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Deepwater sculpin status and recovery in Lake Ontario

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A B S T R A C T

Deepwater sculpin are important in oligotrophic lakes as one of the few fishes that use deep profundal habitats and link invertebrates in those habitats to piscivores. In Lake Ontario the species was once abundant, however drastic declines in the mid-1900s led some to suggest the species had been extirpated and ultimately led Canadian and U.S. agencies to elevate the species' conservation status. Following two decades of surveys with no captures, deepwater sculpin were first caught in low numbers in 1996 and by the early 2000s there were indications of population recovery. We updated the status of Lake Ontario deepwater sculpin through 2016 to inform resource management and conservation. Our data set was comprised of 8431 bottom trawls sampled from 1996 to 2016, in U.S. and Canadian waters spanning depths from 5 to 225 m. Annual density estimates generally increased from 1996 through 2016, and an exponential model estimated the rate of population increase was ~59% per year. The mean total length and the proportion of fish greater than the estimated length at maturation (~116 mm) generally increased until a peak in 2013. In addition, the mean length of all deepwater sculpin captured in a trawl significantly increased with depth. Across all years examined, deepwater sculpin densities generally increased with depth, increasing sharply at depths >150 m. Bottom trawl observations suggest the Lake Ontario deepwater sculpin population has recovered and current densities and biomass densities may now be similar to the other Great Lakes.

Introduction

Deepwater sculpin, *Myoxocephalus thompsonii*, are a unique benthic, profundal species found only in the Great Lakes and a small subset of deep, oligotrophic Canadian lakes (Sheldon et al., 2008). As their name implies, they inhabit deep portions of lakes and have been captured at depths >360 m (Scott and Crossman, 1973). As a prey fish, deepwater sculpin play a critical role in offshore food webs linking profundal energy sources to higher level consumers, such as lake trout, *Salvelinus namaycush* (Dymond, 1928; Madenjian et al., 1998), and burbot, *Lota lota* (Fratt et al., 1997). As a glacial relict, they often co-occur with the crustaceans *Mysis relicta* and *Diporeia* spp., both of which are common prey items (Londer, 2011; O'Brien et al., 2009). A biogeographical study concluded the species distribution was narrow and static, such that dispersal between inland Canadian lakes was unlikely (Sheldon et al., 2008). Because of the species' preferred deep water habitat, populations can be threatened by eutrophication and subsequent reduced dissolved oxygen concentrations in deep waters (COSEWIC, 2006). Deepwater sculpin are considered common in Lakes Superior, Michigan and Huron (Bronte et al., 2003; Madenjian et al., 2005; Riley and Adams, 2010). In Lake Erie, where deep water habitat is less abundant, deepwater sculpin are considered absent except for occasional catches of larvae that likely drift downstream from Lake Huron (Roseman et al., 1998). In Lake Ontario their abundance has fluctuated dramatically over the past 70 years (Lantry et al., 2007).

At one time, Lake Ontario deepwater sculpin abundance was great enough that the species was considered a nuisance to commercial gill netters, however the population suffered a sharp decline in the early 1900s (Scott and Crossman, 1973). Dynamics of their decline are poorly described because of a lack of fishery-independent sampling during the 1940s through the 1950s (Lantry et al., 2007). Consistent annual Lake Ontario bottom trawl surveys began in the 1970s. Despite considerable annual bottom trawling effort on both northern and southern shores of Lake Ontario, deepwater sculpin were rarely observed and no individuals were captured from 1978 to 1995 (Lantry et al., 2007). Various factors have been suggested to contribute to their seemingly drastic decline in Lake Ontario including negative interactions with alewife (Lantry et al., 2007; Madenjian et al., 2005) and slimy sculpin (Brandt, 1986). The prolonged absence of deepwater sculpin in Lake Ontario catches made the species a target for native fish recovery efforts (Zimmerman and Krueger, 2009).

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The species' rare occurrence, deep habitat preference, and sensitivity to eutrophication lead Canadian and U.S. agencies to elevate the conservation status of the deepwater sculpin. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) classified the Great Lakes-Western St. Lawrence Populations as 'Threatened' in 1987 and in 2006 designated the species as 'Special Concern' (COSEWIC, 2006). The COSEWIC species reports mention concern for Great Lakes populations such as in Lake Ontario as well as inland lake populations where more recent extirpations were likely the result of changing environmental conditions (COSEWIC, 2006; Sheldon et al., 2008). Similarly in the United States, the New York State Department of Environmental Conservation listed the deepwater sculpin as endangered in 1993 because of their absence in surveys. Since then, Lantry et al. (2007) reported on the reappearance of deepwater sculpin in Lake Ontario bottom trawl catches including observations through 2005. At that time, Lantry et al. (2007) noted it was not clear if the population would continue to increase, or if factors that caused their decline would again limit their range and abundance.

We quantified the current status of deepwater sculpin in Lake Ontario using bottom trawl observations from 1996 through 2016 to inform binational resource management and conservation processes. Our specific objectives included: 1) determine whether trawl catches indicate that Lake Ontario deepwater sculpin density has increased over the past eight years, 2) determine how the use of different sets of observations, which vary in effort and maximum depths sampled, influenced our understanding of deepwater sculpin population dynamics, 3) estimate the size at initial reproduction, 4) quantify changes in deepwater sculpin size and condition over time, 5) determine if there is a positive relationship between mean deepwater sculpin length and depth and 6) describe deepwater sculpin density according to lake depth. We discuss our results in the context of deepwater sculpin biology from other ecosystems to better understand the current Lake Ontario population status.

Methods

Trawl surveys

Deepwater sculpin observations were derived from multiple annual bottom trawl surveys conducted by the United States Geological Survey, Lake Ontario Biological Station (USGS), the New York State Department of Environmental Conservation, Cape Vincent Fisheries Station (NYSDEC) and the Ontario Ministry of Natural Resources and Forestry, Lake Ontario Management Unit (OMNRF). Most of the observations used in this paper derive from four, annual collaborative bottom trawl surveys conducted in U.S. waters by the USGS and NYSDEC and a survey conducted in Canadian waters of Lake Ontario (Table 1, Fig. 1). Substrates at bottom trawl sites generally consisted of soft sediments including clay, sand, mud and silt (Thomas et al., 1972). Because deepwater sculpin were not caught in Lake Ontario until 1996, we describe field surveys from 1996 through 2016, but note most of the surveys began in the 1970s. Additional historical Lake Ontario trawling information regarding deepwater sculpin is available in Lantry et al. (2007).

The April bottom trawl survey targeted alewife and sampled depths of 8–225 m primarily in U.S. waters of Lake Ontario. In the 1990s and early-2000s, the April survey was adjusted to include deeper sampling to account for shifts in the bathymetric distribution of prey fish (O'Gorman et al., 2000). Additional deep (>180 m) and shallow tows were also added to the survey in 2012, to create a more comprehensive sample of available lake depths. In 2016, this survey was expanded to include Canadian portions of Lake Ontario with six additional transects added in the western and northern portions of the lake.

The June bottom trawl survey targeted rainbow smelt, and sampled depths from 8 to 180 m in U.S. waters of Lake Ontario. The maximum depths sampled increased in 2000, 2006, and 2012 to 130, 150 and 180 m respectively to account for shifts in the depths inhabited by rainbow smelt (Weidel et al., 2015). The last year for this survey was 2014, after analyses suggested that rainbow smelt population dynamics could be assessed during the April survey (Weidel et al., 2015).

The July bottom trawl survey targeted juvenile lake trout in U.S. waters and sampling depths have changed as lake trout habitat use has changed (O'Gorman et al., 2000). The shallowest depths sampled ranged between 8 and 20 m over time, while the maximum depth sampled has increased from 85 m in the late 1990s to 175 m in 2016.

The October bottom trawl survey targeted benthic prey fishes across depths ranging from 8 to 225 m. From 1998 to 2014 the survey was conducted at six transects along the southern Lake Ontario shore. Since 2012, this survey has experimentally sampled alternative transects to be more extensive in the characterization of benthic fish distributions and assess all benthic prey fish population dynamics, including deepwater sculpin and round goby. In 2015, this survey was collaboratively expanded, adding five additional transects in Canadian waters and two transects in eastern Lake Ontario.

Annual bottom trawl observations from OMNRF-conducted surveys were also included in the analysis. From 1998 to present, three shallow sites (20–35 m) were consistently sampled in the Kingston Basin, three times annually, with four, 926 m long bottom trawls collected during each visit. In 1997, a deep water site was added outside the Kingston Basin region, which is sampled approximately twice annually with a trawling distance of 1852 m and a sampling depth of approximately 100 m.

An addition to the four US-initiated surveys, 258 trawls, that were not part of standard surveys, were also included in the analyses. These tows were conducted at similar times to the surveys described above, sampled depths from 8 to 170 m and were collected for trawl and vessel comparisons.

Trawl descriptions and changes in surveys

Two different trawl and trawl door combinations account for the majority of the observations. The original trawl used in USGS and NYSDEC surveys was a nylon Yankee-style trawl, with an 11.8 m headrope, a cod end made of ~12.5 mm knotless nylon, and a loop-chain sweep attached directly to the footrope. The Yankee trawl was

Table 1
Characteristics of Lake Ontario bottom trawl surveys used to quantify deepwater sculpin recovery, 1996–2016.

Survey attribute	April	June	July	October	OMNRF	Additional
Target species	Alewife	Rainbow Smelt	Lake Trout	Slimy Sculpin	community	various
Years	1996–2016	1996–2014	1996–2016	1996–2015	1996–2015	1997–2015
Primary trawls	3N1[a]	3N1[a]	3N1[a]	3N1, Yankee	Yankee	Various
Seasonal range	Apr–May	May–Jun	Jul	Sep–Oct	Jun–Oct	Apr–Oct
Depth range (m)	7–225	7–175	8–175	6–225	20–140	6–220
Spatial extent	U.S. waters[b]	U.S. waters	U.S. waters	U.S. waters[b]	Kingston Basin	U.S. waters
Number of trawls	2162	1879	2263	1072	783	272

[a] Yankee trawl used in 1996.
[b] Spatial extent expanded to whole-lake.

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