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Lake Whitefish Relative Abundance, Length-at-Age, and Condition in Lake Michigan as Indicated by Fishery-independent Surveys

Robin L. DeBruyne[1,†,*], Tracy L. Galarowicz[1], Randall M. Claramunt[2], and David F. Clapp[2]

[1]*Department of Biology*
Central Michigan University
217 Brooks Hall
Mount Pleasant, Michigan 48859

[2]*Michigan Department of Natural Resources*
Charlevoix Fisheries Research Station
96 Grant Street
Charlevoix, Michigan 49720

ABSTRACT. *In the mid 1990s, growth and condition of lake whitefish* (Coregonus clupeaformis) *declined within commercial catches in Lake Michigan. However, underlying mechanisms responsible for the declines have not been thoroughly explored. Using fishery-independent survey data, we examined growth and relative abundance of adult whitefish over historical (1980–1990) and recent (1996–2005) time periods in three regions of Lake Michigan: north, mid, and south. Relative abundance was assessed from catch-per-unit-effort (CPUE) of independent surveys, and changes in growth conditions were evaluated using size-at-age estimates. Relative abundance increased in the mid and south regions between the two time periods and decreased in the north region. Length-at-age significantly declined between the two time periods in the north, mid, and south regions; the north region consistently had the lowest length-at-age. Condition also declined between the two time periods in each region. The decline in growth and condition coupled with increases in relative abundance suggest density-dependent mechanisms are contributing to the observed population changes in the south region. The north region does not appear to be regulated by density, suggesting density-independent mechanisms, such as food web changes, are influencing stocks. Changes in the mid region are likely from a mixture of increased lake whitefish abundance and food web changes. Using fishery-independent population data, our results suggest that multiple factors are potentially contributing differentially within three Lake Michigan regions to cause similar declines in length-at-age and condition of whitefish. These factors (e.g., food web changes, lake whitefish density) should be considered when managing the commercial fishery.*

INDEX WORDS: *Lake whitefish, growth, relative abundance, fishery-independent survey.*

INTRODUCTION

Lake Michigan has undergone major ecosystem changes over the last 60 years (Madenjian *et al.* 2002). Establishment of exotic species (e.g., sea lamprey (*Petromyzon marinus*), alewife (*Alosa psuedoharengus*), rainbow smelt (*Osmerus mordax*), Pacific salmon (*Oncorhynchus* spp.)) and increases, with subsequent reductions, in nutrient loadings have altered the trophic dynamics of the ecosystem. More recently (1989), zebra mussels (*Dreissena polymorpha*) invaded Lake Michigan (Marsden *et al.* 1993) and are currently distributed throughout the lake. The establishment of zebra mussels in southern Lake Michigan was followed by a decline in *Diporeia* spp. (Nalepa *et al.* 1998), an energy-rich amphipod and preferred food for lake whitefish (*Coregonus clupeaformis,* hereafter whitefish) and other benthivores (Pothoven *et al.* 2001, Hondorp *et al.* 2005). In 1997, another invasive mollusk, the quagga mussel (*Dreissena bugensis*), was found in northern Lake Michigan (Nalepa *et al.* 2001) and now is found in high densities and

*Corresponding author. E-mail: rld87@cornell.edu
†Present address: Cornell Biological Field Station and Department of Natural Resources, Cornell University, 900 Shackelton Point Road, Bridgeport, New York 13030 USA

at consistently deeper depths than the zebra mussel (Nalepa *et al.* 2005). Impacts of the dreissenid invasion may be primarily evident in the benthic community, but higher trophic levels may also be affected.

Commercial fishing on Lake Michigan is a multimillion dollar industry, with whitefish being the primary commercial species, comprising over 60% of the harvest in 2004–2005 (USGS 2007). Harvest has fluctuated over the past 100 years, due to factors such as pollution, overfishing, and sea lamprey predation (Wells and McLain 1973, Christie 1974). However, with sea lamprey control implemented, the whitefish fishery rebounded, and commercial yields increased from 180 metric tons (mt) in 1959 to a peak of 3,200 mt in 1993 (Wells and McLain 1973, Madenjian *et al.* 2002). Since 1993, commercial landings have been in excess of 1,500 mt annually (Madenjian *et al.* 2002). Whitefish commercial fishing operations in Lake Michigan have also varied over time and are implemented by both state-licensed and Native American fishers. During the mid 1960s through the early 1970s, the State of Michigan established new policies for commercial fishing in Lake Michigan that regulated state-licensed fishers through limited entry and a zone-restrictive management plan (Legault *et al.* 1978, Keller and Smith 1990, Rybicki and Schneeberger 1990). These regulations for state-licensed fishers, combined with a court-ordered agreement in 1985 with the 1836 Tribes to cooperatively manage the fishery (Western District Court of Michigan 1985), resulted in changes to the allocation of the fishery and distribution of effort in Lake Michigan. Under that agreement, state-licensed operations were reduced or redistributed and tribal commercial fishing opportunities were increased, mainly in northern Lake Michigan. The 15-year agreement was renegotiated, resulting in the 2000 Great Lakes Consent Decree (*U.S. vs. Michigan* 2000), which further defined how fisheries resources would be allocated, managed, and regulated in the future (2000–2020).

Under both of these agreements, a technical group was established to recommend annual harvest limits (using population models) and to develop standardized surveys for assessing whitefish stocks (Ebener *et al.* 2005). Data from the standardized sampling were to be used to complement current commercial fishery information in the population models. Commercial catch-per-unit-effort (CPUE), as an indicator of abundance, is difficult to standardize because differences in gear, soak time, gear saturation, season, target fish size, and operator efficiency influence the abundance estimate (Gunderson 1993). Fishery-independent surveys provide age, size-at-age, and abundance information without the selectivity of the commercial fishery. The graded-mesh gill nets used in fishery-independent surveys sample a large range of size classes vulnerable to the gear, encompassing the adult size ranges (> 250 mm) of whitefish (McCombie and Fry 1960, Berkes and Gönenc 1982), and sample stocks at random locations and various depths. Since relative abundance from the fishery-independent surveys can be assumed proportional to absolute population size, changes in survey CPUE can be regarded as changes in the population size (Ney 1999).

Declines in size and condition of the commercially-harvested stocks of the Lake Michigan whitefish population appeared in the mid 1990s (Pothoven *et al.* 2001, Madenjian *et al.* 2002). These declines appear to have stabilized, but more information is needed to understand the factors causing these changes when they occur. Because the commercial fishery selectively keeps larger, healthier individuals, surveys assessing the entire population may provide an early indicator of change, and therefore aid in identifying the mechanism(s) responsible. The goals of this study were to evaluate population trends of growth and relative abundance for whitefish in Lake Michigan during the past 25 years, using fishery-independent data. We compare trends in relative abundance and size-at-age on both spatial (regions in Lake Michigan) and temporal (1980–2005) scales to determine if there is evidence of past or present density-dependent growth. Two time periods, historical (1980–1990) and recent (1996–2005), were chosen because of the consistency in methods of collection within each of the time periods and the significant ecosystem changes that occurred between time periods. Whitefish surveys were not conducted from 1991–1995, during which dreissenids became established and *Diporeia* spp. declined in Lake Michigan. Commercial fishing regulations also changed in Lake Michigan throughout this study period as a result of the previously-mentioned, court-ordered agreements. Data collected provide insight into the mechanism(s) for change in the Lake Michigan whitefish population and the validity of hypotheses for the decline in growth of whitefish. These hypotheses include a density-dependent effect from increasing whitefish abundance, as well as density-independent effects from changing lower trophic level structure. This study is unique because it directly compares growth and condition from