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Ostracods and other prey survive passage through the gut of round goby (*Neogobius melanostomus*)

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ABSTRACT

The round goby (*Neogobius melanostomus*) is a Ponto-Caspian invader of North America that preys heavily on dreissenid mussels (*Dreissena polymorpha* and *Dreissena rostriformis bugensis*) in its native and invaded ranges. Efficient predation on mollusks by fish requires crushing of shells so that digestive enzymes can access soft tissue of the prey. The purpose of this experiment was to determine if dreissenids and other prey survive passage through the digestive system of round gobies. *N. melanostomus* were collected from Presque Isle Bay of Lake Erie and a nearby invaded pond (Erie Co., Pennsylvania) and placed individually into containers filled with aged tap water. After 24–48 h of isolation, feces were surveyed under a stereomicroscope for moving prey. Neutral red, which stains lysosomes of living cells, was also used to determine if intact bivalves were alive. No dreissenids survived passage through the gut of *N. melanostomus*, but variable numbers of other prey, including 16.6% of ostracods, were recovered alive. These results suggest that *N. melanostomus* is adapted to feeding on dreissenids, but round gobies may be less well-adapted to feeding on other hard-bodied prey. Passage of live prey through the gut also has implications on energy budgets of the round goby and its ability to function as a dispersive agent for other species.

Introduction

The round goby (*Neogobius melanostomus*) is native to the Ponto-Caspian region of central Eurasia and appears to have been introduced to North America by ballast water transfer (Brown and Stepien, 2009). In North America, it was first detected in the Saint Clair River in 1990 (Jude et al., 1992) and has since spread throughout much of the Laurentian Great Lakes and into the Mississippi River drainage (Brown and Stepien, 2009; reviewed by Kornis et al., 2012). The round goby has received considerable attention due to its ability to compete with native fishes (Janssen and Jude, 2001; Lauer, 2004), prey on the eggs and young of other fishes (Chotkowski and Marsden, 1999; Steinhart et al., 2004), and alter macroinvertebrate community composition (Jude et al., 1995; Krakowiak and Pennuto, 2008; Kuhns and Berg, 1999; Ratti and Barton, 2003).

The round goby is known to prey heavily on dreissenid mussels in both its native and invaded ranges (Jude et al., 1995; Simonović et al., 2001; Andraso et al., 2011a). Coevolution of the round goby with dreissenids in the Ponto-Caspian region appears to have resulted in anatomical and behavioral adaptations including the ability to break byssal threads of dreissenids using torsion (Houghton and Janssen, 2013) and a robust pharyngeal feeding apparatus that facilitates crushing of dreissenids (Ghedotti et al., 1995; Andraso et al., 2011b). Although round gobies larger than about 70 mm total length (TL) possess a pharyngeal apparatus well-suited to crushing hard-bodied prey (Andraso et al., 2011b) and the majority of dreissenids recovered from round gobies in one Lake Erie study were crushed (Andraso et al., 2011a), some dreissenids appear to pass through the digestive tract of round gobies intact (Andraso et al., 2011a).

Effective digestion of mollusks by fish appears to require crushing of shells so that digestive enzymes can access soft tissue of the prey (Aarnio and Bonsdorff, 1997). The presence of intact dreissenids in round gobies (Andraso et al., 2011a) suggests that they may be able to pass through the digestive tract alive. Passage of mollusk prey through the digestive system has been documented in other fish species. Haynes et al. (1985) demonstrated that the snail *Potamopyrgus jenkinsi* could survive at least a 6 h gut passage in rainbow trout (*Oncorhyncus mykiss*); Aarnio and Bonsdorff (1997) found that up to 92% of gastropods of the genus *Hydrobia* survived gut passage in juvenile flounder (*Platichthys flesus*); and Brown (2007) demonstrated that pea clams (Sphaeriidae) and valve snails (Valvatidae) readily survived passage through the digestive systems of humpback whitefish (*Coregonus pidschian*) and broad whitefish (*Coregonus nasus*). In addition to mollusks, ostracods (Vinyard, 1979; Aarnio and Bonsdorff, 1997) and copepod eggs (Conway et al., 1994) have also been shown to survive passage through the digestive systems of fish.

The objective of this study was to determine if dreissenids and other prey survive passage through the gut of round gobies. If prey do survive gut passage, it would cause us to reconsider energy budgets of the round

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goby and its ability to function as a dispersive agent for other species (Aarnio and Bonsdorff, 1997; Brown, 2007).

Methods

Sampling was conducted in Erie County, Pennsylvania between 18 June and 23 August, 2013. Round gobies were collected from three sites within Presque Isle State Park: the south pier of the shipping channel that connects Presque Isle Bay to the main body of Lake Erie (Andraso et al., 2011a,b); Marina Lake, a shallow, macrophyte-rich, 40 ha embayment that is connected to Presque Isle Bay by a short, navigable channel (Grant et al., 2012); and Presque Isle Bay near the entrance to Marina Lake (N 42° 08.951′, W 80° 06.715′). Round gobies were collected from Presque Isle State Park (hereafter referred to as Presque Isle) by a combination of methods that included angling with ultralight fishing gear; trawling with a 4.9 m semi-balloon bottom trawl with a 38 mm mesh body and a 32 mm mesh bag lined with 6.4 mm stretch knotless nylon netting (Brunson Net and Supply, Foley, Alabama); and seining with a 9.1 m × 1.2 m beach seine constructed of 4.8 mm stretch knotless nylon netting with a 1.2 m × 1.2 m × 1.2 m bag located at its center (Brunson Net and Supply, Foley, Alabama).

Round gobies were also collected from the Fairview Gravel Pit (N 42° 01.818′, W 80° 16.802′), a nearby pond located within the Lake Erie watershed. The site (hereafter referred to as the Gravel Pit) is a 4.0 ha spring-fed pond with a maximum depth of approximately 4 m and substrate consisting of sand, gravel, and scattered large rocks. Dense beds of Eurasian watermilfoil (*Myriophyllum spicatum*) grow in the Gravel Pit's clear waters, and it receives annual stockings of brown trout (*Salmo trutta*) from the Pennsylvania Fish and Boat Commission. Other fish species that occur in the Gravel Pit include largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), carp (*Cyprinus carpio*), and goldfish (*Carassius auratus*). Round gobies were first detected in the Gravel Pit in March 2010 and appear to be an established population (U.S. Geological Survey, specimen ID 269188). Round gobies were collected from the Gravel Pit by angling with ultralight fishing gear. The small size of the Gravel Pit, steeply sloped banks, and scattered large rocks make sampling methods such as seining, trawling, and electrofishing difficult at the site. Unlike the waters of Presque Isle, dreissenids have not been reported in the Gravel Pit, and inspection of the substrate and macrophytes at the site indicate that they are absent.

Upon capture, round gobies were placed in a 19 L bucket filled with water from the site and equipped with a battery-powered aerator. All specimens were returned to the laboratory within 2 h of capture. Round gobies were thoroughly rinsed under running tap water to dislodge any animals that may have been transported with them from the field then placed individually into 1 L or 2.5 L plastic containers equipped with air stones. In an effort to control for differences in oxygen consumption and excretion among different-sized round gobies that could lead to differences in water quality within holding containers, individuals smaller than about 85 mm TL were held in 1 L containers and larger individuals were held in 2.5 L containers. Holding containers were filled from a 76 L reservoir aquarium containing tap water that had been dechlorinated, aerated, and aged for at least 48 h. The reservoir aquarium was thoroughly cleaned prior to the study to ensure that it did not serve as a source of live animals. Laboratory temperature was maintained at 19.1–22.0 °C and photoperiod was 14 L:10D.

After being held in the laboratory for 24–48 h, round gobies were removed from containers and euthanized in a 300 mg/L solution of MS-222 (tricaine). After being euthanized, TL and sex were recorded and each round goby was dissected to ensure that all prey items had cleared the digestive system. Feces were collected by pouring the contents of the holding container over 60 μm plankton netting and rinsing the container with water from the 76 L reservoir aquarium. The plankton netting was then inverted over a petri plate and rinsed with a squirt bottle containing water from the reservoir aquarium to transfer feces into the petri plate.

Feces were teased apart and inspected under a Unitron Z10 stereo microscope (Unitron, Commack, New York). Living and dead prey were identified to a variety of taxonomic levels and enumerated. Movement served as the primary indicator of live prey. Stationary prey items were prodded to help assess if they were alive. Fragmented mollusks and those with no soft tissue inside of them were considered dead. If intact bivalves were recovered, neutral red stain (0.001%, 10 mg/L) was used as a secondary method to determine if specimens were alive (Cole and Hepper, 1954; Allison and Young, 1964).

Results and discussion

In total, 49 round gobies were analyzed for the presence of live prey in their feces (Table 1). Of the 38 specimens collected from Presque Isle, 26 were from the South Pier, five were from the entrance to Marina Lake, and seven were from Marina Lake proper. All round gobies from Presque Isle were collected between 18 June and 5 August, 2013. Eleven round gobies were collected from the Gravel Pit between 10 August and 23 August, 2013. Sex ratios and length distributions of round gobies from Presque Isle and the Gravel Pit were similar (Table 1).

All 49 round gobies used in the study survived the 24–48 h laboratory holding period. Inspection of digestive tracts after isolation in the laboratory revealed that residence time of prey was generally less than 24 h after capture, and digestive tracts of all round gobies were empty by 48 h after capture. A total of 4170 prey items were identified in feces of the 49 round gobies (Table 2). Feces of the 38 round gobies from Presque Isle contained a total of 775 prey items (range = 0–94, mean = 20, SD = 19 prey items per round goby). In contrast, feces of the 11 round gobies from the Gravel Pit contained a total of 3395 prey items (range = 74–748, mean = 309, SD = 240 prey items per round goby). Linear regression analyses revealed no relationship between TL and number of prey items recovered from feces of round gobies from Presque Isle ($F_{1,36} = 2.277$, $p = 0.140$, adjusted $r^2 = 0.033$), but number of prey items in feces increased with TL for round gobies from the Gravel Pit ($F_{1,9} = 5.359$, $p = 0.046$, adjusted $r^2 = 0.304$).

Based on items identified in their feces, the diets of round gobies from Presque Isle and the Gravel Pit appear to be markedly different (Table 2). Mollusks (dreissenids, pea clams, snails, and limpets) comprised 46.2% of prey items in round gobies from Presque Isle. Ostracods (22.2%) and dipterans (14.5%) were the next most abundant items in round gobies from Presque Isle, and a variety of other crustaceans, insects, and arachnids were also identified. In contrast, cladocerans of the genus *Daphnia* (67.4%) and ostracods (25.6%) numerically dominated prey recovered from the feces of round gobies from the Gravel Pit. Only 19 of 3395 (0.6%) prey items in round gobies from the Gravel Pit were mollusks. However, it should be noted that determining diet based on fecal analysis is probably less accurate than stomach content analysis because many soft-bodied prey items are likely digested beyond recognition by the time they pass through the digestive tract.

Of the 4170 prey items identified in the feces of the 49 round gobies used in this study, 184 (4.4%) were alive (Table 2). Live prey items were identified in the feces of 16 of the 49 round gobies (32.7%). Feces of round gobies from Presque Isle contained 775 prey items, 16 (2.1%) of

Table 1
Sex and length composition of 49 round gobies analyzed for live prey in their feces. Presque Isle Bay, Lake Erie (Presque Isle); Fairview Gravel Pit, Erie Co., Pennsylvania (Gravel Pit).

Site	n	F:M	Total length, TL (mm)		
			Range	Mean	s.d.
Presque Isle	38	16:22 (0.73)	55–137	88	22
Gravel Pit	11	5:6 (0.83)	58–113	82	18
Total	49	21:28 (0.75)	55–137	87	21