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Changes in growth and diet of smallmouth bass following invasion of Lake Erie by the round goby

Derek P. Crane [a,*], Donald W. Einhouse [b]

[a] Lake Superior State University, 650 West Easterday Avenue, Sault Ste. Marie, MI 49783, USA
[b] New York State Department of Environmental Conservation, Lake Erie Fisheries Research Unit, Dunkirk, NY 14048, USA

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ABSTRACT

Upon invading the Great Lakes, the round goby (*Neogobius melanostomus*) was rapidly incorporated in the diet of native predators. The smallmouth bass (*Micropterus dolomieu*) is an abundant nearshore predator and readily consumes round goby; however, the effects of round goby on growth of smallmouth bass have not been examined for a wide range of smallmouth bass ages. We compared smallmouth bass diets from New York waters of Lake Erie before and after the invasion of round goby and analyzed 19 years (pre-round goby = 1993–1998; post-round goby = 2001–2013) of length-at-age data (ages 2–10) to investigate the effects of round goby on growth of smallmouth bass. Analysis of variance was used to test hypotheses about the effects of sex, age, and round goby presence on length-at-age of smallmouth bass, and von Bertalanffy models were used to identify changes in growth patterns. Crayfish (Decapoda spp.) were the most common prey of smallmouth bass prior to invasion of round goby (observed in 53.5% of diets). Round goby became the dominant prey of smallmouth bass after its invasion (observed in 73.3% of diets), and crayfish were only observed in 5.8% of diets in the post-round goby time period. Length-at-age increased following invasion of round goby and the greatest increases in length (11–15%) were observed for ages 2–4. The von Bertalanffy growth coefficient, K, increased for both male and female smallmouth bass. Results from this study demonstrate how aquatic invaders can rapidly change population characteristics of native predators.

Introduction

Invasive species can have substantial effects on population characteristics and life histories of native fauna. The Great Lakes is one of the most invaded aquatic ecosystems in the world (Ricciardi, 2006), and the round goby (*Neogobius melanostomus*) is one of the most successful invaders of the Great Lakes and its tributaries. Round goby were first detected in the St. Clair River in 1990 (Jude et al., 1992) and have continued to spread throughout the Great Lakes, its connecting channels, tributaries, and adjacent lakes over the past 25 years (Kornis et al., 2012). Densities of 1–14 round goby m^{-2} are frequently reported (Barton et al., 2005; Johnson et al., 2005a; Ray and Corkum, 2001), and densities of >100 individuals m^{-2} have been observed (Chotkowski and Marsden, 1999). The round goby is a benthic dwelling species and able to successfully occupy a variety of habitats spanning a broad range of thermal regimes, salinities, dissolved oxygen levels, and physical structure (Kornis et al., 2012). In the Great Lakes round goby are found in habitats ranging from coastal wetlands (Cooper et al., 2007; Farrell et al., 2010) to 150 m deep profundal zones (Walsh et al., 2007). Restructuring of energy (Campbell et al., 2009; Johnson et al., 2005b) and contaminant pathways (Hogan et al., 2007), extirpation and decreased abundance of native benthic fishes (Janssen and Jude, 2001; Kornis et al., 2012; Lauer, 2004), dramatic shifts in diet (Johnson et al., 2005b), and associated changes in body condition (Crane et al., 2015) and growth of piscivores (Stapanian et al., 2011; Steinhart et al., 2004a) have been attributed to the round goby.

Growth is a defining life-history characteristic and is frequently studied by biologists. Growth characteristics can have important implications for other life history traits such as age-at-maturity and mortality, as has been well studied for fishes (He and Stewart, 2001; He and Stewart, 2002; Madenjian et al., 1996; Pauly, 1980). Resource managers often evaluate growth of fishes to assess management practices or productivity of a body of water for a particular species. Somatic growth of fishes is dictated by a number of factors including competition, environmental conditions, forage availability and quality, maturity status, and activity (Diana, 2004). Invasive prey fishes have the potential to alter growth of native piscivores by causing shifts in diet and foraging strategies and affecting the availability of native prey. Although the round goby has resulted in decreased abundance of native benthic prey fishes in some regions of the Great Lakes (J.M. Farrell, State University of New York – College of Environmental Science and Forestry, unpublished data, March 2014; Janssen and Jude, 2001; Lauer, 2004), it has also

* Corresponding author at: Coastal Carolina University, 111 Chanticleer Drive East, Conway, SC 29526, USA. Tel.: +1 843 349 4065.
E-mail address: dcrane@coastal.edu (D.P. Crane).

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become an important food resource for many native piscivores (Dietrich et al., 2006; Jacobs et al., 2010; Johnson et al., 2005b; Kornis et al., 2012; Madenjian et al., 2011). Thus, the round goby has the potential to significantly change the growth of predatory fishes in the Great Lakes (Stapanian et al., 2011; Steinhart et al., 2004a).

The smallmouth bass (*Micropterus dolomieu*) is a relatively abundant predator in many shallow water areas (defined here as water depth < 15 m) of the Great Lakes, its connecting channels, and tributaries (Einhouse et al., 2002; Fielder et al., 2013; Lantry, 2014; McCullough and Gordon, 2014). Smallmouth bass are most frequently found in areas with coarse rocky substrate (Brown et al., 2009) which are also preferred by round goby (Johnson et al., 2005a; Kornis et al., 2012; Kornis et al., 2013; Ray and Corkum, 2001). Following invasion of Lake Erie by the round goby, round goby quickly became the dominant prey item of smallmouth bass (Johnson et al., 2005b; Steinhart et al., 2004a). Based on proportion of diet, round goby is consumed more by smallmouth bass than any other Lake Erie fish, except burbot (*Lota lota*), which consume round goby in similar proportions as smallmouth bass (Johnson et al., 2005b).

The effect of round goby on growth of smallmouth bass in the Great Lakes has not been investigated for most smallmouth bass ages. Steinhart et al., (2004a) investigated changes in growth of age-0 smallmouth bass in western Lake Erie following invasion of round goby, and McCullough (2012) and Lantry (2014) documented long-term trends in smallmouth bass length-at-age for St. Lawrence River and Lake Ontario populations. However, examining the effects of round goby on smallmouth bass growth in the St. Lawrence River and eastern Lake Ontario was confounded by compensatory growth observed prior to invasion of round goby (Lantry, 2014). Sex-based differences in the response of smallmouth bass growth to the presence of round goby have also not been explored. The round goby is an egg predator and its presence has energetic costs for male smallmouth bass during nest guarding, which are not incurred by females (Steinhart et al., 2005). Here, we examine changes in diet and growth of smallmouth bass following invasion of eastern Lake Erie by round goby. The objectives of this study were to (1) describe the diet of smallmouth bass prior to and after invasion of round goby, (2) identify changes in smallmouth bass length-at-age and differences in growth trends between the pre- and post-invasion time periods, and (3) determine if growth responses to the invasion of round goby differed between male and female smallmouth bass. We hypothesized that (1) similar to other areas of the Great Lakes (Johnson et al., 2005b; Lantry, 2014; Reyjol et al., 2010; Steinhart et al., 2004a; Taraborelli et al., 2010), round goby is an important part of smallmouth bass diets in New York waters of eastern Lake Erie, (2) smallmouth bass growth increased following round goby invasion, (3) and females experienced greater increases in growth than males.

Methods

Study system and fish collection

Lake Erie is the shallowest and most productive of the Laurentian Great Lakes. The nearshore zone of the eastern basin of Lake Erie (Fig. 1) is classified as oligotrophic to mesotrophic (Markham, 2014) and supports a diverse community of warm- and coolwater fishes. Smallmouth bass were collected from 1981 to 2013 as part of the New York State Department of Environmental Conservation (NYSDEC) Eastern Lake Erie Warmwater Fish Community Assessment. From 1981 to 1992, fish were collected with multifilament gill nets during early September through early October. Nets were fished overnight at fixed stations in water <12 m. Beginning in 1993, the sampling strategy was altered to align with an interagency gill net assessment for Lake Erie (Ryan et al., 1993). This investigation primarily focuses on the 1993–2013 time period. Sampling during 1993–2013 was conducted with monofilament gill nets from early September through early October at fixed and randomly selected locations. Sampling occurred in two depth strata: <15 m (9 fixed and 16 randomly selected locations per year) and 15–<30 m (15 randomly selected locations per year). Nets were set from 1200 to 1700 h and retrieved from sunrise through 1200 h. All waters <30 m in the New York portion of Lake Erie were available for sampling. Nets were fished on the bottom at all locations but were not set if an area selected for sampling included the thermocline. The gill nets were 213.4 m long and consisted of 14, 15.2 m long × 1.8 m deep panels. Each panel contained a single size stretch mesh ranging from 3.2 to 15.2 cm and the panels were randomly ordered. The 15.2 cm panel was discontinued in 2005 due to poor performance and excessive net damage. Tangled, damaged, or fouled nets were omitted. The total length (TL; nearest mm) and sex of each smallmouth bass were recorded, and scales and sagittal otoliths were collected for age determination. Beginning in 2000, smallmouth bass were infrequently sub-sampled if the catch was >10 for a particular mesh size, during a single net set.

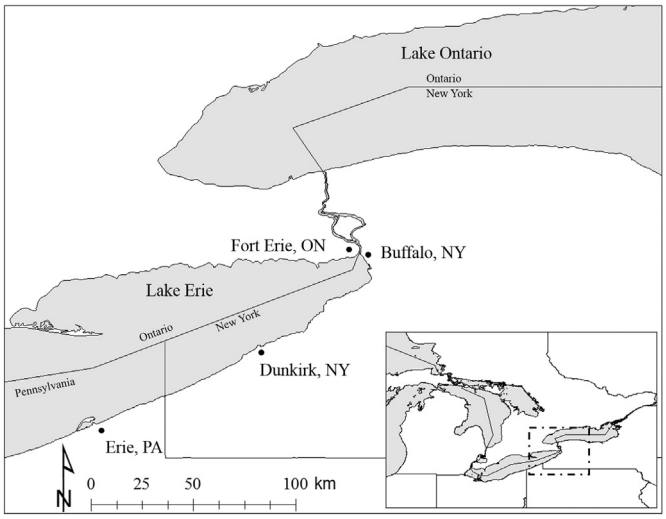

Fig. 1. Map of New York waters of eastern Lake Erie.

The smallmouth bass dataset was divided into pre- and post-round goby time periods based on annual forage trawl survey data. Round goby were first detected in annual forage trawls in New York waters of eastern Lake Erie in 1999 (Markham and Einhouse, 2014). Therefore, prior to 1999 was defined as the pre-round goby time period and 1999–2013 was defined as the post-round goby time period. Diet data were collected opportunistically and available for 1985–1987, 1992, 1999–2002, and 2006–2007. Because the main objective of the diet analysis was to demonstrate change in smallmouth bass diet following invasion of the round goby in eastern Lake Erie, all available diet data were included. For growth analyses, the 1981–2013 dataset was reduced to prevent potential biases related to age determination methods, gear selectivity, and age distribution of the catch in relation to invasion of round goby. First, samples collected prior to 1993 were removed due to changes in age determination protocols beginning in 1993. Prior to 1993, scales were used to estimate ages of all fish. From 1993 to 2013 scales were used to estimate ages of small fish and otoliths were used to estimate ages of larger fish (see below). Next, smallmouth bass that lived in both the pre- and post-round goby time periods were removed to make more reliable growth comparisons between time periods. Finally, fish <age-2 and >age-10 were removed because smallmouth bass were not fully recruited to the gill nets until age-2 and catches for individuals >age-10 were rare (only 2% of smallmouth bass included in the pre−/post-round goby time periods were > age-10). Subsequently, all fish collected during 1999 and 2000 were omitted from growth analyses (except for use in time series plots of length-at-age) because no fish could satisfy the requirements of being ≥age-2 and only living during either the pre- or post-round goby time period.

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