Project Title: Yellow Perch Stock Assessment in Drowned River Mouth Lakes and Nearshore Lake Michigan
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Background/Overview

Project Description

Stock delineation is essential for conserving the genotypic and phenotypic diversity of wild fish populations (Begg et al. 1999, Stephenson 1999). Genetic analysis has become a fundamental tool for establishing regulations that will limit impacts on evolutionary processes and minimize overexploitation of sensitive stocks (Hauser & Carvalho 2008). Simultaneous analysis of multiple population parameters, such as genetic structure and life history variation, can further improve the likelihood that stock definitions accurately reflect a species' biology (Begg & Waldman 1999). This dual approach has been employed successfully in the past. For example, analyses of genetic variation and life history patterns (inferred from otolith isotopic signatures) have led to management strategies that better preserve stock structure of Atlantic cod *Gadus morhua* (Campana et al. 1994, Ruzzante et al. 2000). Also, maintenance of stock diversity is critical for Pacific salmon conservation, a conclusion that is supported by extensive genetic and life history research (Shaklee et al. 1999, Hilborn et al. 2003). However, a multi-pronged approach to stock delineation has not been applied frequently to Great Lakes fisheries.

Yellow perch *Perca flavescens* is among the most economically and ecologically prominent fish species in the Great Lakes. Understanding their stock structure is therefore an important research goal with substantial management implications (Clapp & Dettmers 2004). Researchers have discovered that yellow perch in the Great Lakes are not made up of a single, panmictic population, but rather show complex patterns of genetic structuring and life history variation (e.g., Sepulveda-Villet & Stepien 2011). For example, in Lake Michigan, genetic and movement analyses suggest stock divisions between the southern basin, northern basin, and Green Bay (Miller 2003, Glover et al. 2008). Gaps persist regarding the stock structure of yellow perch in certain regions, particularly nearshore eastern Lake Michigan and its connecting water bodies.

Drowned river mouth (DRM) lakes, which are protected river mouths that link tributaries to Lake Michigan, may provide critical yellow perch habitat. Current management (prior to the 2019 fishing season), which treats DRMs as inland lakes (MDNR 2016), may be inappropriate in some cases because yellow perch from Lake Michigan likely migrate into DRM lakes during winter (Schneider et al. 2007, Seites 2009, Tonello 2012). Genetic and recruitment studies suggest that distinct resident populations occupy DRM lakes and nearshore Lake Michigan (Parker et al. 2009, Janetski et al. 2013); however, these studies did not sample areas where

migrants from Lake Michigan are likely to be found, namely deep-water DRM habitats in winter (Wesolek 2014). Thus, the origin of purported migrants, including their genetic relatedness to DRM and Lake Michigan residents, has not been adequately examined using an appropriate study design and sample size.

Assessing yellow perch migrations is important because they may fundamentally change how DRM lakes are managed and how harvest of Lake Michigan yellow perch is quantified. For instance, during winter 2003, anglers harvested over 50,000 yellow perch from Muskegon Lake (a DRM lake; Hanchin et al. 2007). By comparison, since 2000, between 200,000 and 400,000 yellow perch were harvested annually from southeastern Lake Michigan (statistical districts MM-6 to MM-8; Clapp et al. 2012). Thus, by not accounting for harvest of Lake Michigan yellow perch in DRM lakes during winter, managers may underestimate the total harvest for southeastern Lake Michigan by as much as 20%. Inclusion of harvest from all DRM lakes where yellow perch angling occurs would further increase the harvest estimate. Understanding genetic structure and life history variation in Lake Michigan in relation to DRM lakes will ensure more accurate harvest estimates of particular stocks in the Lake Michigan basin.

Our overarching goal was to determine the stock structure of yellow perch in nearshore and DRM habitats of eastern Lake Michigan. Specifically, we (1) established the genetic structure of yellow perch in nearshore Lake Michigan and DRM lakes, including that of purported migrants, and (2) assessed the timing and prevalence of migrations between Lake Michigan and DRM lakes by using otolith isotope signatures to infer habitat occupancy patterns. These two techniques consider variation at different temporal scales (i.e., genetic patterns reflect changes occurring over generations, whereas otolith isotope signatures occur during a single individual's life) and will thereby provide better delineation of stock structure and life history strategies in our study area than either technique alone. Our study provided a more comprehensive evaluation of the genetic structure and life history patterns (i.e., Lake Michigan resident, DRM resident, and migratory) of yellow perch by testing four competing hypotheses (not all of which are mutually exclusive). Hypotheses #1-2 primarily relate to genetic structure, and hypotheses #3-4 mainly relate to life history strategies assuming genetic structure exists (i.e., DRM and Lake Michigan types are genetically distinct, but migrations also occur between the two habitats). The four hypotheses were:

1) *Panmixia* –No stock structure between the two habitats (i.e., individuals from different locations are genetically indistinguishable); this is our null hypothesis.
2) *No migration* – DRM and Lake Michigan types are genetically distinct, but no migration occurs between the two habitats.
3) *Migration to DRM lakes* – Resident and migratory types are present; migrants originate in Lake Michigan and periodically move to DRM lakes to feed or spawn.
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Significant Changes

The actual sample sizes reported in the genetic (Chorak et al. *in review*) and the otolith isotope studies (Senegal et al. *in prep*) varied from what we originally reported due to a combination of

factors. First, we had difficulty collecting the target number of yellow perch in every season and habitat. We overcame this challenge by sampling over multiple years of the study and conducting more field sampling than we budgeted for in our GLFT proposal. Second, we had difficulty extracting usable DNA from yellow perch that were frozen prior to tissue collection. This made it more difficult to link the genetic and otolith data sets. We originally planned to perform genetic and otolith isotope analyses on the same fish, but this was not always possible because we might have yellow perch that were sampled in both habitats of a DRM lake that could be used otolith isotope analyses but genetic results were lacking. Overall, this challenge did not hinder our ability to achieve the intended outcomes for the project.

We are currently in the process of completing the laser ablation to quantify isotopes along otolith transects. These results are not yet available for this report. The laboratory techniques for performing this analysis proved more challenging than expected, but we are making good progress. We plan to complete this work and report our results in a third manuscript for publication. Although the analyses based on laser ablation should provide additional evidence of movement between Lake Michigan proper and DRMs, we already have a strong basis to infer such movements based on genetic (Chorak et al. *in review*) and isotopic analyses of otoliths and tissues (Senegal et al. *in prep*). Thus, this challenge did not hinder our ability to achieve the intended outcomes for the project.

Outcomes

Advancement of Scientific Knowledge

This project has greatly improved the scientific understanding of the population structure and habitat use of yellow perch in eastern Lake Michigan. In general, the importance of DRM tributaries have received less attention from scientist than those studying Lake Michigan proper or the upstream tributary. Our work suggests that DRM habitats contribute to genetic and phenotypic diversity of yellow perch. Moreover, our work provides evidence (both genetic and isotopic) that yellow perch from Lake Michigan move into DRMs in autumn), which has important fisheries management implications (discussed below). This project provides a platform to further investigate the role of DRMs on the population structure of fishes in eastern Lake Michigan. In that regard, the patterns we reported for yellow perch provides a basis to begin to formulate hypotheses about how the landscape affects the population structure of other fishes.

Training of Students

This project contributed to the training of two master's students (Chorak and Senegal) at two institutions (Grand Valley State University and Purdue University), supporting the bulk of their thesis research. These students were immersed in their respective research projects, gaining hands-on experience in field methods and laboratory skills (e.g., techniques in population genetics and stable isotopes) applied to Great Lakes fishery management issues. These students also have worked to disseminate their research, which included giving presentations at scientific conferences and the Lake Michigan Technical Committee (see *Presentations*), and both are leading manuscripts that we intend to publish in scientific journals. One manuscript is currently under consideration in *Ecology and Evolution* (it has been accepted pending minor revisions, and

a revised draft was re-submitted) and the second manuscript is being prepared for *Canadian Journal of Fisheries and Aquatic Sciences* (see *Manuscripts*).

In addition to the two graduate students mentioned above, other students were involved in various aspects of this research including the sampling of yellow perch and processing fish in the laboratory. Most students involved were from either Grand Valley State University or Purdue University; however, students from Indiana University of Pennsylvania (IUP) were involved with field collection and aging fish (see *Presentations* by Colasante, which were led by IUP) and two junior researchers (a laboratory technician and a master's student) from the University of Utah were involved with analyzing isotope ratios of water and otoliths as well as performing a novel laser ablation-isotope ratio mass spectrometry method. Overall, this project has had substantial involvement of students, which opportunities for them to gain critical skills that should better facilitate Great Lakes fishery management.

Build Relationships

This project provided an opportunity to build new collaborations and deepen past relationships. It supported the first collaboration between Ruetz (GVSU) and Höök (Purdue) and allowed Ruetz to establish his first collaboration with a new faculty member at GVSU (Partridge) with expertise in molecular ecology. Ruetz served on the Purdue student's (Senegal) graduate committee, and he expects to continue to collaborate with Höök on future research questions related to fisheries management in Lake Michigan. This also was the first opportunity for Partridge to work on issues related to Great Lakes fisheries management.

This project also provided an opportunity to support and grow existing collaborations. For instance, Höök worked extensively with Bowen (University of Utah) on analyzing the isotopic ratio in otoliths and water, and an opportunity for Ruetz to continue to work with the Michigan Department of Natural Resources (MDNR) via Clapp's involvement in this project.

Management Implications

The findings from this project have significant implications for Great Lakes fishery managers and have already been used in developing recommendations for a new statewide yellow perch regulation in Michigan. MDNR law enforcement personnel have expressed concerns about enforcing special regulations or regulation exceptions when they occur on connected waters, such as tributaries or DRM lakes. Since the mid-1990s, the daily possession limit for yellow perch on most of Lake Michigan (35 fish/day) has been less than the limit on adjacent and connected DRM lakes (50 fish/day). This research provided quantitative evidence of interchange among these populations (i.e., nearshore Lake Michigan and connecting DRMs) and supported the proposal to implement a common regulation across all of these habitats (Clapp et al. 2019, MDNR 2019).

Most Important Outcomes

The two most important outcomes of this project are: (1) a clearer understanding of yellow perch population structure and habitat use in eastern Lake Michigan, focusing on the importance of

DRMs, and (2) the fact that the results from this work helped to influence the MDNR decision to change the harvest limits in DRM lakes to a statewide limit of 25 fish per day (when the harvest limit in DRM lakes had been higher than Lake Michigan).

Related Efforts

This project was largely a standalone effort funded by the GLFT. GVSU received additional internal funding in the form of a Presidential Research Grant to Chorak ($1500).

The primary "spinoff" project made possible from this work was the assessment of yellow perch growth rates across DRM lakes. Specifically, we (led by Janetski at IUP) aged anal spines to compare size at age of yellow perch collected in August 2015 from littoral habitats of nine DRM lakes (n = 29-52 fish per lake) along a north-south gradient. Our hypothesis was that yellow perch from southern DRM lakes would have larger size at age than northern lakes due to longer growing season and higher productivity. The results showed some support for our hypothesis, as southern lakes, such as Muskegon Lake, tended to have higher size at age than northern lakes such as Portage Lake and Manistee Lake. However, a notable exception to this trend was Betsie Lake, the second northernmost lake, where size at age was 40% and 48% higher than nearby Portage Lake for age groups 1 and 2, respectively (sample sizes were too low to permit meaningful comparisons for other age groups). This unexpected result may be due to relatively high productivity in Betsie Lake, which is more similar to southern lakes like Muskegon Lake than to surrounding northern lakes. These findings suggest that yellow perch growth may be strongly influenced by environmental variation across habitats in eastern Lake Michigan. We are continuing to build upon this work by carrying out size-at-age analysis of yellow perch sampled from Lake Michigan. Inclusion of Lake Michigan fish will permit us to test the hypothesis that growth is slower in Lake Michigan than in DRM lakes due to lower productivity in Lake Michigan. Higher growth rates in DRM lakes may help explain why Lake Michigan yellow perch appear to migrate to DRM lakes. Two IUP students are in the process of analyzing ~70 anal spine samples, and we anticipate they will report their findings within 2 months.

Communication/Publication of Findings

Presentations

Chorak, G.M., C.R. Ruetz III, D.J. Koopmans, A.D. Weinke, D.J. Janetski, B.A. Biddanda. 2016. Hypolimnetic hypoxia across a gradient of Lake Michigan drowned river mouth lakes. Poster presentation at the Midwest Fish and Wildlife Conference, Grand Rapids, Michigan. January 24-27.

Chorak, G., C.R. Ruetz III, R.A. Thum, C. Partridge, D. Clapp, and D.J. Janetski. 2017. Habitat heterogeneity shapes population genetic structure of yellow perch (*Perca flavescens*) in eastern Lake Michigan. Oral presentation at the Annual Meeting of the Ecological Society of America, Portland, Oregon. August 6-11.

Chorak, G., C.R. Ruetz III, R.A. Thum, C. Partridge, D. Clapp, and D.J. Janetski. 2017. Genetic stock structure of yellow perch in drowned river mouths of eastern Lake Michigan. Oral presentation at the Annual Meeting of the Michigan Chapter of the American Fisheries Society (AFS), Mackinaw City, Michigan. March 15-16.

Colasante, J.M., G. Chorak, D.J. Janetski, C.R. Ruetz III, and D. Clapp. 2017. Size at age comparison of yellow perch across a north-south gradient of lakes connected to Lake Michigan. Poster presentation at the Annual Meeting of Society for Freshwater Science, Raleigh, North Carolina. June 4-8.

Colasante, J.M., G. Chorak, D.J. Janetski, C.R. Ruetz III, and D. Clapp. 2017. Size at age comparison of yellow perch across coastal drowned river mouth lakes. Poster presentation at the Annual Meeting of the Michigan Chapter of the AFS, Mackinaw City, Michigan. March 15-16.

Ruetz, C.R., III. 2018. Fish use of Lake Michigan drowned river mouths: how common are migratory life history types? Oral presentation at "Big Lakes – Small World" a joint conference of the International Association of Great Lakes Research and European Large Lakes Symposium, Evian, France. September 23-28.

Ruetz, C.R., III. 2018. Fish use of Lake Michigan drowned river mouths: a conceptual model of life history types. Oral presentation at the Annual Meeting of the Society for Freshwater Science, Detroit, Michigan. May 20-24.

Ruetz, C.R., III. 2018. Connectivity and movement of fishes inhabiting Lake Michigan drowned river mouths. Invited seminar at the Graduate Seminar Series, Department of Forestry and Natural Resources, Purdue University (West Lafayette, Indiana). January 23.

Senegal, T.J., C.R. Ruetz III, D.J. Janetski, G. Chorak, and T.O. Höök. 2018. Morphological variation in Yellow Perch *Perca flavescens* in Lake Michigan and drowned river mouth lakes. Poster presentation at the International Association of Great Lakes Research conference. June 19.

Senegal, T.J., C.R. Ruetz III, D.J. Janetski, G. Chorak, and T.O. Höök. 2018. Morphological variation in Yellow Perch *Perca flavescens* in Lake Michigan and drowned river mouth lakes. Poster presentation at the Purdue University Department of Forestry and Natural Resources Research Symposium. April 13.

Senegal, T.J., C.R. Ruetz III, D.J. Janetski, G. Chorak, and T.O. Höök. 2018. Morphological variation in Yellow Perch *Perca flavescens* in Lake Michigan and drowned river mouth lakes. Poster presentation at the Indiana AFS Chapter spring meeting. February 27.

Senegal, T., C.R. Ruetz III, D.J. Janetski, G. Chorak, and T.O. Höök. 2018. Morphological variation in yellow perch *Perca flavescens* in Lake Michigan and drowned river mouth lakes. Poster presentation at the Midwest Fish and Wildlife Conference, Milwaukee, Wisconsin. January 28-31.

Senegal, T.J., C.R. Ruetz III, D.J. Janetski, G. Chorak, R.A. Thum, D.F. Clapp, G. J. Bowen, and T.O. Höök. 2019. Differential movement patterns of Yellow Perch *Perca flavescens* between eastern Lake Michigan and drowned river mouth lakes. Oral presentation at the Lake Michigan Technical Committee Winter Meeting. January 24.

Senegal, T.J., C.R. Ruetz III, D.J. Janetski, G. Chorak, R.A. Thum, D.F. Clapp, G. J. Bowen, and T.O. Höök. 2019. Differential movement patterns of Yellow Perch *Perca flavescens* between eastern Lake Michigan and drowned river mouth lakes. Oral presentation at the Indiana AFS Chapter spring meeting. February 27.

Senegal, T.J., C.R. Ruetz III, D.J. Janetski, G. Chorak, R.A. Thum, D.F. Clapp, G. J. Bowen, and T.O. Höök. 2019. Differential movement patterns of Yellow Perch *Perca flavescens* between eastern Lake Michigan and drowned river mouth lakes. Oral presentation at the International Association of Great Lakes Research conference. June 13 [Planned].

Efforts to Engage Managers

Information concerning ongoing research efforts was regularly communicated to Lake Michigan researchers and managers at GLFC committee venues (Lake Michigan Technical Committee meetings, Lake Michigan Committee annual meetings), and within Michigan to MDNR biologists at Research Section meetings and meetings of management biologists (annual Division meeting, basin team meetings). Clapp was primarily responsible for these efforts. Additionally, Senegal made a formal presentation to the Lake Michigan Technical Committee (see above). Efforts to communicate our research findings are ongoing, as final analyses and publication of these findings are currently being completed. We plan to continue to communicate our finding to managers, primarily focusing on the MDNR, by making sure our publications are distributed to managers as they become available and having Clapp provide updates to MDNR staff. We also will make at least one more presentation on this research (see presentations, Senegal et al. 2019 at IAGLR).

Manuscripts

Chorak, G.M., C.R. Ruetz III, R.A. Thum, C.G. Partridge, D.J. Janetski, T.O. Höök, and D.F. Clapp. *In review*. Yellow perch genetic structure and habitat use among connected habitats in eastern Lake Michigan. *Ecology and Evolution*.

Senegal, T.J., C.R. Ruetz III, D.J. Janetski, G.M. Chorak, D.F. Clapp, G.J. Bowen, and T.O. Höök. *In preparation*. Differential movement patterns of Yellow Perch *Perca flavescens* between eastern Lake Michigan and drowned river mouth lakes. (Target: *Canadian Journal of Fisheries and Aquatic Sciences*)

We are requesting that the GLFT restrict access to the two manuscripts (Chorak et al. *in review*; Senegal et al. *in prep*) for the maximum of duration of 18 months. The manuscript by Chorak et al. that is in review in the journal *Ecology and Evolution* has been revised based on reviewer comments and currently is awaiting a final decision. The manuscript by Senegal et al. that is in preparation will constitute a chapter in Senegal's master's thesis at Purdue University and is targeted for submission to the *Canadian Journal of Fisheries and Aquatic Sciences*. We will provide electronic reprints of all published manuscripts to the GLFT as soon as they become available.

Discussion

The discussion of our results is included in the two attached manuscripts summarizing our findings (see Chorak et al. *in review*, Senegal et al. *in preparation*). Note that Chorak et al. summarizes the genetic findings of this work, focusing on elucidating the population genetic structure of yellow perch in eastern Lake Michigan and providing evidence of movement between Lake Michigan and DRMs, whereas Senegal et al. focuses on summarizing the otolith isotope results as related to movement between habitats. Overall, our research supported hypothesis #3 (see *Project Description* in Background/Overview) that resident and migratory types are present (i.e., DRM and Lake Michigan types are genetically distinct) with migrants originating in Lake Michigan and periodically moving to DRM lakes to feed or spawn.

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