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Moving toward ecosystem-based fisheries management: developing an integrated ecosystem assessment of Lake Erie as a case study

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ABSTRACT:

Lake Erie's fish community and the fisheries that they support have varied during the past half-century for reasons that remain uncertain but are likely in part linked to human-driven environmental change. Toward describing key changes in the Lake Erie ecosystem and their relative influence on Lake Erie's fish communities and fisheries, we accumulated more than 150 long-term datasets representing abiotic (i.e., physiochemical and anthropogenic drivers) and biotic (i.e., fish, zooplankton, and birds) components of the ecosystem, and analyzed them as part of four independent, integrative studies. Our first study sought to identify trends in Lake Erie's fish, zooplankton, and waterbird assemblages, as well as the biological, physicochemical, and socioeconomic drivers of these trends, using datasets of varying duration (50-year, 35-year, and multiple 20-year intervals). Our findings revealed that measures of agricultural land use were the strongest predictors of change in all of these biological indicator groups when using the long-term (50-year) and intermediate-length (35-year) datasets, whereas physical drivers (e.g., winter temperatures) and in-lake nutrient and sediment concentrations and tributary loading became more important within the short-term (20-year) datasets. In addition to highlighting that the mechanisms regulating Lake Erie's biota shifted through time, our findings revealed the need to consider the timescale of analysis and types of indicator groups used, as both can influence the interpretation of the drivers of ecosystem change. In our second study, we quantified the primary drivers of change during 1969-2018 in Lake Erie's "sentinel fish" assemblage, which consists of rare species that can serve as bioindicators of environmental change and are not heavily fished or preyed upon by walleye (*Sander vitreus*). Our analyses of western and central Lake Erie's assemblages identified anthropogenic nutrient inputs as the principal driver of both species and species-trait compositional changes, with invasive fishes and climate warming being less important. Our third study focused on Lake Erie's forage-fish assemblage, which comprise species that are commonly preyed upon by walleye, the lake's most abundant large-bodied top predator and most economically important species. In contrast to sentinel species, changes in the walleye prey-fish assemblage appear to have been driven by numerous human-driven stressors, including nutrient inputs, commercial walleye harvest, warming, and the expansion of non-native white perch (*Morone americana*). As a result, white perch have become one of the most abundant forage species, now play a key functional role in supporting walleye growth, and appear to have eliminated a density feedback between adult (age 3+) and sub-adult (age-1 and age-2) walleye that historically limited subadult size. Finally, given the clear, consistent importance of nutrient inputs in driving change in Lake Erie's fish communities

and fisheries during the past 50 years, for our fourth study, we analyzed historical (1915-2011) data on the commercial harvest of walleye, yellow perch (*Perca flavescens*), and lake whitefish (*Coregonus clupeaformis*) and lake productivity to identify the degree to which fisheries production depends on ecosystem productivity (as measured by total phosphorus inputs). Our analyses indicated that the harvest of each fishery was maximized at distinct levels of ecosystem productivity, and that the total harvest of our three focal taxa was highest at the highest productivities. We also learned that future management efforts to improve water quality by reducing phosphorus inputs is likely to favor some fisheries (e.g., lake whitefish) over others (e.g., yellow perch) owing to taxon-specific dependencies with ecosystem productivity. Thus, no single 'optimum' target range for nutrient inputs appears to exist, which will achieve all valued fishery and water quality objectives, illustrating how the need to balance multiple services in aquatic ecosystems can create a wicked management problem of complex tradeoffs. Jointly, these four studies have offered many new insights into how human-driven environmental change has influenced Lake Erie's fish communities and fisheries, as well as other biota (e.g., zooplankton, waterbirds). These studies have also provided new hypotheses to test with future research, as well as a quantitative foundation to support continued integrative ecosystem assessment of the lake that can support desired efforts to implement an ecosystem-based approach to fisheries management within the basin.