



Photo courtesy of David Kohne.

Steelhead Genetics Project Answers Long-standing Questions of Hybridization between Steelhead and Kamloops Rainbow Trout

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The Minnesota Department of Natural Resources (MNDNR) has maintained fishable populations of two strains of Rainbow Trout in North Shore tributaries to Lake Superior. Kamloops, a domesticated hatchery strain, were originally introduced into Lake Superior in 1941 through stocking into the Montreal River, Ontario (Eastern Lake Superior). Kamloops were introduced to Minnesota waters in the early-1970s. Steelhead, a wild strain of Rainbow, was first introduced to Ontario waters of Lake Superior in 1883, allegedly from multiple West Coast sources, and was introduced into Minnesota waters in 1895. Steelhead quickly adapted to the hostile conditions of North Shore streams and have become naturalized in many streams. Over the last two decades, restrictive harvest regulations and targeted stocking efforts have increased Steelhead populations on the North Shore and since 1997, Steelhead fishing has been restricted to catch-and-release only. Simultaneously, to provide a harvest fishery the MNDNR continued to stock Kamloops into North Shore streams.

Steelhead, although not native to the Great Lakes, are an incredibly popular sportfish and provide the most sought-after stream fishery on Minnesota's North Shore. If you take a drive up Highway 61 along Lake Superior's North Shore in the spring you are likely to see a bevy of vehicles parked by the tributary

rivers. Those vehicles are full of “Steelheaders,” who transform the North Shore streams into a swarm of imitation egg flies, nymphs and spawn bags. At this time of the year, around April or May, Minnesota’s Steelhead find their way back to the streams where they were hatched about 4 or 5 years ago with one goal in mind: find a mate and reproduce. These fish put in a lot of effort to build redds, and to find and defend spawning territory, all with the goal of providing the best opportunity for their offspring. Little do they know (or maybe they do?), their choice of a mate(s) during spawning could dictate how many of their offspring survive. This brings us back to the Kamloops. Despite Steelhead and Kamloops both being Rainbow Trout, they really are quite different. A number of studies conducted on the North Shore have indicated if a Steelhead spawns with a hatchery-produced Kamloops fewer of their offspring will survive to become adults than if a Steelhead spawns with another Steelhead. This suggests that continued maintenance of both strains could be detrimental to Steelhead populations.

What have previous studies told us?

Most previous research addressed the contributions of hatchery-produced Kamloops and wild-produced Steelhead and whether hybridization could limit recruitment (survival) of naturalized Steelhead. Krueger et al. (1994) studied genetic diversity of Steelhead populations and effects of hatchery stocks and found no evidence that Kamloops had introgressed (mixed genes by interbreeding) with Steelhead populations in Minnesota waters. However, the genetic markers and analytical techniques available at the time of Krueger et al. (1994) likely lacked the ability to detect introgression unless it was occurring at really high levels (L. Miller, unpublished data). Negus (1999) found that the survival of offspring from an eyed-egg (developed eyes but has not hatched yet) to a swim-up fry (hatched from the egg and used up its attached food source-called a yolk sac) stage was greater for Steelhead x Steelhead pairs than for Kamloops x Kamloops pairs in the hatchery, while survival of hybrid Steelhead x Kamloops was intermediate to the two pure crosses. Negus (1999) concluded that if Kamloops spawn with Steelhead, fewer fish may be produced and Steelhead gametes would essentially be wasted. Close (1999) introduced fecund (ready to spawn) adult Kamloops and Steelhead into a previously uninhabited, above-barrier section of the Lester River (near Duluth, MN) and found that hybrids were produced and survived at least one winter. Miller et al. (2004) evaluated survival of juvenile Steelhead, Kamloops and their hybrids from the swim-up fry stage to age-1 and found that Steelhead were better adapted and outperformed hybrids or Kamloops in the stream environment. ***Cumulative relative survival of cross types combining hatch rates and juvenile survival showed a 42-70% reduction in survival to age-1 of a hybrid compared to a Steelhead x Steelhead cross*** (Miller et al. 2004). More recently, Page et al. (2011) modeled the effects of Kamloops stocking on wild Steelhead populations and concluded that continual stocking of Kamloops greatly increases the risk of extinction of wild Steelhead through hybridization, particularly where population size is small. These reports and others are available online: <http://www.minnesotasteelheader.com/SGP.html>.

Shared Concerns

Research over the last two decades have heightened the concern about the effects of genetic introgression (mixing) of Kamloops in Lake Superior Steelhead populations. Genetic mixing of the two types could have negative long-term effects on the sustainability of Lake Superior Steelhead populations. Although Steelhead have rebounded over the last decade, genetic introgression could still be occurring in the wild and slowing progress toward reaching a completely self-sustaining status. It is assumed that Steelhead abundance will increase and fishing continue to improve only if the factors limiting Steelhead survival are identified and mitigated, such as reduced survival from hybridization. Members of the Lake Superior Advisory Group voiced these concerns during the revision of the MNDNR Fish Management Plan for Minnesota Waters of Lake Superior, and made apparent that a reevaluation of Steelhead genetics was needed.

Why now?

Genetics of Steelhead today could be different than 20 years ago. The genetic markers and computer programs used to analyze genetic data available today are much more powerful than were available to Krueger et al. (1994). Using modern genetic tools and computing power scientists are now able to answer many questions with more resolution and detail. The changes in these technologies is sort of like moving from a magnifying glass to a 100x magnification dissecting microscope with a camera and built-in software! Also, it has been over two decades since the first study evaluated the genetics of Minnesota's Steelhead and over 1.5 million more Kamloops have been stocked over that time.

Steelhead Genetics Project: Cooperative Fisheries Research along Minnesota's North Shore

In 2016 and 2017, the MNDNR coordinated a "Steelhead Genetics Project" to reevaluate hybridization rates between Kamloops and Steelhead in Minnesota waters. The project was a cooperative research where at least 50 anglers were permitted by MNDNR to collect genetic samples (small amount of scales) from wild adult Steelhead (no fin clips) caught and released via angling in Minnesota waters, both in streams and in Lake Superior. Many of these anglers were part of Minnesota Steelheader, Trout Unlimited, or the Lake Superior Steelhead Association, while some were charter captains who fish Minnesota or Michigan waters, and others were unaffiliated. The MNDNR also collected genetic samples (fin clips) from newly hatched, juvenile (young-of-year) Steelhead in streams, wild adult Steelhead that returned to traps, and captive adult Steelhead broodstock. In 2017, the MNDNR was also contacted by the Wisconsin Department of Natural Resources (WIDNR) who wanted to test juvenile and adult Steelhead from Wisconsin's Bois Brule River, where over 100 adult Kamloops were recorded on video ascending upstream of the fish trap.



Over the two years, anglers provided scale samples from 741 adult fish caught among 30 North Shore rivers, 65 adult fish caught in Minnesota waters of Lake Superior, and 8 fish caught in Michigan waters of Lake Superior. In 2016, fin clips were collected from 1,353 young-of-year fish from 27 North Shore streams. A total of 928 adult Knife River captive Steelhead broodstock (previously at French River Coldwater Hatchery) and 277 adult feral (wild-return) Steelhead broodstock that returned to the French River trap were also analyzed in 2016 and 2017. The WIDNR provided fin clips from 87 juveniles and scales from 43 adult Steelhead collected from the Bois Brule River in 2017.



What have we learned from the Steelhead Genetics Project?

Samples collected in 2016 and 2017 confirmed genetic introgression (mixing) of Kamloops genes into Steelhead populations. Kamloops ancestry was found in juvenile and adult Steelhead sampled along the North Shore and in Wisconsin's Bois Brule River, in adults caught by anglers in Minnesota and Michigan waters of Lake Superior, and in the French River wild Steelhead broodstock and Knife River captive Steelhead broodstock. Nearly everywhere we looked we found Kamloops genes in Steelhead populations. A detailed summary of results are provided in Tables 1 and 2. General overview of results:

- ***Genetic introgression (mixing) is geographically widespread, but relatively low, among North Shore Steelhead populations.*** Hybrids or pure Kamloops juveniles were found in 24 of the 27 streams sampled in 2016, and 15% of all fish collected likely had a recent Kamloops ancestor (for example, a parent, grand parent, or great-grandparent was a pure Kamloops). Adult hybrids or pure Kamloops were found in 15 of 30 streams sampled by anglers, and approximately 8% of these fish had a recent Kamloops ancestor. Fifteen percent of adult fish caught by anglers fishing Lake Superior had a recent Kamloops ancestor. The levels of hybridization among North Shore streams were the highest in the lower shore, intermediate in the middle shore, and lowest in the upper shore. Higher levels of introgression generally corresponded to rivers in close proximity to where Kamloops were stocked in the last few decades (Lester and French rivers).
- ***Naturally-produced juvenile and adult Kamloops exist in the wild and without genetic testing these fish are indistinguishable from wild Steelhead.*** Naturally-produced (no fin clips) Kamloops were found among juveniles collected from five North Shore streams (French River, Sucker River, Encampment River, Kadunce River and Farquhar Creek). They were also found among adults caught by anglers in seven North Shore streams (Stewart River, Split Rock River, Palisade Creek, Baptism River, Cascade River, Nature Boy Creek, and Devil Track River), and among adults caught by anglers fishing Lake Superior.
- ***Naturally produced, pure Kamloops and hybrids were found in the French River wild Steelhead broodstock, and hybrids were found among Knife River captive Steelhead broodstock.*** Approximately 11% (48 of 277) of all unclipped adult Rainbow Trout that returned to French River in 2016 and 2017 were Kamloops x Steelhead hybrids, and 18 of these fish were pure Kamloops that were visually indistinguishable from Steelhead (no fin clips). Approximately 2% (14 of 928) of all 2016 and 2017 Knife River captive Steelhead broodstock were hybrids, and zero were pure Kamloops. The source of the Knife River brood comes from juveniles collected at the Knife River trap emigrating downstream from the Knife River. Approximately 10% of all young-of-year Steelhead analyzed from Knife River were a Kamloops x Steelhead hybrid.
- ***Introgression was detected in both juvenile and adult Steelhead from Wisconsin's Bois Brule River.*** Approximately 10% (9 of 87) of young-of-year and 5% (2 of 43) of adult samples provided by WIDNR in 2017 were hybrids. No juvenile or adult fish were pure Kamloops.

Implications for Rainbow Trout Management

Adult Rainbow Trout (both clipped Kamloops and unclipped Steelhead) are collected at French River each spring. All fish are examined for clips during workup and spawning to assure that data from each type is recorded correctly and so clipped Kamloops are not spawned with unclipped Steelhead. Finding unclipped, wild-produced Kamloops and hybrids that were indistinguishable from wild Steelhead at French River is very concerning. Finding juvenile hybrids in all three stations sampled in the Knife River and in the Knife River captive broodstock was also concerning because these sources provide brood for the Steelhead fry stocking program. These results have forced MNDNR into genetic testing every fish used during Steelhead spawning operations. Any fish with Kamloops genes found in 2016 and 2017 were not spawned. The MNDNR will continue to test all unclipped fish that return to the French River in coming years to limit the unintended spread of hybridization from stocked fish.

Confirmation of Kamloops genetic introgression into wild Steelhead populations was one of the criteria in MNDNR's *Fisheries Management Plan for the Minnesota Waters of Lake Superior* that would justify a re-evaluation and potential phase-out the Kamloops program. This means there are two competing goals in the management plan, 1) rehabilitate Steelhead populations to allow a limited angler harvest, and 2) continue to stock Kamloops for harvest opportunities until Steelhead are rehabilitated (reach harvestable

levels). Hybridization was not isolated to Minnesota waters. Kamloops have been positively identified passing through Wisconsin's Bois Brule River fish trap and genetic introgression was found in juvenile and adult samples from Wisconsin's Bois Brule River. Minnesota is obligated, through the Great Lakes Fishery Commission's Joint Strategic Plan, to ensure its management strategies do not negatively impact other jurisdictions on Lake Superior. Continuation of Kamloops stocking would further enhance hybridization and jeopardize gains made towards the development of self-sustaining Steelhead populations in Minnesota and Wisconsin over the past 20+ years. More information about the management of Rainbow Trout in Minnesota waters of Lake Superior is outlined in the MN DNR's *Fisheries Management Plan for the Minnesota Waters of Lake Superior* (available online: <http://www.dnr.state.mn.us/areas/fisheries/lakesuperior/management.html>).

The level of introgression observed among North Shore streams was concerning given the negative affects introgression can have on recruitment (survival) of Steelhead. Although introgression was geographically widespread, the majority of fish analyzed were pure Steelhead and introgressed populations were more apparent in lower shore rivers closer to where Kamloops were stocked in recent years (Lester and French rivers). This suggests that, although introgression is occurring, the genetic integrity of Steelhead populations is not completely compromised and can still be protected. Suspension of the Kamloops stocking program would be the best method to prevent further introgression among North Shore populations.

The MNDNR met with the Lake Superior Advisory Group on October 23, 2017 to present results from the first two years of the project. Advisory Group representatives were asked to provide feedback from their groups on whether or not Kamloops should still be stocked and if they are ok with the risk vs reward for continuing the Kamloops program, and were provided with several scenarios on where to go with the future of Rainbow Trout management. In general, feedback from Lake Superior Advisory Group supported immediate discontinuation of the Kamloops program. Most groups were reluctant to open up harvest on wild Steelhead populations, thinking we have not yet developed completely self-sustaining populations; however, there was also a desire amongst certain groups to provide harvest opportunities. One group did not support discontinuation of the Kamloops program. Using this input, the MNDNR will develop program options that will get us closest to meeting these two main concerns and discuss with the LSAG in coming months.

THANK YOU ANGLERS!

Thanks to all anglers who participated in 2016 and 2017! The Steelhead Genetics Project would not have been possible without support from anglers. Spring is a very busy time for MNDNR and it was physically and financially impossible to collect samples from adult Steelhead in 2016 and 2017. The project allowed us to develop great relationships with many passionate North Shore Steelhead anglers and angling groups who, in turn, used this project as a platform to reach out and educate others and promote Minnesota's North Shore Steelhead fishery. To those groups, *WE REALLY APPRECIATE WHAT YOU DO, KEEP UP THE GREAT WORK!* We plan to continue the Steelhead Genetics Project in 2018 to answer other genetics questions and advance our understanding of our North Shore fisheries. Many of the anglers who participated said that collection of genetic samples was relatively straight forward and did not interrupt their fishing experience. If you would like to be involved with the Steelhead Genetics Project please contact Lake Superior Area Fisheries (<http://www.dnr.state.mn.us/areas/fisheries/lakesuperior/index.html>). More information about the project can be found at: <http://www.minnesotasteelheader.com/SGP.html>.

