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Assessing the health of lake whitefish populations in the Laurentian Great Lakes: Lessons learned and research recommendations

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ABSTRACT

Although lake whitefish *Coregonus clupeaformis* populations in the Laurentian Great Lakes have rebounded remarkably from the low abundance levels of the 1960s and 1970s, recent declines in fish growth rates and body condition have raised concerns about the future sustainability of these populations. Because of the ecological, economic, and cultural importance of lake whitefish, a variety of research projects in the Great Lakes have recently been conducted to better understand how populations may be affected by reductions in growth and condition. Based upon our participation in projects intended to establish linkages between reductions in growth and condition and important population demographic attributes (natural mortality and recruitment potential), we offer the following recommendations for future studies meant to assess the health of Laurentian Great Lakes lake whitefish populations: (1) broaden the spatial coverage of comparative studies of demographic rates and fish health; (2) combine large-scale field studies with direct experimentation; (3) conduct multi-disciplinary evaluation of stocks; (4) conduct analyses at finer spatial and temporal scales; (5) quantify stock intermixing and examine how intermixing affects harvest policy performance on individual stocks; (6) examine the role of movement in explaining seasonal fluctuations of disease and pathogen infection and transmission; (7) evaluate sampling protocols for collecting individuals for pathological and compositional examination; (8) quantify sea lamprey-induced mortality; and (9) enact long-term monitoring programs of stock health.

Introduction

Lake whitefish *Coregonus clupeaformis* is an economically, ecologically, and culturally important species throughout the Laurentian Great Lakes. From an economic perspective, the commercial harvest of lake whitefish contributes millions of dollars annually to the gross domestic products of the United States and Canada (Ebener et al., 2008a). Ecologically, lake whitefish direct energy and nutrients from benthic to pelagic areas of the Great Lakes by feeding on a variety of benthic organisms. In terms of cultural importance, Native American tribes and First Nation communities have fished for lake whitefish for thousands of years and contemporary fishing provides a means for Native Americans and First Nation Aboriginals to maintain ties to their spiritual and traditional pasts while supporting their families (Brown et al., 1999; Ebener et al., 2008a). Many non-native fishing communities throughout the Great Lakes region also were developed around the lake whitefish fishing industry, and these communities remain strongly linked to this fishery.

Lake whitefish populations in the Great Lakes have rebounded remarkably from the low abundance levels of the 1960s and 1970s (Ebener et al., 2008a). This recovery has been attributed to sea lamprey *Petromyzon marinus* control efforts, improved environmental conditions, more restrictive and better informed harvest policies, and favorable weather conditions promoting survival of larvae (Spangler and Collins, 1980; Spangler et al., 1980; Ebener, 1997; Ebener et al., 2008a). As evidence of this recovery, lake whitefish commercial harvest in lakes Huron and Michigan has on average met or exceeded harvest goals set by fishery management agencies since the 1990s (Schneeberger et al., 2005; Ebener et al., 2008b,c). Presently, there are concerns that the recovery of Great Lakes lake whitefish stocks may be

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in jeopardy because of recent declines in fish growth and condition (Hoyle et al., 1999; Hoyle, 2005; Mohr and Ebener, 2005; Schneeberger et al., 2005; Ebener et al., 2008b). Several reasons for these declines have been postulated by researchers, including density-dependent regulation due to the burgeoning abundance of lake whitefish, food web changes that have at least partly resulted from invasion and expansion of dreissenid mussels (*Dreissena polymorpha* and *D. bugensis*), and environmental change stemming from global warming (Nalepa et al., 2005; Kratzer et al., 2007; Wright and Ebener, 2007; Debruyne et al., 2008; Rennie et al., 2009). Irrespective of its exact cause, the declines in lake whitefish growth rates and condition in the Great Lakes is troubling as such declines have preceded the collapse of other high-value fisheries (Lambert and Dutil, 1997).

Concerns over the possible effects of reduced growth and condition on future sustainability of Great Lakes lake whitefish stocks were the impetus for the natural mortality and recruitment research projects from which many of the articles in this special issue were derived. These two research projects ran concurrently and were both funded by the Great Lakes Fishery Trust, which had identified lake whitefish as a priority species for research in Lake Michigan (GLFT, 2000). The purpose of the natural mortality study [Project Title: Magnitude and Potential Causes of Mortality in Four Lake Whitefish Populations in Lakes Michigan and Huron: A Multidisciplinary Approach; Principal Investigator: Michael Jones (Michigan State University)] was to relate measured differences in natural mortality rates among four lake whitefish stocks in northern lakes Huron and Michigan to various measures of fish health (e.g., fatty acid composition, percent water content, prevalence of infectious diseases). The purpose of the recruitment study [Project Title: Does Adult Body Condition Affect Recruitment Potential in Lake Whitefish?; Principal Investigator: Trent Sutton (University of Alaska - Fairbanks)] was to explore the consequences of reduced growth and body condition on factors that could govern recruitment success, such as fecundity, gamete quality, and early life-history dynamics. Although both projects yielded valuable information on lake whitefish stocks in the Great Lakes, particularly in lakes Huron and Michigan, both also encountered difficulties relating measures of individual and population health to stock demographic rates. These difficulties stemmed from several factors, most notably the limited degree of contrast in measurements among stocks (Blukacz et al., 2010; Claramunt et al., 2010; Ebener et al., 2010-a; Faisal et al., 2010-a,-b; Wagner et al., 2010). Our goal for this concluding paper of the special issue is to take what was learned during the natural mortality and recruitment studies to provide recommendations for future studies attempting to improve understanding of linkages between ecological factors affecting individual lake whitefish health and important population demographic attributes.

Recommendations

Broaden the spatial coverage for comparative studies of demographic rates and fish health

Both the natural mortality and recruitment studies involved spatial comparisons of important demographic rates as a means to evaluate how changes in health, growth, and condition might affect long-term sustainability of lake whitefish stocks. For the natural mortality study, comparisons were made among four stocks in northern lakes Huron and Michigan. For the recruitment study, comparisons were made primarily among six to ten stocks distributed throughout Lake Michigan, with additional, but less extensive, comparisons with stocks in lakes Erie and Superior. Despite the relatively large areas over which stocks were evaluated, both the natural mortality and recruitment projects found relatively little contrast in measured variables (Blukacz et al., 2010; Claramunt et al., 2010; Ebener et al., 2010-a; Faisal et al., 2010-a,-b; Wagner et al., 2010). We suggest that there were two major reasons for this lack of contrast. First, although the stocks were strongly segregated during the spawning season, there was substantial intermixing of lakes Huron and Michigan stocks during the remainder of the year (Ebener et al., 2010-b). As a result, fish from the different spawning stocks were likely experiencing similar ecological and environmental conditions during large portions of the year. We expect this to have resulted in similar physical and biological conditions of fish, even when they returned to their respective spawning areas. Second, the Laurentian Great Lakes lie at the southern end of the native range of lake whitefish (Scott and Crossman, 1973) and, as a result, contrasts in environmental conditions among Great Lakes populations may be relatively small relative to the range of conditions experienced by lake whitefish over their entire geographic range.

To better identify relationships between demographic rates and measures of stock health, growth, and condition, we recommend that future studies consider broadening the spatial coverage over which stocks are evaluated. Although expanding the spatial overage to include more stocks in lakes Erie, Ontario, and Superior would undoubtedly be helpful, comparisons should not be limited solely to the Great Lakes. Rather, the expanded coverage should include areas that span the native range of the species and that have not been as severely impacted by anthropogenic disturbances. Useful candidates for such comparisons include Great Slave and Great Bear lakes in the Northwest Territories of Canada. The small, relatively undisturbed lakes studied by Mills et al. (2005), where lake whitefish stocks appear to experience much lower natural mortality rates compared to lakes Huron and Michigan stocks, also may provide useful contrasts.

A common problem when conducting spatial comparisons of fish stocks is that it is often necessary to rely on information collected from several different political jurisdictions or institutions that employ different sampling procedures (e.g., gear types, temporal collection strategies, random versus fixed sampling locations, etc). Such differences can confound comparative assessment of demographic rates or stock health. So long as comparative studies rely on opportunistic sampling from multiple agencies, where sampling protocols reflect local needs as well as broader objectives, this challenge will persist. Nevertheless, the design of future comparative studies should carefully assess the limitations created by differences in sampling protocols, and, where possible, take steps to mitigate these negative effects (e.g., with a partially common sampling strategy). The high value of spatial comparisons among fish populations for creating useful recommendations for guiding future management decisions should argue in favor of comparable sampling strategies among jurisdictions.

Combine large-scale field studies with direct experimentation

Although the natural mortality and recruitment studies were beneficial in that they provided stock-level estimates of important demographic rates, such large-scale field studies may not be optimal for evaluating how changes in health, condition, and growth directly impact stock demographic rates. For one, establishing causal linkages from field studies will be difficult because of the many, potentially confounding factors that influence demographic rates and fish health in natural systems. Elucidation of causal linkages between demographic rates and measures of fish health, condition, and growth would be facilitated by controlled laboratory experiments, where fish health, growth, and condition can be manipulated under controlled settings and demographic responses are measured (Ebener and Arts, 2007). For example, laboratory experiments conducted using age-0 cisco *Coregonus artedi* allowed for the determination of the effects of body size and condition, lipid stores, and feeding history on winter survival and tolerance of rapid temperature changes (Pangle et al., 2004, 2005; Pangle and Sutton, 2005).