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Habitat and diet differentiation by two strains of rainbow trout in Lake Superior based on archival tags, stable isotopes, and bioenergetics

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ABSTRACT

Three analytical tools including archival tags, stable isotope analysis, and bioenergetics modeling were applied to two strains of rainbow trout *Oncorhynchus mykiss* in the Minnesota waters of Lake Superior to determine habitat and trophic position. Between 2006 and 2009, archival tags that recorded time, temperature, and pressure were surgically implanted into the peritoneal cavities of 34 steelhead ("STT") and 93 Kamloops ("KAM") which were released into Lake Superior. After the initial spawning season, 10 STT and 9 KAM tags were recovered, with up to two years of recorded data. Both strains were surface-oriented, spending more than half of their time as adults in the top 1 m of water, and 80% of their time in the top 2 m. Diel vertical movements were noted more often in STT, likely reflecting higher consumption of *Mysis diluviana*, while the frequencies of other vertical movement patterns were similar between the two strains. Mean temperatures recorded by tags were used in bioenergetics simulations to estimate consumption of prey species. Temperatures recorded by archival tags were warmer than the water temperatures used in earlier bioenergetics simulations in Minnesota waters, and estimated consumption of prey fish by STT and KAM populations at the warmer temperatures was about 23% greater. Stable isotope analyses reflected higher consumption of small fish by both predator strains than identified in prior diet summaries based on stomach contents. Based on these analyses, habitats occupied by both strains are similar, and their impact on prey fish populations in nearshore waters is greater than previously estimated.

Introduction

Information about the thermal, bathymetric, and predator–prey relationships of fish is essential for managers and anglers who want to understand community dynamics and habitat use by various species in a lake. A number of tools, chemical analyses, and models have been developed to collect and analyze individual aspects of habitat and trophic level. However, the coordinated use of these methods can provide a more complete picture of community dynamics. Three analytical devices, specifically archival tags, stable isotope analysis, and bioenergetics modeling were applied to two strains of potamodromous rainbow trout *Oncorhynchus mykiss* in the Minnesota waters of Lake Superior to demonstrate how they can be used in concert to describe habitat and trophic position of this species in the lake.

Rainbow trout *O. mykiss* provide a popular fishery in Minnesota waters of Lake Superior, with two different strains that offer angling opportunities in different seasons. Steelhead, the anadromous form from the west coast of North America, were first introduced into Minnesota's portion of Lake Superior in 1895 (MacCrimmon, 1971). These steelhead (STT) have become naturalized, and reproduce in tributary streams (Close and Hassinger, 1981; Hassinger et al., 1974; Schreiner, 2003), exhibiting a potamodromous life history (migratory, but confined to freshwater). Angling pressure led to an apparent decline in STT abundance in the 1970s, and a domesticated hatchery strain, locally referred to as "Kamloops" (KAM), was introduced during this period as an attempt to bolster the fishery and to provide harvestable rainbow trout while the STT stock was being restored (Negus et al., 2012; Schreiner, 2003). Since 1997, STT harvest has been prohibited, and only KAM over 41 cm (16 in.) may be harvested in Minnesota waters, but harvest of both strains is permitted in other parts of the lake.

Currently, STT are stocked into tributaries as unmarked swim-up fry, and KAM are stocked into the lower reaches of tributaries as fin-clipped yearling smolts (Negus et al., 2012). Stocking of KAM is restricted to three rivers near Duluth (Fig. 1), while most STT are placed in rivers farther north (Schreiner, 2003), in an attempt to spatially segregate the two strains during spawning and reduce crossbreeding. Both strains are stocked into the French River, where a fish trap enables the recapture of returning spawners, and gametes are harvested for hatchery propagation at the French River Coldwater Hatchery (FRCWH). Naturally reproduced STT are monitored at a trap in the Knife River. All STT and KAM captured in both the French and Knife river traps receive colored t-bar anchor tags, to identify them as repeat spawners in future

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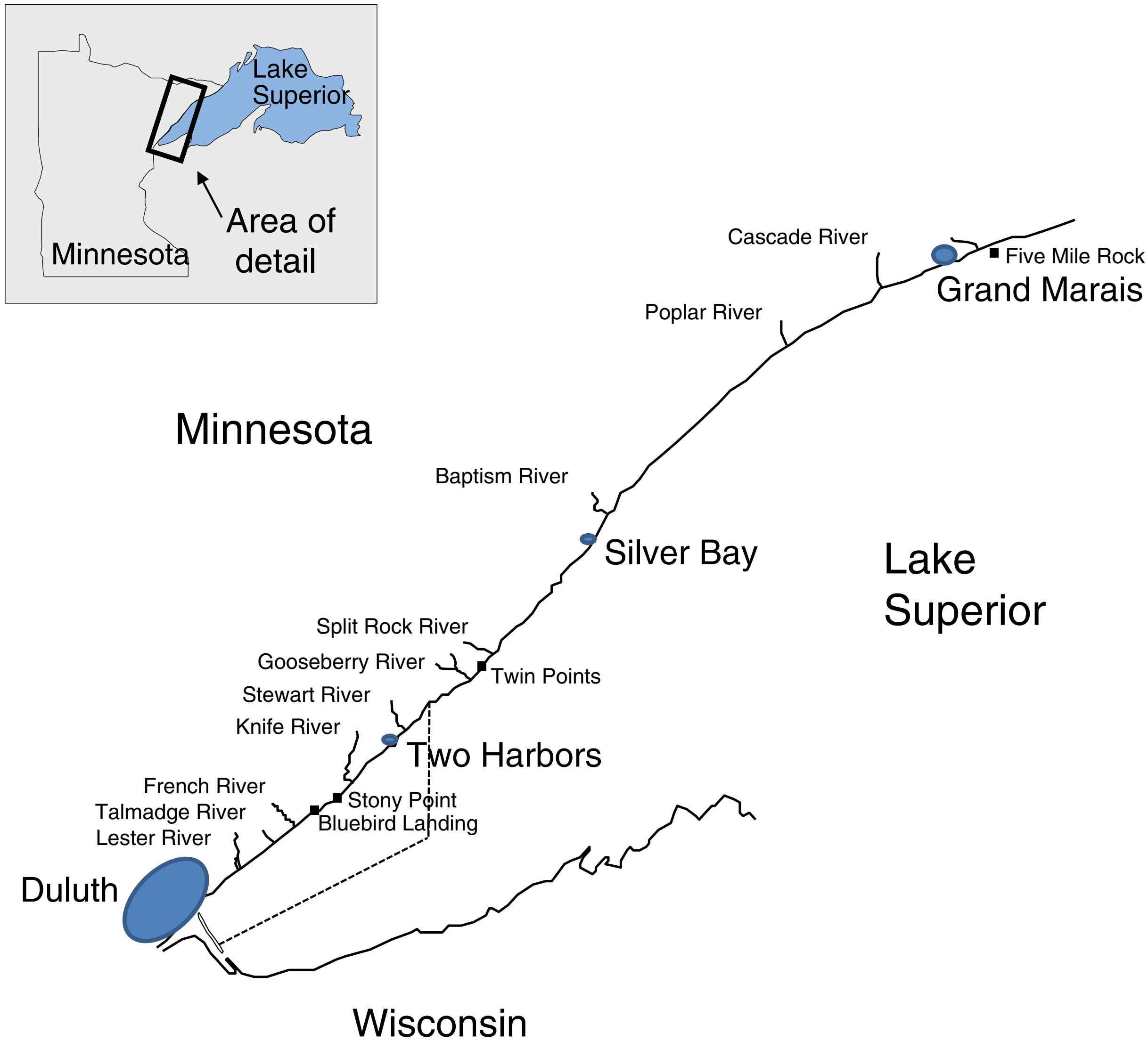

Fig. 1. Western arm of Lake Superior showing the French and Knife rivers where STT and KAM were initially captured in traps, various release locations for tagged fish, rivers where fish were recaptured, and other reference points. Lake Superior management zone MN-1 is located within the dotted line. Populated areas shown by gray ovals.

years. Based on past returns to fish traps and anglers, about 35% of Knife River STT and 10% of French River KAM are recaptured in future years, while about 27% of KAM are recaptured by anglers during the spawning season shortly after they are counted at the French River trap (Ward, 2010).

Although these strains exhibit differences in behavior and temperature tolerance at the egg and fry stages, and behavior variations during spawning (Negus, 1999), these differences are not well understood in adult fish that inhabit the lake. Anglers report that STT are frequently caught near the surface of the lake during summer months, but KAM are captured much less frequently at that time (Halpern, 2011). KAM provide an excellent winter fishery as they stage near river mouths (Schreiner et al., 2006); whereas STT are not typically captured nearshore at that time of year. As these two strains are stocked primarily to provide recreational opportunities, a better understanding of their distribution and habitat use would benefit managers and anglers alike.

Predator populations in Minnesota waters of Lake Superior were previously evaluated with bioenergetics modeling, to estimate their prey demands and the potential for prey and habitat limitation (Negus, 1995; Negus et al., 2008). However, in both studies, temperature inputs for STT and KAM were drawn from one point source (the water intake pipe for the FRCWH located just offshore at a depth of 18 m) or from lab-based temperature preference studies (Wismer and Christie, 1987). The lack of direct thermal habitat measurement thus raises questions about the bioenergetics estimates of predatory impact by STT and KAM. Moreover, temperature preferences reported for rainbow trout (Wismer and Christie, 1987) suggest that STT and KAM in Lake Superior are near the edge of their thermal tolerance. Thus, more accurate temperature and depth data are needed to assess if thermal habitat is limiting, and if the two strains are competing for that habitat.

Habitat use by STT and KAM in this study was characterized using two different but complementary approaches — archival tags and ecological chemical tracers (stable isotopes). First, temperature and depth information was obtained from STT and KAM in Lake Superior through the use of surgically implanted archival tags. Second, tissues were sampled for carbon and nitrogen stable isotope ratios ($\delta^{13}C$, $\delta^{15}N$) which are acquired in consumers from their prey (Peterson and Fry, 1987). On average, aquatic consumers have values that are +0.5‰ $\delta^{13}C$ and +3.4‰ $\delta^{15}N$ higher than that of their prey (Vander Zanden and Rasmussen, 2001). Where prey items have distinct $\delta^{13}C$ and $\delta^{15}N$ values, consumer $\delta^{13}C$ and $\delta^{15}N$ values can be used to quantify the amount of tissue production supported by their respective prey items. Further, because of the large difference between consumer and prey $\delta^{15}N$ values (i.e., the "trophic fractionation"), the $\delta^{15}N$ value can be used to determine trophic level.