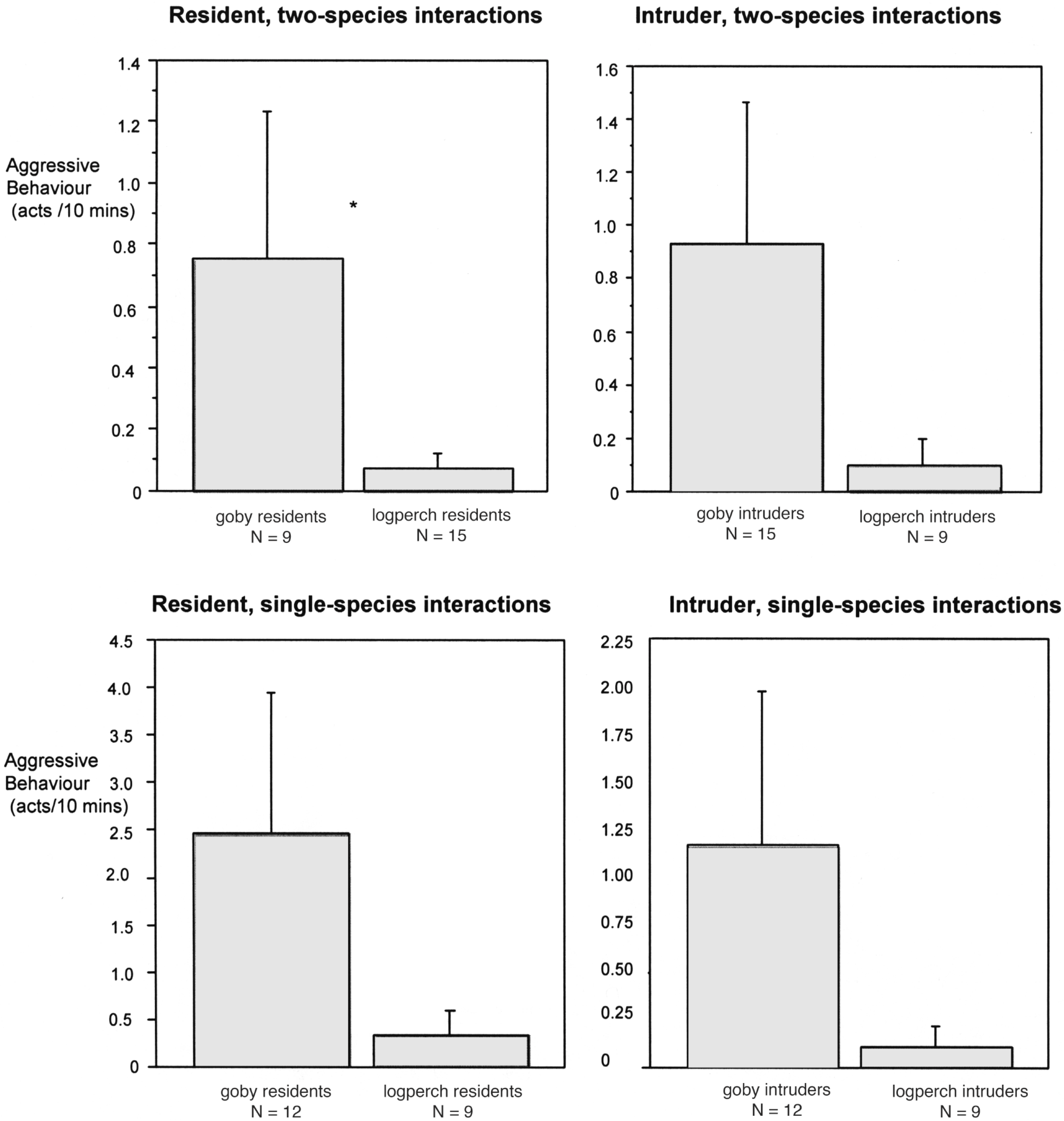

FIG 4. The mean (±S.E.) number of aggressive behaviors exhibited by round gobies and logperch as residents and intruders in both two-species (round goby vs. logperch and logperch vs. round goby) and single species (round goby vs. round goby and logperch vs. logperch) interactions.

= 15, P = 0.003). Round goby intruders and logperch intruders spent similar amounts of time under shelter in the trials involving only one species (Mann Whitney U test, U = 52, $N_{goby} = 12$, $N_{logperch} = 9$, P = 0.84).

Resident round gobies won shelter more often than resident logperch. In 88.9% of trials resident round gobies won but resident logperch won in only 33% of the trials (chi-square test, $\chi^2 = 6.99$, df = 1, P = 0.008). The greater the body size differences between resident and intruder fish the more time the resident spent in the shelter (Spearman's Rank cor-

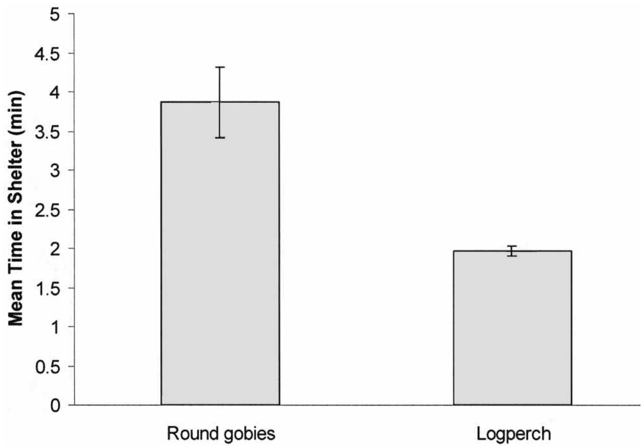

FIG. 5. The overall mean (±S.E.) time (in minutes) spent in shelters by round gobies versus logperch.

relation, $\rho = 0.652$, $N = 45$, $P < 0.001$) and the less time the intruder spent in the shelter ($\rho = -0.659$, $N = 45$, $P < 0.001$).

Round Goby Versus Logperch Abundance in Hamilton Harbour

In June of 1995, 40 logperch and no round gobies were caught in 10 electrofishing transects (Table 2). In June of 2001 in the 10 date and location matched transects, a total of 26 logperch (2.6 logperch per transect) were caught in comparison to a total of 501 round gobies (50.1 round gobies per transect, Wilcoxon signed ranks test, $z = -2.805$, $p = 0.005$). However, the apparent decrease in logperch numbers was not significant ($z = -1.022$, $P = 0.30$), nor was there a negative correlation between the number of round gobies and logperch caught (Spearman's Rank correlation, $\rho = 0.152$, $N = 10$, $P = 0.80$).

DISCUSSION

Previous research has suggested that round gobies are likely to compete with logperch for habitats (Jude *et al.* 1992, Jude *et al.* 1995); this study suggests that logperch are likely to lose such competitions. Our study provides quantitative support for the notion that round gobies are overall more aggressive than logperch and are better able to secure shelter (win a battle for a flowerpot) compared with logperch. Hence we essentially provide a possible mechanism for the frequently made observation that logperch populations are declining in the presence of invasive round gobies (Jude *et al.* 1992, Jude *et al.* 1995, Jude and DeBoe 1996, Chant 2002). Round gobies monopolized the shelter more often than logperch and this was not a result of a differential preference for the shelter, as resident logperch and round gobies spent similar amounts of time in shelters prior to the introduction of intruder fish. Based on these results, we assume that in the wild, round gobies would be capable of taking shelters or breeding substrates away from logperch interfering with their reproduction. Future studies using natural observations of fish in the wild will possibly confirm these predictions.

The population declines of several native species have been associated with the presence and range expansion of the round goby (Jude *et al.* 1995, Janssen and Jude 2001, Kuhns and Berg 1999, French and Jude 2001). Our study documents an apparent logperch decline and a dramatic increase in round gobies in Hamilton Harbour (however no direct negative correlation between the abundance of two species was detected). Our findings are consistent with findings by other researchers and for other parts of the Great Lakes, (Jude *et al.* 1995; Chant 2002; Christine Brousseau, Canada Centre for Inland Waters, personal communication, 2003). Researchers have long assumed that the round gobies aggressive nature has resulted in the decline of native benthic fish species (Jude *et al.* 1995, Janssen and Jude 2001). Our study joins one conducted by Dubs and Corkum (1996) as the first experimental tests to validating the assumption of round gobies aggressive nature. Dubs and Corkum found that round gobies were more aggressive than mottled sculpins and that round gobies were capable of sequestering shelter from sculpins. Hence both studies jointly provide important insights for habitat restoration attempts, lake ecology, and fisheries management. The implications of our results are that logperch will suffer deleterious consequences as the round goby continues to expand its range and population size. In addition to competing with logperch for resources, our study conclusively showed that round gobies can kill and even consume this native species, at least in the laboratory. Field research is now required to determine if round gobies indeed kill and/or consume logperch in their natural habitats, as well as to examine the circumstances under which round gobies are likely to displace logperch from potential breeding sites and shelters.

One common behavioural finding is that residents almost invariably defeat challengers in territory disputes (Rosenberg and Enquist 1991, Jennions and Blackwell 1996, Tobias 1997). This phenomenon, sometimes known as the "owners always win" convention, has been explained by the existence of an asymmetry in the value of the resource (the territory) (Maynard Smith and Parker 1976, Grafen 1987). An inherent asymmetry exists in the value the resident's territory has for the resident versus the intruder; residents have already invested considerable energy in establishing territory ownership, exploring the various available resources on the territory such as food and shelter (Nijman and Heuts 2000). Hence a territory owner loses more than an intruder when losing the contest over a territory and this asymmetry will increase the resident's motivation to win the fight over intruders. Interestingly, in this study, residency status did not affect the amount of aggression displayed by a fish, or the amount of time it spent in a shelter. This result suggests that prior residency status is unlikely to assist native species (such as logperch) in holding resources such as breeding shelters when confronted by round gobies.

The data also show that both aggression and shelter dominance are affected by the size differences between competing fish. In our study, round gobies were an average of 2.5 ± 0.4 cm larger than logperch. The range of size differences and their associated behavior in the laboratory are likely to parallel those experienced in the wild. In the field, round gobies are, on average, 2.4 cm larger than logperch. Differences in resource holding potential may also influence the outcome of contests and as a result one might have expected gobies to win more often. However, theory suggests that obvious asymmetries between the contestants will not always be used to settle the dispute in animal contests (Grafen 1987). Grafen argued that if winning the contest plays a major part in gaining reproductive success then individuals would not be expected to respect an asymmetry and may actually fight for the resource despite the asymmetry. Shelter was expected to be an important resource for both species and both logperch and round gobies did display aggressive behavior over this resource. In our study, to ensure that the flowerpots were considered an important resource, behavioral observations were conducted during daylight hours because previous work has shown that gobies spend relatively more time in shelter during the day compared to the nighttime (Dubs and Corkum 1996). Nighttime observations may have revealed even more dramatic results as gobies have a well developed lateral line system and can forage and move around efficiently in the dark (Jude *et al.* 1995).

In conclusion, round gobies were present in Hamilton Harbour in 2001 but not 1995. Using an experimental approach, we show that round gobies were shown to be more aggressive than logperch in the laboratory. These behavioral differences may help to explain the success of round gobies in the Great Lakes. To date, little work has been done to directly elucidate the interactions between round gobies and other fishes and most existing studies have simply assumed a decline in native species in the Great Lakes may be a result of the population and range expansion of round gobies. Hence our study provides a useful contribution. The experimental approach allows for a more direct quantification of a relationship that has been previously merely implied by other investigations. Finally, the results suggest that the round goby's impact on logperch is likely to be significant and that this new invasive species may be capable of substantially altering the benthic fish community structure.

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