ECOFORE: Forecasting the Causes, Consequences and Potential Solutions for Hypoxia in Lake Erie

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Overview and Objectives

The overall objective of this project is to create, test, and apply models to forecast how these stresses influence hypoxia formation and ecology of Lake Erie's Central Basin, with an emphasis on fish production potential. These models will integrate the multiple factors that interact to create hypoxia on Lake Erie, such as surface water flow, phosphorus input, lake dynamics, climate variation, fish movement patterns and fish and Dreissenid biology and physiology. The forecasts will be conducted within an Integrated Assessment (IA) framework, which is a formal approach to synthesizing existing natural and social scientific information in the context of a natural resources policy or management question.

Accomplishments

WATERSHED Many activities in the Watershed Team are being conducted and completed concurrently. Phosphorus (P) loading data is being compiled and summarized to be used as model inputs for the Hypoxia Team. Watershed nitrogen (N) and P budgets are being created to better understand N and P sources over time as well as to aid in forecasting scenarios. The Distributed Large Basin Runoff Model (DLBRM) and the Soil and Water Assessment Tool (SWAT) are be parameterized and calibrated to be later used in climate and land management practice change forecasting scenarios.

P loading efforts

Monthly and daily river export load series for the Raisin, Maumee, Sandusky, Cuyahoga, and Grand rivers have been completed for the period of record. Missing data has been filled in, and the complete time series have been posted to the project website.

Lake Erie total phosphorus loading estimates for 2003-2005 have been completed. In January, the Watershed Team and the Hypoxia Team agreed that the Intensive Years to be modeled would be 2005, 1976, and 2007. Daily loadings at 26 spatial nodes were needed on a calendar year (CY) basis. Because all previous estimates had been made on a water year (WY, October - September) basis, the 2005 estimates were completed for both WY and CY. A database of historic Great Lakes Total Phosphorus Loading has been acquired from the International Joint Commission (IJC) and this information combined with archived tributary data is being used to reconstruct the 1976 loadings at the same level of spatial detail as that for the 2005 loadings. Detailed point source load estimates for total phosphorus in 1997 and 2002 have been de-archived and provided for SWAT modeling. Collection of point source and tributary data for 2006 and 2007 is ongoing.

N and P budgets

Net anthropogenic phosphorus input (NAPI) budgets are mostly completed for all 25 Lake Erie watersheds in Canada (CA) and U.S. for 2002 and for U.S. watersheds for 1987, 1992, and 1997. NAPI budgets include P fertilizer, atmospheric P deposition, net trade of P in food and feed, and P import in dishwasher detergent. Alternative P budgets have also been constructed and consider different P input components including P fertilizer, animal P manure, atmospheric P deposition, human P excretion (including P input from septic, sludge, and point discharge), P dishwasher detergent, P input from industrial sources, and P in harvested crops. These alternative budgets were completed for all Lake Erie watersheds (CA and U.S.) for 2002, for only the U.S. watersheds for 1997. Budgets for 1987 and 1992 will be completed after we obtain data on industrial P discharges for those years from the IJC. Currently, we are trying to estimate N budgets using the net anthropogenic nitrogen input (NANI) method for 1987, 1992, and 1997 for only the U.S. watersheds and for 2002 for all watersheds (including U.S. and CA). This will be completed by May.

Modeling efforts

Multiple databases of land use, soil, digital elevation model (DEM), hydrography, and agricultural management practices have been acquired, processed, and analyzed to develop dynamic input parameters for the DLBRM and the revised universal soil loss equation (version 2) (RUSLE2) for the 6 watersheds on the U.S. side (Grand-OH, Cuyahoga, Sandusky, Maumee, Huron, and Raisin). We have acquired and processed multiple databases of land use, soil, digital elevation model (DEM), and hydrography for the Grand River –Ontario. A computer program was written to spatially link the Ontario soil attribute database with the polygon database for extracting the soil input parameters. Input parameters for the DLBRM were derived. We are currently working to derive the N and P loading input for the DLBRM on the Grand River –Ontario.

We have also built basic model application databases (daily meteorology, land use, soils, elevation, and hydrography) for all 17 US Lake Erie watersheds and are working on the same for the Grand (Ontario) and we completed DLBRM daily calibrations for five Erie watersheds: Huron, Raisin, Maumee, Sandusky, and Grand (Ohio). We are now calibrating the DLBRM for the remaining 12 US Erie watersheds. We estimated sediment and nutrient transport for two non-Erie watersheds and are doing the same now for the Maumee watershed on Lake Erie. We are now adding transport mechanics to the DLBRM. We developed automatic near real time "Resource Shed" processing for 18 watersheds, including the five Erie watersheds mentioned previously. Resource shed maps for the last 31 days are available daily and will soon be accessible via the WWW.

SWAT models are being developed for the same 7 Lake Erie watersheds being modeled by DLBRM – Huron, Raisin, Maumee, Sandusky, Cuyahoga, Grand (in Ohio), and Grand (in Ontario, Canada). Primary SWAT modeling efforts have transitioned from data gathering and reformatting to inputting data into SWAT models and setting initial model parameter values. Data gathering and reformatting for model input has been largely completed over recent months. Data obtained includes reference watershed boundaries, digital elevation models, stream networks, stream discharge time series, land cover, soil types, climate time series (precipitation, temperature, wind speed, relative humidity, solar radiation), agricultural management data, point source dischargers, reservoir and pond characteristics, and atmospheric N deposition. Data processing and reformatting has been completed for most of these data types. All 7 SWAT models have been created and at least have the subwatershed delineation completed. The Raisin model is parameterized and is currently being calibrated. Other models are in various stages of data input and parameterization. All watershed models have also been recently upgraded to the ArcSWAT 2.0 interface using ArcGIS 9.2.

HYPOXIA: A 1D version of the Princeton Ocean Model was applied to Lake Erie to model vertical thermal structure. The model is driven with momentum and heat fluxes calculated from standard meteorological observations at Cleveland using overland-overlake correction for wind speed. The model was calibrated with 1994 data and evaluated with 2004-2005 temperature observations at mid-lake location. Next, the model was run for a 1972-2005 period to provide input for a water quality model, and to study inter-annual variability in thermocline depth and sharpness (vertical temperature gradients).

Using the output of the 1D temperature profile model, the level 1 hypoxia model, developed in the previous year, was applied for a period of 1987-2005, the continuous period where data had been acquired for boundary conditions and calibration. This is a 1D (vertical) model aimed at identifying the relative importance of the establishment of temperature profile and associated hypolimnion volume due to hydrometeorological factors (i.e., wind, solar radiation) on the timing, duration, and magnitude of hypoxia in the central basin. The model generates a thermal and mixing profile for the central basin and estimates the dissolved oxygen profile. Kinetic formulations include a layer specific deoxygenation rate in the water column and sediment oxygen demand effective in the bottom layer. The model performs well when compared to epilimnion and hypolimnion average dissolved oxygen concentrations. However, smaller scale variations in the dissolved oxygen data are not captured well. This suggests that other processes are significantly influencing the oxygen dynamics.

This year, we have also developed the next level of hypoxia model. This model utilizes the same 1dimensional thermal model, but includes a limnological model to better represent eutrophication mechanisms in the lake. Model processes include phytoplankton growth, respiration, and decay, nutrient (phosphorus) uptake and limitation, light limitation, as well as feedback from the sediments. This model is currently being applied for 1987-2005.

We have also been reviewing the literature on estimation of modeling uncertainty in an effort to develop a methodology for quantifying model uncertainty for use in this project. Initial efforts are underway to apply a parameter estimation or optimization algorithm to the level 1 model. This approach will allow us to assess the optimal parameter values and compare to expected values. This can help determine which processes are important, but not being represented in model. Additionally, the parameter estimation framework will allow us to estimate parameter uncertainty.

<u>ECOLOGICAL EFFECTS:</u> The Ecological Effects team is developing a suite of models to explore how hypolimnetic hypoxia impacts ecological interactions and fisheries production in the central basin of Lake Erie. Our ultimate goal is to apply these models to forecast how fish production in Lake Erie would be affected by potential, future nutrient loading scenarios and hypoxia dynamics.

In applying our models, we build directly on the efforts of other project components (i.e., we will use the output from Watershed and Hypoxia forecasting models as input for our models). Thus, the thrust of our model application efforts will occur towards the end of the project (i.e., after other project components have generated watershed and hypoxia forecasts).

During the initial phase of the project, we primarily work to develop and parameterize ecological models. To accomplish this goal, we rely on a variety of existing data: physical measures (temperature, water clarity, oxygen concentration), fisheries harvest data, annual fisheries-independent stock assessments, hydro-acoustic estimates of fish biomass, benthic macroinvertebrate surveys, zooplankton surveys (from optical plankton counter, net collections and pump samples), and fish samples (midwater and bottom trawl caught fish allowing for quantification species-specific vertical distributions and diet contents). Most of these data were collected through the IFYLE

(International Field Years on Lake Erie) program and state/provincial agency-based monitoring efforts. Most of the data which we use for model development and parameterization have been previously collected and analyzed (primarily through IFYLE-related efforts). However, some previously collected data require compilation, processing and analyses before they can be used for model development and parameterization. To this end, we have analyzed biological data (zooplankton, benthic macro-invertebrate, and fish) and compiled historical fisheries and fisheries-independent data (including manual data entry from paper copies).

To date, we have developed bioenergetics growth rate potential models for rainbow smelt, yellow perch and walleye. We have applied these models 1) using physical, chemical and biological data collected during 2005 IFYLE cruises in central Lake Erie and 2) using preliminary output from 1-dimensional hypoxia models. We have also initiated a retrospective statistical analysis to explore how hypoxia may have impacted key Lake Erie fish species in the past. Finally, we are currently actively searching for three post-doctoral fellows who will facilitate the further development and application of our ecological models.

Publications

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