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Evidence of a remnant self-sustaining strain of lake trout in the Lake Michigan basin

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ABSTRACT

Managers have long embraced the need to maintain diversity as a requisite condition for population and community sustainability. In the case of Great Lakes lake trout, diversity has been severely compromised. The identification of new gamete sources may be beneficial to lake trout reintroduction efforts, particularly in situations where native stocks have been completely extirpated such as in Lake Michigan. Lake trout from Elk Lake, Michigan, are genetically distinct from domestic hatchery strains and historical forms of lake trout from Lake Michigan. Importantly, Elk Lake fish were genetically distinct from Marquette strain lake trout which were previously stocked into Elk Lake. Elk Lake fish were most similar to Lake Michigan basin-derived Lewis Lake (LLW) and Green Lake (GLW) hatchery strains and to historical Lake Michigan populations from the Charlevoix, Michigan area. While all individuals exhibited characteristics of lean form lake trout, the body shape of lake trout from Elk Lake, stocked lean fish from Lake Michigan and Lake Superior wild lean strains from near Isle Royale differed. Elk Lake fish were more fusiform, elongate, and streamlined with a narrower caudal peduncle compared to hatchery lean strains and wild lean forms from the Isle Royale region of Lake Superior. The lake trout population in Elk Lake is a remnant of a now extirpated native Lake Michigan population that was established either by natural colonization or stocking from historical Lake Michigan populations. Elk Lake lake trout is as genetically diverse as other strains used in Great Lakes reintroduction efforts and likely represent a viable gamete source representing genetic diversity lost from Lake Michigan.

Introduction

Lake trout *Salvelinus namaycush* are a relatively long-lived species (Eshenroder et al., 1995) that exhibits considerable genetic and phenotypic diversity (Burnham-Curtis et al., 1995; Krueger and Ihssen, 1995; Chavarie et al., 2013; Muir et al., 2015). The range of lake trout is restricted to northern North America, and current populations originated from glacial refugia and thereafter diversified in large lakes (Eshenroder, 2008; Muir et al., 2015; Wilson and Hebert, 1998; Wilson and Mandrak, 2004; Zimmerman et al., 2006, 2007). A wide variety of lake trout forms occurred in the Great Lakes that were both genetically and phenotypically diverse (Goodier, 1981; Hansen, 1999; Holey et al., 1995; Krueger and Ihssen, 1995; Moore and Bronte, 2001). With the exception of Lake Superior, much of this diversity was lost in the Great Lakes during the mid-20th century when commercial exploitation, habitat degradation, and sea lamprey *Petromyzon marinus* predation decimated populations (Baillie et al., 2016; Hansen, 1999; Holey et al., 1995). The lower lakes, including Lake Michigan, became subjects for extensive lake trout reintroduction efforts as anthropogenic perturbations resulted in near complete extirpation of the species and the many forms that had developed (Dawson et al., 1997; Holey et al., 1995).

Prior to their extirpation, lake trout in Lake Michigan had been abundant and diverse with many lean nearshore forms (Brown et al., 1981; Holey et al., 1995) and offshore deep water siscowet-like forms (Krueger and Ihssen, 1995). Co-occurrence of distinct phenotypic, genetic, and behavioral lake trout forms demonstrated that diversity among historical lake trout populations likely resulted from adaptations to spatially and temporally variable Great Lakes environments. Lake trout diversity was historically an important component in establishing a resilient fish community in the basin (Goode, 1884; Thomson, 1883). Low genetic and phenotypic diversity in hatchery strains employed for reintroduction efforts can limit the potential for successful re-establishment (Burnham-Curtis et al., 1995). Reintroduction efforts in the Great Lakes could benefit by identifying new sources of genetic diversity

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represented by as yet untapped remnant stocks within the basin (Bronte et al., 2008; Burnham-Curtis et al., 1995; Holey et al., 1995).

In recent years, emphasis has been placed on inclusion of deep water lake trout strains for re-introductions. The increased focus on deep water forms was intended to expand behavioral and genetic diversity and increase the potential for adaptation to survive and reproduce in alternate habitats (Bronte et al., 2008; Janssen et al., 2007; Eshenroder and Burnham-Curtis, 1999). Integral to implementing this action, is the need to identify and further understand reproductively viable populations of lake trout located within the Lake Michigan basin, especially those known to occupy deep water niches. Such forms would have the highest likelihood of having developed adapted traits of particular benefit to the basin.

We present evidence of a self-sustaining and possible Lake Michigan remnant lake trout population in Elk Lake, Michigan and evaluate its potential as a source for future reintroduction efforts. Elk Lake was connected to Lake Michigan via Grand Traverse Bay until the mid-1850s, when a hydroelectric dam constructed on the Elk River severed connectivity. We hypothesize that the lake trout in Elk Lake are remnant to the Lake Michigan basin and therefore represent a segment of genetic diversity which was lost to the basin. Herein we characterize the Elk Lake strain of lake trout using genetic and morphometric methods and make comparisons to contemporary and historical populations from Lakes Michigan and Superior. Our objectives were to: 1) characterize genetic relationships between Elk Lake lake trout and hatchery strains stocked into the Lake Michigan basin to determine how closely they are related; 2) characterize genetic relationships between Elk Lake lake trout and historical wild lake trout from Lake Michigan commercial fisheries in the 1940s to determine how closely they are related; and 3) compare morphometric characteristics of Elk Lake lake trout to those of fish stocked into Lake Michigan and wild lean forms from Lake Superior to gain insight into similarities or differences between Elk Lake fish which may indicate behavioral or foraging preferences. If reintroduction efforts in Lake Michigan continue to rely upon stocking, known self-sustaining populations such as those found in Elk Lake may warrant consideration for inclusion in future reintroduction efforts, especially if they display deep-water spawning characteristics.

Methods

Study site

Elk Lake is located in Antrim and Grand Traverse Counties in the Northwest Lower Peninsula of Michigan. Historically, Elk Lake was connected and flowed freely into Lake Michigan via the Elk River and East Grand Traverse Bay. Hydrological separation occurred in 1856 when a dam (now producing hydroelectricity) was constructed on the Elk River (Scott, 1921). The lake is directly adjacent to East Grand Traverse Bay, and is the furthest downstream waterbody in the Elk River Chain of Lakes watershed (Fig. 1). Elk Lake is a moderately large (14.6 km long, 2.09 km average width, 61 m maximum depth) oligotrophic inland waterway covering nearly 34 km^2 (Scott, 1921). The substrate composition is primarily clay marl with some cobble in nearshore zones (unpublished data, MDNR). Thermal stratification occurs in the summer months (June through October), and the maximum thermocline depth is approximately twenty meters (unpublished data, MDNR, 2015). Suitable thermal habitat for lake trout is readily available throughout the year in Elk Lake (Bergstedt et al., 2003). Smelt (*Osmerus mordax*), yellow perch (*Perca flavescens*), cisco (*Coregonus artedi*) and deepwater sculpin (*Myoxocephalus thompsonii*) are available as forage for lake trout.

There is a long history of stocking lake trout into Elk Lake, and this is likely the reason that many biologists and managers did not consider the population a candidate for reintroduction efforts. Lake trout were stocked into Elk Lake (±730,000; Joyce Bahr, Michigan Department of Natural Resources, personal communication) from 1895 to 1978. The status of lake trout in Elk Lake prior to the first stocking event in 1895

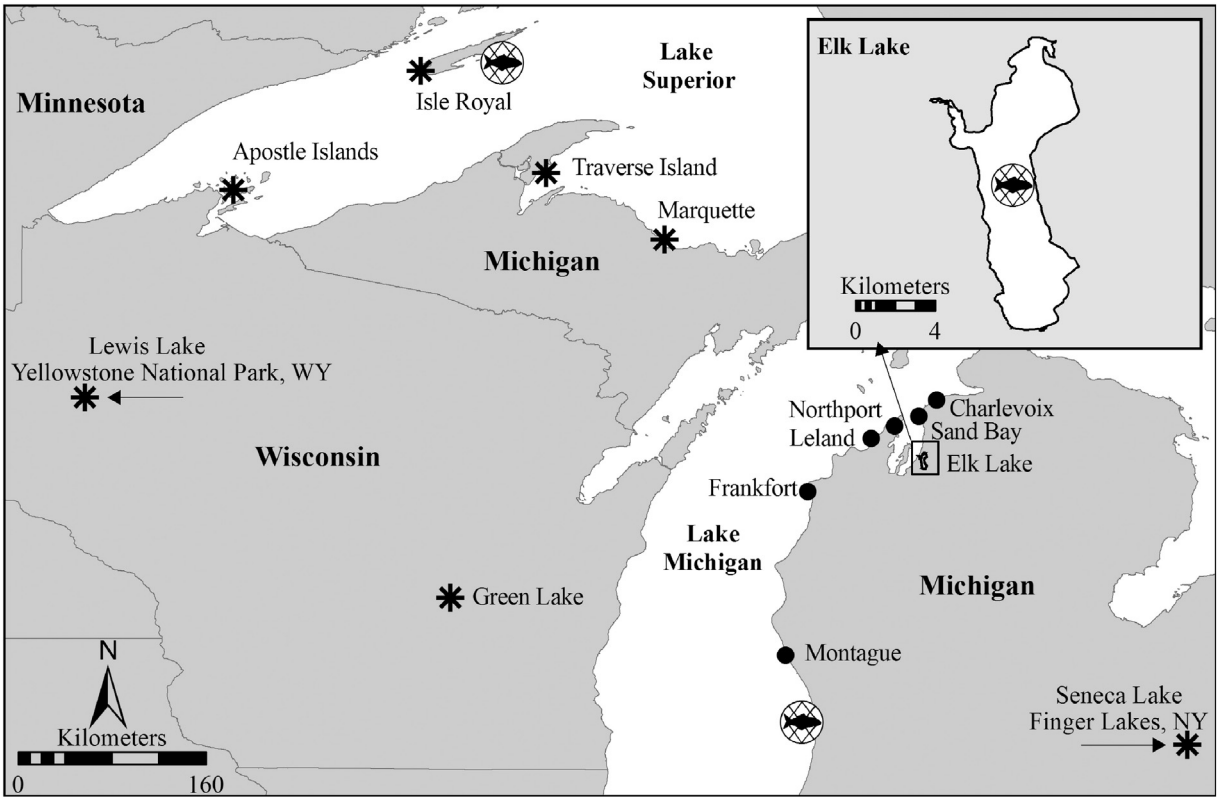

Fig. 1. Map indicating origins of USFWS hatchery populations (asterisks), locations of historical wild populations (black circles), and locations where fish were collected for present day geometric morphometric and genetic evaluations (fish symbols).

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