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Short communication

Angling to estimate the density of large round goby (*Neogobius melanostomus*)

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ABSTRACT

We introduce an angling technique for estimating the density of the round goby (*Neogobius melanostomus*). Sampling is conducted from a boat that is securely anchored in a randomly selected site. By taking advantage of the aggressive nature, small size, and limited home range of the round goby, two anglers are generally able to deplete the local aggregation of gobies in a 20 min period. Density is estimated using a depletion curve and reliable estimates were produced in 76% (52/68) of field trials where round gobies were present. Relative abundance was estimable for 100% of trials. An experimental procedure indicated that refuge status (gravel or rock), density, or temperature had no effect on round goby capture efficiency using this technique ($p > 0.05$ in all cases). Angling is a relatively inexpensive and simple technique that is useful in providing a relative measure of the density of gobies larger than 50 mm TL, and is especially useful in situations where round gobies can evade capture or detection by other methods. Although most appropriate for sampling species with similar behavioural characteristics to the round goby, this novel sampling procedure also demonstrates that angling continues to be a useful tool for assessing fish populations.

1. Introduction

Determining population density is central for the estimation of fish populations, but density can be difficult to assess for small bodied cryptic fish like gobies. The round goby (*Neogobius melanostomus*) is a demersal fish that originates in the Ponto-Caspian region and is now found in the Laurentian Great Lakes and a number of their tributaries. The invasion of this fish prompted research efforts to assess population densities, and techniques have included trawling (OMNR, 2005), seining and visual estimation with SCUBA (Schaner et al., 2009), a remotely operated vehicle (Johnson et al., 2005), snorkelling transects (Ray and Corkum, 2001) and a boat mounted underwater camera apparatus (Schaner et al., 2009). Despite the advantages presented by each technique and their practicality under particular environmental conditions, each technique is severely limited by high cost, capture inefficiency and/or limited ability of use in certain habitats occupied by the species (Johnson et al., 2005; Schaner et al., 2009). In an attempt to quantify round goby density in the Trent River, Ontario, we initially utilized the underwater camera apparatus that worked well in the Bay of Quinte (Schaner et al., 2009); however the large, angular rocks in the channel made it difficult to detect gobies, and the variable current and high boat traffic made it difficult to maintain a steady course in this river. To suit these conditions, we developed an angling technique to produce density estimates using the principles of the depletion method (Zippin, 1958; Carle and Strub, 1978). In this paper, we describe the angling system and a test of its efficiency and size selectivity in a laboratory experiment.

2. Methods

2.1. Equipment and field procedure

Angling was conducted from a 16′ Jon boat by two individuals using ultra-light weight spinning rods, 0.15 mm diameter zero-stretch fishing line, one or two size 4 split-shot sinkers and #20 fly fishing hooks baited with a small portion of scented plastic maggot (white). Sites for angling were selected using a program that randomly generated longitudinal and latitudinal points (www.geomidpoint.com). The boat was anchored from the bow and the stern to prevent it from shifting position, and angling was conducted within a 1.5 m^2 area delineated by a foam quadrat fixed over the side of the boat. There was a 5 min waiting period after the boat was anchored. Each angler then attentively fished and awaited strikes that could, at times, be subtle. Upon capture, gobies were measured for total length and sexed by examining their urogenital papillae which is triangular on males and rectangular on females (Charlebois et al., 1997). Captured gobies were kept in a pail of

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Table 1
Descriptive statistics of catch per unit effort and the MWL estimates (Carle and Strub, 1978) for density (per m^2) of round gobies from the area of first introduction and the upstream and downstream reaches of their range in Trent River, 2008. Mean CUE and mean density was calculated from sites where gobies were found and actual catch values were used to calculate mean density where MWL values were inestimable.

	Upstream segment	Area of first introduction	Downstream segment
Separation (km) from area of introduction	1	–	10
Mean CUE (±1 SE)	7.8 (1.1)	12.0 (1.4)	5.1 (1.2)
Mean Carle and Strub CUE (±1 SE)	10 (1.2)	15 (2.1)	9.2 (2.9)
Mean MWL density estimate (±1 SE)	5.8 (0.78)	9.6 (1.3)	3.9 (0.97)
Number sample sites with gobies	22	32	14
Total number of sample sites	33	33	29

water. Angling was conducted for four consecutive 5 min periods, which was the selected cut-off time because the number captured at the end of 20 min was often around zero.

This method assumes that immigration and emigration does not occur during an angling period (the population size only changes through sampling), an assumption we believe to be reasonable because round goby exhibit high site fidelity (Ray and Corkum, 2001) and because an underwater camera showed that round gobies were apparently absent after an angling trial (Gutowsky, personal observation). We also assume that the probability of capture is equal among gobies, and the boat and anchors have minimal and equal affects on goby behaviour among sites.

Field trials to test this method were conducted between 8:30 and 15:30 from June to October, 2008. Tests occurred in one of three areas of the Trent River: the area where round gobies were introduced as first noted in 2003 (personal communication, MacDonald, Ontario Federation of Anglers and Hunters) and the upstream and downstream segments of the population range as of 2008 (in Raby et al., 2010). The length of river sampled has an average depth of 4.1 m in the navigational channel (map data, Canadian Hydrographic Service), and a mean monthly flow of approximately 167 $m^3\,s^{-1}$ in April and 32 $m^3\,s^{-1}$ in August (unpublished data, Parks Canada). Water temperatures ranged from 15 °C in April, 25 °C in late August, and back to 15 °C in October. The habitat available to round gobies in the Trent River includes sand, gravel, large rocks (>200 mm diameter) and aquatic macrophytes. Angling trials were most often conducted over large rocks (71%) and gravel (14%; Raby et al., 2010). A total of 95 sites were sampled and 72% of sites contained at least one round goby (Table 1).

Since we were aware that immigration and emigration must occur to some extent, we conducted a short field experiment to quantify the mean maximum distance along a submerged measuring tape gobies could be visually angled and coaxed to bait presented over gravel and rock covered substrate. The tape was laid between rocks so that goby sight was thought to be unimpeded and the weights were bounced off the substrate to also attract gobies.

2.2. Capture efficiency experiments

Capture efficiency experiments used round gobies collected between October 8 and October 14, 2010 by seine net from the Trent River. All individuals used in the main experiments were ≥50 mm TL, as previous field sampling and preliminary lab experiments showed that smaller fish are rarely sampled with this method. Prior to use in the experiments, gobies were held for 1–3 d in an opaque cylindrical tank with a basal area of 1 m^2 and a water depth of 1 m, and were fed a 10% body weight daily ration of shrimp pellets. Fish were placed in cylindrical opaque angling tanks 24 h before trials to allow acclimatization to the test environment.

Angling tanks had the same dimensions as the holding tank. These units were situated on a base 1 m above ground so that anglers were not visible to gobies and vice versa. Tanks were filled with sand-filtered Otonabee River water and allowed to reach room temperature (19 °C). To approximate field conditions where round gobies were typically found, a 60 mm thick gravel (20–40 mm diameter range of stones) substrate was used in these trials. The average PAR light intensity at substrate level was 59.5 $\mu m\,s^{-1}\,m^{-2}$.

Trials consisted of densities of 5, 10, and 15 fish per m^2 in two simulated habitat types, simple and complex. The simple habitat had a gravel bottom, while the complex habitat had a gravel bottom with approximately ten randomly placed rocks (200–320 mm diameter range of rocks). Angling was conducted with the same gear that was used for field sampling. Like field sampling, each trial consisted of two anglers fishing for a 20 min time period. Gobies were chosen for each trial at random by blindly dipping a net into the holding tank. Time of capture, sex, and length were recorded for each captured goby. Each density and habitat treatment was angled three times for a total of 18 trials. To examine the effect of body size on the capture efficiency following angling, round gobies were separated into small (≤70 mm TL) and large (>70 mm TL) size classes. These sizes have been identified as the point in which dreissenids are included as a major constituent of the round goby diet (Ray and Corkum, 1997).

Round gobies were also angled at temperatures of 15, 20, and 25 °C in the simple habitat type at densities of 10 per m^2 with 3 replicates at each temperature. Fish were held in angling tanks for 48 h before sampling to allow for temperature acclimation. The 25° tank was heated with a 1000 watt Blue M laboratory immersion heater. The 20° tank was heated with a 50 watt thermal compact heater, and the 15° tank was cooled with a constant flow of Otonabee River water (13° in April). The inflow produced negligible current (maximum flow <0.1 $m\,s^{-1}$). It should also be noted that gobies were euthanized with an overdose of MS222 following every experimental trial.

2.3. Data analysis

For the field study, round goby densities were estimated from removal data using the maximum weighted likelihood estimator (MWL) from the Carle and Strub depletion method (Carle and Strub, 1978). Changes in daily catch rates within the area of first introduction, upstream segment and downstream segment of the Trent River were tested with linear correlations.

For the lab experiment, paired *t*-tests were used to test for the effects of body size and sex on capture efficiency. The 5 per m^2 density trials were removed from the analysis of sex effect due to a lack of 3 individuals from each sex. The effects of habitat type and fish density on the capture efficiency of round gobies (percent of individuals captured) were analyzed using a two-way fully factorial ANOVA. To determine if estimated densities (MWL estimates) were different from actual densities, one-sample t-tests were performed on the slope and intercept of the line of best fit. The effect of temperature on the capture efficiency of round gobies was examined using a one-way ANOVA. All catch data were arcsine transformed to meet the assumptions of normality and all statistical analyses were conducted at alpha = 0.05.

3. Results

3.1. Field results

The MWL estimator only resulted in one rejected model (model acceptance at $p > 0.20$, Seaby and Henderson, 2007). Three sites failed to meet the criteria of the model (e.g., when no fish are captured during the first interval, followed by low catches in successive intervals) and 13% of sites were inestimable because the final two intervals were catches of zero. The abundance and density was estimated for the 76% of angled sites that contained round goby. MWL estimated densities were 5.8 per $m^2 \pm 0.78$ SE in the upstream segment, 9.6 per $m^2 \pm 1.3$ SE in the area of first introduction, and 3.9 per $m^2 \pm 0.97$ SE in the downstream segment (Table 1). Catch per angling trial did not change between 8:30 and 15:30 in the area of first introduction ($r = -0.12$, $p = 0.50$), or the upstream ($r = -0.14$, $p = 0.44$) and downstream segments ($r = -0.26$, $p = 0.27$).

The short field based angling experiment designed to determine the mean maximum distance travelled to an angled bait revealed that in <1 min, 90% of gobies would travel a mean maximum distance of 55 cm ± 2.4 SE (max 80 cm, $n = 37$ different gobies) to a continuously jigged bait. The remaining 10% would fail to pursue the bait from a distance greater than 50 cm.

3.2. Experimental results

Round gobies used for angling test trials ranged in size from 52 to 103 mm TL, with an average length of 72 mm TL. There was no effect of size on the capture efficiency of round gobies (paired t-test; $t = 1.32$, $p = 0.21$, $df = 17$). The average capture efficiency of females (93%) was higher than that of males (78%), and the difference was statistically significant (paired t-test; $t = 3.18$, $p = 0.009$, $df = 11$). There was no effect of habitat type (ANOVA; $F = 0.19$, $p = 0.67$, $df = 1$) or fish density (ANOVA, $F = 0.10$, $p = 0.91$, $df = 2$) on the capture efficiency of round gobies, and no interaction effect was recorded (ANOVA, $F = 0.36$, $p = 0.71$, $df = 2$).

There was a consistent relationship between actual and predicted round goby density (Fig. 1). The equation of the line of best fit was $y = 0.17 + 0.98(x)$. The intercept was not significantly different from zero (one sample t-test; $t = 0.17$, $p = 0.87$, $df = 17$) and the slope of the line of best fit was not different from one (one sample t-test; $t = 0.18$, $p = 0.86$, $df = 17$).

The average capture efficiency of round gobies in temperature trials was 90% at 15 °C, 90% at 20 °C, and 97% at 25 °C. Although capture efficiency was higher at 25 °C than the lower temperatures, there were no significant differences among treatments (ANOVA; $F = 1.22$, $p = 0.36$, $df = 2$).

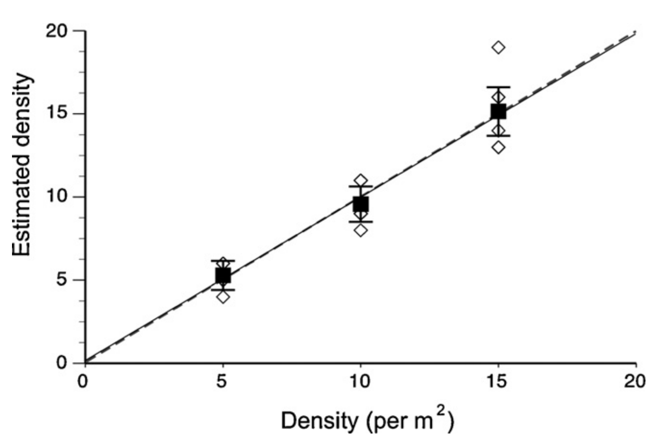

Fig. 1. Actual round goby density vs. estimated density (±SE) using the Carle and Strub (1978) method on angling removal data from lab experiments. Each density was angled for 6 trials in 1 m^2 tanks. Density results are pooled for simple and complex habitat trials. The solid line is the line of best-fit and the dashed line is $y = x$. White triangles represent estimated density from each trial, and the black squares represent the average estimated density ±1 SE.

4. Discussion

The angling technique described in this study is practical because it is inexpensive, simple, and allows for the rapid depletion of localized aggregations of round goby. The technique works well because, much like traditional active sampling techniques [e.g., seining nearshore fish communities (Pierce et al., 1990; Bayley and Herendeen, 2000), electrofishing for stream salmonids (Peterson et al., 2004), or trawling lakes (Tuten et al., 2010)], it exploits a species' habitat requirements (e.g., refuge use) and behavioural characteristics (e.g., aggression and/or home range size) to provide estimates for a population (also see Hayes et al., 1996). Angling can be used to measure CUE to give an assessment of relative round goby abundance, or used with the MWL estimator to provide an estimate of density under the assumption that immigration/emigration is negligible. The barrier itself does not restrict the movement of gobies, however the anglers spent little time at the edges of the apparatus and thus including distance travelled in the density estimates was deemed unnecessary. The barrier needed to be large enough so that two anglers could both present their bait at multiple angles to maximize detection probability and also capture more than only a few gobies while fishing in areas of low density. Although projecting the floating barrier to the bottom and reporting absolute density is inappropriate, the angling technique can provide relative density as long as anglers spend the majority of their time fishing near the centre of the barrier and assume that high site fidelity in gobies (Ray and Corkum, 2001) results in mostly short distance movements during a sampling trail.

There are several benefits to using this technique; for example, the specialized lateral line of the round goby (Charlebois et al., 1997) makes angling applicable in low light levels and in rocky habitat types where gobies may be sheltered. This method also requires a minimal amount of training if those collecting samples have angling experience. Although skill likely has some influence on the results, taking multiple samples from a particular area should help reduce the variation and provide a reasonable estimate. Sampling issues including decreased sensitivity to strike detection when in the deepest water in the Trent River (approximately 7 m), sampling in wind, and sampling in dense macrophytes may be improved by adding more weight to the line. The capture efficiency also differed between males and females, however the MWL estimate is robust to violations of the assumption of equal capture efficiency (Carle and Strub, 1978). As with other sampling methods such as beach seining and electrofishing (Pierce et al., 2001), angling should be attempted at night when round gobies are thought to most actively feed (Johnson et al., 2008). The inability to reliably sample gobies <50 mm TL may be more difficult to resolve and could be achieved using an alternative technique, for example minnow traps (Diana et al., 2006).

The angling removal technique proves to be a reliable estimate of large round goby density at temperatures of 15–25 °C. In our experience we have found that round gobies are aggressive towards bait in the field from May to October at temperatures within this range. This is consistent with a bioenergetics model that demonstrated food consumption changes drastically at temperature extremes but under the conditions present during our angling, changes little (see Lee and Johnson, 2005). Poikilotherms ultimately depend on temperature to dictate their activity levels (Wootton, 1998), thus a thorough investigation into the target species' temperature requirements is necessary prior to field work.

Plotting the cumulative variance of the catch indicated that ten sites must be sampled to produce the minimum variance estimate in the area of first introduction (high density) whereas the lower density upstream segment showed that variance ceased to decrease after five samples. The downstream area had too few sites with ≥1 goby to produce a minimum sample number. Even though our experimental results suggested otherwise, factors such as habitat may act as a source of variation in catch and should be considered when conducting estimates in the field. Indeed, along with thermal requirements, habitat and the target species' behavioural characteristics (e.g., aggressiveness, home range) must be considered when designing sampling protocols to estimate density, abundance, or the occurrence of fishes (Chao et al., 2005; MacKenzie and Royle, 2005; Lapointe et al., 2006; Ebner et al., 2008).

A broad coverage of the upstream and downstream "edges" of the population range was required to produce CUE and density estimates for the Trent River field study (Raby et al., 2010). Although the minimum number of sampling sites is relatively few when the MWL method produces an estimate for low density conditions, areas of low density may have high variability among angling sites (Table 1) and some trials can produce inconsistent rates of depletion, an inestimable parameter, and/or large confidence limits. These issues can be countered by either increasing the length of the angling period, removing the final angling interval if interval three and four are zero, or using the actual catch to produce conservative estimates. When provided by a successful angling trial, the MWL estimator for the CUE nearly always produced a two to three animal overestimate of actual catch, which is both consistent with experimental results (Fig. 1) and realistic given that some of the most cryptic fish will undoubtedly remain after angling.

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