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Steelhead return rates and relative costs: A synthesis of three long-term stocking programs in two Minnesota tributaries of Lake Superior

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ABSTRACT

Hatchery augmentation of steelhead *Oncorhynchus mykiss* was evaluated over 20 years in Minnesota tributaries of Lake Superior using three approaches — stocking fry or yearlings of a naturalized strain (STT), and yearlings of a domesticated strain (KAM). The STT strain was introduced over 100 years ago and became naturalized to Lake Superior and its tributaries, unlike KAM, which has not been shown to reproduce successfully in streams. We compared smolt–adult return rates to anglers and in-river traps, and production costs per adult for these three programs in the French and Knife rivers. STT smolts derived from stocked fry in the French River resulted in the highest smolt–adult return rates to traps and anglers (13.3%), and lowest cost per returning adult ($46). STT stocked as yearling smolts produced the lowest return rate (1.5%) and highest cost per returning adult ($192) for both rivers combined. KAM stocked as yearling smolts were intermediate in return rate (2.6%) and cost per adult ($90). Differences in return rates of the three strains were attributable to the extent of domestication selection, size at stocking, season of stocking, and summer lake temperatures. Smolts derived from fry-stocked STT were strongly influenced by summer lake temperatures in their first lake year. Yearling-stocked STT were influenced by size at stocking and summer lake temperatures. KAM yearlings benefitted from summer stocking at larger sizes. Based on poor survival and fiscal constraints, the STT yearling program was discontinued. Stocking programs will continue to evolve according to changing biological, financial, social, and political pressures.

Introduction

Stocking of various strains and life stages of steelhead *Oncorhynchus mykiss* in Lake Superior to augment naturally reproducing (naturalized) populations and to support sport fisheries has met with varying success (Close and Hassinger, 1981; Hassinger et al., 1974; Schreiner, 2003; Seelbach and Miller, 1993). Steelhead, the anadromous form of rainbow trout from the west coast of North America, were first introduced into Minnesota's portion of Lake Superior in 1895 (MacCrimmon, 1971). Since that time, steelhead have become naturalized in Lake Superior, exhibiting the lacustrine-adfluvial form (lake dwelling, ascending streams to spawn) of a potamodromous life history (migratory, but confined to freshwater). Steelhead are able to access about 467 km of habitat in 54 Minnesota tributaries. However, only a reduced portion is suitable for spawning and nursery habitat (Hassinger et al., 1974; Schreiner, 2003).

From the 1940s through the 1960s, Minnesota tributaries supported a good steelhead fishery (Schreiner, 2003). Beginning in the 1970s and continuing through the 1980s, angling pressure increased sharply and anglers observed a decline in steelhead abundance. In response, the Minnesota Department of Natural Resources (MNDNR) initiated several programs to increase steelhead abundance, including modification of natural barriers to allow passage and increase availability of spawning and nursery habitat, in-stream habitat improvement, stocking of unfed steelhead swim-up fry above natural barriers, and the initiation of a put-grow-and-take program in 1976 using a domesticated hatchery stock of steelhead (Schreiner, 2006). (Hereafter, we will call this domesticated Minnesota stock “KAM”, and the naturalized stock will be called “STT”. The term “steelhead” will refer to all potamodromous *O. mykiss* stocks in general.) KAM were initially stocked to provide a harvestable fishery while the

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naturalized STT population recovered. Although the KAM stock is known locally as “Kamloops”, implying that these fish descended from the resident, non-anadromous stock found in the Kamloops region of British Columbia, genetic analyses have revealed that these fish are actually descendants of a West Coast steelhead stock (Krueger et al., 1994). KAM exhibit lacustrine-adfluvial spawning behavior, but natural reproduction by this stock is apparently unsuccessful (Krueger et al., 1994).

Despite the enhancement programs, STT abundance measured in creel surveys and returns to the fish trap located in the French River continued to decline through the early 1990s, causing renewed concern among both anglers and biologists. To gather information necessary to rehabilitate STT stocks in the Minnesota waters of Lake Superior, the MNDNR developed management plans for both STT and KAM stocks that included: restrictive angling regulations, revised stocking strategies, the construction of fish traps, juvenile electrofishing monitoring stations on selected tributaries, steelhead genetic studies, enhanced beaver control, and an experimental yearling stocking study, among others (Schreiner, 1992, 2003, 2006). The ultimate management goal was to “rehabilitate STT stocks using Minnesota strain fish to achieve a level that will allow limited angler harvest largely supported by naturally reproducing populations” (Schreiner, 1992, 2003, 2006). The success of these strategies is evident, as STT are now widely distributed in Minnesota waters of Lake Superior, and provide a popular stream fishery during the spring spawning run and a less intense lake fishery during summer months. In 2011, fishing pressure for rainbow trout reached 60,000 angler-hours (a threefold increase since 1997), with a total catch of about 9000 unclipped STT (including wild and fry-stocked fish) and 3100 clipped steelhead (including both KAM and STT stocked as yearlings) (Ward, 2011). Total catch of unclipped STT included fish caught more than once, as this is a catch-and-release fishery; harvest of clipped KAM and STT is allowed.

This synthesis describes the stocking of juvenile steelhead, and enumeration of returning adults for three approaches the MNDNR has taken to augment populations of *O. mykiss* — stocking of STT fry, STT yearlings, and KAM yearlings. Unfed STT swim-up fry were stocked into upstream reaches that were inaccessible to wild spawners due to migration barriers (Schreiner, 2003), to augment the wild population with a product that could potentially interbreed and only pose a minimum of genetic risk due to limited hatchery selection and residence time. STT yearlings were stocked as a put-grow-and-take fishery for anglers who preferred the sport fishing characteristics of the naturalized strain, with some potential for augmenting the naturalized population in future generations through natural reproduction. KAM were also stocked as yearlings, and although the original intent was to provide a put-grow-and-take fishery that would reduce fishing pressure on naturalized populations, they also support a popular shore fishery in fall, winter, and spring as they stage off river mouths prior to the spawning season (Schreiner, 2006). All stocked yearlings, both STT and KAM, received fin clips to identify that they were hatchery-origin fish. Although these stocking programs were developed independently and were not designed with parallel controlled research protocols to facilitate comparisons, valuable insight was gleaned from each.

We describe comparisons of smolt–adult return rates and production costs for fish stocked into the French River, where all three programs have been enacted over many years. Additional information on smolt–adult return rates from stocked STT yearlings in the nearby Knife River is also provided. The objectives of this paper are to evaluate and compare the smolt–adult return rates from the three programs to anglers and to fish traps located in both rivers; compare the costs per returning adult from each program; investigate the most appropriate stocking sizes and dates for yearlings, and examine the effects of environmental variables on smolt–adult return rates for each program. These assessments can be used to direct future steelhead stocking in Lake Superior and the other Laurentian Great Lakes.

Study site

This study focuses on steelhead stocked in the French and Knife rivers (Fig. 1) where in-stream traps enable the assessment of migrating fish populations. These rivers have low alkalinities ranging from about 15 to 50 ppm, and low productivity (Waters, 1977), minimal groundwater input, are subject to high spring runoff and widely fluctuating flows, and in some years form anchor ice with surface flows in winter. Spring water temperatures often exceed optimum temperatures of 7 to10 °C for rainbow trout egg development (Kwain, 1975; Negus, 1999) or up to12 °C (McCullough, 1999). The temperature maximum (12 to13 °C) for successful smoltification (Adams et al., 1975; Hoar, 1988; Zaugg and Wagner, 1973) is also exceeded in some spring seasons (Negus, 1999). Summer water temperatures can exceed optimal growth temperatures of 11 to19 °C for juvenile steelhead (Cech and Myrick, 1999; Hokanson et al., 1977), and daily mean temperatures occasionally exceed 24 °C in the lower reaches in some years (French River unpublished data). Given these constraints, in-stream rearing capacity for steelhead is limited and survival is variable. In contrast to the warm summer temperatures encountered in these streams, steelhead adults in Minnesota waters of Lake Superior occupy temperatures below their optimal growth temperatures of 13 ° to 20 °C (Niemuth, 1970; Talmage and Coutant, 1980; Wismer and Christie, 1987) from November to June, with mean monthly temperatures falling below 4 °C in March, the coldest month (unpublished data from ongoing study).

The French River was used to assess stocked fry survival rates because two traps and a dam create a closed system where emigrating smolts and returning adults can be effectively monitored. Inmigrating adult fish cannot bypass the traps and a 5-m dam prevents access to upstream habitat, so natural reproduction cannot occur upstream. No stream-resident rainbow trout populations have ever been found based on extensive annual electrofishing assessments over the past 20 years. The adult fish trap located 100 m upstream from the mouth has been in operation since 1970, and is used as an assessment tool to evaluate in-migrating adult returns from stocking events in the French River. This trap, built into a steel fenced framework that spans the river, blocks upstream passage of adults but permits downstream movement of juveniles. Natural spawning habitat below this trap is essentially nonexistent (predominantly bedrock), and adults are never transported above the trap. A juvenile or “smolt” trap, constructed as part of an existing 5-m high concrete barrier dam located 0.25 km upstream from the river mouth, has been in operation since 1994 (Dexter and Schliep, 2007) to monitor the emigration of juveniles that result from fry stocked upstream of the dam, where approximately 15 km of nursery and rearing habitat are available to these fish. The median river flow (measured at a station located between the adult trap and the smolt trap) was 0.03 m^3/s and the range was 0.01 to 3.26 m^3/s based on daily mean values recorded from 1995 to 2006 (MNDNR file data).

The Knife River system, whose confluence with the lake is approximately 11 km northeast of the French River (Fig. 1), is the only Minnesota tributary to Lake Superior that is accessible to migratory fish for its entire length, containing approximately 115 km of spawning, nursery and juvenile rearing habitat for steelhead (Hassinger et al., 1974). This river constitutes almost 40% of the total tributary stream habitat accessible to migrating steelhead in Minnesota (Schreiner, 2006). The Knife River basin has had two combination adult/smolt traps for capturing migrating adult and juvenile fish. A combination adult/smolt trap located in the Little Knife River (Fig. 1) was operated from 1990 to 1999, but has since been removed. A second combination adult/smolt trap built in the main stem of the Knife River, 0.5 km upstream from the river mouth, has been in operation since 1996 (Dexter and Schliep, 2007). The median river flow was 0.59 m^3/s and the range was 0 to 137 m^3/s based on daily mean values recorded from 1973 to 2010 (USGS, online data).