River Discharge as a Predictor of Lake Erie Yellow Perch Recruitment

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Overview

We have found that Maumee River (MR) discharge during spring (March-May) is a strong predictor of Yellow Perch (YP) recruitment to age-2 (high discharge leads to strong recruitment events). The mechanisms underlying this relationship, however, are enigmatic. Owing to the recent oligotrophication of Lake Erie, and the increased importance of MR phosphorus (P) inputs to west basin P dynamics, our primary hypothesis is that MR discharge benefits YP via P inputs that stimulate zooplankton (ZP) production for larvae and young juveniles. Our hypothesis is supported by the fact that springtime MR discharge is positively related to:

- Springtime P inputs
- West Basin age-0 YP abundance in August (i.e., thus, regulation occurs during the larval/early juvenile stage)
- May-June west-basin copepod ZP biomass

However, MR discharge also is highly correlated with total suspended solid inputs (sediments). Thus, MR discharge may also benefit YP by reducing predation mortality on larvae (via enhanced turbidity). We propose to use innovative field, lab, experimental, and modeling approaches to explore the relative importance of both hypotheses by contrasting larval YP foraging, growth, and survival inside and outside of the Maumee River plume in the west basin. We seek to provide Lake Erie Committee agencies with knowledge of the relative roles of oligotrophication-driven ZP availability and predation mortality in regulating YP recruitment, and ultimately substantiate use of MR discharge as a means to provide early forecasts of YP recruitment to the fishery.

Objectives

1. Determine if ZP availability and larval YP foraging, growth and condition are enhanced in areas receiving P-rich water from the MR relative to other west basin areas, and if differential growth and habitat use as larvae influence survival to the juvenile stage
2. Determine if predation on YP larvae is lower in the turbid MR plume, relative to the rest of the west basin, and how mortality varies with a) physical plume attributes (e.g., turbidity, light), b) larval size, c) alternate prey for predators, and d) predator abundance
3. Use a modeling approach to synthesize our findings and quantify habitat suitability for YP larvae in the sampling sites across the west basin

Methods

To identify mechanisms underlying the river discharge-YP recruitment relationship, we will use field sampling coupled with innovative laboratory and modeling techniques. We will use field collections to quantify how Maumee River discharge influences west basin physical habitat and food (ZP) for larval YP, and how spatial differences in habitat (e.g., conditions in the Maumee vs. Detroit River plume and their corresponding spatial extent) influence larval YP spatial abundance patterns, feeding, growth, and condition). As part of this effort, we will use otolith microchemistry to quantify how growth disparities arising from differential habitat availability and use (e.g., Maumee River plume vs. Detroit River plume) as larvae, influence survival to the juvenile stage (when recruitment is set). We also will combine field sampling with bioenergetics modeling and quantitative genetics to explore the role of predation mortality in explaining the river discharge relationship . Finally, we will use a spatially-explicit, individual-based modeling approach, to synthesize our findings and further assess how river-generated plumes drive habitat suitability for YP, and ultimately their eventual recruitment potential

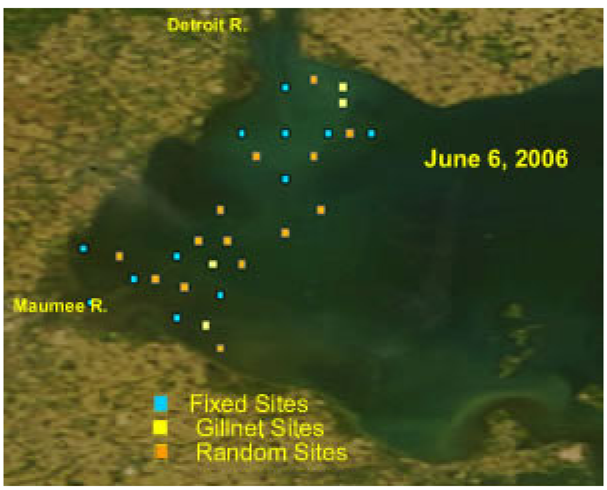

Figure 1: *Map of west basin sampling locations on June 6, 2006. At each station, we sampled ichthyoplankton (targeting larval Yellow Perch.), zooplankton prey, and a suite of habitat characteristics (e.g., temperature, chlorophyll a, light climate, conductivity) throughout the water column. At the gillnet sites, both bottom and surface (canned) gillnetting (1- to 3-hr sets) was conducted to sample potential predators on larval Yellow Perch*.

2007 Plans

Determine climate change impacts on YP recruitment to the fishery

We would use the baseline period of 1961-1990 and a future 30-yr period (2040-2069) from recent General Circulation Model (GCM) simulations to estimate Maumee River discharge during March, April, and May. Specifically, we would use GCM simulations from 1) the Canadian Climate Centre (warm-dry runs, CGCM2 A21, and less warm-dry runs, CGCM2 B23], and 2) Great Britain's Hadley Centre (warm-wet runs, HadCM3 A1FI, and less warm-wet runs, HadCM3 B22). These four scenarios were selected in a recent IJC study of Lake Ontario-St. Lawrence River Regulation as encompassing the range of future GCM simulations under increasing greenhouse gases. We would use differences between the two 30-yr periods to modify historical meteorology and simulate resulting hydrology changes. Estimates of outflow from the Maumee River into Lake Erie during March, April, and May would be extracted, and used to predict future recruitment to the fishery at age-2 for both western and central Lake Erie. Further, the latter predictive relationship between future spring Maumee River discharge and YP recruitment would be used in a Bayesian modeling framework to allow incorporation of model uncertainty as well as uncertainty in the inputs. In this way, our forecasts of YP recruitment under future climate scenarios would be probabilistic. This model could be readily updated as new data are acquired. Stow would provide probability estimates for the four GCM scenarios in the near term by interviewing experts in the field, and using their opinions in a Bayesian framework to narrow down appropriate probability estimates.

Provide forecasts of YP recruitment earlier than is currently possible, which might benefit harvest quota decisions

A second forecast that we propose to generate is a daily probabilistic outlook of YP recruitment for up to two years into the future from the present day, running in real time. We would use GLERL's Advanced Hydrologic Prediction System and extract probabilistic outlooks of Maumee River flow for spring months (March, April, and May) to estimate probabilistic YP recruitment two years ahead.

At present, agencies can only forecast Yellow Perch recruitment to the fishery two years in advance, based on 1) age-0 abundance indices generated in August (i.e., August abundance indices and age-2 recruitment are positively correlated), or 2) using observed river discharge (i.e., our model) from March through May. Importantly, both of these forecasts can only be made after the annual LEC meeting in March, when harvest quota decisions for the upcoming year are made. Thus, when these harvest quota decisions are made in March of any given year (e.g., 2007), they only have an estimate of how many Yellow Perch would recruit to the fishery during 2007 (based on 2005 age-0 abundance indices) and 2008 (based on 2006 age-0 abundance indices). At present, the LEC has no way to estimate age-0 abundance during the upcoming year (2007) or recruitment to the fishery two years later (2009).

Using GLERL's Advanced Hydrologic Prediction System, which can be used to forecast Maumee River discharge months in advance, we propose to forecast 1) the strength of the upcoming Yellow Perch year-class (e.g., 2007 age-0 abundance) and 2) recruitment of age-2 Yellow Perch (in 2009) prior to the annual LEC meeting in March. In essence then, these forecasts would provide the LEC with an extra year of forecasted recruitment so that in 2007 (for example), the LEC would have an indication of what recruitment would be like during 2007, 2008, and 2009. These forecasts would be probabilistic so that agencies could know how confident they should be in that forecast. This information (i.e., a forecast of upcoming year-class strength, and in turn, a forecast of age-2 Yellow Perch recruitment an extra year down the road) could be valuable in making harvest quota decisions. These early probabilistic forecasts are of great interest to the LEC (Roger Knight, LEC Chair, personal communication).

Further, by running the models in hindcasting mode (i.e., after river discharge happens and the year-class if produced), the LEC could evaluate the success of the model. Thus, during 2008, we would extend this forecasting model by extracting actual and simulated flows for the immediate past two years to estimate YP recruitment 0 and 1 years ahead, and then use these same outputs in “hindcast” mode to check the accuracy of our forecasts (i.e., compare observed YP recruitment to forecasted YP recruitment). In this way, agencies would have a way to evaluate the accuracy of our predictions. As part of this future hindcasting effort, we also would quantify the accuracy of predictions made 12, 6, 3, 1, and 0.5 months in advance of the annual LEC meeting so as to determine the earliest point at which reliable predictions could be made.

Ultimately, by merging Ludsin’s empirical Maumee River discharge-YP ecruitment modeled with real-time forecasts from GLERL’s Advanced Hydrologic Prediction System (in a Bayesian modeling framework), we seek to make forecasts of Lake Erie YP recruitment fully operational and available to managers. As far as we are aware, a forecasting model of this nature would be the first of its kind.

Use historical remote sensing data to create an index of the amount of area encompassed by the Maumee River plume just prior to and during the YP larval period (March-June), which can be used to help understand variation in YP recruitment.

Moderate-Resolution Imaging Spectroradiometer (MODIS) 250-m resolution, true color, near real-time imagery from the Terra and Aqua satellites, in addition to visible band channels, would be used to map and track tributary plumes in western Lake Erie. Through an agreement with the University of Wisconsin, which operates a real-time receiving station for MODIS direct broadcast data, MODIS imagery would be subset into four Great Lakes CoastWatch scenes. These scenes would be converted into true color images, downloaded daily, and made available to the project via the Great Lakes CoastWatch website. Individual bands in the visible and near infrared also would be available.

These processed images would be used explore the hypothesis that enhanced Maumee River discharge promotes YP survival by providing a greater areal extent of favorable habitat (e.g., high copepod zooplankton; per Table 1) for larvae. Using ArcView Geographic Information System (GIS) software, we would quantify the areal extent of the west basin that is affected by the Maumee River plume on a weekly basis during each year of our investigation and create an annual index to describe this coverage (e.g., average surface area influenced by the Maumee River plume during March through May). We also would create an index value for years in which we have historical remote sensing data (2000-present).

In turn, this index, in combination with average P and sediment loading into the system from the Maumee River during the same years, would help us determine whether it is the actual amount of P (or sediment) loading into the system that is important, or whether it is how those loads (regardless of absolute size) are distributed as plumes, via wind-driven circulation, that is important to YP recruitment. These data would be compared against observed estimates of zooplankton availability and Yellow Perch recruitment from 1999-present (data from ODNR, OMNR), and our own collections).

Continue water quality monitoring in the Detroit and Maumee River plumes

During 2006, Tom Johengen graciously conducted some pilot water quality work to help us verify that our assumptions about higher phosphorus, turbidity, and chlorophyll levels in the Maumee River plume versus Detroit River plume were correct. Specifically, Tom analyzed total suspended matter (TSM), total phosphorus (P), total dissolved P, and chlorophyll at four stations in each of the plumes , finding that levels of each of these variables was indeed higher in the Maumee River plume than in the Detroit River plume.

During 2007, we seek to quantify these same attributes. This information would be valuable in three ways. First, the data could be used to calibrate CTD information (e.g., transmissometer, fluorometer data) collected at these and other stations. Secondly, these data would benefit future manuscripts that compare zooplankton abundance and larval Yellow Perch growth, condition, and survival between plumes by removing the need to make any assumptions about turbidity and P levels. Finally, these collections could lead to another large-scale proposal concerning how river plumes influence the flow of energy through the food web. This work would likely involve GLERL and non-GLERL researchers (led by Johengen) who were involved in an earlier NOAA COP proposal back in 2003 regarding the same topic as this proposal.

Continue conducting field and laboratory work to determine the mechanisms underlying the relationship between Maumee River discharge and Yellow Perch recruitment

To identify mechanisms underlying the river discharge-YP recruitment relationship, we would use rigorous field sampling coupled with innovative laboratory and modeling techniques. We would use field collections to quantify how Maumee River discharge influences west basin physical habitat and food (zooplankton) for larval YP, and how spatial differences in habitat (e.g., conditions in the Maumee vs. Detroit River plume and their corresponding spatial extent) influence larval YP spatial abundance patterns, feeding, growth, and condition. As part of this effort, we would use otolith microchemistry to quantify how growth disparities arising from differential habitat availability and use (e.g., Maumee River plume vs. Detroit River plume) as larvae, influence survival to the juvenile stage (when recruitment is set). We also would combine field sampling with bioenergetics modeling and quantitative genetics to explore the role of predation mortality in explaining the river discharge relationship.

To help determine whether Maumee River discharge might be influencing YP via effects on food availability, larval YP would be collected weekly in the west basin in spring, 2006-09. Remote sensing would guide sampling to contrast areas influenced by the Maumee River versus other areas. Larval diet analyses would determine consumption of zooplankton (prey) and size and taxonomic-selectivity among areas. Otolith analyses (daily aging/growth, microchemical) of larvae and juveniles would be used to quantify growth differences among areas (as larvae), and detect potential differential selection for larval habitat use and growth rate. RNA:DNA analyses would be used to contrast larval fish condition.

To assess the relative importance of predation, potential predators would be captured using 3hr gillnet sets and bottom trawling. Larvae in predator diets would be identified to species morphologically and using genetic methods (quantitative real-time PCR of mtDNA fragments with sequencing of sub-clones to estimate relative abundance). Validation of relative abundance would be performed using lab studies.

Finally, the suite of findings would be incorporated into a spatially-explicit, individual based model to quantify habitat suitability for larvae across our study areas. Ideally, this analysis, combined with our empirical research, would provide LEC agencies with knowledge of the relative roles of oligotrophication-driven ZP availability and predation mortality in regulating YP recruitment. In so doing, we seek to substantiate use of MR discharge as a means to provide early forecasts of YP recruitment to the fishery.