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Changes in age-0 yellow perch habitat and prey selection across a round goby invasion front

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ABSTRACT

Round gobies (*Neogobius melanostomus*) are reported to have negative impacts on benthic invertebrate prey and are now highly abundant throughout most of the Laurentian Great Lakes. This study used the initial spread of round gobies north and south from the Milwaukee Harbor as a natural experiment to assess the competitive interactions between age-0 yellow perch and round gobies in western Lake Michigan. Habitat selection and diet of age-0 yellow perch in relation to round goby abundance were analyzed using fish captured in micro-mesh gillnets in 2006 and 2007 at six study locations from Sheboygan to Wind Point, Wisconsin. An age-0 yellow perch shift in habitat preference from rock to sand was associated with relatively high round goby abundance at rock sites. An increase in round goby catch per unit effort was also correlated with a decrease in benthic prey (chironomid larvae + amphipods) abundance at rock sites and occurrence of these prey items in age-0 yellow perch stomach contents. Our results suggest that age-0 yellow perch may have undergone local niche shifts as a consequence of competition with round gobies. Further study may help elucidate the causal mechanism behind our observations and determine what effect round gobies are having on the yellow perch population of western Lake Michigan, as a whole.

Introduction

Invasions of non-native organisms are altering ecosystems and the Laurentian Great Lakes have had several invaders, e.g. sea lamprey (*Petromyzon marinus*, a trophically top-down invader) and dreissenid mussels (a middle-out invader), that rendered their ecological communities vastly different than they were a century ago. Among the significant invaders is the round goby (*Neogobius melanostomus*), which was first detected in 1990 (Jude et al., 1992). Round gobies are associated with dramatic reductions or extirpations of certain native benthic species such as mottled sculpin (*Cottus bairdi*; Janssen and Jude, 2001; Lauer et al., 2004), and johnny darters (*Etheostoma nigrum*; Lauer et al., 2004), with other benthic fishes likely at risk (Poos et al., 2010).

Mechanisms of extirpation or population reduction by non-indigenous species can be difficult to demonstrate with predation likely the easiest to reveal (e.g. sea lamprey predation on lake trout (*Salvelinus namaycush*)). Competition is more difficult to demonstrate in part because, a weakened losing competitor may be more vulnerable to predation. For example, Rice et al. (1987) argued that, for bloater (*Coregonus hoyi*) in the Great Lakes, exploitative competition for zooplankton with alewife (*Alosa pseudoharengus*) could reduce growth and/or predator escape capability and thus render poor competitors more susceptible to predation.

We use a natural field experiment to demonstrate a general hypothesis that round gobies can compete with yellow perch (*Perca flavescens*), at least under the conditions of western Lake Michigan. We discuss nuances of western Lake Michigan further in the Discussion section but here note that macrophytic vascular vegetation, a common feature of yellow perch habitats in smaller lakes and ponds, are absent from the open coasts of Lake Michigan. Instead, the preferred habitat of both round gobies and yellow perch in western Lake Michigan is rock habitat (see Kornis et al., 2012 for a review of round goby ecology and Janssen and Luebke, 2004; Janssen et al., 2005 for yellow perch habitat selection).

One potential consequence of competition, hence a potential test, is niche shifts (competitive displacement) between competing species. Niche shifts have been used to justify competition as the operating mechanism in relatively easily observed organisms such as birds (Diamond, 1970), lizards (Schoener, 1975), and plants (Grace and Wetzel, 1981). Fishes are less easily observed than plants and diurnally active terrestrial vertebrates, but the observational challenge does not mean that niche shifts do not exist. Interspecific competition in fishes has been assessed using nonindigenous species (NIS; sensu Chisolm, 2009) introductions and resulting niche shifts as natural experiments in the Laurentian Great Lakes (Crowder, 1986) as well as the African Great Lakes (Wanink and Witte, 2000). Wanink and Witte (2000)

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documented niche shifts in habitat selection and prey preferences in dagaa (*Rastrineobola argentea*), by following the dagaa population before the Nile perch (*Lates niloticus*) introduction as well as through the Nile perch's spread and population boom in Lake Victoria. In Lake Michigan, Crowder (1986) used the introduction of nonindigenous alewife as a natural experiment to infer competition with bloater. Crowder (1986) theorized that interspecific exploitative competition for zooplankton prey was the driving factor behind observed habitat and prey shifts of bloater after the alewife's introduction.

While observational studies of niche shifts are an important tool to assess interspecific competition in the wild, they lack the ability to distinguish what competitive mechanisms are causing observed differences (Matthews, 1998). Experimental manipulation of the densities of competing species and limiting resources in enclosed systems have offered researchers the ability to assess these underlying mechanisms. Studies on interspecific competition between fish species often use experimental ponds (Werner and Hall, 1977) and enclosures (Duncan et al., 2011) that allow species densities and habitats to be manipulated and controlled. Manipulative studies allow researchers to precisely control the factors being assessed. However, mesocosm experiments often do not accurately represent conditions in the wild (ex. unreal fish densities or habitats), hence such enclosure experiments are more likely to show competition than unenclosed experiments (Schoener, 1983). While, on the other hand, studies of competition in the wild, often due to their inherent size and natural variability, are criticized for not controlling enough factors to adequately assess their contribution to an observed response.

The goal of the present study was to use the population density gradient along a round goby invasion front as a natural experiment to assess interspecific competition between round goby and a native species, yellow perch. We focus our study on exploitative competition. However, round gobies are known to be antagonistic toward other species and conspecifics (Dubs and Corkum, 1996; Ray and Corkum, 2001). Interference competition between round gobies and age-0 yellow perch is also possible, and both forms of competition are not mutually exclusive. Our study was performed during the initial invasion of the round goby to the western shores of Lake Michigan originating at Milwaukee, Wisconsin (pers. comm. Pradeep Hirethota WI DNR, Milwaukee, Wisconsin). Round gobies were first observed in the Milwaukee Harbor in 1999. They were first seen outside of the harbor in 2004 and slowly radiated north and south along the coastline from this initial introduction site (Houghton pers. obs.).

The progression of the round goby invasion presented a unique opportunity to assess changes in two niche dimensions of age-0 yellow perch, habitat and prey, along a gradient of round goby densities in the wild. Previous work using similar sampling methods (micro-mesh gillnets set on rock versus sand substrates) showed a strong site affinity of age-0 yellow perch toward rock substrates (Janssen and Luebke, 2004), which are also the preferred habitat for round gobies (Kornis et al., 2012). Habitat and prey use by age-0 yellow perch occurring with round gobies along the round goby invasion front was used to determine the effect of round gobies on age-0 yellow perch in the wild. Effects of round goby abundance on rock associated benthic invertebrates were also assessed with the goal of determining if competitive displacement of age-0 yellow perch may result as a consequence of exploitative competition for prey. We also used our data set as an opportunity to assess the variation of both invertebrate prey abundance at rock habitats and the occurrence of invertebrate prey in age-0 yellow perch stomach contents. Patchiness could lead age-0 yellow perch to use search behaviors effective at finding clusters of prey (Humphries et al., 2012). In diving predators, such as seals, patch quality and prey encounter rates are an important factor in the decision to forage on a patch of prey or continue to search (Thompson and Fedak, 2001). Likewise, it is likely that prey patchiness is an important factor in the prey and habitat choices made by age-0 yellow perch. We therefore had three general hypotheses:

Hypothesis 1. Age-0 yellow perch habitat selection changes with increasing numbers of round gobies at rock sites.

Hypothesis 2. There is evidence of exploitative competition: benthic invertebrate abundance at rock sites decreases with increasing round goby densities at rock sites.

Hypothesis 3. Age-0 yellow perch undergo a diet shift: age-0 yellow perch feed on lower amounts of benthic invertebrates when round gobies are present at rock sites.

Competitive displacement in the form of a reduction of habitat or prey use by age-0 yellow perch as a response to increasing round goby abundance would provide evidence consistent with interspecific competition between the two species (Hypotheses 1 and 3) while a decrease in benthic invertebrate abundance with round goby invasion may indicate that prey becomes a limiting resource as round goby abundance increases (Hypothesis 2).

Methods

Habitat selection of age-0 yellow perch was assessed at six locations along western Lake Michigan. Each study location consisted of one pair of sites, one rock and one sand. Western Lake Michigan's littoral habitat is composed of a mosaic of different rock, sand, and clay outcroppings (Janssen et al., 2005). Sampling locations were chosen for their proximity to both rock and sand substrates by analyzing aerial photographs of the coastline captured in 2005. Promising locations determined from the photographs, were ground-truthed for suitable substrate type by wading, snorkeling, and scuba diving. Final study locations, from north to south, were: Sheboygan, Donges Bay, Fox Point, Whitefish Bay, Milwaukee, and Wind Point, a longitudinal distance of 112 km (Fig. 1). Across the study locations, “rock” sites were composed of a range of different types of hard substrate consisting of bedrock (Silurian-dolomite limestone at Sheboygan and Wind Point and Devonian mudstone at Fox Point) and clay outcroppings overlain by glacial till ranging in size from cobble to boulders (the other three locations). “Sand” sites at all locations were composed almost entirely of sand deposited from coastal moraine bluffs, with only occasional rocks present. We could find no more than six suitable locations and the yellow perch population becomes scarce north of our most northern location, Sheboygan (Pradeep Hirethota, WI DNR, pers. comm.). The exact areal dimensions of rock patches were unknown because the aerial photographs were only effective to a depth of about 6–8 m.

Habitat selection of age-0 yellow perch was estimated using catch-per-unit-effort (CPUE) from micromesh gillnetting performed at each of the six study locations (replicates). Age-0 yellow perch and round gobies CPUEs were defined as the total number of each species captured in overnight gill net sets. Within each location one gill net was set at the rock site and one at the sand site, resulting in six pairs of gill-net samples per year (Fig. 1). Pairs of rock and sand sites were within 5 km of each other (most within 1 km). Gill net sets were performed in late August and early September, of 2006 and 2007. GPS coordinates for both ends of a net were recorded and the between year variation in study site position was generally less than 50 m.

Gill nets consisted of two panels, one 6 mm and one 8 mm bar monofilament. Each panel was 1.2 m high and 30 m long (60 m total gill-net length). Similar gill nets are now used around Lake Michigan for yearly age-0 yellow perch assessment, and are known to catch age-0 yellow perch and mid-sized round gobies (Diana et al., 2006; Janssen and Luebke, 2004) although it is possible that some small age one perch may have contributed to the catches. At shallow water locations (Sheboygan, Fox Point, Whitefish Bay, and Wind Point), gill nets were set in ~1.5 m of water by wading from shore. These four locations had very large boulders or blocks of bedrock making operating from a power boat hazardous. Gill nets were set in ~4 m depth at locations accessed by boat (Donges Bay and