Influence of Physical Processes on Fish Recruitment Variability in the Great Lakes

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Overview

Over the past 40 years, efforts to rehabilitate populations of native species of concern (SOC; i.e. Lake Trout, Lake Herring, Lake Whitefish) in the lower Great Lakes have met with minimal success. Suspected impediments include inadequate numbers of stocked fish, suboptimal stocking practices, excessive mortality from sea lamprey and fishing, and interactions between Lake Trout and native and non-native species (Bronte et al. 2008). Restoration plans call for stocking efforts in priority areas of limited geographic extent that potentially have the best reproductive habitat, and where exposure to mortality is lessened. However, these attempts may be futile as knowledge or extent of suitable physical habitat conditions is poorly known. In addition, connectivity or movement between spawning and nursery habitats is largely unknown for species of concern. Cost-effective restoration and conservation of critical habitats for Great Lakes fishes depend upon quantifying suitability of habitat conditions for sensitive life stages, and defining geographic range of available habitats for larvae settlement and growth.

Objective

Increase number of fish stocks managed at sustainable levels.

Proposed Work

We hypothesize that recruitment failure of native species of concern (SOC) is due in part to fluctuating temperatures that affect egg and fry development times, and fluctuating current patterns that advect fry away from suitable settlement habitats. We propose to measure physical habitat suitability and predict spawning, egg incubation and fry dispersal of SOC in selected locations in Grand Traverse Bay Lake Michigan, Thunder Bay Lake Huron, and Lake Champlain. For Lake Trout in Grand Traverse Bay, we will combine in-situ measures of temperature and currents with hydrodynamic model predictions of circulation to develop a coupled biophysical model to track development, advection and survival of eggs and fry from spawning to juvenile settlement areas. Results will help identify recruitment bottlenecks for SOC in Lake Michigan, prioritize their restoration efforts, and provide science-based management tools to protect critical life stages from proposed development.

To determine physical processes that may influence spawning success and potential recruitment of SOC, we propose to measure water temperature, and current direction and strength over selected spawning areas for Lake Trout, Lake Herring and Lake Whitefish in Grand Traverse Bay and Thunder Bay Lake Michigan, and for Lake Trout in Lake Champlain.

For Lake Trout and Lake Whitefish in Thunder Bay Lake Huron, we will utilize real-time measures of temperature, currents and fish biomass available from the ReCON buoy (see Ruberg ReCON project) to predict spawning, egg incubation times, and fry emergence and dispersal. In Lake Champlain, we will place 2 ADCPs to measure current patterns near a selected spawning location in the nearshore area. For Lake Trout in Grand Traverse Bay, we also will deploy 2 ADCPs and temperature sensors to measure currents and temperatures during spawning, egg incubation and fry dispersal. We will develop a biophysical model that couples physical transport models and temperature models with individual-based particle models of Lake Trout egg development and larvae to study variation in larval hatch, growth, and settlement in Grand Traverse Bay. The model belongs to a Lagrangian-type, which tracks trajectories of fish larvae over time.

Program

- Install ADCPs and temperature meters to measure water temperature, and current direction and strength on Lake Trout, Lake Herring and Lake Whitefish spawning habitats in Grand Traverse Bay, and Lake Trout reefs in Lake Champlain.
- Run the Lake Michigan hydrodynamics model fine-scale water circulation patterns near fish spawning areas in Grand Traverse Bay, Lake Michigan.
- Correlate water current and temperature measurements and model predictions with MDNR survey densities of Lake Trout egg deposition, incubation and fry production, and indices of year class strength.
- Develop, calibrate and apply a biophysical model of Lake Trout early life history to quantify the potential influence of physical processes on recruitment success of Lake Trout.

Scientific Rationale

The importance of physical processes to variability in fish population structure and recruitment has long been recognized for fish populations, but only recently have physical transport models been used to understand the impacts of ocean-scale hydrodynamics on recruitment. Physical processes in the Great Lakes occur over similar temporal and spatial scales as are found in the coastal ocean, yet coupled physical/biological models to examine importance of these processes on Great Lakes fishes are rare. We propose to combine physical measurements of currents and temperature, with field studies of Lake Trout spawning and recruitment success in Grand Traverse Bay, Thunder Bay Lake Huron, and Lake Champlain to assess the relative importance of physical processes on recruitment of SOC. In year 2 of the project, we will add acoustic measures of spawner biomass from deployment of fisheries acoustics on the ReCON buoy at Thunder Bay. We also will develop a biophysical model of Lake Trout spawning and fry transport similar to an earlier version used to explore the effects of physical factors (temperature and circulation) on recruitment variability of yellow perch in Lake Michigan (Beletsky et al. 2007). The model takes into consideration 3-D circulation and thermal processes, physiology and ecology of fish larvae, and trophodynamics. We will extend this model framework to examine the role that physical processes play in recruitment failures of Lake Trout in Lake Michigan. The biophysical model will be useful for examining Lake Trout recruitment dynamics elsewhere in the Great Lakes, and will serve as a framework for analyzing recruitment variability in other native SOC.

Governmental/Societal Relevance

Although focused on SOC in Lake Michigan, our research is applicable to other areas and species within the Great Lakes basin, given that physical processes are important in all systems, and most fishes of concern have a pelagic larval stage. Our study also will enhance understanding of how habitat pattern and suitability influence fish recruitment, a recommendation of the Great Lakes Regional Collaboration. Quantifying habitat suitability of fish spawning and nursery areas addresses basin-wide priorities of Lake Committees to identify primary impediments to, and options for rehabilitating indigenous species. Our proposal addresses Great Lakes fish and wildlife restoration needs by aiding protection and maintenance of naturally reproducing native species.

Relevance to Ecosystem Forecasting

Relevance to Ecosystem Forecasting: Development of coupled biophysical models and predictions of currents, temperatures and fish reproductive behavior will improve forecasts of fish recruitments and distributions in the Great Lakes. Analysis of factors affecting populations in different areas will improve understanding of physical factors limiting recruitment success.