Impacts of Hypoxia on the Benthos of Central Lake Erie

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Overview

The objective of this project is to determine the impact of low oxygen content in lake water, referred to as hypoxia, on the benthic invertebrate community in the central basin of Lake Erie. Special emphasis is placed on the family Chironomidae because most species within this family are heavily fed upon by benthivorous fish, and thus hypoxia-related impacts may affect fish feeding patterns. Although many species of chironomids are tolerant of short periods of hypoxia, prolonged hypoxia may cause organisms to enter a state of physiological dormancy, resulting in lowered feeding and a decline in physiological condition.

Proposed Work

2008

- count, sort, and identify organisms in 2007 samples
- complete measures of physiological condition of chironomids including an analysis of
    - lipid content
    - glycogen content
    - ETS
    - RNA/DNA
    - Carbon
    - Nitrogen

Data collected will provide information on the extent hypoxia affects the physiological health of Chironomids which serves as an important diet item of fish. The metrics for physiological health will be determined over winter 2008.

Accomplishments

Extensive field-collection years occurred in 2005 and 2007

Benthic Macroinvertebrates

To assess impacts of low oxygen levels on macroinvertebrate populations in the central basin of Lake Erie, ponar grab samples were collected at three primary sites (Stations 7, 8 and 13) and at 6 secondary sites (Stations 7E, 7W, 8E, 8W, 13E, and 13W) in 2005. Two of the primary sites (7 and 8) were located in the hypoxic region and one site (13) was located in a region less prone to oxygen depletion. The secondary sites were located one mile east and one mile west of the primary sites. Samples were collected in quadruplicate at each site on an approximately monthly basis between May and October, 2005.

- A total of 252 samples were collected for sediment nutrient analysis (carbon, nitrogen, biogenic silica, and phosphorus)
- Chironomids were collected at the primary sites for length-weight, lipid, carbon, and nitrogen content.
- All organisms were picked, counted, and sorted by major taxonomic group (*Oligochaeta, Chironomidae, Sphaeriidae, Dreissena,* and other)
- Biomass of the major groups has been determined and lipid, carbon, and nitrogen content of chironomids were measured

In 2007, grab samples were again collected at Stations 7 and 13, and at a new site, Station 18. The new site was located at a shallower depth (18 m compared to 22 m) and was sampled as a control site, in the hopes that it would not experience hypoxia during sampling. Grab samples were taken in quadruplicate at each of the three sites in July, August, September, and October. This time period allowed sampling before, during and after hypoxia.

Zooplankton Studies and Deployment of New PSS

The new laser Plankton Survey System (PSS) was successfully tested in Lake Michigan. In Lake Erie, however, the system choked on the data steam for multi-element (large) particles. Possible problems include faulty software, computer, or other hardware. Another cruise is scheduled in Lake Michigan and Muskegon Lake to find the exact source of the problem. Despite the glitch, the PSS was used to map out all variables except zooplankton during the September hypoxia cruise and was useful in finding the hypoxic edge and transition zone between the hypoxic region and the region where huge concentrations of smelt were found.

During the 2007 cruise, data was collected using the pump system. These data will greatly add to the results for 2005, when the lowest O2 observed was ~ 1 mg/L. Key results include:

- Zooplankton in the hypolimnion region at extremely low oxygen concentrations (0.14 mg/L O2)
- *Bythotrephes* also found in this zone

Fish Acoustics, Trawling, Diet, & Proximate Body Composition

Three cruises were conducted to collect data to supplement 2005 data

1. 4-day cruise (late August): collected fish for diet, RNA:DNA, ETS, lipid, and energetic analyses via bottom trawling. Stations were sampled inside and outside the hypoxic zone, including the edge, with both trawling (midwater and bottom) and acoustics.
2. 7-day cruise (September 4-10): mapped the distributions of hypoxia, temperature, zooplankton and fishes, using PSS towed in parallel with fish acoustics gear.
    - collected both fish and habitat data throughout central basin (Figure 1)
    - data collected on this cruise will allow determination of the areal extent of the 2007 hypoxic zone, and provide insight into where fish reside during hypoxia

3. 4-day cruise (late September): collected fish for diet, RNA:DNA, ETS, lipid, and energetic analyses via bottom trawling. Stations were sampled inside and outside of the hypoxic zone, including the hypoxia edge

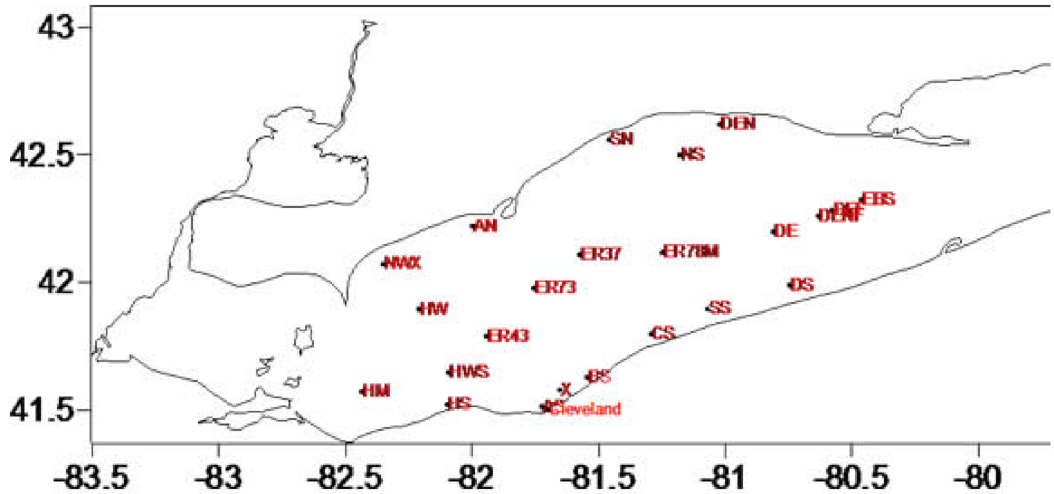


Figure 1: *Final cruise track for the acoustics-PSS cruise during September 4-10, 2007. Red transects were sampled both day and night. Yellow transects were sampled during day only. Blue transects were only be sampled during night. Green transects spanned both day and night. Black transects were for transit only.*

RNA:DNA Analyses

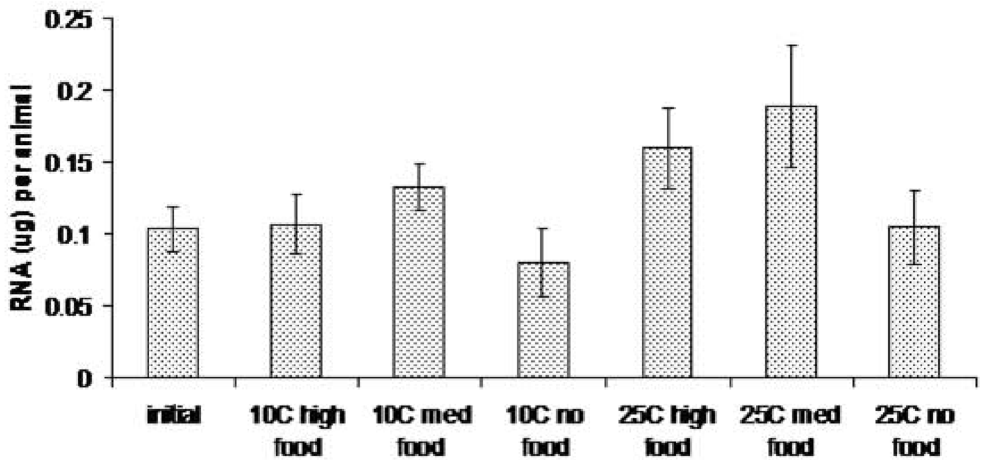
We conducted a set of experiments to determine how nucleic acid contents of yellow perch and *Daphnia mendotae* respond to variation in conditions (temperature, oxygen concentration, food availability; see below). During August and September 2007, we collected muscle tissue samples from yellow perch and rainbow smelt (captured in Lake Erie) for subsequent RNA:DNA analysis. In total, we collected 94 rainbow smelt samples and 164 yellow perch samples.

Experiment 1

To evaluate survival rates of *Daphnia mendotae*, we incubated recently-hatched *Daphnia mendotae* at different temperatures and dissolved oxygen concentrations, and noted survival at regular intervals. Zooplankters survived at a much higher rate at higher dissolved oxygen concentrations.

Experiment 2

To evaluate the effect of temperature and food availability on growth, we incubated recently-hatched *Daphnia mendotae* at different temperatures and with varying food availability. After 30 hrs, zooplankters were removed and RNA per animal was quantified. Results (mean±SE) from this experiment are presented below.



Experiment 3

To develop a temperature-specific relationship between yellow perch RNA:DNA and growth, we reared yellow perch at three different temperatures and various rations. After rearing fish for five days, fish were sacrificed, measured (length and weight to quantify growth) and muscle tissue removed for subsequent RNA:DNA analysis. In total, we collected tissue samples from 62 yellow perch for this experiment.

Consumption Experiments

We conducted a series of experiments to determine the joint effects of temperature and oxygen concentration on the consumption rates of yellow perch and walleye. Our experiments involved introducing fish to experimental conditions (fixed temperature and oxygen, with levels varying among treatments) over a 2 day starvation period. Fish were then fed ad lib for 5 days and each day, total food consumption was noted. At the end of the experiment, fish were sacrificed, measured (length and weight to quantify growth) and muscle tissue was removed for subsequent RNA:DNA analysis.

We were unsuccessful in conducting similar experiments with walleye. We brought groups of live walleye into the lab on multiple occasions, but each time walleye experienced massive mortality events and we were unable to complete this phase of the experiment.

Scientific Rationale

Of the numerous recent human-induced effects on aquatic ecosystems, none has been more prevalent than eutrophication. One typical consequence of eutrophication is severe hypoxia or anoxia (oxygen depletion) in bottom waters due to increased bacterial activities. Eutrophication-driven reductions in oxygen levels are documented in freshwater, marine, and estuarine systems throughout the world, including the central basin of Lake Erie.

Reduced oxygen availability can have dramatic effects on aquatic organisms. Severe hypoxia can reduce population size through direct mortality, and if sustained, can lead to the disappearance all organisms which cannot tolerate conditions. Late-summer hypoxia has occurred in central Lake Erie for the past 50 years and perhaps longer. The benthic community in this area is dominated by two taxonomic groups, Oligochaeta and Chironomidae. Although both groups contain species which can withstand periodic hypoxia, each suffer from reduced feeding and increased metabolic costs, leading to a reduction in growth and development.

Sampling was conducted before, during, and after hypoxia at three sites in July, August, September, and October 2007. The ideal experimental design would have consisted of three sites located in areas of severe, light, and no hypoxia, with the ability to collect the same species of chironomids at all sites. However, hypoxia and chironomid communities are both functions of depth and substrate, so the idealistic design could not be achieved. Species of chironomids found at non-hypoxic, control sites were entirely different from species found at sites that experienced hypoxia. Despite this, the three sites sampled likely experienced different degrees of hypoxia. We know this from the distribution of dreissenids (mussels) because dreissneids are sensitive to hypoxia and were found at some of our sampling sites but not at others.

Governmental/Societal Relevance

Currently, there is much concern by Lake Erie management agencies and user groups about the reappearance of the dead zone in Lake Erie. From an ecological standpoint, it is still unknown if this concern is justified.

This project is part of an effort to provide Lake Erie resource management agencies with an accurate understanding of the relationship between seasonal low oxygen events and the ecology of Lake Erie, including fisheries production. If we find that low oxygen events have little impact on benthic macroinvertebrates and other components of the food web, concern by management agencies is trivial. Lake Erie management agencies can utilize this new information to better manage user group (e.g. commercial and recreational fishers) and their expectations regarding anoxia.

Relevance to Ecosystem Forecasting

Field observations and laboratory analyses will provide an indication of how quantity and quality of benthic invertebrates, particularly chironomids, are influenced by hypoxia. In turn, this information would help us understand likely changes in the diet, condition, and growth of focal fish species in response to hypoxia.

Products

Presentations/Posters

Ludsin, S.A. 2007. *Hypoxia alters species distributions and interactions: implications for food webs and fisheries*. Department of Biology, University of Akron, Akron, OH (invited seminar)

Ludsin, S.A. 2007. *Hypoxia alters species distributions and interactions: implications for food webs and fisheries*. Department of Evolution, Ecology, and Organismal Biology, The Ohio State University, Columbus (invited seminar).

Ludsin, S.A., H.A. Vanderploeg, S.A. Pothoven, D.M. Mason, T. Höök, and S.A. Ruberg. 2007. *Hypoxia effects on habitat and prey availability for rainbow smelt in central Lake Erie*. International Association for Great Lakes Research, University Park, PA (contributed presentation)

Liebig, J.R., H.A. Vanderploeg, G.A. Lang, J.F. Cavaletto, and M. Clouse. 2007. *Selecting bin sizes to enhance zooplankton information from the optical plankton counter in Great Lakes studies*. International Association for Great Lakes Research, University Park, PA (contributed presentation)

Ludsin, S.A. 2007. *Lake Erie hypoxia: history and management response*. Ecological Impacts of Hypoxia on Living Resources Workshop Symposium, Bay St. Louis, MS. (invited presentation)

Vanderploeg, H, S. Ludsin, S. Pothoven, T. Höök, J. Roberts, S. Ruberg, J. Cavaletto, J. Liebig, G. Lang, and S. Brandt. *Influence of hypoxia on the distribution, behavior, and foraging of zooplankton and planktivorous fish in central Lake Erie: field observations and future research directions*. Ecological Impacts of Hypoxia on Living Resources Workshop Symposium, Bay St. Louis, MS. (invited presentation)

Höök, T., S. Ludsin, S. Pothoven, J. Roberts, T. Nalepa, H. Vanderploeg, S. Ruberg, and S. Brandt. 2007. *Influence of hypoxia on the ecology of zooplanktivorous and benthivorous fishes in Lake Erie's central basin*. Ecological Impacts of Hypoxia on Living Resources Workshop Symposium, Bay St. Louis, MS. (invited presentation)

Pothoven, S.A., S.A. Ludsin, H.A. Vanderploeg, and T.O. Höök. 2007. *Effects of Lake Erie hypoxia on pelagic fish feeding ecology*. International Association for Great Lakes Research, University Park, PA (contributed poster)

Roberts, J.J., T.O. Höök, S.A. Ludsin, S.A. Pothoven, H.A. Vanderploeg, and T.F. Nalepa. 2007. *The ecological response of yellow perch to hypoxia in Lake Erie's central basin*. International Association for Great Lakes Research, University Park, PA (contributed presentation)

Rae, C., S. Ludsin, K. Hozyash, and D. Kimmel. 2007. *Hypoxia effects on fish in the Northern Gulf of Mexico*. 21st National Conference on Undergraduate Research, Dominican University of California, San Rafael, CA (contributed poster)

Ludsin, S.A. 2007. *Ecological effects of hypoxia: a comparison of the Baltic and Great Lakes regions. The North American Great lakes: comparison with the Baltic Sea*, Workshop Series-I. University of Michigan, Ann Arbor (invited presentation).

Ludsin, S.A. 2006. *Ecological Consequences of Hypoxia in Coastal Systems: Case Studies of Lake Erie, Chesapeake Bay, and the Northern Gulf of Mexico*. NOAA-GLERL, Ann Arbor, MI (invited seminar)