Final Report: Impacts and Drivers of Round Goby Invasion in Great Lakes Tributaries

SECTION A. SUMMARY

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Abstract

The abundance and persistence of the invasive round goby (*Neogobius melanostomus*) has often resulted in antagonistic interactions between the invasive and its native competitors. In this study, I quantified the consequences and environmental context of these interactions in Great Lakes tributaries. Specifically, I aimed to identify changes in feeding and reproductive behavior in a native competitor in response to goby invasion, identify ways to increase regular stream monitoring by partnering with citizen science programs, and quantify the environmental context of successful goby invasion. I conducted fish and habitat surveys over three years in seven Michigan tributaries to the Great Lakes. Feeding and reproductive behaviors were examined for round goby and native Johnny darters (*Etheostoma nigrum*) to identify changes associated with invasion. Results suggest that Johnny darter feeding strategies and reproductive timing change when goby are present. Citizen science may provide valuable monitoring for these negative interactions, despite differences in sampling methodology. Volunteer-produced data exhibited systematic differences when compared to traditional research, but differences were observed in predictable taxonomic groups and did not impact stream quality assessment. Finally, data was combined to produce a model of the environmental context of sites invaded by round goby. Low native species diversity, altered riparian land cover, and high metal concentrations were common among invaded sites. Information on the nature of round goby invasion, and how best to prevent and mitigate further spread can ultimately allow more efficient management of native species and ecosystems to increase resistance to and reduce the impacts of invasion.

Keywords: Round goby, invasion, tributaries, competition, citizen science

Executive Summary

One of the foremost concerns for the Great Lakes is the introduction of non-indigenous species. Those that become invasive (aquatic invasive species, or AIS) can cause declines in native biodiversity, negatively affect water quality, and disrupt food webs and ecological processes, reducing overall environmental health. While much of the focus on invasive species is on the Great Lakes themselves, tributaries are of increasing concern due to the secondary spread of AIS to inland waters. Tributaries serve

as important spawning and nursery habitat for some life stages of many Great Lake fishes, and are inextricably linked to the nutrient, contaminant, and biological processes occurring in the Great Lakes.

The round goby (*Neogobius melanostomus*), a benthic fish invasive in the Great Lakes, is becoming increasingly common in inland waters of the Great Lakes. Round goby is a novel competitor to many species of stream fishes and is a known predator of eggs for migratory lake fishes like lake trout, sturgeon, walleye, and smallmouth bass. Tributaries that traverse urban or heavily agricultural areas may be particularly vulnerable to the impacts of invasive species because these habitats are exposed to multiple stressors which may weaken the resilience of native communities against invasive species.

In this project, we surveyed seven Great Lakes tributaries to determine the extent of round goby distribution, their impacts on native species, and how to better manage them in the future. We identified competition between round goby and native species (specifically Johnny darter) over food and reproductive resources which resulted in a decline in native species. A disruption of the species composition in stream fish assemblages may have lasting impacts on ecosystem function. However, a greater understanding of round goby biology may allow more effective management. For example, based on our results we would expect to find large round goby populations in areas close to a source population, with low native diversity, with urban and agricultural land use near the water's edge, and in areas high in chemical contaminants. We thus suggest that prioritizing conservation of native ecosystems is a way to increase resistance to invasion.

Finally, we partnered with watershed organizations that host citizen science events to monitor stream quality. We found that data produced by citizen volunteers has some consistent differences to data produced by academic researchers but reaches similar conclusions about stream quality. We thus suggest that investing in citizen science is a great way to increase monitoring across the Great Lakes basin, to identify streams and rivers that require restoration, areas where human activities may be negatively influencing aquatic habitat, and potentially identifying new areas of invasion. Importantly, watershed organizations also have decades of data on Great Lakes tributaries that can provide background information on invasion and overall ecosystem health. We thus suggest that watershed organizations are an under-utilized resource and would benefit from further citizen and agency support.

SECTION B. ACCOMPLISHMENTS

Introduction

Invasive species can impact all levels of biological organization from genes to ecosystems. Invaders can cause declines in native biodiversity (e.g., Molnar et al. 2008) and disrupt community composition (Schultz and Dibble 2012) and ecological processes (Ashton et al. 2005; Vilà et al. 2011). Because of the large potential for non-native species to alter ecosystems, investment in invasive species research is among the foremost priorities for biological conservation. Thoroughly documenting the role of an invader is an important step in designing effective prevention and mitigation strategies for invasive species. This is especially important for widespread, rapidly invading species where a full understanding of their ecological niche can help to prioritize conservation resources (Byers et al. 2002).

One of the more prolific invaders in North America in recent years has been the round goby (*Neogobius melanostomus*). In the last thirty years, round goby has spread to all five Great Lakes, and is currently undergoing secondary invasion to tributaries and inland lakes (Campbell and Tiegs 2012). While understanding the nature of this invasion has been a research priority in the Great Lakes, most of the current knowledge about round goby in North America was gained directly from lake populations. Information from the lakes provides valuable background data upon which to base predictions and potential management strategies, but application of knowledge gained from one system to another is not always straightforward. Understanding the context of the current secondary spread of round goby across the Great Lakes basin would provide the best opportunity to curtail consequences on native species and ecosystems.

Through this research, I investigated the nature of round goby secondary spread and answered some key questions about the impact of this invasion in Great Lakes tributaries.

Goal 1: I identified the specific consequences incurred by a native competitor along the round goby invasion front.

Goal 2: I combined physical, biological, chemical, and land use data to develop a model which identified the environmental characteristics common among areas invaded by round goby.

Goal 3: I proposed a means for increasing monitoring efforts for degradation of site quality, and potential methods for early identification of invaders by evaluating citizen science data.

Project Narrative

I examined the relationship between stressors and invasion success by comparing existing stress levels to round goby presence and abundance in seven Great Lakes tributaries in Michigan (Au Sable, Clinton, Muskegon, Ocqueoc, Rifle, Rouge, & Stony Creek). Three stream reaches from each river were sampled, including locations where round goby were present, or where only native species occurred. I was thus able to compare sites between invaded and uninvaded habitats at multiple stream orders.

At each sampling event, I also conducted a Rapid Habitat Assessment (EPA - Barbour et al. 1999) to determine overall site quality. Water quality and biotic metrics including temperature, dissolved oxygen, conductivity, turbidity, dissolved metal concentrations, presence of sensitive benthic invertebrate taxa, and fish communities were measured for each site during the spring spawning season over three years (2015-2017).

Round goby and native competitors (Johnny darter, *Etheostoma nigrum*) were dissected in the lab for gut content and gonad analyses. Muscle tissue was harvested and analyzed for stable isotopes of carbon and nitrogen to identify competitive interactions between round goby and native species. Overall, I produced evidence for competition between round goby and the native Johnny darter that resulted in a decline in darter abundance in the sites with the greatest underlying stress levels. While this decline in darter abundance was not observed at sites which were higher in overall quality, the evidence for interspecific competition over food and reproductive resources was common to all watersheds.

Macroinvertebrate monitoring data were obtained from two watershed organizations which hold annual citizen science events – the Friends of the Rouge and the Clinton River Watershed Council. Citizen-produced data was directly compared to macroinvertebrate samples obtained during my sampling to determine differences between the two collection types. This comparison allowed the identification of systematic differences in volunteer and ‘academic’ assessments that can help integrate watershed

organization data into a larger research framework in the future. I also identified areas where citizen and academic assessments fall short and provide suggestions for how they can be better utilized in the future.

Finally, I evaluated the composition of upstream riparian land cover (Homer et al. 2015) for all sites using ArcGIS. Land cover data were combined with site assessments for a robust analysis of factors influencing invasion, establishment, and impacts of round goby. I found that round goby populations were largest in areas closest to source populations (lakes in this case) that had been invaded for some time. Additionally, sites with low native diversity, high proportions of anthropogenic land use in riparian buffers, mid-size stream habitat, and high concentrations of dissolved copper were most likely to support large populations of round goby. Given these data, prioritizing conservation of native species and maintaining adequate riparian buffers may provide increased resilience to invasion.

Research/Management Implications

Through this research, system-specific data on round goby, one of the Great Lakes' most prolific invaders, was produced. Fully characterizing the biology of this invader can ultimately inform management of round goby populations throughout the Great Lakes basin and potentially elsewhere. My research has also contributed information on the round goby's tolerance levels in its introduced range. In assessing correlation of round goby presence and abundance with various environmental characteristics, I have provided valuable information for the management and control of this invasive species.

This work further adds to the discussion of streams and rivers as an important vector for secondary dispersal of invasive species (Bronnenhuber et al. 2011). Although this concept is not new, work on invasion in lotic waters has lagged in comparison to research on the Great Lakes themselves. Because rivers are more intimately linked to the landscape than lakes, they provide important context for species invasions. Understanding the interaction between anthropogenic activities and the associated consequences for invasion success is critical for combatting the secondary spread of nonnative species (Blanchet et al. 2009). While the interaction between landscape and ecosystem function of rivers has been studied for a long time (Allan 2004), how these interactions influence invasion is relatively novel. This research has thus contributed to understanding the linkage between tributary, lake, and terrestrial ecosystems.

Potential Applications, Benefits, and Impacts

This work has resulted in a method of identifying areas vulnerable to round goby invasion across the Great Lakes. By increasing understanding the environmental, biological, and chemical context associated with successful invasion, this work not only tests long-standing ecological hypotheses about invasion, but also adds to existing knowledge of the environmental tolerance of round goby. This information may ultimately contribute to efficient methods to identify areas potentially vulnerable to round goby invasion and contribute to effective prevention strategies.

Finally, as part of this research I worked closely with a local nonprofit watershed organization, the Friends of the Rouge. My research has identified consistent differences in data produced by citizen volunteers and that from traditional academic monitoring. Understanding these differences will allow for greater utilization of the decades of information watershed organizations have produced on tributaries to the Great Lakes. This partnership further allowed for the direct engagement of over 160 citizen volunteers over the course of the funding period. As part of citizen science events, volunteers were able to learn about their watershed, why it is worth monitoring and conserving, and had face-to-face interactions with the people driving stewardship and research in the area.

Future applications of this project will include more informed management practices for round goby invasion by understanding the environmental requirements for successful invasion. This will allow efficient concentration of management and conservation resources by identifying areas most vulnerable to round goby invasion and impacts. I have also provided recommendations for increasing resilience of native ecosystems to invasion. From a long-term perspective, ideas generated in this research can be applied to urban planning perspectives; incorporation of the concepts outlined in this project could protect future biologic and economic interests, particularly in urban systems. This would ultimately reduce the economic consequences of invasion and better maintain the biological integrity of Great Lakes tributaries.

Research Outputs or Products

Presentations (*undergraduate presenters underlined*)
Aug 2018 Ecological Society of America, New Orleans, LA (oral presentation)

Krabbenhoft, C.A.* and D.R. Kashian. Response of a native fish along the round goby invasion front.

May 2018 Society for Freshwater Science, Detroit, MI (oral presentation)
Krabbenhoft, C.A.* and D.R. Kashian. Diet and reproductive investment of native benthic stream fish in response to round goby invasion**.**

May 2018 Society for Freshwater Science, Detroit, MI (oral presentation)
Krantz, N.I.*, C.A. Krabbenhoft, and D.R. Kashian. Using citizen science data to evaluate the effects of land use on macroinvertebrate communities in an urban river.

May 2018 Society for Freshwater Science, Detroit, MI (poster)
Roose, R.E.*, C.A. Krabbenhoft, and D.R. Kashian. Effect of habitat quality on round goby (*Neogobius melanostomus*) and white sucker (*Catostomus commersonii*) in streams.

Mar 2018 CLAS Undergraduate Research Fair, WSU, Detroit, MI (poster)
Krantz, N.I.*, C.A. Krabbenhoft, and D.R. Kashian. Using citizen science data to evaluate the effects of urban land use on stream quality.

Upcoming Presentations

Jun 2019 International Association for Great Lakes Research, Brockport, NY
Krabbenhoft, C.A.* and D.R. Kashian. Native species diversity and riparian land cover influence round goby invasion. (*abstract accepted*)

May 2019 Society for Freshwater Science, Salt Lake City, UT
Krabbenhoft, C.A.* and D.R. Kashian. Urban and agricultural development of riparian corridors aids success of round goby invasion. (*abstract submitted*)

Citizen Science Events

Oct 2018 Friends of the Rouge Fall Bug Hunt
The fall citizen science event gathered 89 citizen volunteers to sample and identify macroinvertebrates at 42 sites in the Rouge River watershed. Monitoring report available online: https://drive.google.com/file/d/19_x2mLsZjhzdUI0aEGJafJOwdxASP3Ja/view

Apr 2018 Friends of the Rouge Spring Bug Hunt
The spring event involved 75 citizen volunteers who sampled 46 sites. Monitoring report available online: https://drive.google.com/file/d/1Y-XvNFbco4_8CLku4_JtSNM0EyRqSCEk/view

Michigan Sea Grant Fellowships Blog Posts

Jan 2019 "An invader's wishlist: Corey Krabbenhoft on her dissertation research"
http://msgfellowship.blogspot.com/2019/

Jul 2018 "An Upper Peninsula field trip with Corey Krabbenhoft"
http://msgfellowship.blogspot.com/2018/07/

May 2018 "Stream sampling and goby guts: Graduate student research with Corey Krabbenhoft"
http://msgfellowship.blogspot.com/2018/05/stream-sampling-and-goby-guts-corey.html

Partners

Collaborators were limited to the academic and agency advisors listed in the original proposal:

- Donna Kashian, Wayne State University, served as academic advisor to Corey Krabbenhoft
- Sally Petrella, Friends of the Rouge, served as a collaborator for citizen science events and data production
- Ed Rutherford, NOAA GLERL, provided guidance on study design and analysis

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