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Trends in growth and recruitment of Lake Huron lake whitefish during a period of ecosystem change, 1985 to 2012

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ABSTRACT

We use fishery-independent survey data to describe trends in growth and recruitment for lake whitefish (*Coregonus clupeaformis*) in the southern main basin of Lake Huron. We also used a model selection approach to evaluate the potential contribution of key variables (population biomass, temperature, dreissenid mussel establishment in 1993, and the regime shift in 2003) to trends in growth and recruitment. Overall, mean growth of juvenile whitefish (i.e. back-calculated growth occurring between ages 1 and 2 years) has been reduced to approximately half of what it was before dreissenids invaded. The number of recruits per kg spawner biomass averaged 36.1 before dreissenids were established, 2.48 between dreissenid establishment and the regime shift, and 4.61 thereafter. Accounting for the timing of dreissenid establishment and the regime shift greatly improved the ability of both density-dependent growth and stock-recruitment relationships to explain the variation in growth and relative recruitment over time, providing evidence that both of these relationships have been altered by recent ecosystem changes. Current rates of growth and recruitment are much lower than before dreissenids became established, likely reducing the productivity of these populations, and in turn affecting sustainable harvest levels.

Introduction

The Laurentian Great Lakes have undergone large-scale ecosystem changes over the last century. Invasion by sea lamprey (*Petromyzon marinus*), overharvesting, and habitat degradation impacted the Great Lakes leading to declines and collapses of several native fish species during the 1950s and 60s (Bunnell et al., 2014). More recently, the establishment of several Ponto-Caspian invasive species has spurred further ecosystem change in several of the lakes (Vanderploeg et al., 2002; Bunnell et al., 2014). Most notably, dreissenid mussels (*Dreissena* sp.) considerably changed the benthic invertebrate community (Pothoven et al., 2001; McNickle et al., 2006; Nalepa et al., 2009a,2009b; Barbiero et al., 2011a,2011b), consequently altering the distribution of nutrients and energy in the lakes (Hecky et al., 2004; Nalepa et al., 2009a,2009b; Higgins and vander Zanden, 2010).

Lake Huron in particular has experienced significant change over the last decade. In 1993, dreissenid mussels invaded the lake; after which, nearshore benthic invertebrate communities became dominated by dreissenids while open-water zooplankton exhibited declines without precedent (Barbiero et al., 2009). Round goby (*Neogobius melanostomus*) invaded Lake Huron in 1997 and spread farther into the offshore as their densities increased (Schaeffer et al., 2005). In 2003, the alewife (*Alosa pseudoharengus*) population, once among the most abundant species in offshore benthic trawl catches, collapsed and has yet to recover (Riley et al., 2008; Dunlop and Riley, 2013). At about the same time as the expansion of dreissenids, *Diporeia*, an important food source for fishes such as lake whitefish (*Coregonus clupeaformis*) declined in abundance (Barbiero et al., 2011a, 2011b). Other fishes including lake whitefish, lake trout (*Salvelinus namaycush*), burbot (*Lota lota*) and bloater (*Coregonus hoyi*) showed declines in bottom trawl catches (Riley et al., 2008), and the numbers and characteristics of fish schools were also significantly altered (Dunlop et al., 2010). Fish distributions have also changed (Riley and Adams, 2010; Rennie et al., 2009a), signaling a spatial component to the ecosystem changes. Together, these recent changes suggest that a regime shift has occurred in Lake Huron (Riley and Adams, 2010; Ridgway, 2010), with potential implications for commercially important fishes.

Lake whitefish (herein referred to as whitefish) support the largest and most valuable commercial fishery in the Laurentian Great Lakes

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(Kinnunen, 2003; Ebener et al., 2008). Most whitefish are harvested from Lake Huron where they comprise 97% of the coregonine harvest, with yields that averaged 3.2 million kg annually between 2005 and 2010 (Ebener, 2013). Declines in whitefish growth have been reported for various areas of Lake Huron and for other Great Lakes' populations following reductions in their main prey, *Diporeia* (Lumb et al., 2007; Rennie et al., 2009b; Ebener, 2013; Fera, 2014). At the same time, trends in growth have varied widely across lakes and populations (Fera, 2014). In some locations, declines in whitefish growth appear to have preceded the loss of *Diporeia* (Fera, 2014), which has been attributed to density-dependence (Kratzer et al., 2005). Following the near disappearance of *Diporeia*, whitefish switched to consuming an energetically inferior diet comprised mainly of *Dreissena* and other molluscs (Pothoven et al., 2001; McNickle et al., 2006; Pothoven and Madenjian, 2008; Nalepa et al., 2009a, 2009b; Rennie et al., 2009a). It is now clear that the invasion of dreissenid mussels has had some effect on the somatic growth of whitefish in several Great Lakes, with the main mechanism likely being alterations in whitefish diets (Fera, 2014). However, few studies have considered how a broad range of factors that influence growth may have changed with the loss of *Diporeia* (but see Rennie et al., 2009b).

Trends in whitefish growth and recruitment are of concern because these processes are important determinants of a fishery's productivity, and therefore influence sustainable harvest levels. Much uncertainty surrounds the future of this fishery given the substantial ecosystem changes that have taken place in Lake Huron. Our study adds to the current understanding of changes occurring in Great Lakes whitefish populations by examining how more recent ecosystem change (i.e. the regime shift) has further affected growth and recruitment for one of the most important whitefish populations in the Great Lakes. We assess the degree to which shifts in growth or recruitment coincide with two key events: the establishment of dreissenid mussels in 1993 and the regime shift that was signaled by the collapse of alewife in 2003. We also explore how ecosystem changes associated with these events may have altered density-dependence of growth and recruitment, in the southern main basin of Lake Huron.

Material and methods

Data and study area

For this study we used whitefish data collected by the Ontario Ministry of Natural Resources and Forestry (OMNRF) as part of their offshore index netting survey (Speers, 2013) for the QMA 4–5 management area of Lake Huron (Fig. 1). We focused on whitefish collected in this region because of the large amount of data available from the offshore index netting survey and because it supports an important commercial fishery. This offshore index netting program employs standardized monofilament gill nets consisting of a 15 m panel of 32-mm mesh (added in 2002), a 25 m panel of 38-mm mesh, and 50 m panels of 51-mm, 76-mm, 89-mm, 102-mm, 114-mm, and 127-mm mesh (stretch-measure). Typically, nets were set for 20–24 h and are configured parallel to one another 400–600 m apart, and perpendicular to depth contours. Surveys were conducted in the spring and fall of every year from 1984 to 2012, with the exception of 1996 in which no surveys were conducted. The program provides a fishery-independent source of information on biological attributes of whitefish, including

Fig. 1. Map of Lake Huron management areas, highlighting the source of data used for this study. Quota management areas (QMAs) are shown, with QMA 4–5, the source of data for the current study, highlighted in gray.