Food Web Response to Invasive Species and Hypoxia in Lake Erie, Saginaw Bay Lake Huron, and Southeast Lake Michigan

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Overview

Nutrient loading, invasive species and hypoxia are believed to affect the biomass, species composition and distributions of lower trophic levels, but their impacts on fish production and fisheries are relatively poorly known. Recent surveys conducted by NOAA GLERL and its research partners (universities, state agencies, US EPA, Ontario Ministry) in Lake Erie, Saginaw Bay and southeastern Lake Michigan have quantified temporal and spatial changes in biomass and species composition of lower trophic levels and fish in response to dreissenid mussel invasions and hypoxia. We propose to incorporate these data into a food web simulation analysis to predict changes in fisheries yield and suggest management options in response to dreissenid invasions and hypoxia. The results will complement ongoing sampling and modeling efforts to address ecosystem response to nutrient loading and invasive species in Lake Erie, Saginaw Bay Lake Huron, and southeastern Lake Michigan.

Objective

Increase number of regional costal and marine ecosystems delineated with approved indicators of ecological health and socioeconomic benefits that are monitored and understood.

Proposed Work

We will use EcoPath/EcoSim (EwE) (http://www.EcoPath.org) to forecast responses of the food web in each area to different hypoxia or invasive species scenarios, and their consequences for harvest of native (Walleye, Yellow Perch) or non-native species (Chinook Salmon, Rainbow Smelt). EwE is an effective modeling tool for analyzing food web effects on fisheries, and has been applied to evaluate lake trout restoration scenarios on food webs of Lake Superior. The software combines trophic mass balance (biomass and flow) analysis with dynamic modeling capabilities. Changes in habitat structure and rate-determining attributes (e.g., dissolved oxygen) can be incorporated through an extension of EcoSim called EcoSpace.

We will support the food web model analysis with historic databases and data collected during related monitoring and research studies off Muskegon in Lake Michigan (Pothoven and Vanderploeg, Muskegon River watershed study), Saginaw Bay (Vanderploeg, MultiStressor project), and Lake Erie (IFYLE/Ecofore). The EwE food web model for Lake Erie will be conducted by a postdoctoral fellow funded under a University Michigan subcontract to Mason and Rutherford. The EwE model for Saginaw Bay already has been configured using historic data (‹1996) collected under a previous Michigan Sea Grant project to Adlerstein, Rutherford, Vanderploeg and Nalepa; it will be updated with more recent data collected under MultiStressor project, and with acoustic surveys conducted seasonally to estimate planktivore and zooplankton biomass (see below). The EwE model for the Muskegon River Estuary (including Muskegon River, Muskegon Lake and nearshore Lake Michigan) will incorporate data on lower trophic levels and fish collected from 1996 through present by Vanderploeg, Pothoven and Nalepa during NOAA GLERL biomonitoring projects, and in Muskegon River from 2003 to 2004 by Rutherford and colleagues. Trophic interactions critical to food web analysis are available from extensive diet analyses in each area, and from stable isotope studies of the Muskegon estuary food web conducted by Katharine Marko, Brian Eadie and Rutherford.

The EwE modeling process is two-staged. EcoPath is first used to construct and parameterize a “balanced” food web. In turn, this food web is used as the initial conditions to a system of coupled differential equations of trophic interactions that depict changes in biomass with time. Spatial arrangement of habitats, and food webs associated with these habitats, are then incorporated in this modeling application by replicating EwE over a spatial grid (EcoSpace). EcoSpace tracks the dispersion and advection of biomass between spatial compartments or habitats, providing the capability to evaluate how changes in a habitat may impact adjacent habitats, food webs, and the fishery.

Ecopath data requirements are generally already available from past GLERL and IFYLE studies, stock assessment, or the literature, and include biomass estimates, total mortality estimates, consumption estimates, diet compositions, and fishery catches. The initial food web will be constructed, parameterized and balanced in EcoPath, and then replicated in EcoSpace. In Lake Erie, we will use spatial measures of dissolved oxygen and water temperature to define our initial spatial grid in EcoSpace. Saginaw Bay will be simulated in EwE as one spatial unit, while in Lake Michigan different spatial units will be configured for Muskegon River, Muskegon lake and nearshore Lake Michigan in EcoSpace. Simulations then will be run using Ecosim to gain insight into the implications of hypoxia or invasive species (dreissenids, round gobies) for food web interactions, fisheries harvest and different management strategies (maximize harvest, maximize profits, maintain ecosystem structure). Model-data fits will be examined and improved via a suite of nonlinear optimization routines, and also via a feedback-process by examining some of the crucial ecological parameters in the EwE model (notably otal mortality rates and the settings for top-down/bottom-up control).

In addition, we will conduct acoustic and PSS surveys to obtain seasonal estimates of planktivore and zooplankton biomass in Saginaw Bay. Previous agency surveys of Saginaw Bay have provided gillnet catch rate data to index relative abundance of planktivores and piscivores at a few sites. These gillnet estimates are heavily biased by net mesh size and fish behavior, and are limited in spatial scale. Acoustic estimates and PSS surveys will provide more reliable and comprehensive estimates of fish biomass by size category over wider spatial scales.

Core Program

- Input data from historic and current monitoring programs into EwE framework,.
- Conduct acoustic surveys in Saginaw Bay to refine planktivore and zooplankton biomass estimates.
- Calibrate model, run simulations, and analyze response of Lake Erie food web to hypoxia, and response of Muskegon Estuary and Saginaw Bay to invasive species introductions. Simulate potential fishery management actions given invasive species introductions.
- Write and submit manuscripts to journals.

Scientific Rationale

Simulation models are useful tools for analyzing the response of food webs and fisheries to invasive species, overharvest, or habitat degradation. Substantial changes have occurred in the pelagic food webs in Lake Erie, Saginaw Bay Lake Huron, and southeast Lake Michigan that have coincided with hypoxia events or introductions of invasive dreissenids. For example in Lake Michigan, a dramatic reduction in offshore spring primary production has recently occurred compared to the 1980s, and coincided with altered community composition and biomass declines in some groups (*Daphnia* spp, cyclopoid copepods, *Mysis*) between 1994-2003 and 2007-2008, as coincident increases in biomass of invasive Cercopagis pengoi and *Hemimysis*. In Saginaw Bay, Lake Huron, the recent severe decline of non-native Alewife has coincided with increases in reproduction by native species, including emerald shiner, Walleye and Yellow Perch, while mayfly populations that disappeared during the 1950s still have not recovered. GLERL and its university and resource agency partners have collected extensive biological, physical and chemical data in Lake Michigan, Huron and Erie that, when complemented by targeted additional sampling, can serve as inputs to models to evaluate food web response to hypoxia or invasive species in the context of natural variation within the physical environment.

Governmental/Societal Relevance

Following the severe decline of *Diporeia* in the Great Lakes, the importance of Great Lakes, the importance of *Mysis* and zooplankton as food sources for forage and commercial fishes has increased. Fishery managers need to know the impacts of invasive species and hypoxia on forage fish and game fish production in the Great Lakes, and what management actions can be taken to help maintain healthy fish populations and sustainable fisheries.

Relevance to Ecosystem Forecasting

By understanding how invasive species and hypoxia may alter energy flow and trophic linkages in food webs, we will be able to better predict the ability of Great Lakes ecosystems to produce healthy and sustainable fishery stocks. Following the decline of *Diporeia*, fishery managers are concerned whether the lower food web can support current levels of fish production and stocking in the Great Lakes. A food web analysis will enable us to predict energy flow to fish prey and fish under scenarios of invasive species (dreissenid spp, round goby) or hypoxia.