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Movement patterns and spatial segregation of two populations of lake trout *Salvelinus namaycush* in Lake Huron

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ABSTRACT

Movement ecology is an important component of life history and population dynamics, and consequently its understanding can inform successful fishery management decision-making. While lake trout populations in Lake Huron have shown signs of recovery from near extinction in recent years, knowledge of their movement behavior remains incomplete. We used acoustic telemetry to describe and compare movement patterns of two Lake Huron lake trout populations: Drummond Island and Thunder Bay. Both populations showed high spawning site fidelity, with no evidence of co-mingling during non-spawning season. Detections between spawning periods were mainly limited to receivers within 100 km of spawning locations, and suggested that the two populations likely remained segregated throughout the year. Drummond Island fish, which spawn inside the Drummond Island Refuge, primarily dispersed east into Canadian waters of Lake Huron, with 79–92% of fish being detected annually on receivers outside the refuge. In contrast, Thunder Bay fish tended to disperse south towards Saginaw Bay. Large proportions (i.e., >80%) of both populations were available to fisheries outside the management zone containing their spawning location. Thunder Bay fish moved relatively quickly to overwinter habitat after spawning, and tended to repeat the same post-spawning movement behavior each year. The consistent, predictable movement of both populations across management zones highlights the importance of understanding population dynamics to effective management of Lake Huron lake trout.

Introduction

An understanding of the movement ecology of fish populations can benefit fishery management because movement is a primary component of life history, diversity, and population dynamics (Nathan et al., 2008), and is critical to understanding and controlling fishery mortality. For example, knowledge of population-specific movement patterns can contribute to management decisions by informing the appropriate location for management boundaries (Hourston, 1982), identifying potential sources of mortality (Cooke et al., 2004; Keefer et al., 2008), defining appropriate spatial requirements and layout of sanctuaries constructed for population/community conservation (Halpern and Warner, 2003; Quesne and Codling, 2009), and identifying the composition of mixed stock fisheries (Rooker et al., 2014; Veinott et al., 2012). This knowledge is especially valuable for highly mobile species like lake trout, *Salvelinus namaycush*, which have high social and economic value, and which have been the subject of extensive restoration efforts in the Laurentian Great Lakes since the 1950s, following a basin-wide crash due to over-harvest and predation by invasive sea lampreys, *Petromyzon marinus* (Hansen, 1999; Muir et al., 2012).

Restoring self-sustaining lake trout populations in the Great Lakes has been slow, with most populations outside of Lake Superior still dependent on juvenile stocking programs. In Lake Huron, however, lake trout have seen a substantial increase in wild recruitment since the early 2000s which has been attributed to improved sea lamprey control in the St. Marys River, a reduction in fishing mortality due to the 2000 Consent Decree, and the lake-wide crash of alewife, *Alosa*

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psuedoharengus (He et al., 2012; Johnson et al., 2015b; Madenjian et al., 2008; Riley et al., 2007). Additionally, two lake trout refuges (Drummond Island Refuge in northern Lake Huron, and Six Fathom Bank Refuge in central Lake Huron) were established on historic spawning areas on the Michigan side of Lake Huron in the 1980s to protect populations from fishing mortality (Stanley et al., 1987). However, because we do not know to what extent lake trout remain within these sanctuaries, our understanding of the degree to which they serve to improve recruitment in Lake Huron remains limited.

Currently, lake trout fisheries in Lake Huron are regulated based on 18 statistical grids (inset in Fig. 1) established in the 1960s (Smith et al., 1961), which make up a total of 15 management units; the four southernmost statistical grids on the Michigan side (i.e., MH-3, MH-4, MH-5, and MH-6) were merged to form a single management unit. The biological significance of the management zone boundaries is unclear because little information exists on movement patterns of lake trout in Lake Huron. Most of what is known about lake trout movements in the Great Lakes comes from conventional mark-recapture studies on lakes Superior (Eschmeyer et al., 1953; Kapuscinski et al., 2005; Rahrer, 1968), Michigan (Bronte et al., 2007; Eck and Wells, 1986; Schmalz et al., 2002; Smith and Van Oosten, 1940), and Ontario (Elrod, 1987; Elrod et al., 1996). The majority of studies have suggested that adult lake trout show relatively high fidelity to spawning locations, which for hatchery-reared fish is often near stocking locations (Binder et al., 2016; Bronte et al., 2002, 2007; Eschmeyer, 1955; Rahrer, 1968; Swanson, 1973).

Between spawning seasons, adult lake trout can disperse widely. Adult movements in western Lake Superior were cyclical, with lake trout remaining close to spawning sites during October and November, dispersing between December and July, and then moving back towards spawning locations in August and September (Kapuscinski et al., 2005; Rahrer, 1968). Movements >200 km have been observed in lakes Superior (Eschmeyer et al., 1953; Kapuscinski et al., 2005; Rahrer, 1968) and Michigan (Schmalz et al., 2002), but these long-distance movements appear to be rare. The majority of studies have suggested that lake trout tend to remain within about 100 km of their respective spawning grounds (Eschmeyer et al., 1953; Rahrer, 1968; Schmalz et al., 2002). However, these studies have relied on fishery recaptures and reporting, so it is possible that movements are more extensive than the spatial extent of fishery operations.

As far as we are aware, no published observations of population-specific lake trout movement patterns exist for Lake Huron. Therefore, our objective was to describe the movement patterns of two Lake Huron lake trout populations and determine if these two populations segregate spatially during spawning and non-spawning periods. Acoustic transmitter detections collected over ~2.5 years were used to compare movement patterns of lake trout populations spawning in the Drummond Island Refuge (DI array; Fig. 1), in northern Lake Huron,

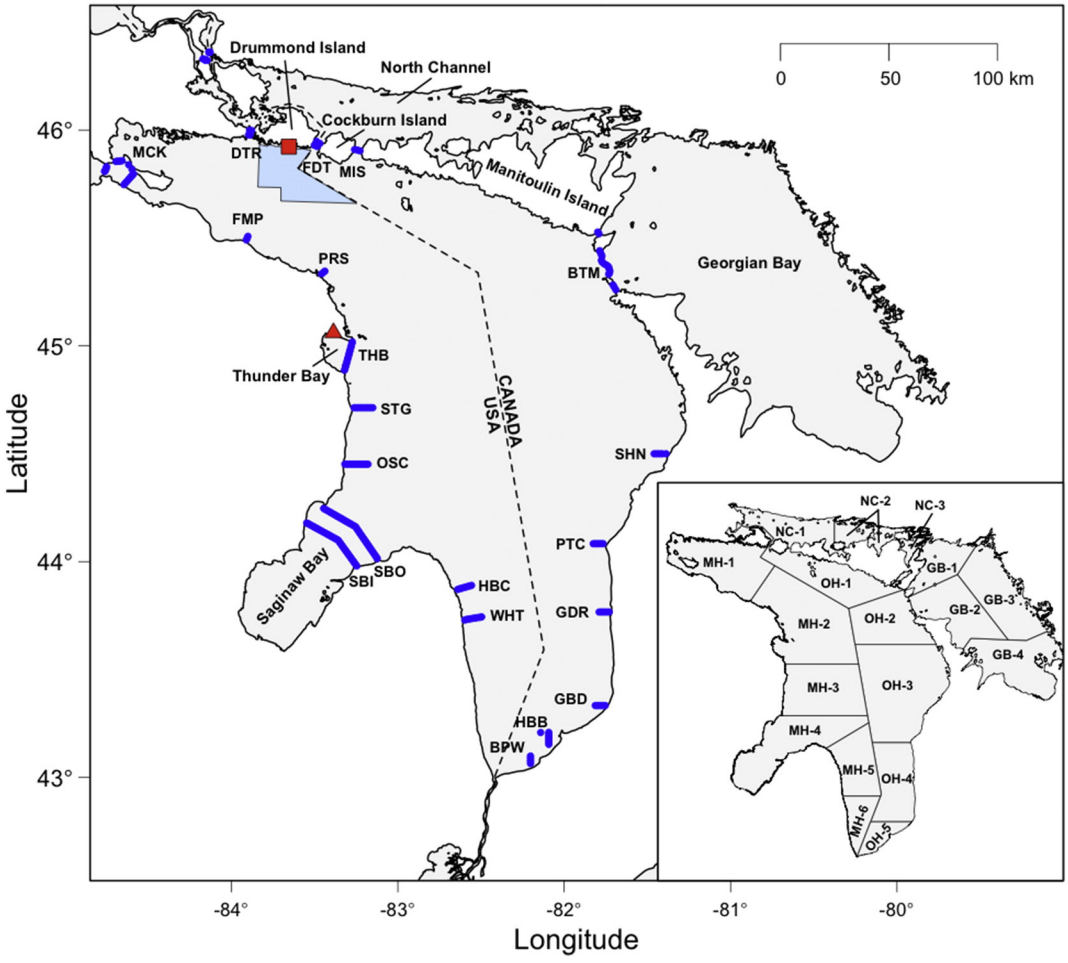

Fig. 1. Location of acoustic receivers in Lake Huron (blue dots labeled with their three-letter GLATOS array codes in capitals) that contributed detection data to the GLATOS detection database from October 2012 to May 2015. The Drummond Island spawning location and Thunder Bay spawning location are indicated by a red square and red triangle, respectively. The blue polygon along the south shore of Drummond Island shows the extent of the Drummond Island Refuge. The dotted line indicates the border between the USA and Canada. Inset: Map of Lake Huron with Michigan and Ontario statistical districts for regulating lake trout fisheries identified. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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