Bioenergetics of Lake Whitefish in the Great Lakes

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Project Sponsor: Great Lakes Fishery Trust

Overview

This project will provide fishery managers with predictions on Lake Whitefish size (growth) and numbers (production) under different diet, abundance, and thermal conditions.

Recent declines in growth and condition of Lake Whitefish have elicited concern by fishery managers and commercial fishermen. We propose to use bioenergetics modeling to examine how changes in diet, abundance, interactions with other species, and changes in thermal regimes may contribute to growth and condition declines. One method that can be used to explore the factors that are contributing to declines in fish growth is bioenergetics modeling. We recently evaluated and modified the bioenergetics model for Coregonus spp. applied to Lake Whitefish using a two-tiered approach that included testing in the laboratory and field. We now propose to apply the bioenergetics model to Lake Whitefish populations in Lake Michigan and Huron to examine which biological and physical factors are most important for assessing Lake Whitefish growth and production.

Project Plans

- Model Lake Whitefish growth and consumption in Lakes Huron and Michigan using diet, thermal preference, and energy density data collected during 1998-2003.
- Use bioenergetics modeling to evaluate how changes in diet and thermal regimes affect Lake Whitefish growth and consumption.
- Use bioenergetics modeling to evaluate how much of the available food production is consumed by Lake Whitefish and other planktivorous fish in different regions of Lake Michigan and Huron.

Scientific Rationale

Historically, Lake Whitefish (Coregonus clupeaformis) have been a mainstay of the commercial fishery in the Laurentian Great Lakes (Fleischer 1992). The average commercial harvests of Lake Whitefish from lakes Michigan and Huron in the 1990s were 34 and 42 thousand metric tons/year and accounted for nearly 50% of the total commercial catch (Schneeberger et al. 2005, Mohr and Ebener 2005). Recent declines in growth and condition of Lake Whitefish have elicited concern by fishery managers and commercial fishermen. Declines in growth may be caused by a number of biological and physical factors. Growth declines may be related to the consumption of low-quality food items such as Zebra mussels *Dreissena polymorpha* and other molluscs and to the virtual loss of the high-energy food *Diporeia* spp. (Pothoven et al. 2001). Lake Whitefish populations also experience density dependence growth reductions and record high numbers may exacerbate the effects of declining prey quantity and quality. Finally, Lake Whitefish may be moving into deeper, colder water to find alternative prey such as Mysis relicta, which could affect their thermal regime and diets.

Bioenergetics Modeling Efforts for Great Lakes Whitefish

Individual data sets collected throughout Lake Michigan on Lake Whitefish diet (1998-2000 (Pothoven et al. 2001, Pothoven 2005), Lake Whitefish condition (1985-2000) (Schneeberger et al. 2005), and benthic invertebrates (1980-2000) (Nalepa et al. 2000) suggest that a more comprehensive approach is needed to manage Lake Whitefish. One method that can be used to explore factors contributing to declines in fish growth is bioenergetics modeling. A bioenergetics model is a balanced energy equation where consumption is equal to the sum of metabolic costs, waste, and growth (Hewett and Johnson 1989). Bioenergetics models require inputs of bioenergetic parameters, water temperature data, growth data, energy density data, and diet data. In the Great Lakes, bioenergetics modeling has been used effectively to evaluate predator-prey dynamics between salmonine predators and prey fish (Stewart and Ibarra 1991; Hansen et al. 1993), to better understand the trophic ecology of lake trout (*Salvelinus namaycush*) (Madenjian et al. 1998), and to quantify the consumption of invertebrates by populations of planktivorous fish (Rand et al. 1995). Understanding diet patterns and bioenergetics of Lake Whitefish was recently identified as a top-priority research item for funding by the Lake Huron and Michigan Technical Committees, under the auspices of the Great Lakes Fishery Commission Lake Committees.

In 1994, a bioenergetics model for Coregonus spp. was developed using some physiological parameters for Lake Whitefish (Rudstam et al. 1994). However, the model was never tested in either the laboratory or in the field. Based on a recent comparison of the model's predictions of food consumption and growth with observed consumption and growth, the authors concluded that the bioenergetics model furnished significantly biased estimates of both food consumption and growth by Lake Whitefish (Madenjian et al. in press). The source of the bias was likely an overestimation of respiration rate, which was adjusted to obtain a good fit of the model to the observed consumption and growth. Until the measurement of Lake Whitefish respiration rates is repeated in the laboratory, it was recommend that the revised bioenergetics model be applied to Lake Whitefish (Madenjian et al. in press).

We propose to evaluate individual Lake Whitefish growth and consumption under different diet and thermal scenarios. Individual growth and consumption data will be expanded to the population level using abundance estimates obtained from fishery management agencies. Lake Whitefish diets in the Great Lakes appear to be changing in response to Dreissena invasions and subsequent *Diporeia* declines. These changes have resulted in diets that are often dominated by low-energy prey types (Pothoven et al. 2001). There is concern among fishery managers in the Great Lakes that changes in the diets of Lake Whitefish could affect growth, production, and commercial harvests of this species. Bioenergetics modeling will be used to provide insight into important management questions including:

- How will ongoing and future changes in the diet of Lake Whitefish affect growth?
- Can prey resources support ongoing changes in the diet of Lake Whitefish?
- How does inter- and intra-species specific competition affect the growth of Lake Whitefish?
- How will changes in the temperature regime experienced by Lake Whitefish affect growth?

Bioenergetics modeling is a tool that can be used by managers to predict the consequences and the utility of certain management decisions before they are implemented. Managers have several options available to manage Lake Whitefish, including harvest quotas and size, depth, and season restrictions. Because bioenergetics modeling provides a more comprehensive understanding of ecological problems than individual data sets, our results will help managers understand how to best implement future management strategies and regulations. Results from our bioenergetics modeling can also be used in comprehensive, multi species food web assessments in the future

Accomplishments

We evaluated the Wisconsin bioenergetics model for Lake Whitefish Coregonus clupeaformis in the laboratory and in the field. For the laboratory evaluation, Lake Whitefish were fed rainbow smelt Osmerus mordax in four laboratory tanks during a 133-day experiment. Based on comparison of bioenergetics model predictions of food consumption and growth with observed consumption and growth, we concluded that the bioenergetics model furnished significantly biased estimates of both food consumption and growth by Lake Whitefish. On average, the model overestimated consumption by 61% (Figure 1) and underestimated growth by 16%. The source of the bias was likely an overestimation of respiration rate. We therefore adjusted the respiration component of the bioenergetics model to obtain a good fit of the model to the observed consumption and growth in our laboratory tanks. Using the adjusted model, predictions of food consumption over the 133-day period fell within 5% of observed consumption in three of the four tanks and within 9% of observed consumption in the remaining tank. We used polychlorinated biphenyls (PCBs) as a tracer to evaluate the Lake Whitefish bioenergetics model in the field. Based on our laboratory experiment, the efficiency, γ, with which Lake Whitefish retained PCBs from their food was estimated at 0.45. We applied the bioenergetics model to Lake Michigan Lake Whitefish, and then, using PCB determinations of both Lake Whitefish and their prey from Lake Michigan, we estimated γ in the field. Application of the

original model to Lake Michigan Lake Whitefish yielded a field estimate of 0.28, implying that original formulation of the model overestimated consumption by Lake Whitefish in Lake Michigan by 61%. Application of the bioenergetics model with the adjusted respiration component resulted in a field estimate of γ of 0.56, implying that this revised model underestimated consumption by Lake Whitefish in Lake Michigan by 20%. Until the measurement of Lake Whitefish respiration rates is repeated in the laboratory, we recommend that our revised bioenergetics model be applied to Lake Whitefish.

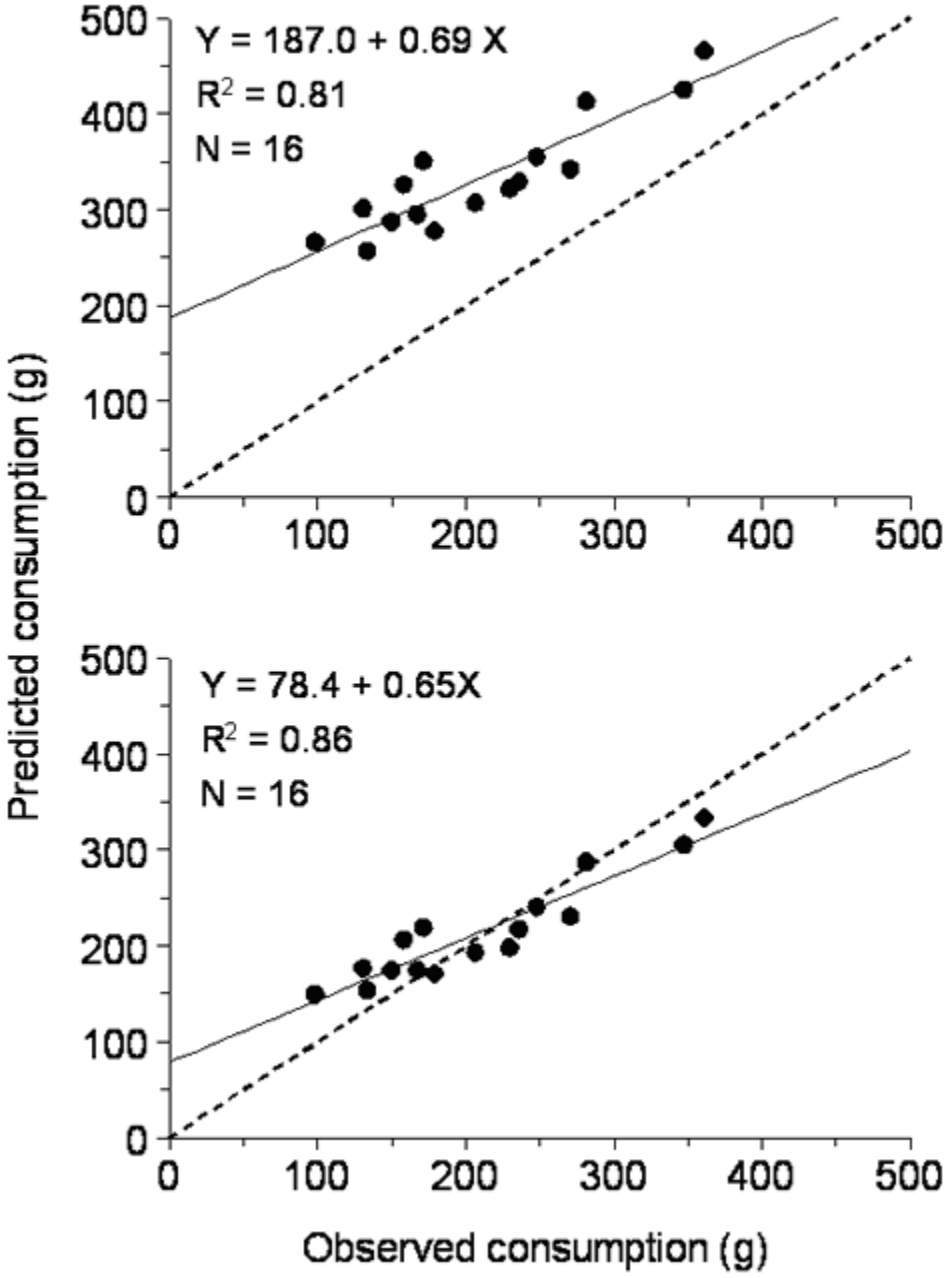

***Figure 1**: Predicted consumption, based on the generalized coregonid bioenergetics model by Rudstam et al. (1994) (upper panel) and based on our revision of the generalized coregonid bioenergetics model (lower panel), by an average lake whitefish in a test tank (4 tanks used in the laboratory experiment) during a test period (4 periods per tank) as a function of observed consumption by an average lake whitefish in a test tank during a test period. Each test period was about one month long. The solid line represents the regression line fitted to the points. The dashed line represents the line of 1:1 correspondence between predictions and observations.*

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Products

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Presentations

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