

SEA GRANT PROJECT SUMMARY FORM 90-2 DEVELOPMENT PROPOSAL

INSTITUTION: Illinois Natural History Survey, University of Illinois at Urbana-Champaign

(a) **ICODE:** XXX

TITLE: Modeling the 10-year changes of juvenile fish assemblages in Lake-Michigan near-shore water

INITIATION DATE: Oct. 1, 2009

COMPLETION DATE: Sep. 30, 2010

PRINCIPAL INVESTIGATOR: Yong Cao

- a) **EFFORT:** one month
- b) **AFFILIATION:** University of Illinois
- c) **AFFILIATION CODE:**

CO-PRINCIPAL INVESTIGATOR: Sergiusz Czesny

- a) **EFFORT:** one month
- b) **AFFILIATION:** University of Illinois
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S.G. FUNDS: \$9,950

RELATED PROJECTS:

- a) Yellow Perch Population Assessment in Southwestern Lake Michigan – Sport Fish Restoration
- b) Growth and Survival of Near-shore Fishes in Lake Michigan – Sport Fish Restoration

SEAGRANT STRATEGIC PLAN CLASSIFICATION: Great Lakes Health

OBJECTIVES:

- a. To examine how species richness, composition, and total abundance of larval and juvenile fish assemblages have changed over past 11 years (1999-2009) at sampling stations along IL shoreline of Lake Michigan
- b. To evaluate what and how abiotic (e.g., weather, habitat, and water quality) and biotic factors (e.g., food supplies, species competition) collectively affect the temporal dynamics of these changes by modeling and multivariate analysis
- c. To develop a strong conceptual and a robust technical framework for a future project that will be focused on the meta-analyses of basin-wide changes in larval and juvenile fish assemblages in relation to physical environment, climate changes, and invasive species.

PROBLEM:

The Great Lakes ecosystems have and are still experienced dramatic changes. These changes adversely affect both sport and commercial fisheries, and ecosystem functions of the lakes. Assesses causes of change, in Great Lakes fish communities, particularly the substantial declines in the populations of many native fish species (e.g., yellow perch and lake trout) is one research priority (Great Lakes Fishery Commission 2001). One of key factors that account for the

population decline has been identified to be recruitment failure (Great Lakes Fishery Commission 2001).

Many factors have been reported to contribute to recruitment failure, including short food supplies, predation and competition by invasive species, and reduced spawning stock by over-fishing (e.g., Dettmers et al. 2003, Bremigan et al. 2003, Clapp and Dettmers 2004, Creque et al. 2007). These findings provide valuable guides for fisheries management (Clapp and Dettmers 2004). However, three questions remains and need to be addressed rigorously. First, many natural environmental factors strongly affect year-to-year variability of recruitment, including weather conditions in spawning months, lake current, and river discharge (e.g., Hoff 2004, Höök et al. 2006). The substantial among-year natural variability makes it a great challenge to accurately quantify the effect of specific factors of management interests (e.g., harvesting, food supply, and predation) on recruitment, and to predict the responses of fish assemblages to restoration efforts or anticipated environmental changes (e.g., climate, water quality, and invasive species).

Second, most studies have been focused on the recruitment of individual species, particularly sport fishes (e.g., yellow perch and walleye). However, such studies are unlikely to adequately explain or predict the change of whole fish assemblages. The interactions among species or different assemblages can be important. For example, food competition among larvae and juveniles of different species may significantly affect the recruitment of individual species. Similarly, predation pressure on the larvae/juvenile of a specific species can be affected by the larval/juvenile abundance of other species. Examining a juvenile fish assemblage as a whole could provide new insights into the problem of recruitment. The changes in species composition and abundance of zooplankton assemblages also could selectively affect different fish species and then can be useful predictors of juvenile fish abundances.

Finally, previous studies have been largely concentrated on the effects of individual biotic and abiotic factors, such as food supplies or predation. However, in reality, these abiotic and biotic factors likely work together with complex interactions to determine the change of larval and juvenile fish abundances. Therefore, the relative contributions of different factors likely vary with species, locations, habitat type, and time. Simple modeling approaches (e.g., linear regression and correlation) that were often used in previous studies may not be effective to reveal potentially non-linear and complex relationships of juvenile fish assemblages with various biotic and abiotic factors.

RATIONALE (IMPACT OF PROBLEM):

In this proposed study, we will directly address one of the Sea-Grant core topics, “Great Lakes Health (especially Lake Michigan)” In specific, we will seek to fill the three knowledge gaps as identified above. We believe that our study will significantly improve our understanding on how different abiotic and biotic factors affect juvenile fish assemblages collectively, and our ability of predicting future changes of juvenile fish and their possible responses to certain management practices in the Lake Michigan.

Several recent studies have highlighted the importance of considering multiple factors in explaining the recruitment of specific species (e.g., Hoff 2004, Clapp and Dettmers 2004, Redman et al., 2009). However, how different biotic and abiotic factors affect juvenile fish assemblages as a whole has been poorly understood. The conceptual and technical framework that we will develop in this study will provide a general model similar studies and a base for a developing basin-wide project that can be expected to attract further federal and state funding.

METHODOLOGY:

1) Framework

We will conduct two types of analyses. First, we will model the change in total juvenile fish abundance and species richness based on a range of abiotic and biotic factors. The abiotic factors will include nutrient concentrations, light input, and water temperature, Secchi depth. These factors affect primary productivity and therefore zooplankton abundances. Water temperature, wind speed, and water level also affect the growth and survival of larval fish and available habitats. We will also consider a variety of biotic factors, including total zooplankton abundance, the abundance of each species or taxon (not all juveniles can be identified to species level). Both factors have been shown to be important for recruitment (Clapp and Dettmers 2004, Redman et al. 2009). We also consider adult abundance of common species (e.g., yellow perch, alewife) and larval fish densities in the previous year. However, two potentially important factors could not be included in our modeling. One is lake current, which may significantly change the density of larval fish at certain locations and then affect juvenile abundance (Clapp and Dettmers 2004). However, water-mass movements appear highly variable and difficult to track (Höök et al. 2006). We also do not have enough data to evaluate effects of predation. However, the effects do not appear highly significant (Clapp and Dettmers 2004).

In the second analysis, we will use multivariate techniques to examine how changes in juvenile fish assemblages as whole are related to the biotic and abiotic factors described above, particularly to the abundances of different zooplankton species.

2). Data Sources

We will base our analysis primarily on a long-term monitoring project conducted by Illinois Natural History Survey (INHS) at the Lake-Michigan Biological Station. The project was initialized in 1999, focusing on larval and juvenile fish assemblages in South Chicago and Waukegan areas. Two sampling stations were established in each area. Samples of zooplankton, larval fish, and juvenile fish were collected from each station 2-4 times in summer months in the past decade. We will also obtain abundance data of adult yellow perch, alewife, and some other common species at our sampling stations or adjacent areas from IL Department of Natural Resources, and include them in our modeling.

Water temperature has been recorded daily and Secchi depth twice a month in summer at our sampling stations. We will compile weather and hydrology data for the study period from online database (e.g., USGS, USEPA, and NOAA). The variables we are interested in include water level, monthly precipitation, light input, wind direction and speed. We also will obtain data for a range of water-quality variables, particularly, nutrients, from IL-EPA for our sampling locations or adjacent areas.

3) Analytic Approaches

We will use Random Forests (Brieman 2001) to model the changes of species richness of juvenile fish, their total abundance, and the abundance of key species (e.g., yellow perch). Random Forests can effectively deal with non-linear responses, interactions among predictive variables, and over-fitting issue (Cutler et al. 2007, Olden et al. 2008). The relative importance of various biotic and abiotic factors and how each predicted assemblage attribute responds to a given factor will be examined using the summary tools of Random Forests.

We will also use non-metric multidimensional scaling, a robust ordination technique, to examine how juvenile fish assemblages changed over time. Correlation and randomization tests,

such as Procrustes test (Peres-Neto and Jackson, 2001), will be used to examine how different biotic and abiotic factors affect juvenile fish assemblages. All analyses will be implemented within R-package (R Development Core Team, 2009).

EXPECTED RESULTS AND IMPACT:

- 1) A primary database for juvenile fish and related biotic and abiotic variables at the two sampling areas. We will use this database and the conceptual and technical framework developed in this study to develop a major proposal that will be submitted to Federal or State funding agencies (e.g., NSF, USEPA and NOAA).
- 2) Predictive models for near-shore juvenile fish species richness and abundance. The models can be used to infer the role of different factors in fish recruitment and to predict the effectiveness of certain management practices.
- 3) Assessments of relative contribution of different abiotic and biotic factors to the long-term changes in juvenile fish species composition and relative abundances. This information is critical for developing an ecosystem-based management strategy for Lake-Michigan fisheries and will also be used in future proposal development.
- 4) One presentation at a regional or national scientific conference.
- 5) One or two publications in peer-reviewed ecological or fisheries journals.

Literature Cited:

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EDUCATION

Shandong Normal University, China	Biology	B.S.	1982
Chinese Academy of Science, China	Limnology	M.S.	1986
University of London, England,	Ecology	Ph.D.	1995

Appointments:

- Stream Ecologist at INHS, Champaign, IL, Aug. 2007-present
- Senior Ecologist, Utah State University at Logan, 2001-2007.
- Research Associate at US-EPA Lab, Corvallis, Oregon, 1999-2001
- Biostatistician in Boojum Research, Ltd., Toronto, Ontario, Canada, 1998-1999
- Research Associate at the University of Toronto at Scarborough, Canada, 1996-1998
- Lecture of Ecology at Suzhou Institute of Environmental Protection, China, 1986-1990

Professional Memberships

- Ecological Society of America
- North American Benthological Society

Publications related to the proposal

- 1) Hawkins, C.P., Y. Cao, and B. Roper. 2009. Method of predicting reference condition biota affects the performance and interpretation of ecological indices. *Freshwater Biology* (accepted).
- 2) Cao, Y., C.P. Hawkins, D.P. Larsen, and J. Van Sickle. 2007a. Effects of sample standardization on mean species detectabilities and estimates of relative differences in species richness among assemblages. *American Naturalist* 170: 381-395.
- 3) Cao, Y., C.P. Hawkins, J. Olsen, and M. Nelson. 2007b. Modeling natural environmental gradients improves the accuracy and precision of diatom-based indicators for Idaho streams *Journal of the North American Benthological Society* 26:566-585.
- 4) Cao, Y., and C.P. Hawkins. 2005. Simulating biological impairment for evaluating ecological indicators. *Journal of Applied Ecology* 42: 954-965
- 5) Cao, Y., C.P. Hawkins and A.W. Storey. 2005. Measuring the comparability of sampling methods in stream assemblage surveys. *Freshwater Biology* 50:1105-1115.
- 6) Cao, Y., D. P. Larsen & D. White. 2004. Estimating regional species richness with a limited number of survey units. *Ecoscience* 11:23-35.
- 7) Cao, Y., C. Hawkins, & M. Vinson. 2003. Measuring and controlling data quality in ecological assemblage surveys with a special reference to stream benthic macroinvertebrates. *Freshwater Biology* 48:1898-1911.
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- 9) Cao, Y., D. P. Larsen, & R. Hughes. 2001. Evaluating sampling sufficiency in fish surveys – a similarity-based approach. *Canadian Journal of Fisheries and Aquatic Sciences* 58: 1782-1793.
- 10) Cao, Y., D.D. Williams, & N.E. Williams. 1999. Data transformation and standardization in multivariate analysis of river water quality. *Ecological Applications* 9: 669-677.
- 11) Cao, Y., D. D. Williams, & N.E. Williams. 1998. How important are rare species in community ecology and bioassessment. *Limnology & Oceanography* 43: 1403-1409.
- 12) Cao, Y., W.P. Williams, & A.W. Bark. 1997. Analyzing the change of benthic community changes along a pollution gradient: a framework for the development of biotic indices. *Water Research* 31: 884-892
- 13) Cao, Y., Williams, W.P., & Bark, A.W. 1996. Measuring the responses of macro-invertebrate communities to organic pollution: A comparison of multivariate approaches, diversity and biotic indices. *Hydrobiology* 341:1-19.

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EDUCATION

Ph.D. The Ohio State University, Environmental Sciences Program, Columbus, OH, 2000

M.S. University of Lodz, Department of Applied Ecology, Poland, 1993

POSITIONS HELD

- June 2006 - present: Assistant Professional Scientist, Aquatic Ecologist/Field Station Director, Lake Michigan Biological Station, University of Illinois, Institute of Natural Resource Sustainability, Illinois Natural History Survey, Zion IL.
- June 2005 - May 2006: Associate Research Scientist/Associate Director, Illinois Natural History Survey, Lake Michigan Biological Station, Zion IL.
- Sept. 2000 - May 2005: Post-Doctoral Researcher, Illinois Natural History Survey/University of Illinois, Lake Michigan Biological Station, Zion IL.
- Jan. 1995 - Aug. 2000: Graduate Research Assistant. School of Natural Resources, The Ohio State University, Columbus OH.
- Nov. 1993 - Dec. 1994: Research Assistant. School of Natural Resources, The Ohio State University, Columbus OH.
- June 1992 - June 1993: Graduate Research Assistant. Department of Applied Ecology, University of Lodz, Poland.

PROFESIONAL MEMBERSHIPS

American Fisheries Society

American Fisheries Society – Early Life History Section

The Fisheries Society of the British Isles

REFEREED PUBLICATIONS

- Czesny, S.**, Dettmers, J.M., Rinchar, J., Dabrowski, K. 2009. Linking Egg Thiamine and Fatty Acid Concentrations of Lake Michigan Lake Trout (*Salvelinus namaycush*) with Early Life Stage Mortality *Journal of Aquatic Animal Health*. In press.
- Vuori, K.A., Paavilainen, T., Nikinmaa, M., **Czesny, S.** and Rinchar, J. 2009. Molecular markers of yolk-sac fry of lake trout show differences between EMS and M74. *Journal of Aquatic Animal Health*. In press
- Lee, B-J., Jaroszevska, M., Dabrowski, K., **Czesny, S.** and Rinchar, J. 2009. Effects of Vitamin B1 (Thiamine) Deficiency in Lake Trout (*Salvelinus namaycush*) and Preventive Treatments. *Journal of Aquatic Animal Health*. In press.
- Jaroszevska, M., Lee, B-J., Dabrowski, K., **Czesny, S.**, Rinchar, J., Trzeciak, P., and Wilczynska, B. 2009. Effects of vitamin B₁ (thiamine) deficiency in lake trout (*Salvelinus namaycush*) alevins at hatching stage. *Comparative Biochemistry and Physiology*, Available on-line July 2009.
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