Habitat Quality as a Driver of Lake Erie Walleye Population Dynamics: Past, Present & Future

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ABSTRACT:

Lake Erie's walleye (*Sander vitreus*) population and the fisheries it supports have varied considerably during recent decades for reasons that are not fully understood but are likely linked to human-driven changes in habitat quantity and quality. Toward helping fishery management agencies better understand linkages between habitat conditions and walleye recruitment to Lake Erie's fisheries, we conducted four independent modeling studies. Our **first study** used Lake Erie walleye recruitment and environmental data (1980-2015) to introduce a novel modeling framework to help construct accurate, reliable models to understand and predict how changing environmental conditions influence recruitment. Specifically, we *(i)* demonstrated an objective way to identify the intra-annual window(s) of environmental conditions that best predict annual walleye recruitment, *(ii)* used two time-series cross-validation approaches to detect shifts in the predictive performance of these environment-recruitment models, and *(iii)* applied an information-theoretic approach to quantify non-stationarity in environment-recruitment relationships. Our findings showed why environment-recruitment models often fail retests with new data, which can help to understand their limited utility in fisheries management contexts. Our framework also offers a new means to understand how environment conditions influence fish recruitment, even in ecosystems undergoing change. In our **second study**, we linked a bioenergetics model of walleye early life growth with output from a three-dimensional hydrodynamic model of Lake Erie to explore how spatial and temporal variability in thermal conditions during 2003-2014 influences larval stage duration, and in turn, walleye recruitment potential. Our modeling results demonstrated that *(i)* temporal trends in larval stage duration differed among Lake Erie's three basins, *(ii)* intra-annual timing of larval walleye hatching could have substantial impacts on larval stage duration that vary with the environmental context (e.g., larval consumption, thermal regime), and *(iii)* thermal heterogeneity across the lake held the potential to differentially influence stock-specific recruitment by through effects on larval stage duration. We used these findings to anticipate how increases in spring warming might affect future walleye recruitment potential by altering growth and survival during the larval stage. In our **third study**, we

used a spatially-explicit regression modeling approach to quantify the non-additive and non-stationary effects of adult population size and thermal conditions on walleye recreational harvest patterns in western and central Lake Erie during 2006-2015. We identified nonlinear, additive, and spatially-dependent effects of both walleye population size and thermal conditions on harvest rates. In addition, we showed how a population's spatial ecology can influence fisheries harvest rates and simultaneously demonstrated how applying spatially-explicit modeling approaches could benefit fisheries management, especially in ecosystems that have been experiencing both demographic and environmental change due to human-driven perturbations. Finally, for our **fourth study**, we used linked climate, watershed-hydrology, and biological models to test hypotheses regarding how climate change and the anticipated implementation of agricultural conservation practices to curb eutrophication might affect recruitment of Lake Erie *(i)* walleye, *(ii)* yellow perch (*Perca flavescens*; a native percid with higher thermal and ecosystem productivity requirements than walleye), and *(iii)* white perch (*Morone americana*; a non-native invasive species of lesser fishery value and a known predator on the early life stages of percids). Our modeling results showed that continued climate change can be expected to negatively affect walleye and yellow perch but positively affect white perch. Additionally, our findings demonstrated the potential for tradeoffs between improving water quality and maintaining fisheries production in the face of anticipated climate change. Collectively, these four studies have provided new insights into how changes in habitat conditions associated with both natural environmental variation (e.g., meteorology) and human-driven environmental change (e.g., climate change, altered nutrient inputs) might influence the potential for the Lake Erie ecosystem to support its economically, culturally, and ecologically important walleye population. These studies have also provided new hypotheses to test with future research, as well as new tools to help Lake Erie agencies manage this important population and the expectations of their constituents with continued human-driven environmental change.