Alberta Native Trout Science Workshop Proceedings

February 1-3, 2023

Alberta Species at Risk Report No. 173

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Cover photos (credit): Biogeosciences Institute at Barrier Lake (Ashley Meek) and westslope cutthroat trout from upper Waiparous Creek (Lindsay Marley).

Andrew J. Paul, Ben C. Kissinger and Jeannine Goehing. 2024. Alberta native trout science workshop proceedings: February 1-3, 2023 | Alberta Environment and Protected Areas

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Editor's Note:
The American Fisheries Society's (AFS) 8th edition of common and scientific names for fishes was released in September 2023 (Page et al. 2023). Cutthroat trout are now recognized as four distinct species (Page et al. 2023). The four species are: coastal cutthroat trout *Oncorhynchus clarkii* (Richardson, 1836); Lahontan cutthroat trout *O. henshawi* (Gill & Jordan, 1878); westslope cutthroat trout *O. lewisi* (Girard, 1856); and, Rocky Mountain cutthroat trout *O. virginalis* (Girard, 1856). Although the workshop occurred prior to release of Page et al. (2023), the editorial team has applied this most current scientific nomenclature to these proceedings.

Page, L.M., K.E. Bemis, T.E. Dowling, H.S. Espinosa-Pérez, L.T. Findley, C.R. Gilbert, K.E. Hartel, R.N. Lea, N.E. Mandrak, M.A. Neighbors, J.J. Schmitter-Soto, and H.J. Walker, Jr. 2023. Common and Scientific Names of Fishes from the United States, Canada, and Mexico, 8th edition. American Fisheries Society Special Publication 37, Bethesda, Maryland. https://doi.org/10.47886/9781934874691

Foreword

In 1983, my dad and I spent two weeks fishing Alberta's Forestry Trunk Road. We were not alone and big trout were easier to imagine than catch. Regardless, we eagerly started our mornings with a fry of pan-sized bull trout before heading out on ever increasing hikes to find those "trout to 3 lbs" described in the fishing guide. Although a wonderful time, the story gives me nightmares to this day. First, my dad is from the tiny island of Guernsey where residents grow tomatoes, drink milk and eat fish, so if you could legally keep a fish in Alberta we did. Second, regulations of the day were five trout of any species and any size. Third, we told ourselves these regulations were based on conservation, so our take must be sustainable. We said we believed these things. Yet every day we hiked longer, and the farther we got from the road, the better the fishing seemed.

Times were changing. Recognized declines of fish across Canada brought massive changes to fisheries nationwide over the next 10 years. By 1994, Canada's eastern cod fishery had unequivocally collapsed from overfishing; bull trout in Alberta were one step away from catch-and-release regulations (minimum 40 cm size limit); and, a conference was held that year in Calgary focused entirely on understanding and conserving this native trout. Perhaps as penance for the past, I enrolled the following year in graduate school to study bull trout and proceedings from the Calgary conference (Mackay et al. 1997) became a guiding document to my program. Through the tireless efforts of Kerry Brewin and Trout Unlimited Canada, several more conferences on Alberta's native fishes and their habitat occurred over the next decade including a second bull trout conference in 1999 at Canmore (Brewin et al. 2001). After a long hiatus, Dr. Ben Kissinger approached me in 2022 with the idea of holding another native trout conference to discuss the ongoing science in Alberta. With support from the Office of the Chief Scientist, fRI Research and a dedicated planning team (see Appendix B), the Alberta Native Trout Science Workshop was held February 1-3, 2023 at the University of Calgary's Biogeoscience Institute in Kananaskis Country. These proceedings reflect the work presented at that workshop.

Conference or workshop proceedings are not peer-reviewed scientific publications and should not be treated as such. However, proceedings offer something that is otherwise difficult to obtain from the scientific literature – a collective window into the perceived state of a system at a given point in time, including knowledge, issues and attitudes. Dust off the 1994 proceedings and read the entire section on why native trout should matter. Read the late Dr. David Schindler's earnest call in Canmore (1999) for effective endangered species legislation in Canada. Check out Pat Clancey's abstract from the same conference on how recovery efforts can get stalled by seemingly insurmountable legal challenges; then be sure to read his 24-year follow up in these proceedings for a lesson in tenacity and commitment.

Fisheries management should not be a Markovian process. It is our responsibility to learn, or remember, what came before us. I hope these proceedings help serve that purpose.

Dr. Andrew J. Paul

Mackay, W.C., M.K. Brewin and M. Monita. 1997. Friends of the bull trout conference proceedings. Bull Trout Task Force (Alberta), Trout Unlimited Canada, Calgary, Alberta.

Brewin, M.K., A.J. Paul and M. Monita. 2001. Bull trout II conference proceedings. Trout Unlimited Canada, Calgary, Alberta.

Abstracts and Extended Abstracts

Arranged in alphabetical order by authors' last names

A synopsis of five-years of ACA-led westslope cutthroat trout conservation activities

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For the past decade, the Alberta Conservation Association (ACA) has conducted numerous studies to support westslope cutthroat trout (*Oncorhynchus lewsi*; WSCT) conservation in the province. I provide a synopsis of recently-completed, ongoing, and future activities aimed at WSCT recovery. To date we have generated a five-year population-monitoring dataset in the Upper Oldman River drainage, as well as ongoing watershed temperature monitoring and literature-based evaluation of potential receiving waterbodies for future conservation-stocking considerations. We developed a fish-passage barrier assessment tool and field manual to evaluate invasion-threat of non-native species and the conservation-potential of natural fish passage barriers to prevent invasion. We assessed summer temperature suitability and overwintering potential of the thermally fragmented Hydrologic Unit Code (HUC) 10 watershed Callum Creek, to evaluate its conservation potential at the fringe of the current WSCT range. Current initiatives include assessing the conservation-stocking potential at 23 select high-mountain lakes using outlet and shoreline habitat surveys to inform spawning potential and suitability; and targeted eDNA analyses to provide insight on current and legacy fish assemblages. In addition, we are analyzing angler-count data from remote camera surveys at a cross section of eight high-mountain lake fisheries to assess and compare angling pressure on a popular native WSCT fishery relative to access-difficulty and other novel trout fisheries. Moving forward, we plan continued development of overwintering and spawning detection tools including thermal infrared drones to detect upwellings and investigate their potential linkage with spawning locations. Future objectives include identification of WSCT gamete source locations in the Waiparous Creek watershed to guide gamete collections and strengthen WSCT broodstocks.

Characterizing and managing recreational angling impacts on native trout in Alberta

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Recreational fisheries have impacts on fish populations and their ecosystems that vary widely in their extent and degree. The nature of recreational fisheries and their impacts depends on a combination of social factors (e.g., participation rates, angler priorities and behaviours), biological factors (e.g., species ecology and stressor sensitivity), and their interactions. When fishing pressure is high, overexploitation is common and management actions are required to achieve conservation goals. A variety of management approaches are available, the most effective of which for a given scenario are dependent upon these fishery characteristics. Examples include seasonal or spatial restrictions, gear requirements, and harvest or catch-and-release (C&R) restrictions. I will discuss how fisheries often affect fish populations in relation to fisheries and environmental characteristics, information needs, and the variety of management options, including each of their benefits, caveats, and considerations for efficacy. Of these, C&R is an increasingly popular strategy to maintain social and economic benefits while alleviating stress on exploited fish populations. However, these positive outcomes are not always accomplished, depending on the fishery. I will discuss how C&R practices impact fishes and the importance of applying 'best angling practices' to ensure C&R is consistent with conservation endpoints. Importantly, management approaches can be implemented through top-down (i.e., legal regulatory) or bottom-up (e.g., angler education, shifting cultural norms). Some elements of fisheries can be managed far more effectively with bottom-up approaches, which is an often-underappreciated tactic. Social factors such as angler priorities, behavioural tendencies, and learning styles are also commonly overlooked elements of fisheries management. Overall, I aim to provide broad context for these concepts from recreational fisheries around the world, with interpretation for the specific issues facing Alberta's native trout fisheries.

Evaluation of catch-and-release sport fishing regulations for westslope cutthroat trout in Picklejar Lakes, Kananaskis, Alberta

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Picklejar Lakes are a series of four high elevation mountain lakes located in the headwaters of the Highwood River in Kananaskis Country, Alberta. Lakes #2 and #4 contain genetically pure non-stocked populations of westslope cutthroat trout (*Oncorhyncus lewisi*), listed as Threatened under Alberta's *Wildlife Act* and the federal *Species at Risk Act.* Prior to 2015, Picklejar Lakes had an allowable harvest of two fish of any size. In 2015, a zero-harvest regulation was implemented. Population assessments were conducted in 2014 and 2021 to evaluate if the implementation of catch-and-release sport fishing regulations resulted in a change in the abundance and population structure.

Results from the assessment suggest a positive population response to the zero-harvest regulation. 2021 population estimates were 3,421, 95% CI [2761 – 4299] and 2,165, 95% CI [1846 – 2581] for Lakes #2 and #4, respectively. Due to broad confidence intervals around the 2014 estimates, evaluation of population abundance between years is inconclusive. A generalized linear model was used to predict fork length with year and waterbody, with the interaction term of waterbody and year. Fish in both lakes were significantly larger in 2021 (Lake 2 $p=0.012$, Lake 4 $p<0.001$), with an increase in maximum length also observed at Lake #4 (Table 1). Differences in fish size between the two lakes were also observed in both years, with fish in Lake #4 being significantly larger than fish in Lake #2 ($p<0.001$). Differences in fish size and growth between lakes may be attributed to differences in habitat and productivity. Results of this assessment provides fishery managers with valuable baseline data for continued evaluation of this unique alpine sport fishery, and supports the maintenance of current catch-and-release regulation at Picklejar Lakes.

Table 1. Mean and maximum fish length, Picklejar Lakes.

Year	Waterbody	Mean / maximum fork length (mm)	Sample Size
2014	Lake 2	177 / 283	247
	Lake 4	198 / 279	260
2021	Lake 2	185 / 236	752
	Lake 4	222 / 340	812

Monitoring bull trout in the upper Ghost River, Alberta

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The assessment of fish populations is fundamental to managing, allocating and recovering fish species, especially those at risk. Bull trout (*Salvelinus confluentus*) are the primary species found in the upper Ghost River watershed and are listed as Threatened under Alberta's *Wildlife Act* and the federal *Species at Risk Act*. The river headwaters are located in a Wilderness Area, while the middle reaches flow through a Public Land Use Zone. While there is no development in the Wilderness Area, water management infrastructure existed immediately downstream in the form of a water diversion structure, canal and river training structures. The diversion was built in 1942 and diverted water and fish into Lake Minnewanka to augment water supply for hydroelectric generation. In 2013, the diversion was destroyed by a flood and the entire flow of the upper Ghost Watershed now remains in the Ghost River. Alberta Environment and Protected Areas conducted a five-year study that aimed to quantify population response following these events in the watershed.

Results from the assessment indicated increased abundance of all life stages of bull trout relative to previous years surveyed. The 2022 data suggested that bull trout are currently in a low to very low risk state when compared to provincial Fish Sustainability Assessment metrics. We expect this data will be valuable to direct species recovery and inform future land use planning in the area.

Whirling disease confirmed as a significant threat to pure westslope cutthroat trout populations in the upper Bow River, Alberta

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Canada's first detection of *Myxobolous cerebralis* (Mc) occurred in 2016 and since then, the parasite has been confirmed throughout much of the province. In 2019, the first known epizootic outbreak of whirling disease was confirmed in rainbow trout (*Oncorhynchus mykiss*) populations in the Crowsnest River. The Crowsnest River study determined that a qPCR assay could be used to detect the infective actinospore stage (TAM) of Mc and the necessary TAM density for whirling disease to occur. Currently, it is unknown if Mc is established within near-pure and pure westslope cutthroat trout (*Oncorhynchus lewisi*; WSCT) populations, and if present, if the density of TAMs in these populations is sufficient to cause whirling disease.

In 2021, we conducted a series of TAM water filtrations and *Tubifex tubifex* (Tt) worm collections throughout the upper Bow River drainage basin and applied subsequent qPCR assays to determine if Mc is established in pure or near-pure WSCT populations and whether TAMs were found in densities sufficient to result in whirling disease.

Our results found one near-pure WSCT population, Sibbald Creek, with TAM densities exceeding the threshold necessary for whirling disease. In addition, Tt worms were found positive for Mc in two pure WSCT sites, Etherington Creek and Ghost River, confirming Mc has now established in these vulnerable populations. These results confirm that whirling disease poses a serious risk to WSCT populations in the upper Bow River and therefore, recovery strategies and management actions should be reconsidered in the context of managing this impactful disease.

Westslope cutthroat trout restoration in southwest Montana with emphasis on the Cherry Creek Project in the Madison River drainage

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Extended Abstract

Westslope cutthroat trout (*Oncorhynchus lewisi* spp.; WCT) occupy the Columbia, Missouri and South Saskatchewan River drainages in Montana. They historically occupied an estimated 27,866 km of habitat in the Upper Missouri River Drainage of southwestern Montana, east of the continental divide, but by 2006 remained in only 836 km (3% of historic) (Shepard et al. 2003). The remaining populations were restricted to primarily headwater areas of small streams, generally less than 8 km in length and 0.08 m^3/s discharge.

To address the declining status of WCT, Montana Fish, Wildlife & Parks (FWP) held a series of open forum meetings beginning in 1996 when the state's Governor convened a conservation summit and invited representatives from state and federal agencies, Native American tribes, agricultural producers, resource extraction industries, conservation organizations and private landowners to attend and become involved in WCT conservation. These meetings led to the formation of a Westslope Cutthroat Trout Steering Committee, composed of representatives from many of these varied interests, which developed a Memorandum of Understanding and Conservation Agreement for Westslope Cutthroat Trout in Montana (WCTMOU 1999). Among the goals of the document was a call to ensure the self-sustaining persistence of WCT in Montana, protection of all "core" (genetically pure) and "conservation" (<10% introgressed) populations and conservation of the genetic diversity represented by remaining pure populations. One element of the conservation program called for expanding the overall WCT distribution to 20% of historic distribution in multiple sub-basins of the Missouri Drainage, including establishing populations in >80 km connected habitat.

An important catalyst for the Cherry Creek Project occurred about 10 years before the project was conceived. In the late 1980's, whirling disease, caused by the parasite *Myxobolus cerebralis*, was introduced into the Madison River, likely through an illegal rainbow trout (*O. mykiss*) introduction. Routine monitoring of trout populations in the Madison River detected a widespread and significant decline of the rainbow trout population. By 1996, the number of rainbow trout larger than 300 millimeters decreased from a long-term average of 620/km to 125/km. FWP decided to restore native WCT in selected tributaries to the Madison River as part of the solution to restore the trout population, and subsequently, angling in the Madison River. This effort was designed to accomplish two objectives: 1) to initiate a long-term WCT conservation and restoration program that contributed toward meeting the goals outlined in the developing WCTMOU, and 2) to provide source populations of trout potentially less affected by whirling disease that could provide fish to the Madison River via downstream fish movement to diversify and improve recreational angling opportunities. FWP expected that chemical removal of non-native fish would be necessary in some locations to achieve goals of the WCTMOU and the WCT conservation and restoration program.

After learning of FWP's conservation effort through a local newspaper article, Ted Turner, founder and chairman of Turner Enterprises, Inc. (TEI), directed his staff to contact FWP to inquire about the feasibility of including the Cherry Creek drainage, on Turner's Flying D Ranch and U.S. Forest Service land, in the program. These discussions led to an agreement between FWP and TEI that allowed FWP to lead a short-term, intensive effort to survey the upper Cherry Creek basin to assess its suitability for WCT. Upon completion of the surveys and additional discussions, FWP, TEI and the Custer Gallatin National Forest entered into a 3-way agreement to conduct a project to eradicate non-native trout from 100 km of Cherry Creek above an 8-meter waterfall and establish a WCT population from genetically pure 'nearest neighbor' wild populations.

FWP conducted public scoping and an Environmental Assessment (EA) prior to implementing the project (Clancey et al. 2019). After considering public comments, a final EA and formal Decision Notice were finalized allowing the project to move forward. Several project opponents enacted challenges to the project, including contacting both of Montana's U.S. Senators and sole member of the U.S. House of Representatives to investigate the project, challenging every permit and authorization necessary to implement the project, and ultimately filing three lawsuits in state and federal courts, including the U.S. Ninth Circuit Court of Appeals. All challenges were resolved by the courts in FWP's favor, but delayed project implementation for five years.

Due to the large size of the project area, we broke the area into smaller sections, or 'phases', for treatment. Natural or man-made barriers were used to separate the phases and prevent fish in untreated downstream phases from migrating upstream into treated phases between years. Project design called for chemical treatment of each phase for two consecutive years. Removal of non-native trout was accomplished from 2003 to 2010 using the piscicides Fintrol (antimycin) and CFT Legumine (rotenone). Potassium permanganate was used to deactivate the CFT Legumine rotenone at the mouth of Cherry Creek

Canyon, approximately 1.1 km below the 8-meter waterfall. WCT were introduced as eyed eggs in remote site incubators (RSI) and young-of-the-year from four 'nearest neighbour' wild populations and one wild hatchery brood stock from 2006 to 2014. The most recent estimates suggest over 60,000 WCT occupy the Cherry Creek treatment area, and they have emigrated into the lower 13 km of Cherry Creek and the Madison River. Anglers along Cherry Creek report catch rates as high as 1 fish/minute (personal observation, P. Clancey). The success of the Cherry Creek Project facilitated annual native trout restoration projects throughout their range in Montana.

Pre- and post-treatment fish abundances in monitoring sections indicated that WCT abundance increased rapidly and surpassed nonnative trout abundances three to five years after they were first translocated as fry (Figure 1).

In 2022, WCT occupy an estimated 1,641 km (5.9%) of historic habitat in southwestern Montana's Upper Missouri River Drainage with individual populations other than Cherry Creek occupying up to 24 km of stream with up to 0.34 m^3/s discharge. Completion of ongoing projects will add another 157 km of occupied habitat. To achieve the occupancy goal of 20% of historic habitat in the Upper Missouri Drainage, WCT must occupy a total of 5,575 km of stream habitat.

Figure 1. *Comparison of mean total length and number of fish greater than 75 mm total length per 100 m for non-native trout and WCT in six sections of Cherry Creek during pre-treatment (orange) and post-treatment years (green). Non-native trout consisted of eastern brook trout (EBT) and rainbow trout (RB).*

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Status of native trout populations at the margins of their range: a baseline assessment of bull trout in the Little Red Deer River watershed

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In 2023, the Alberta Conservation Association will begin a project to characterize presence and densities of adult bull trout (*Salvelinus confluentus*) in the Upper Little Red Deer River Hydrologic Unit Code (HUC) 10 watershed. Despite being at the margin of their historic range, with the population presumed to be declining, a watershed-level assessment of the bull trout population has never been completed. Local population status combined with a better understanding of limiting factors to recovery, such as habitat fragmentation from culverts and locating cold and groundwater influenced streams, is needed for strategic remediation efforts. Sites for population assessment will be randomly selected and we will focus on abundance and distribution around two culverts expected to be acting as migratory barriers. In upper sections of the watershed, instream temperature will be monitored with twenty loggers from spring 2023 to spring 2024. Improving connectivity to habitat that provides stable summer and winter temperature requires identifying locations of groundwater input. We will fly drones with forward facing infra-red cameras in headwater tributaries of the Little Red Deer River to identify patches of temperature heterogeneity for further investigation. Our work will provide baseline information on fish populations and identify priorities for culvert remediation to improve connectivity to bull trout critical habitat.

The role of science in species conservation: reviewing research progress and gaps for SARA-listed species

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Effective species conservation requires a strong foundation of science. Scientific research on at-risk species builds a body of knowledge that is used to directly inform conservation decision-making, and thereby improves the chance that recovery measures will accomplish their intended objectives. Without a strong foundation of science, the chance of making poor management decisions increases. To illustrate the role of science in the conservation of at-risk species, I will review the results of a recent gap analysis of science to support the *Species at Risk Act* for fishes and mussels in the Great Lakes basin (Drake et al. 2021). A simple research classification framework is presented, which involves broad themes related to population ecology, habitat, threats, and recovery. These themes inform the key management pillars of SARA, from identifying recovery potential, to identifying and protecting critical habitat, establishing population and distribution objectives, understanding the severity of threats, and implementing recovery measures like habitat enhancement, threat mitigation, and species reintroduction. For fishes and mussels in the Great Lakes, greatest success has been achieved for population ecology and habitat-related topics, but striking gaps remain for most threat and recovery topics. Moving forward, awareness of SARA research themes and their relative progress can ensure that limited research resources are used wisely and that species conservation continues to be informed by best-available scientific knowledge.

Ultimately, these findings and the path forward have strong relevance for the conservation of species across Canada. Continued effort is warranted to take stock of key scientific successes and key uncertainties, which will ensure that species conservation is informed by best-available scientific knowledge.

Associated Publication

Drake, D.A.R., K.A. Lamothe, K.E. Thiessen, T.J. Morris, M.A. Koops, T.C. Pratt, S.M. Reid, D.A. Jackson, and N.E. Mandrak. 2021. Fifteen years of Canada's *Species at Risk Act*: evaluating research progress for aquatic species in the Great Lakes - St. Lawrence River basin. Canadian Journal of Fisheries and Aquatic Science. 78:1205–1218. https://doi.org/10.1139/cjfas-2021-0143.

Working with people to create and apply science in bull trout conservation

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Engagement of stakeholders and rights-holders in the process of producing science they need to make decisions is becoming increasingly common. Here we describe a range of engagement processes that we refer to collectively as co-production of science. The case of bull trout (*Salvelinus confluentus*) is our example. Bull trout is recognized as a conservation concern across its broad distribution in North America. Recent work on this species provides some instructive examples of what the process of co-production might look like. Co-production involving local knowledge in developing species distribution models (Chelgren et al. 2023) and applying these models with stakeholders to evaluate recovery priorities for bull trout (Brignon et al. 2023) represent linked and broad-scale co-production efforts that have assisted planning for conservation investments. On a local level, several applications of structured decision making (e.g., Benjamin et al. 2019) have involved longer-term and more intensive forms of engagement and co-production of models to inform specific, on-the-ground decisions such as species introductions, influences of barriers, and other factors that are often in play for recovery of bull trout. Looking forward, decisions in the future face critical uncertainties related to the likelihood of ecological transformation. The Resist-Accept-Direct (RAD) framework was developed to address this novel challenge. Past actions to benefit native salmonids such as bull trout have mostly relied on Resist as the alternative (favoring actions that resist transformation to maintain systems in existing states or to restore to historical conditions). Increasingly, however, opportunities offered by Accept (allowing systems to change autonomously) or Direct (actively shaping change in systems to move toward new preferred conditions) are emerging as valid alternatives. A recent study of bull trout and management responses for addressing threats posed by introduced brook trout (*S. fontinalis*) showed that each RAD alternative can deliver successful outcomes. Gaining acceptance of these alternatives is an ecological and social process (Dunham et al. 2022). This collection of work on bull trout provides many useful examples of co-production and stakeholder engagement, but much work remains to be done (Dunham et al. 2018). Whereas it is obvious to most experienced practitioners that fisheries management involves people as much as it does fish, emerging concepts, tools, and applications involving co-production promise to greatly improve the role of both ecological and social science to improve real-world outcomes for native fish such as bull trout.

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Spatial delineation of genetic information of westslope cutthroat trout within their historic native range in Alberta watersheds

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Westslope cutthroat trout (*Oncorhynchus lewisi;* WSCT) are federally and provincially listed as a species at risk in Alberta (ASRD and ACA 2006; Government of Canada 2002). WSCT populations have declined throughout much of their historic native range due to overharvest, habitat degradation and loss, introduction of non-native competitor fish species, and hybridization with introduced non-native trout, primarily rainbow trout (*O. mykiss;* RNTR) and other non-native cutthroat trout species such as Yellowstone cutthroat trout (*O. virginalis* spp.) and coastal cutthroat trout (*O. clarkii;* AWCTRT 2013).

Rainbow trout were introduced within the native range of WSCT beginning more than 100 years ago. WSCT can interbreed with non-native salmonids, primarily RNTR and other cutthroat trout species, and can successfully produce fertile hybrid offspring. Hybridization with RNTR and other species then causes gradients of genetic purity to occur in populations with multiple genetically compatible species. Pure WSCT are defined federally by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; DFO 2019) as having ≥99% of the sampled genetic material of a population attributed to WSCT genes. Alberta Environment and Protected Areas' (AEPA) management objectives for WSCT are to preserve remaining pure populations of WSCT within their habitat, reduce hybridization in populations where possible, and expand their distribution within the historic native range.

In order to meaningfully manage WSCT on the landscape, an understanding of genetic status and distribution across the landscape is required. This information is also needed to identify genetically suitable broodstock fish, appropriate for recovery or range expansion initiatives. AEPA developed a geographical information system tool to delineate the extent of pure and hybridized WSCT populations in watersheds across their historic native range in Alberta (outside of National Parks). Watercourses are mapped and colored using Geographic Information Systems (GIS) software based on inferred genetic status of WSCT populations as proportions of hybridization with non-native RNTR and other *Oncorhynchus* species.

There are many benefits and applications of these data which include the ability to:

- inform the development of provincial and federal species recovery plans for WSCT;
- inform and/or support regulatory and land use decisions and planning processes;
- inform federal critical habitat delineation by providing detailed data on pure WSCT locations;
- identify existing data deficiencies and assist regional fisheries staff in prioritization of future work;
- support identification of sites for stakeholder involvement in species recovery on the landscape; and,
- identify risk to WSCT from industrial development, agricultural land use and recreational use.

Data to inform the map comes from *Oncorhynchus spp* tissue samples (in the form of fin clippings) which are collected from populations throughout the historic range of WSCT in Alberta from headwater streams in the Rocky Mountains to the mainstem rivers on the eastern edges of their native range. A minimum sample size of fish combined with maximizing the number of sequenced DNA base pairs (loci) used in the genetic assessment provides us the statistical power to detect the presence of non-native *Oncorhynchus spp* for that sample site. Locations with less than the minimum sample size increased uncertainty of hybridization status of the local *Oncorhynchus spp* community.

To date, tissue samples have been analyzed for hybridization levels using microsatellite analysis between 2006 and 2015, and by increasingly detailed single nucleotide polymorphism (SNP) analysis since 2016. Continuous development and improvement of methodologies in the field of genetic analysis has improved precision and reliability of the analysis, which is reflected in the certainty and precision of the results.

Each fish is scored on a scale of 0 to 1; 1 represents 'pure' WSCT, with the number declining as the proportion of genetic influence from RNTR (or another non-WSCT species) increases. The average score forms the basis of the genetic categories that are assigned to fish at sampling sites and subsequently assigned to fish in adjacent stream reaches. Average WSCT genetic admixture score was separated into three different categories which are represented with different colours on the maps: *pure = green* (≥ 0.985), *near-pure = yellow* (< 0.985 but ≥ 0.945) or *hybridized* = orange (< 0.945). Assigning each stream segment a genetic-status category based on nearby sampling sites was based on a comprehensive set of rules (currently unpublished) developed for the project.

Summary maps were completed at the Hydrologic Unit Code (HUC) level 8 watershed scale (Figure 1) for the historic range of WSCT. In addition to the coloured stream segments, each map indicates sample site locations, genetic analysis technique, a measure of confidence in the data (low or high depending on sample size, analysis method, age of data), barriers, major roads, and land designation.

Genetic status and WSCT presence/absence cannot be mapped with absolute certainty as only subsamples of all fish in a population are sampled and the number of sites across the landscape are limited and chosen to best cover a large area effectively while relying on some level of inference. The rule set ensures that assignment is made consistently, utilizing our best interpretation of existing information on current genetic status. Assignments can, and likely will, change over time as new information is added and as fish populations evolve.

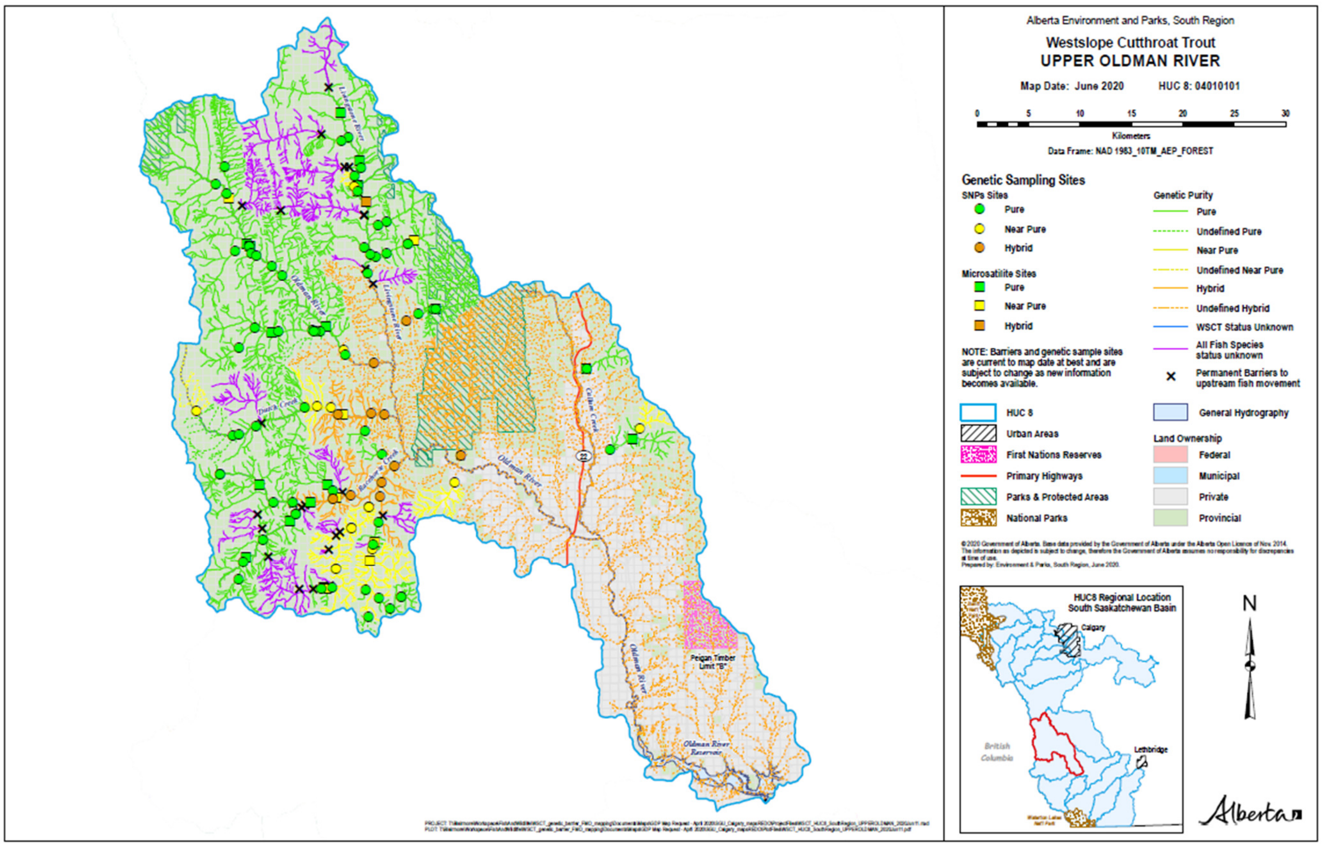

Figure 1. Sample map of westslope cutthroat trout genetic status in the Upper Oldman River Hydrologic Unit Code 8 watershed (as of June 2020). Stream segments are assigned a genetic status based on nearby sampling sites and a comprehensive set of rules developed for the project.

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Estimating angler effort at high mountain lakes in Alberta: A native westslope cutthroat trout case study

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Introduction

A challenge to balancing the socio-economic and environmental demands on Alberta's fisheries resources is the relatively high recreational angling effort and limited angling opportunities. High mountain lakes, that provide unique opportunities to help distribute angling effort across the landscape, have been identified as valuable locations for conservation stocking of native trout, and provide thermal refugia for native trout. Long-term management plans for these lakes require a current baseline of angler effort and an understanding of how changes in fishing effort will impact populations in the future. Among one of the most popular westslope cutthroat trout (*Oncorhynchus lewisi*; WSCT) fisheries is Picklejar Lakes; a series of four hydrologically connected lakes with a population of self-sustaining native WSCT and suspected high angler effort. We estimated angling effort at Picklejar Lakes and contrast with angler effort at five additional high mountain lakes (Commonwealth, Burstall (upper and lower), Chester, Carnarvon, and Rawson lakes) in native WSCT range (Figure 1). These other five lakes are sustained either through annual stocking or naturalized populations of cutthroat trout and Dolly Varden (*Salvelinus malma*). The relatively small size (2 - 20 ha) and remote nature of our study lakes make them ideal candidates for use of low effort trail cameras for estimating angling effort. Lakes ranged from easy to moderately difficult angler access.

Methods

We installed two trail cameras at each of Picklejar Lakes two and four and one camera at the other study lakes. Cameras with security housings were locked to trees and programmed to take photographs at 30-minute intervals from 06:00 to 23:00. Our goal was to have trail cameras installed and collecting data before opening day of the fishing season (for lakes that have a seasonal closure), however late snowmelt and trail closures did not permit this in all cases. Fishing seasons, trail camera data collection dates and spatial coverage of trail cameras at study lakes is shown in Table 1. Where possible, trail cameras were oriented facing north to minimize sun glare in photos. Anglers in each photograph were counted and these counts were bootstrapped (10,000 replicates) to develop a distribution of mean instantaneous counts. Angler hours in the field of view of the camera were estimated by multiplying the mean instantaneous count distribution by the total available hours in the sample frame (sum of hours from half hour before to half hour after sunset daily from July 1 to September 30). To spatially correct and extrapolate in-camera effort estimates to un-surveyed spatial strata (area of the lake not covered by photos), we used the ratio of area surveyed by the camera to the total area of the waterbody.

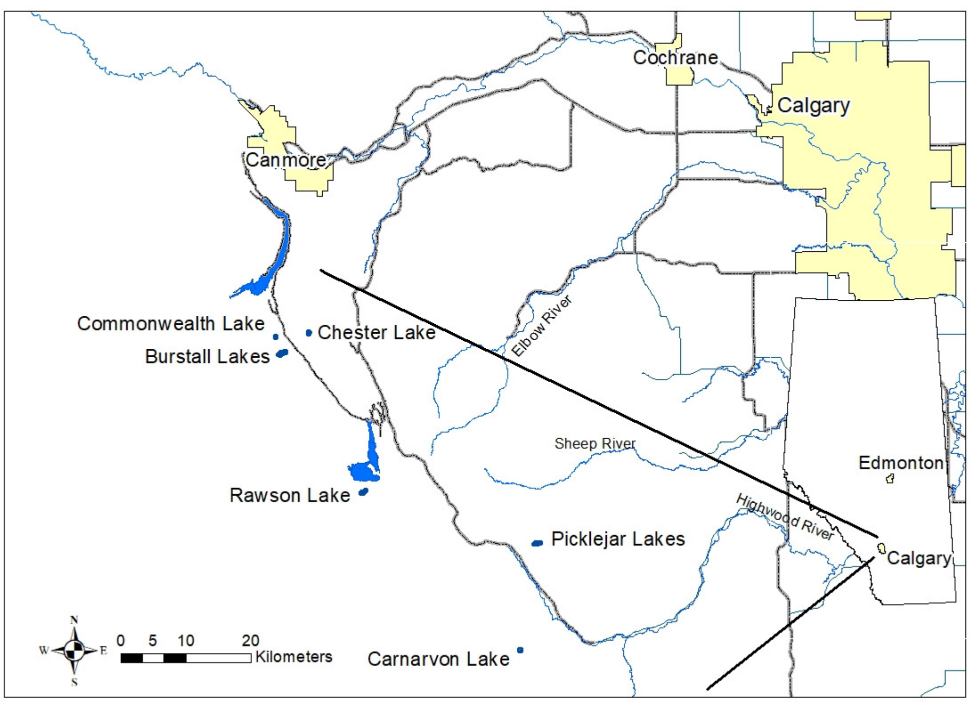

Figure 1. *High mountain angler effort study lakes.*

Results and Discussion

Estimated total angler effort ranged from 1.7 to 1,387 hours at Commonwealth and Rawson lakes, respectively (Table 1). Standardized by lake area, angling hours/ha ranged from 0.1 to 320 at Commonwealth and Picklejar 4 lakes, respectively. Total angler counts in the camera field of view ranged from 2 to 942 anglers at Commonwealth and Rawson lakes, respectively.

Our estimates of angler effort suggest a wide range of angler use at the study lakes. Suspected high angler use at Picklejar Lakes is confirmed by the hours/ha estimate at Picklejar Lake one being the highest of all estimates (Table 1). Relatively high angler effort was also documented at Carnarvon, Chester and Picklejar 2 lakes.

Table 1. Fishing season, data collection period, surface area and estimated angler effort per collection period (hours and hours/ ha) at high mountain study lakes. Camera spatial coverage is the proportion of the lake's surface area within the camera's field of view.

Lake	Fishing Season[1]	Data collection period	Surface Area	Camera spatial coverage (%)	Total Angling Hours[2]	Angling Hours/ha
Carnarvon	Open all year	Jul 20-Sep 13	6.4	17	802 (664-955)	124 (103-147)
Commonwealth	Open all year	Jul 15-Sep 15	1.8	86	1.7 (0-4.2)	0.09 (0-2.27)
Picklejar 4	Jul 1-Oct 31	Jul 5-Sep 13	1.5	78	457 (404-510)	320 (284-357)
Picklejar 3	Jul 1-Oct 31	Jul 5-Sep 13	1.1	53	3.6 (0-9.8)	3.35 (0-9.02)
Picklejar 2	Jul 1-Oct 31	Jul 5-Sep 13	3	98	228 (196-262)	77 (66-88)
Picklejar 1	Jul 1-Oct 31	Jul 5-Sep 13	2.1	74	6.8 (1.4-13.7)	3.26 (0.65-6.52)
Chester	Jul 1-Oct 31	Jul 14-Sep 19	5.1	44	573 (496-654)	113 (98-129)
Rawson	Jul 16-Oct 31	Jul 12-Sep 20	18.4	45	1,387 (1,259-1,519)	76 (66-83)
Burstall Upper	Open all year	Jul 19-Sep 15	9.3	52	36 (19-56)	4 (2-6)
Burstall Lower	Open all year	Jul 19-Sep 15	5	36	8 (0-18)	1 (0-2)

[1] As per the 2023 Alberts Guide to Sportfishing Regulations

[2] Estimated total angling hours from instantaneous counts (bootstrapped 95% confidence intervals) extrapolated to daylight hours, fishing days in the open season and field of view.

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Investigating the extent of hybridization between native bull trout and introduced brook trout in Alberta

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Investigating the extent of hybridization between two species can provide insight into the evolutionary processes occurring between sympatric species. While hybridization between native species can occur naturally, the movement of non-native species outside of their natural distributions can result in hybridization between species that would have been historically isolated and result in negative effects. For example, hybridization with non-native species results in loss of recruitment for native species, and potentially loss of genetic integrity in introgressed populations, the extent of which varies among hybrid crosses. Bull trout, *Salvelinus confluentus*, are a native species to Alberta watersheds and are currently designated as "Threatened" under the provincial *Wildlife Act* and federal *Species at Risk Act* for their Saskatchewan-Nelson distribution Bull trout populations are affected by the introduction of non-native brook trout, *Salvelinus fontinalis*, a species initially introduced into Alberta watersheds through stocking. As brook trout occupy similar ecological niches as bull trout, competition contributes to bull trout declines. In addition to the demographic effects of competition and hybridization with brook trout, it is unclear whether bull trout experience declines due to extensive introgression with brook trout resulting in loss of genetic integrity. Our research aims to quantify the extent of hybridization between bull trout and brook trout in various Alberta populations using single nucleotide polymorphisms. Our objectives are to investigate the proportion of backcrosses within our sampled populations, the proportion of hybrids found in populations where brook trout are highly persistent, and the distribution of hybrids found across the landscape of Alberta. Additionally, by understanding which populations have a high proportion of hybrids (especially backcrossed hybrids), we can determine which populations may be in imminent need of attention to ensure the persistence of bull trout in Alberta.

Returning rotenone to the restoration tool box in Banff National Park, Canada. Reflections on public engagement and communication tools to address public interest in a National Park context

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Rotenone has not been commonly used in the province of Alberta or the Canadian mountain national parks in recent decades. In 2018, Banff National Park completed the first of a series of eight planned rotenone applications to restore threatened westslope cutthroat trout (*Oncorhynchus lewisi*) after over 40 years of non-use. We were not sure what to expect in terms of public concern or interest. We have now completed seven of the eight applications and can reflect on our progress. We will outline some of the public communication activities completed before, during and after our rotenone treatments that we believe contributed to low public concern. Some activities such as typical interested stakeholder meetings and conventional media including radio, television and newspaper were utilized but we have also used some less common methods including active interpretive stations during application, use of drone footage to create video suitable for social media content, satellite linked stream side school events and guided interpretive hikes focused on species at risk and our restoration process.

Westslope cutthroat trout population monitoring in the upper Oldman watershed

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In 2018, the Livingstone-Porcupine Hills Land Footprint Plan was introduced to reduce cumulative impacts on the landscape to allow existing land disturbance to recover. The resulting Public Land Use Zone encompassed the largest remaining westslope cutthroat trout (*Oncorhynchus lewisi;* WSCT) core area in Alberta. Starting in 2018, the Alberta Conservation Association (ACA) began a multi-year WSCT monitoring study to determine potential population responses to these land-use changes. The study was designed to collect time-series data to explore interannual variations of WSCT populations. From 2018 to 2022, ACA collected WSCT relative abundance data using backpack and tote barge electrofishing methodologies in four high priority watersheds in the upper Oldman (UOM) River watershed. WSCT was the most abundant species comprising the majority of the catch and was captured at all sites during the study. Overall, of the four watersheds surveyed, relative abundance of all WSCT was highest in the Livingstone River and UOM River watersheds and lowest in the Hidden Creek and Dutch Creek watersheds. Westslope cutthroat trout abundance and distribution varied slightly in each watershed from year to year because of the high seasonal variability during the study period. Average WSCT size was largest in lower reaches of the UOM and Livingstone rivers and smaller in the lower order streams. Results from this study are the first WSCT population time-series data in Alberta that can be used as a baseline to examine ongoing effects of land-use in the UOM River watershed.

Restoring hydro-regulated waters to support native trout species at risk recovery in Banff National Park

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Dams pose a significant threat to freshwater species and regulated rivers are some of the most degraded ecosystems globally. Banff National Park is no exception. For example, hydro-electric dam infrastructure and operations on the Cascade and Spray rivers have reduced habitat quality and native fish species at risk have been displaced. Parks Canada aims to restore the ecological integrity of these hydro-regulated rivers. Significant progress has been made on the Cascade system, including: removal of invasive brook trout (*Salvelinus fontinalis*); increased infrastructure capacity to safely accommodate increased flows; physical habitat restoration; and re-established downstream connectivity with the Lower Cascade and Bow rivers. Ongoing work includes: riparian restoration; holistic environmental flow assessment; native trout reintroduction and development of a long-term monitoring program to facilitate adaptive management. Also, Cascade Creek's frontcountry location provides uniquely accessible opportunities for public engagement in the science and practice of freshwater ecosystem restoration and species at risk recovery. This includes a volunteer program for riparian restoration, interactive interpretive programs and live virtual learning presentations. This work has been possible through collaboration with the dam operator, federal and provincial partner agencies and subject matter experts in both engineering and ecological sciences. Lessons learned and capacity built through restoration of the Cascade system will be applied to future restoration of the Spray River system. The long-term goal is sustainable, climate-smart flow regimes to provide suitable habitat for native fish species at risk within their former ranges into the future.

Climate change risks and big data opportunities for native trout conservation and management

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Anthropogenic climate change already has demonstrable effects on stream ecosystems, is likely to continue for the remainder of this century and poses a variety of challenges to the viability and persistence of many native trout populations. To invest limited conservation resources most effectively, managers and conservation planners need broadscale, spatially precise information about the current status and future trends of key hydroclimatic conditions and species attributes, as these factors continue to evolve. Here, I discuss generalizable approaches to developing accurate, regional stream temperature scenarios (NorWeST), species distribution models for bull trout (*Salvelinus confluentus*) and cutthroat trout (*Oncorhynchus* spp.), and the subsequent application of these models to assess the risks of hybridization (cutthroat trout/rainbow trout hybridization) and predict the locations of long-term climate refugia where local populations are most likely to persist (Climate Shield). Steps required to implement the approaches consists of: 1) collecting and/or aggregating georeferenced temperature and biological survey information to develop central databases, 2) linking the survey information to environmental covariates that are represented as geospatial data layers and can serve as predictor variables, 3) developing probabilistic models that predict temperature or biological attributes from the covariates, and 4) using the models to create prediction maps throughout a species' range or area of interest under current and future scenarios. The prediction maps are useful for refining monitoring strategies to track existing populations or cite additional temperature sensors, designing efficient biological surveys to inventory habitats and document population status in areas of uncertainty, evaluating and executing assisted migration or recolonization efforts, determining where to suppress invasive species, and coordinating protections among stakeholders in watersheds that are most likely to serve as climate refugia. These approaches also create a foundation that can be readily extended to address the conservation and management of other sensitive species of fish, macroinvertebrates, mussels, and amphibians as long as sufficient biological survey data exist. Where these surveys are currently lacking, the rapid adoption of eDNA sampling and the development of taxonomically diverse databases (Aquatic eDNAtlas) could meet this need later this decade.

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Pilot application of a flexible cumulative effects modelling tool for managing threatened species: plains sucker case study

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Multiple ecological and anthropogenic stressors like climate change, severe weather events, and water management simultaneously impact species at risk. Yet, there are few cumulative effects modelling tools that are accessible to a wide range of users and have the flexibility to follow an iterative adaptive management framework while allowing application across a range of data-limited to data-rich scenarios. We are working on a new cumulative effects modelling tool that will help managers identify the relative threat of multiple stressors on species at risk. Specifically, we applied the model on Plains Sucker (*Pantosteus jordani*; previously listed under the S*pecies At Risk Act* as Mountain Sucker, *Catostomus platyrhynchus*). Plains Sucker is a data-limited species with a distribution across the Canadian Saskatchewan-Nelson and Milk River biogeographic zones, where declines in water quality and quantity from climate change and water-use management pose potential threats to the species. Our work acts as a guide for using cumulative effect models to prioritize management efforts for data-limited species.

Can smartphones kill trout? Mortality of memorable-sized bull trout (*Salvelinus confluentus*) after photo-releases

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Mortality associated with catch-and-release (C&R) fisheries is typically estimated as a single value associated with fish that are immediately released after capture. However, with the widespread use of smartphones by anglers, memorable or rare fish may be subjected to prolonged handling time for photographs and measurements, resulting in increased air exposure and subsequent increased potential for post-release mortality. In situations of overfishing, large fish become rarer and their memorable status may increase. This may create a depensatory cycle of additional handling and mortality. The combination of mortality from prolonged handling, immediate release, and illegal harvest is a cumulative C&R-related cryptic mortality that may have population-level effects in high-effort sport fisheries. We investigated the potential post-release mortality of memorable-sized (average length of 60 cm) bull trout (*Salvelinus confluentus*) after simulating prolonged handling (involving photographing and measuring) and immediate release in a controlled angling study at a remote Albertan lake during summer. We found that handling time and air exposure of large bull trout subjected to photography and measurement was long (112 s) and associated post-release mortality was high (10 dead / 30 fish; 33% after 24 h observation). Immediate release mortality was also high (3 dead / 20 fish; 15%). These levels of mortality, combined with high angler effort, can potentially lead to population-scale declines at C&R fisheries. The complexity and difficulty of population-scale and field-level measurements of cryptic mortality suggest that adaptive management experiments in reductions in angling effort and improved fish handling may be effective in increasing understanding of sustainable angling.

Associated Publication

Joubert, B.A., Sullivan, M.G., Kissinger, B.C. and Meinke, A.T., 2020. Can smartphones kill Trout? Mortality of memorable-sized Bull Trout (*Salvelinus confluentus*) after photo-releases. Fisheries Research. 223. https://doi.org/10.1016/j.fishres.2019.105458.

But I would walk 500 miles – 15 years of bull trout redd surveys on Fall Creek

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The Ram River watershed, in particular Fall Creek, provides spawning habitat for bull trout (*Salvelinus confluentus*) from the Ram, North Saskatchewan and Clearwater rivers. Because of this importance, the lower 7.5 km of the creek was closed to angling and classified as a Class A waterbody within the provincial *Water Act*, limiting industrial development. Recently, extensive decommissioning and reclamation of the Fall Creek OHV trail was completed including removing over 50 stream crossings, further reducing the anthropogenic threats within the watershed. Our repeated attempts to estimate adult bull trout abundance by electrofishing in the Ram River were unsuccessful. Highly variable water conditions and the migratory nature of the fluvial population result in a narrow window when sampling conditions are suitable using electrofishing gear. In some years suitable conditions never occur. However, we have been recording bull trout redds in Fall Creek since 2007. Fall Creek is well suited for redd surveys because of its low, clear flows in the fall and the relatively short distance of available spawning habitat. Despite the advantages of redd surveys, several sources of error can make any conclusions relating redd numbers to bull trout abundance difficult. To assess these sources of error, from 2019, we conducted multiple independent surveys with different survey crews to estimate interobserver error; we also installed an underwater video system to estimate bull trout escapement. Based on our preliminary results, we believe the Fall Creek bull trout redd survey is a practical and cost-effective means of assessing the adult bull trout population after multiple management actions.

Westslope cutthroat trout from Daisy Creek, Alberta (credit: Kelly Riehl).

Assessing the effects of changes to brook trout *Salvelinus fontinalis* stocking practices in Alberta

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Abstract

Fish stocking continues to be a key tool in fisheries management throughout the world providing numerous fishing opportunities but has resulted in the introduction of non-native fish species to many locations. Learnings from past stocking events of non-native fish has taught us much about the unforeseen consequences to native species. Here, we review the history of non-native brook trout stocking events and its potential impacts to native bull trout recovery within Alberta, Canada. Assessment of Alberta's Fisheries and Wildlife Management Information System indicates that between 1933 to 2019 brook trout have been stocked in 303 waterbodies, representing a total of 2,034 stocking events of 18,448,412 brook trout in both rivers and lakes. Initially, brook trout were stocked in high numbers throughout bull trout watersheds but following the 1994 Bull Trout Management and Recovery Plan, stocking of brook trout in bull trout watersheds was restricted to a select subset of lakes. Alberta has also taken precautionary actions since 2011 by stocking only triploid brook trout, rather than reproductive viable diploids. While stocking practices have adapted in the 25 years since the Bull Trout Management and Recovery Plan, brook trout populations continue to persist. Since 1995, 10,912 observations of naturally produced brook trout (20 - 70 mm) have occurred at 296 waterbodies suggesting establishment of self-sustaining populations throughout the province predominantly within the Eastern Slopes region. Future research is needed to model temporal and spatial trends in brook trout occupancy to test if presence is increasing and whether trends vary provincially.

Introduction

The introduction and spread of species by humans, whether intentional (i.e., through stocking) or unintentional, is observed worldwide (Britton et al. 2010). Though biological invasions can occur naturally as a result of climatic, geotectonic and other events (Lodge 1993), the scale of movement (i.e., distance) and frequency of occurrence today surpasses what is observed naturally (Britton et al. 2010). While species introductions have become common on the landscape, their impact and ability to establish naturalized populations is highly variable (Langor et al. 2014).

Within Alberta, there is a long history of non-native species introductions through stocking and translocations dating back to the early 1900s for recreational purposes (Meredith and Radford 2008). Many of these introductions have focused on non-native salmonids which have caused problems with close relatives native to Alberta (e.g., hybridization and competition with native cutthroat trout, *Oncorhynchus lewisi,* Allen et al. 2016). However, since the initial establishment of the hatchery system in Alberta, the narrative of what makes a stocked fishery 'successful' has changed as reductions and loss of native species have become common. Many lessons have been learned creating a shift in fisheries management from villainizing and eradicating native species, to protecting and attempting to restore them (Halverson 2011).

Within Alberta, bull trout (S*alvelinus confluentus*) are federally considered Threatened in its Nelson-Saskatchewan River populations, and Special Concern for Western Arctic populations under the *Species at Risk Act*. Impacts to bull trout populations are the result of multiple factors termed cumulative effects (DFO 2019). While effects to bull trout populations differ in severity by location, competition and hybridization with non-native species is deemed a high threat when brook trout are present (Berry 1994). Work on the interactions between bull trout and brook trout suggests that brook trout can outcompete and displace bull trout, often occurring in lower elevation streams (Post and Paul 2001). Additionally, hybridization between brook trout and bull trout has been documented in some locations where these species exist in sympatry, but the larger extent is not well understood (Popowich et al. 2011).

Due to rapidly declining bull trout populations in Alberta, a task team and recovery plan were created and implemented in 1994 by the Fisheries Management Branch (Berry 1994). The main outcomes of the *Bull Trout Management and Recovery Plan* were the recommendation to establish a zero-harvest limit on bull trout, and an emphasis towards research and inventory projects to better describe bull trout status, ecology, and impact from anthropogenic activities (Berry 1994).

Though not explicitly stated in Berry (1994), some changes to brook trout stocking have also occurred, specifically to the locations selected and the use of triploid fish. While some changes have been made and progress has occurred identifying stressors to better understand bull trout ecology, populations continue to decline along the Eastern Slopes (COSEWIC 2012). Despite these declines in native fisheries there is ongoing public support to maintain stocked non-native fisheries (including brook trout) for recreation. For these reasons a deeper understanding of brook trout status will aid in understanding potential impact to bull trout and options for future recovery actions. To better understand brook trout status in Alberta we sought to:

1. Describe changes in brook trout stocking in Alberta;
2. Describe changes in brook trout and hybrid presence in Alberta; and,
3. Identify locations where brook trout have established naturalized populations in Alberta.

Methods

Data was obtained from the Fisheries and Wildlife Management Information System (FWMIS) in September 2019 (AEP 2019). We reference the date of 1995 in many of our summaries as this year represents shifts in management following the completion of *Alberta's Bull Trout Management and Recovery Plan* (Berry 1994). Lastly, for the purposes of this assessment we do not include data from within National Parks.

Changes in brook trout stocking practices

Changes in brook trout stocking practices were assessed using stocking records (Figure 1, AEP 2019). These data only account for records within FWMIS and do not account for private or illegal stocking events. We also subset the data to account for stocking events within bull trout's historic distribution. Stocking of diploid and triploid brook trout were assessed for stocking records from the subset of data within eight-digit hydrological unit codes (HUC8s) with bull trout present. Lotic and lentic brook trout stocking rates within bull trout HUC8 watersheds were assessed using classification from FWMIS hydro arcs and polygons (AEP 2019).

Establishment of brook trout

The establishment of natural reproduction in brook trout was determined by the presence of brook trout between 20-70 mm fork length (FL). The size range of 20-70 mm was selected as few stocking events of fish <70 mm exist (Figure 2) thus brook trout <70 mm likely represent natural recruitment. The lower limit of 20 mm was established to minimize misidentification of small salmonids. Survey data from brook trout captured between 1995 to 2019 was used as all brook trout stocking effort was restricted to lakes within bull trout watersheds, thus, we assume any fish captured in lotic environments between 20- and 70-mm FL would represent natural reproduction and not be a product of stocking.

Hybrid distribution

Hybrid distributions were described using observation records from FWMIS (AEP 2019). Based on personal communications with Fisheries Biologists from these regions and review of published work, the majority of hybrid classifications were made using external characteristics (primarily, dorsal fin colouration, Popowich et al. 2011).

Results

Brook trout have been stocked throughout much of Alberta, with historic (pre-1995) stocking events primarily focused along the Eastern Slopes, and the most northern stocking event being 58.46° N, 110.84° W (Figure 1A). Between 1933 and 2019, 303 waterbodies have been stocked with brook trout in Alberta, cumulatively making up 2034 stocking events of 18,448,412 brook trout (Figure 1A and Figure 3A). Historic brook trout stocking in bull trout watersheds has occurred in most (n = 50 of 74, 68%) bull trout HUC8 watersheds, with higher intensity (number of events and number of fish) occurring in the southern regions of the province (Figure 1). A notable decline in the proportion of brook trout stocking locations in bull trout HUC8 watersheds has occurred since 1995, reducing to eight or 30% of the watersheds (Figures 1B, 1C, 3A and 3B). Stocking of brook trout in rivers within bull trout watersheds has also ceased since 1995 (Figures 3C, 3D); in addition, as of 2011 only triploid brook trout have been stocked in Alberta (Figure 4).

Though reduced stocking intensity and genetic manipulations have reduced propagule pressure in Alberta, brook trout still exist outside of stocking locations and have established self-reproducing populations (Figure 5). Between 1995 and 2019, 10,912 observations of brook trout between 20 and 70 mm have occurred at 296 waterbodies (Figure 5b). In addition, a total of 182 hybrids have been documented within Alberta at 33 different waterbodies representing a presence in the Peace, Athabasca and Saskatchewan-Nelson drainage basins in the Eastern Slopes (Figure 1A).

Discussion

In combination, the reduction of brook trout stocking within bull trout watersheds to eight lakes and no rivers signifies a major shift in stocking practices by year. Additionally, the complete shift by 2011 to only stock triploid brook trout further reduces the risk of potential escapement and establishment of brook trout populations in bull trout waters. While management actions have been taken, the observation of over 10,000 brook trout between 20 - 70 mm FL in hundreds of waterbodies after 1995 suggest past stocking efforts have established naturalized populations throughout Alberta's East Slopes. The establishment of brook trout populations has also led to hybridization with bull trout, which has been documented in 33 different waterbodies across the province. The persistence of brook trout within bull trout waters, along with the observation of hybrids creates a suite of problems which complicate bull trout recovery efforts.

Next steps

Though the data presented here suggest that brook trout populations may be increasing based on a higher number of brook trout observations after 1994, the sampling effort along bull trout's distribution has not been even throughout time and space (Bell et al. 2021). General trends in the FWMIS data suggest that more sampling effort per year in a broader range of locations has happened since 1995. To more accurately assess change in brook trout occupancy over time and space, use of dynamic occupancy models similar to Bell et al. (2021) need to be employed. Future work should also include landscape parameters to improve the predictability of these models and focus management actions to areas of highest concern or highest probability of success.

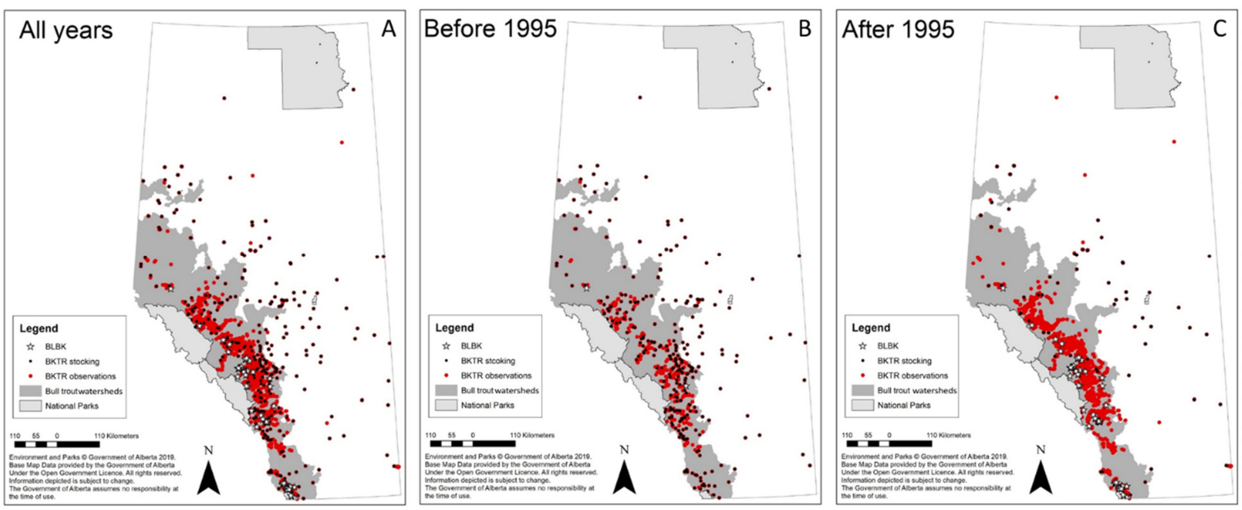

Figure 1. *Brook trout (BKTR) stocking records (black circles) and survey observation data for BKTR (red circles) and bull trout x brook trout hybrid (BLBK, stars). A) all years, B) observations before 1995, C) after 1995.*

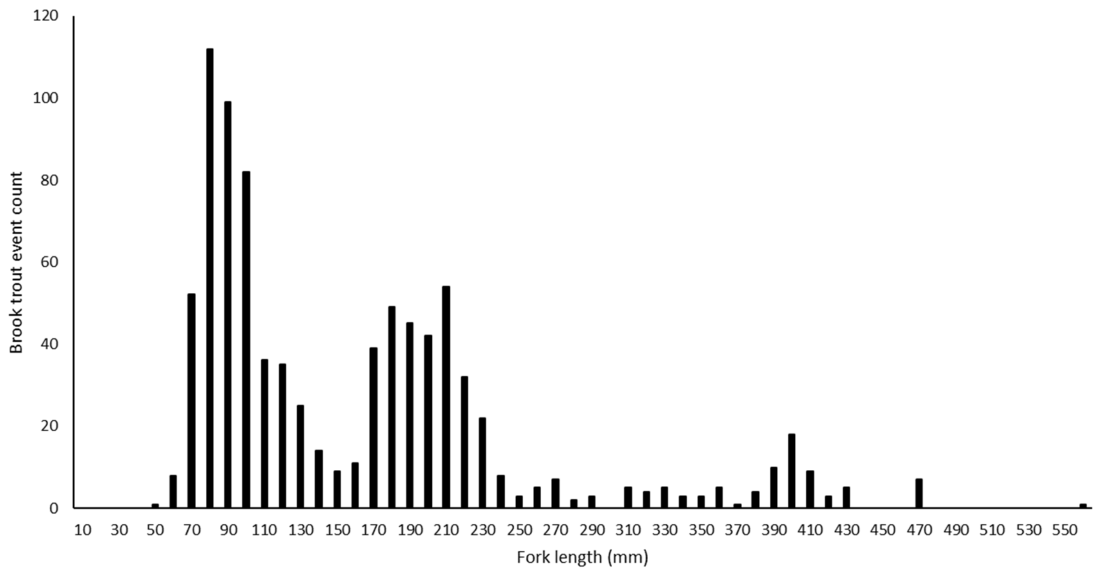

Figure 2. *Fork length distribution (mm) of all hatchery stocked brook trout in Alberta from 1995 to 2019. Each count represents an average fork length reported for each stocking event*

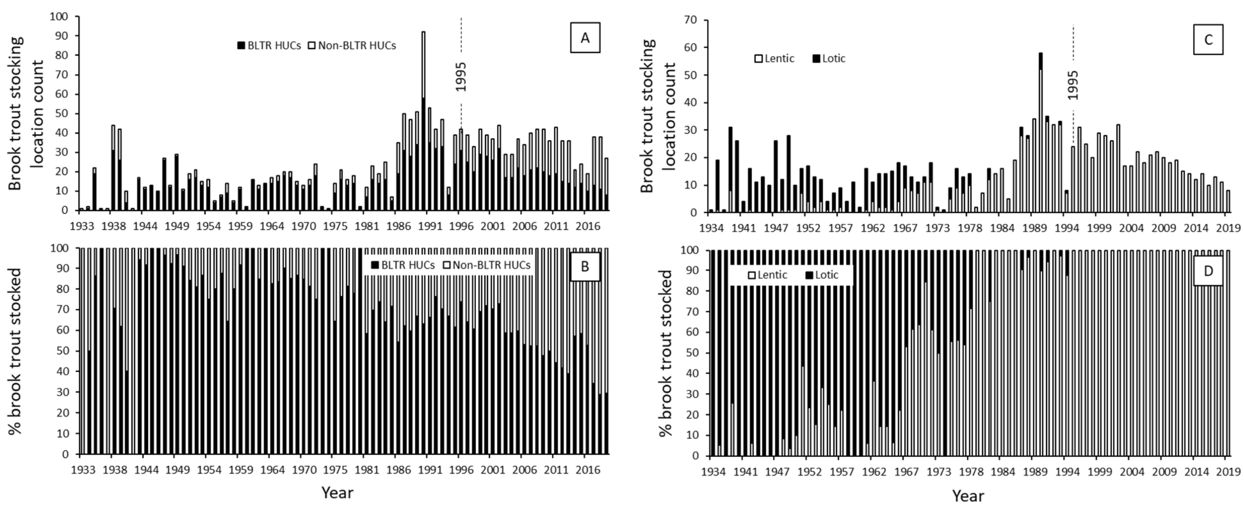

Figure 3. *Trends in brook trout stocking events within Alberta 1933 to 2019, A) as number of locations stocked, B) percent of stocking events in HUC8 watersheds with bull trout, C) as total counts of lentic and lotic stocking within bull trout HUC8 watersheds, and D) percentages of lentic and lotic stocking within bull trout HUC8 watersheds.*

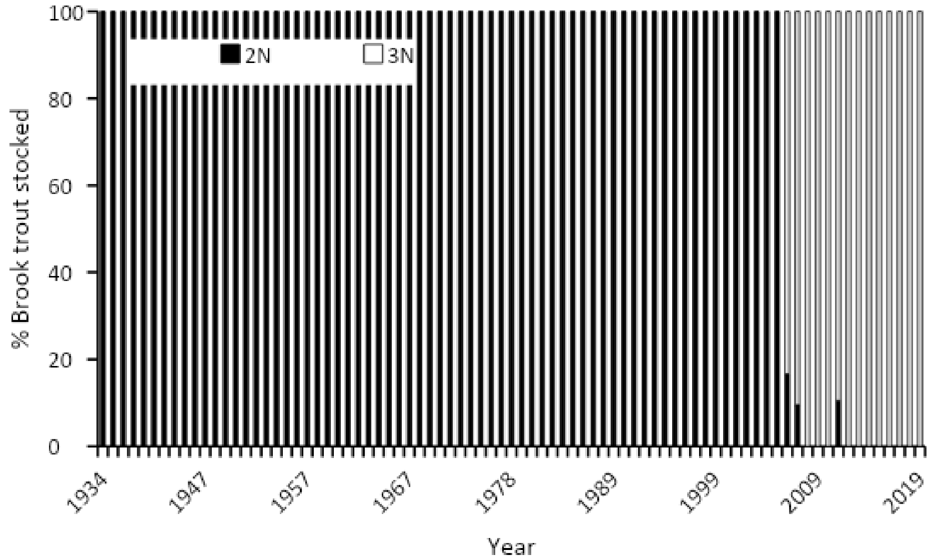

__Figure 4.__ Changes in the percent of stocking locations receiving diploid (2N) or triploid (3N) brook trout, 1934 to 2019 for all of Alberta.

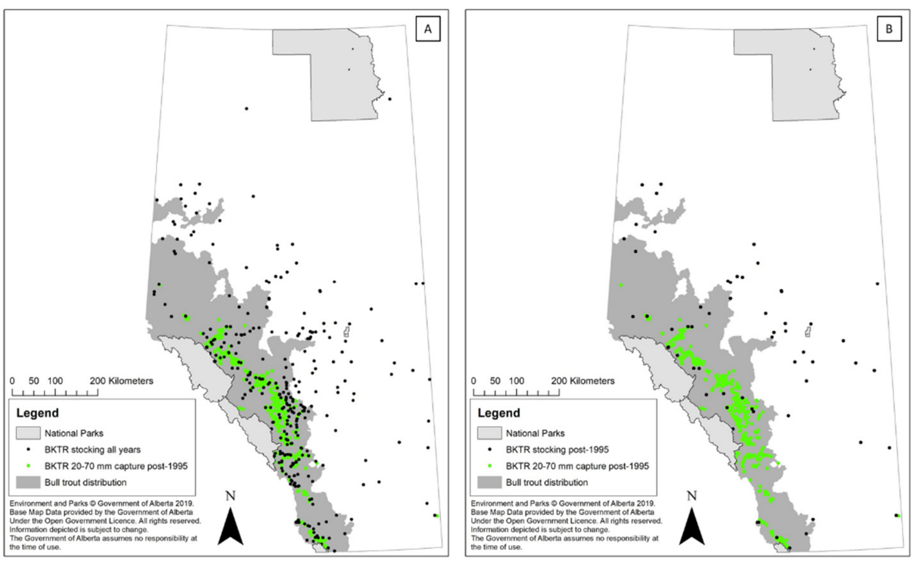

__Figure 5.__ Observations of brook trout between 20 - 70 mm FL captured after 1995 and overlaid on the provincial bull trout distribution for A) all brook trout (BKTR) stocking events from 1933 to 2019 and B) post-1995 stocking events only.

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Bull trout in the Castle River, Alberta (credit: Kelly Riehl).

How four decades of genetic data inform native trout conservation in Montana

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A perfect storm of events in the 1970s and 1980s resulted in Montana adopting a strong fish conservation mission, that in turn, relied heavily on conservation genetic theory and genetic data to inform policy and management action. This explicitly science-driven approach to conservation was enabled and catalyzed by a strong collaborative relationship between Montana, Fish, Wildlife and Parks and the University of Montana that continues to this day. As a result, Montana Fish, Wildlife, and Parks have been using genetics as a critical part of the conservation decision-making process for a growing list of species. This talk will focus on how genetic data have helped inform native trout conservation efforts throughout the state, focusing largely on westslope cutthroat trout (*Oncorhynchus lewisi)*, but with examples from other salmonid species. Broadly speaking, genetic data have been fundamental in helping us understand (1) what we have left, (2) what we need to do to protect them, and (3) what we need to do to increase and restore our native trout species over coming decades. This in turn means that we are increasingly shifting from focusing (largely) on describing hybridization between our native and non-native species, to focusing more holistically on conserving and restoring the evolutionary legacy (genetic variation) of our native trout. By tracing that history and the key developments that led to major changes in our management practices, I hope to provide a road-map or case-study describing how Alberta may be able to use the incredible amount of native trout genetic data that have been produced in recent years.

Bull trout in Lower Kananaskis Lake, Alberta (credit: Kelly Riehl).

Idaho’s experience with catch and release angling on trout

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In Idaho, catch-and-release regulations have been implemented for a wide variety of native and non-native resident trout populations and associated fisheries. Creel survey and population demographic information suggested many northern and central Idaho westslope cutthroat trout (*Onchorhynchus lewisi*) populations were over-exploited by the 1960s. Increasingly restrictive harvest regulations for these fisheries led to marked increases in abundance and size structure in relatively few years. Now, most of these WCT fisheries are managed with mandatory catch-and-release regulations. Stable population status, high fishing effort, as well as good length and age structure indicate this regulation strategy is appropriate for this species in these relative infertile and unproductive drainages. Prominent trout fisheries in more productive southern Idaho possess similarities and differences. Here, angler interest in more protective regulations began gaining momentum much later, in the early-1970s. Population studies provided some evidence of over-fishing, but high growth rates and high natural mortality rates indicated that total catch-and-release regulations were unlikely to produce the same population responses. Nonetheless, social pressure led to adoption of mandatory catch-and-release regulations in several prominent fisheries resulting in instances of substantial conflict between harvest-oriented and non-consumptive anglers. The implementation of total catch-and-release in some of these fisheries was unnecessary from a population perspective, resulted in lost yield, displaced certain harvest-oriented users, and created animosity between user groups. The department urges caution in implementing regulations that do not produce substantial population benefit or lead to the displacement of harvest-, gear-, or bait-oriented anglers because of negative consequences and due to the difficulty in rescinding or altering these regulations once engrained. More recently, catch-and-release anglers have expressed increasing concern with fish handling practices including exposing landed fish to air (i.e., air exposure or time out-of-water) and regulating fishing during elevated water temperatures (i.e., hoot owl). Department staff have conducted extensive study of air exposure in several prominent salmonid fisheries utilizing reasonable fight time and air exposure scenarios. Negative effects to survival and reproductive success are minimal or non-existent in all species and fisheries studied. Similarly, department staff have investigated mortality of stream trout during periods of elevated water temperature. Mortality of individuals increased at higher temperatures, but catch rates declined substantially, indicating that fishing at elevated water temperatures is likely less impactful than fishing at more optimal temperatures. Examination of the effects of air exposure has been very thorough and conclusive; however, we recommend further study of mortality of trout when angled at elevated water temperatures. In summary, staff recommend avoidance of unnecessarily restrictive catch-and-release or fish handling regulations or season structures if they are based on public sentiment or individual fish mortality rates unless the combination of associated metrics (e.g., frequency of encounter, percentage of population, etc.) indicate that population-level declines in abundance or size structure are likely.

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An experimental test of the potential for bull trout conservation translocations, via instream incubation capsules, in Alberta

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There is growing interest in conservation translocations to supplement or restore bull trout (*Salvelinus confluentus*) populations in environments where they were once known to be successful and self-sustaining. We will test the feasibility of translocation of fertilized eggs via instream incubation capsules in Smith-Dorrien Creek (Kananaskis, Alberta), which provides ideal habitat for bull trout rearing. This site was chosen because it is known for having an abundance of redd sites. Our research objectives are to: 1) assess potential for instream incubation capsules for bull trout conservation translocations, and 2) quantify spatial variation in habitat parameters among sites where incubation capsules will be deployed. In spring and summer 2023, we will install temperature loggers to aid in site selection and test associations between temperature and egg survival. Instream incubation capsules will be installed during fall 2023 and removed (along with temperature loggers) after ice-off in 2024. This will be coordinated with the capture of female and male bull trout from Smith-Dorrien Creek through electrofishing. Their gametes will be stripped, and fertilized eggs will be placed into the incubation capsules. Along with the incubation capsules, we will conduct a lab experiment to examine how variability in thermal regimes during incubation influences development and survival. If incubation capsules are deemed a successful method for translocation and reintroduction, research could be expanded to introductions in novel environments. Similarly, if successful rearing is limited to select locations and/or depths, it will provide insight for future site selection and capsule depths to successfully rear bull trout in Alberta.

Development of a westslope cutthroat trout composite brood stock population in Alberta

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Westslope cutthroat trout (*Oncorhynchus lewisi*; WSCT) populations have been significantly reduced in size and extent across most of their historic range in Alberta. Recovery actions address threats of habitat loss and degradation, mortality due to accidental angling mortality and harvest, as well as the threat of hybridization.

Large scale recovery actions will require a brood stock of genetically diverse, pure WSCT within the hatchery system, as simple translocations of adults or gametes from neighbouring watersheds will not be able to support the anticipated need. Since 2021, Alberta Environment and Protected Areas has been developing a WSCT composite brood stock within the provincial fish hatchery system. The choice of source populations was based on existing information of genetically pure populations and an analysis of family relatedness. WSCT gametes were collected in the spring of 2021 and 2022 in tributaries of the Oldman Watershed, and eggs and milt were crossed as 2x2 crosses to maximize genetic diversity. All donor individuals were tested for disease as well as genetic purity before the hatched fry were added to the main hatchery facilities.

The development of the WSCT recovery brood stock remains an ongoing process, with continued additions of genetic material to preserve genetic diversity and suitability for diverse recovery projects across the Alberta East Slopes.

Web-based stream temperature modelling for Alberta's Eastern Slopes

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Cold water species are highly sensitive to stream temperature and are vulnerable to factors that can disrupt thermal and hydrologic regimes, such as climate and land cover change. Cumulatively, angling pressure and environmental change pose substantial threats to cold water salmonids in Alberta. Understanding how thermal regimes vary across the landscape and in response to environmental change is critically important for preserving and potentially recovering native salmonids along the Eastern Slopes. We have developed a web-based stream temperature model and data management portal for the Eastern Slopes of Alberta to further understand thermal regimes at a large scale. This model is state-of-the-art, allowing users to interact with data and develop statistical models on the fly. Outputs from stream temperature simulations across native trout range can be used to inform Alberta's Native Trout Recovery Plan and cumulative effects assessments.

Restoration stocking for westslope cutthroat trout

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Remote streamside incubation (RSI) is a fish recovery stocking strategy allowing for the transfer of gametes into recovery habitats at the egg stage, assuring early on acclimatization of the offspring to the new environment. This method involves identifying spawning locations, capture of spawning fish, stripping gametes from that donor fish population, performing cross-fertilization to maximize genetic diversity, and then incubating eggs streamside to bolster existing populations or for range expansion. The RSI introduction method can be used for translocation by nearest neighbour or to introduce other stocks. Alberta Environment and Protected Areas has been trial implementing this tool to expand a population of native westslope cutthroat trout (*Oncorhynchus lewisi)* in the Crowsnest region of southern Alberta. Fertilized eggs were introduced into a barren section of stream above a natural fish barrier for range expansion purposes over three years with high success of swim up and release of alevins into the natural environment. Long-term success is still being evaluated.

Updating our understanding of aquatic health within the Traditional Land Use area of the Aseniwuche Winewak Nation near Grande Cache, Alberta

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Fisheries resources are important traditional foods for the Aseniwuche Winewak Nation (AWN), however, a recent survey of AWN community members showed that most respondents are concerned about chemicals in fish and water within their Traditional Land Use (TLU) area. Consumption advisories are in place within the middle Smoky River watershed, associated with historic dioxin & furan contamination in mountain whitefish (*Prosopium williamsoni*) muscle tissue from a pulp mill located on the Wapiti River. AWN community members have also expressed concern about other contaminants, such as mercury and selenium from industrial activities, including nearby coal mining operations. Different movement or habitat use patterns among sub-populations of fish can result in unique risks of contaminant exposure across the landscape, and currently little is known about fish movement in the TLU area. Given the gap in our knowledge of contaminant concentrations in fishes within this industrialized region of Alberta, our main goal is to conduct a regional aquatic assessment to improve AWN's understanding of aquatic health and traditional food safety by collecting tissue (muscle and/or eggs) from two commonly fished species, mountain whitefish and rainbow trout (*Oncorhynchus mykiss*) and comparing measured concentrations with human consumption and other relevant guideline values. Additionally, chemical tracers collected from surface water, benthic macroinvertebrates, mountain whitefish, rainbow trout, bull trout (*Salvelinus confluentus*) and Arctic grayling (*Thymallus arcticus*) will be assessed in an effort to infer broad scale movement and exposure patterns to potential contaminants of concern, and to investigate food web ecology in monitored streams.

Climate warming effects on a cold-water stenothermal fish occurring near a northern geographical range boundary

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Broad-scale studies examining effects of climate change on cold-water salmonids have focused mainly on taxa occurring in stream networks at their warmer, southern geographical range, and largely ignored northern populations. However, warming rates are faster in northern areas and distributional boundary extensions could occur to partially offset range contractions in warmer areas. Here, we use a spatially dense occurrence data set to examine how climatic and geomorphic factors influence the distribution of juvenile bull trout (*Salvelinus confluentus*) in the Prairie Creek watershed, Northwest Territories, Canada (61° N, 124° W). Downscaled climate projections from general circulation models were coupled with a species distribution model to forecast the effects of stream temperature warming on the distribution of suitable habitat for contemporary, 2040s, and 2080s periods, based on representative concentration pathway (RCP) 4.5 and RCP 8.5 emissions scenarios. Juvenile bull trout are sparse across this watershed and their patchy distribution is driven by a combination of cold-limiting habitat, the prevalence of perennial groundwater, and stream size. Juveniles occupy streams within a narrow summer thermal niche (4.7℃ – 7.5℃) that are thermally resilient enough to prevent freezing during the winter. Although the thermal properties of these streams will mediate effects of climate warming, suitable habitat, based on both climatic and geomorphic habitat associations, is projected to decline across all warming scenarios. Conversely, availability of thermally suitable habitat (i.e., does not consider other habitat factors) is projected to increase between now and the 2040s, and is consistent with broad-scale predictions of poleward expansion of distributional boundaries, via niche evolution as climate warms. The dichotomy in these projections illustrates the importance of considering other dimensions of the ecological niche when forecasting climate change vulnerability of northern stream fishes.

Habitat vulnerability assessment of bull trout populations across the Alberta East Slopes

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Many bull trout (*Salvelinus confluentus*) populations across the East Slopes of Alberta have declined and managers require information on habitat suitability and vulnerability to develop recovery strategies. Abundance and distributional data from 5-6 populations across this region will be used to model the climatic and geomorphic factors that influence population persistence. In instances where sample size is not sufficient for analyses, we will conduct targeted field sampling. This regional analysis will be nested within a broader analysis to assess vulnerability of critical habitat across latitudinal and perturbation gradients spanning the species' geographic range. We propose to assess two important climatic factors; summer stream temperature and thermal sensitivity, as both are important attributes of critical habitat known to influence population demographics at northern and southern range boundaries. Thermal sensitivity is a metric for quantifying the degree to which a stream is influenced by air temperature. Streams with low thermal sensitivity are resilient to the influence of air temperature, which provides fish with more stable thermal regimes throughout the year. Additionally, thermally resilient streams exhibit slow climate velocities and often represent high quality habitat that is less vulnerable to climate warming. Results of our analysis will be used to refine the classification of critical habitat, assess habitat vulnerability to multiple stressors, and prioritize areas for recovery planning.

Bull trout recovery through OHV trail remediation at Rocky Creek, Alberta

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Rocky Creek is a tributary to the Clearwater River in west-central Alberta that supports a bull trout population currently listed as Threatened under the *Species at Risk Act* (SARA) and the Alberta *Wildlife Act*. The major threats to bull trout (*Salvelinus confluentus)* in the Rocky Creek drainage are believed to be angling mortality and sedimentation from OHV trails. An undesignated OHV trail followed Rocky Creek for ~20 km and contained 31 unmaintained stream crossings that were contributing large amounts of sediment into Rocky Creek, diverting flow from the main channel, and providing motorized access to the majority of the stream length. This trail was reclaimed in 2017 and 2018 by a partnership of Alberta Environment and Protected Areas, Trout Unlimited Canada, Fisheries and Oceans Canada, Alberta Conservation Association and many volunteers. Motorized access to the reclaimed trail was restricted. Following reclamation of the trail and crossings, the bull trout population was monitored for 5 years (2018-2022) to determine the effect of the project on the population. Both immature and mature bull trout in Rocky Creek showed substantial increases in electrofishing catch rates compared to adjacent watersheds over the same time frame. The reclamation of the OHV trail appears to have resulted in an increase in the bull trout population through a reduction in sedimentation and/or a reduction in direct mortality.

Associated Publication

MacPherson, L.M., Reilly, J.R., Neufeld, K.R., Sullivan, M.G., Paul, A.J. and Johnston, F.D. 2023. Prioritizing bull trout recovery actions using a novel cumulative effects modelling framework. Fisheries Management and Ecology. http://doi.org/10.1111/fme.12649.

Updating the at-risk status for bull trout in Alberta

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Bull trout (*Salvelinus* confluentus) are listed as Threatened under both the Alberta *Wildlife Act* and Canada *Species at Risk Act*. An updated assessment is currently being carried out by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to establish current status since the previous national assessment was >10 years ago. Bull trout in Canada are subdivided into five designatable units, two of which are in Alberta: Saskatchewan-Nelson Rivers and Western Arctic. The former is listed as Threatened and the latter listed as Special Concern. Two key uncertainties related to the upcoming reassessment have been identified that could alter the appropriateness of the current at-risk listings. First, revised approaches to identifying designatable unit (DU) structure have been adopted in which evidence of discreteness and evolutionary evidence is required. It is not clear if such evidence is available to differentiate the two DUs purported to exist in Alberta. The second uncertainty involves which of the quantitative criteria are applicable to the Saskatchewan-Nelson Rivers DU, should it remain as a legitimate DU. The 2012 COSEWIC report projects a decline in the number of adult bull trout of >30% over 3 generations, leading to Threatened status. Whereas the Alberta report uses *pers. comm.* that the Index of Area of Occupancy is small, also leading to a Threatened status. There is uncertainty about whether either applies in 2023.

Task-based approach to prioritize bioremediation sites

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The Porcupine Hills Public Land Use Zone (PLUZ), including important habitat for westslope cutthroat trout (*Oncorhynchus lewisi)* in the Trout Creek watershed, is influenced by multiple anthropogenic activities and natural events including but not limited to off-highway vehicle (OHV) trails, cattle grazing, flooding and bank erosion. While restricted activity periods exist to protect fish populations in the Porcupine Hills PLUZ, Trout Unlimited Canada (TUC) requested bioremediation prioritization from AJM Environmental Inc. (AJM) to assist in a strategic reclamation of aquatic and riparian habitat. AJM's scope included: assessment of habitat condition in the Porcupine Hills PLUZ; identification of areas of habitat degradation; and prioritization of habitat reclamation opportunities. AJM implemented a task-based approach to prioritize bioremediation sites: desktop analysis and reclamation planning, drone flight reconnaissance and field site assessments. AJM first analyzed OHV trail data and Road Erosion and Delivery Index modelling, overlaid on a hydrology base layer, to identify clusters of potential features of concern. Strategic drone flight sequencing was then used to create orthomosaic imagery focused within select watershed reaches to examine as many 'hotspots' as possible. Features of concern validated by orthomosaic imagery then received a field site assessment from a Qualified Aquatic Environmental Specialist (QAES), including a final prioritization evaluation using a matrix-based evaluation tool and habitat reclamation prescriptions grounded by predefined Reclamation Suites. AJM's approach enabled efficient and effective diagnosis of anthropogenic influences at a watershed-scale, while resulting in prioritized individual site-level recommendations for reclamation of aquatic/riparian habitat supporting native trout populations.

General considerations for cumulative effects modelling and species at risk (SAR)

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The goal of science is to bring clarity to causation in natural resource management, and to aid decision-making by reducing uncertainty in expected outcomes. Most current investments in species at risk (SAR) recovery are unsuccessful because they target symptoms and fail to address the root causes of endangerment, often due to hidden political, social, or economic trade-offs that constrain acceptable management actions. Making these trade-offs and ultimate constraints transparent is essential for objective assessment of recovery options. Alternatively, recovery often fails because actions target only one of multiple factors that jointly limit abundance, highlighting the importance of correctly identifying multiple limiting factors when overlapping threats are at play (i.e., cumulative effects).

Effective SAR recovery requires: 1) a clear understanding of ultimate causation and the political/social/economic constraints to addressing them; 2) identification of population-specific limiting stressors and the activities that will effectively reduce their impact; and 3) a quantitative planning framework (i.e., modelling tool) that objectively synthesizes available data on population status, stressor levels, and the potential outcome of alternative recovery actions.

I will provide an overview of the key elements of a Cumulative Effects modelling framework for SAR recovery (the "Cumulative Effects Model for Prioritizing Recovery Action" or "Joe Model"), as well as a retrospective on cumulative threats limiting recovery of endangered Salish sucker (*Catostomus* sp. cf. *catostomus*) and Nooksack dace (*Rhinichthys cataractae* ssp.), which are endemic to the highly developed lower Fraser Valley of British Columbia.

Assessing the impacts of warming stream temperatures on Athabasca rainbow trout

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Athabasca rainbow trout (*Oncorhynchus mykiss) are* restricted to the Upper Athabasca watershed and are listed as Endangered under Schedule 1 of the *Species at Risk Act*. A major threat to the species is increasing summer stream temperatures resulting from climate warming. Knowledge gaps concerning physiological temperature tolerance and preference and habitat suitability need to be addressed to effectively manage and recover populations. In this study, fish collected from three streams with varying summer temperature trends in the upper McLeod River watershed were tested for Critical Thermal Maximum Temperature (CTmax) and preferred temperature (Tpref) using a portable streamside laboratory. Broader spatial and temporal sampling of the upper Athabasca River watershed was conducted to compare upstream-downstream density changes between Athabasca rainbow trout, brook trout, and important habitat features across periods of warming temperatures. These recorded occurrences of Athabasca rainbow trout will be combined with existing presence/absence data to model relationships with climatic and geomorphic covariates to predict habitat suitability across the watershed. This work is intended to support the prioritization of recovery locations within the Athabasca rainbow trout's distribution.

Dining hall at the Biogeosciences Institute, February 2023 (credit: Ashley Meek).

No evidence of recovery of native trout in response to sustained angling suppression of invasive brook trout

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Introduction

Many salmonid species were deliberately introduced outside their native range to enhance recreational fishing opportunities; these introductions have been implicated in declines in native aquatic biota. Alongside the introduction, establishment and range expansion of brook trout, *Salvelinus fontinalis*, in western North America, native trout populations (e.g., westslope cutthroat trout, *Oncorhynchus lewisi*, and bull trout, *Salvelinus confluentus)* saw reductions in abundance and range. In the mid-1940s, brook trout were introduced to Quirk Creek, a small creek in the east slopes of the Rocky Mountains in southwestern Alberta and its watershed. A targeted harvesting management program was conducted in response to high brook trout densities and low native trout densities. We used 25 years of electrofishing data from 1978 to 2020 to evaluate the effectiveness of the program to reduce the non-native brook trout population, and to evaluate recovery by native westslope cutthroat trout and bull trout. More complete analyses of this work are provided in Sinnatamby et al. (2023).

Methods

The brook trout suppression project in Quirk Creek ran from 1998 until 2015 with different treatments applied to the upper and lower reaches. It was primarily done using targeted harvest via angling, but limited electrofishing removals were added between 2004 and 2008 to enhance brook trout removal. The data were divided into four treatment periods for analysis and interpretation: early-invasion, pre-suppression, suppression, and post-suppression.

Data from the first pass of multi-pass depletion and mark-recapture surveys were combined with single-pass surveys and divided by sampling reach lengths to determine fish density by species. Statistical differences in mean densities and biomass were estimated among the four periods for all fish species combined, and each species for fish >150 mm, and recruits, using a log-linear mixed effects model, and expressed using Bayesian posterior beliefs. Statistical significance was set at ≥95% belief that density or biomass in a given period either increased or decreased relative to the pre-suppression period.

Species- and reach-specific population estimates were calculated for fish >150 mm to determine the proportion of that population subset removed through harvest (brook trout) or lost to release mortality (cutthroat trout, bull trout). The number of cutthroat trout or bull trout lost to release mortality was simulated across a range of potential release mortalities (0.01, 0.05, 0.1, 0.15) based on literature-derived values (e.g., Hühn and Arlinghaus 2011). We compared fishing mortality estimates to benchmarks based on harvest mortality as a ratio of natural mortality. A benchmark of 0.75 natural mortality was likely to indicate success for a suppression target, and high risk for exceeding sustainable harvest levels, whereas a benchmark of 0.25 represented limited success for suppression or a lower precautionary benchmark for sustainable harvest.

Results

Among fish >150 mm, brook trout held the highest densities in most years, peaking in the late 1990s to early 2000s with densities significantly lower during the early invasion, suppression and post-suppression periods (Figure 1). Cutthroat trout >150 mm typically had the second highest densities and were significantly higher during the suppression period but there was less support for higher densities subsequently during the post-suppression period. Bull trout >150 mm were typically an order of magnitude lower in density than the other species.

Early-invasion densities of brook trout recruits were significantly lower than pre-suppression densities (Figure 2), but brook trout recruit densities were not reduced during the suppression and post-suppression periods. In contrast, densities of cutthroat trout recruits during the suppression period significantly increased (Figure 2).

Brook trout harvest removals (proportion of those >150 mm) in the upper reach peaked in 1999 and declined sharply thereafter, whereas harvest in the lower reach was generally higher and remained high into the late 2000s (Figure 3). Brook trout harvest resulted in fishing to natural mortality ratios that were sufficient to elicit the observed declines, but in later years were likely insufficient to ensure suppression (Figure 3). Overall, estimated release mortalities for cutthroat trout were higher in the lower reach; whereas the potential loss of bull trout >150 mm remained low with the exception of a few years.

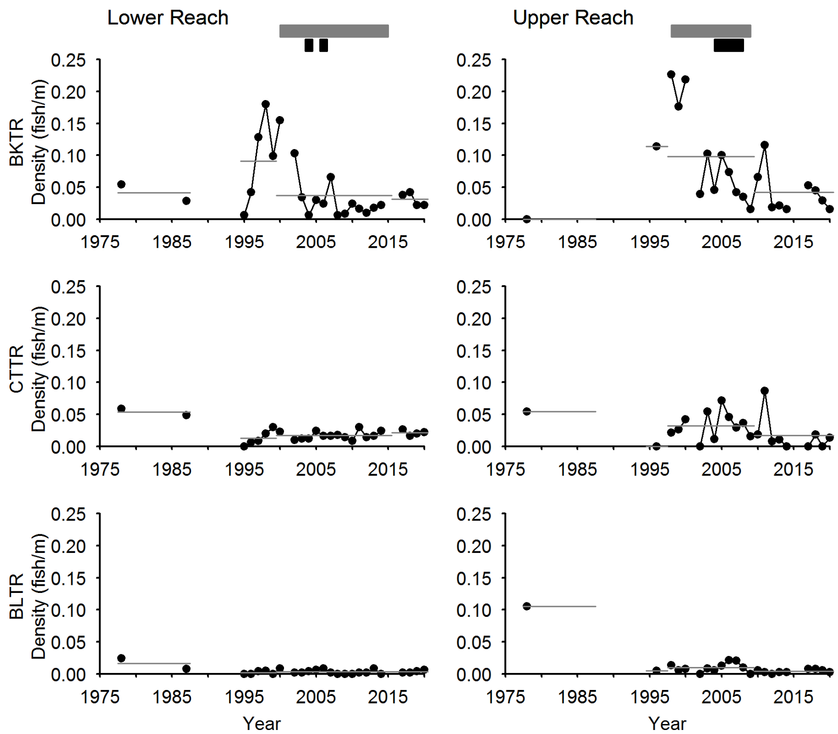

Figure 1. *Density of brook trout (BKTR), cutthroat trout (CTTR) and bull trout (BLTR) >150 mm by reach. The thick grey and black horizontal bars indicate the suppression project and electrofishing BKTR removals, respectively. Thin horizontal lines indicate the mean density calculated for each study period: early-invasion, pre-suppression, suppression and post-suppression. Figure was modified from Sinnatamby et al. (2023).*

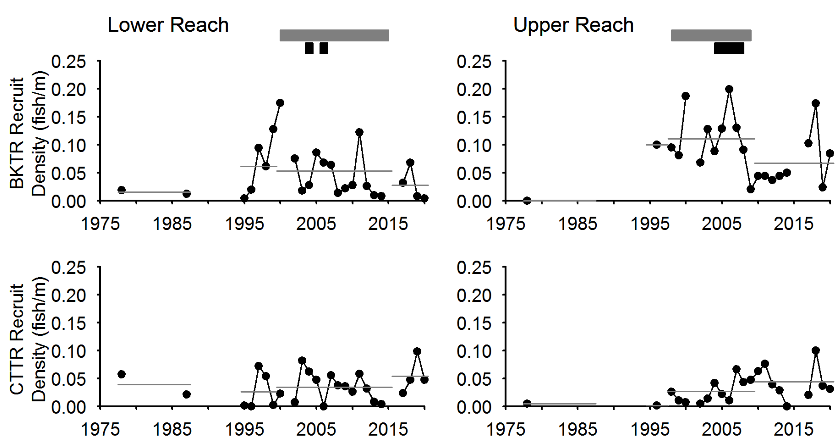

Figure 2*. Density (fish/m) of BKTR and CTTR estimated as age-1 fish. The thick grey and black horizontal bars indicate the duration of the suppression project and electrofishing BKTR removals, respectively. Thin horizontal lines indicate the mean density calculated for four study periods. Figure modified from Sinnatamby et al. (2023).*

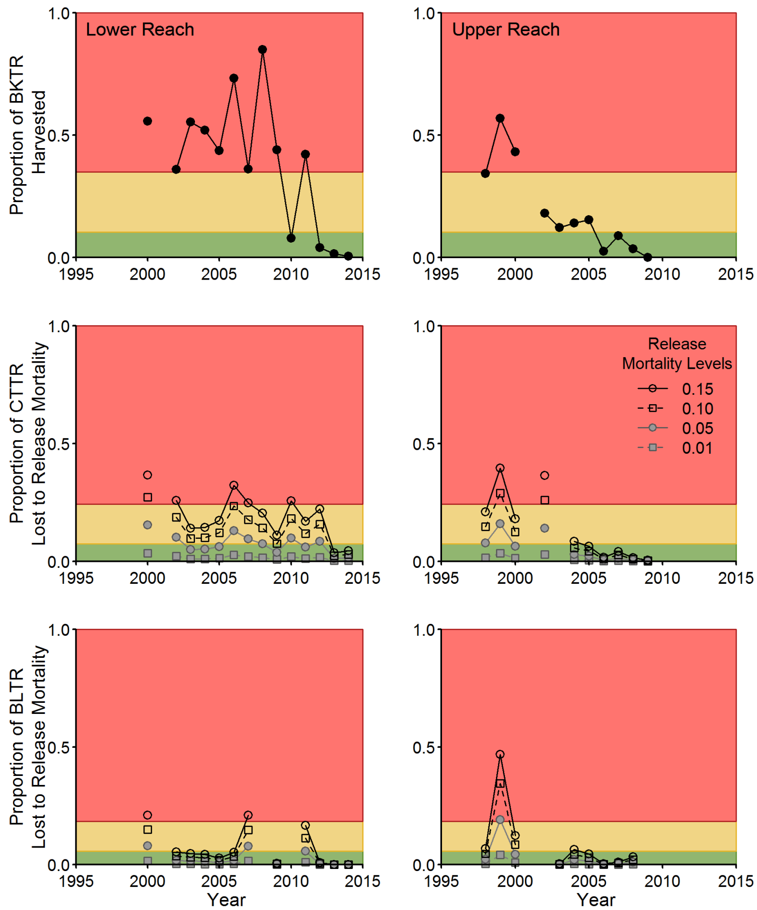

Figure 3. *Proportion of fish >150 mm harvested (brook trout) or potentially lost to release mortality (cutthroat trout, bull trout) during the suppression project and plotted on the backdrop of annual natural mortality rates (m). Green: 0-0.25*m where fishing mortality would likely allow recovery; yellow: 0.25-0.75*m, where some risk of suppression would exist; and red: ≥0.75*m where suppression is most likely to occur. Figure modified from Sinnatamby et al. (2023).*

Discussion

Abundances of brook trout >150 mm declined over the course of the suppression project, most likely as a result of selective harvest by anglers, but abundances of native trout >150 mm did not rebound as expected even after 12-16 years of brook trout suppression by angling. Statistical results suggested that reductions in brook trout >150 mm resulted in increased densities of cutthroat trout >150 mm and recruits while brook trout suppression was active. Despite continued increases in cutthroat trout recruits into the post-suppression period, densities of cutthroat trout >150 mm did not continue increasing and remained below provincial recovery targets of ≥0.09 adult cutthroat trout per m captured by backpack electrofishing. The lack of a meaningful recovery in both native trout species indicated that the suppression project was not effective in meeting its goal to promote native trout recovery. Given little evidence that native trout recovery was hindered by climate change during the study period (Sinnatamby et al. 2021), it is likely that native trout recovery was instead limited by an unknown combination of insufficient brook trout suppression levels or impacts of incidental release mortality while the suppression program was active.

Where brook trout suppression is insufficient, the bottleneck on juvenile native trout survival caused by biotic interactions with brook trout may persist (Peterson et al. 2008) and in Quirk Creek, brook trout still made up a considerable and often dominant proportion of the fish community despite their overall decline. Brook trout's ability to mature at sizes smaller than the angling size vulnerability likely contributed to the challenge of suppressing this species by angling. In the case of Quirk Creek, however, cutthroat trout recruitment increased over the study period, but this did not translate to increased densities of cutthroat trout >150 mm post-suppression.

During the suppression project, incidental release mortality may have contributed to the lack of native trout recovery in Quirk Creek. Presented as a ratio of natural mortality, simulated release mortality rates coupled with high catchability, like those observed in the lower reach for cutthroat trout (Sinnatamby et al. 2021), could result in fishing mortality rates exceeding reference points that would challenge population recovery. The lower reach was also characterised by warmer water temperatures (often above 12 ℃) that can have a significant positive effect on release mortality (Hühn and Arlinghaus 2011; Van Leeuwen et al. 2020). Some other recreational trout fisheries have not shown population-level suppression effects from release mortality (e.g., Carline et al. 2021), but these studies do not necessarily demonstrate that release mortality is inconsequential in other contexts.

Since the end of the suppression project, brook trout have not achieved previous high densities, which is surprising given that other studies on brook trout suppression report a return to high densities after as little as two years post-suppression (Peterson et al. 2008). Despite an increase in cutthroat trout recruitment and alleviation of incidental release mortality during the post-suppression period, densities of cutthroat trout >150 mm did not continue to increase beyond the suppression period, and did not exceed density threshold goals for recovery of this species. This lack of recovery in both species is perplexing and suggests some unknown factor is limiting cutthroat trout and brook trout >150 mm.

Depending on the future goal of Quirk Creek brook trout management (i.e., eradication or suppression), the best options based on a review of non-native fish suppression in several jurisdictions are the application of piscicides or intensive electrofishing over successive years with gaps in treatment of less than two years (Rytwinski et al. 2019). The effectiveness of angling as a suppression tool was not evaluated by Rytwinski et al. (2019) owing to low numbers of studies, but the narrower size selectivity of angling relative to other suppression methods, the relatively low capture efficiency and the dependence of project effectiveness on angler interest suggests that angling as a main suppression tool is unlikely to be successful.

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Native trout restoration in the Mountain National Parks Canada Agency

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Westslope cutthroat trout (*Oncorhynchus lewisi)* are in need of management action to conserve and restore populations throughout their distribution. Parks Canada Agency (PCA) has implemented multiple tools and analyses to facilitate conservation and restoration. Mechanical and chemical removal of non-native fish, barrier improvement construction, gamete collection, DNA analysis, and remote stream incubation have been successfully implemented and will be highlighted. The Lake Louise, Yoho, and Kootenay Field Unit has worked to restore five headwater systems of the upper Bow River over five years. The success of these restoration locations depended on multiple new (to PCA) management techniques and the collaboration of multiple agencies.

A friendly introduction to statistical stream temperature modelling for conservation practitioners

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Statistical stream temperature models are used to predict the fine-scale spatial distribution of water temperatures (thermalscape) to guide stream conservation practitioners working towards species recovery and habitat restoration. However, stream temperature modelling is challenging because of the spatial autocorrelation that arises from the non-independence in sampling, and complex connectivity in dendritic networks. While various types of stream temperature models are reported in the literature, practitioners would benefit from a case-study based guide on methods for addressing spatial autocorrelation. Here, we developed statistical stream temperature models using data from sensors deployed in Canadian Rocky Mountains streams. Two modelling techniques that explicitly controlled for spatial autocorrelation were investigated. The first model used a frequentist modelling framework specifically developed to account for spatial autocorrelation in dendritic stream networks (spatial stream network models; SSN). The second technique used a Bayesian modelling framework, and is more widely used to model spatial autocorrelation, but is not purpose-designed for anisotropic stream network data (integrated nested Laplace approximation; INLA). We evaluated the model performance of our top-ranked SSN and INLA models using spatial leave-one-out cross validation to generate three goodness-of-fit metrics: root mean square error (RMSE), mean absolute error (MAE) and coefficient of determination (r^2). Both model approaches performed similarly (RMSE/MAE ~ 1ºC) with a moderately strong correlation ($r^2 > 0.7$) between observed and cross-validation values. Both modelling approaches were flexible with respect to implementation. However, SSN models required additional preprocessing steps prior to incorporating spatially-correlated random errors. This study provides a demonstration of statistical stream temperature modelling in addition to practical advice to inform model development for non-experts.

Is mitigating cumulative effects the most difficult problem in trout recovery?

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Alberta's three species of native trout have all declined from common sport fish to species at risk. The causes of decline include combinations of habitat loss, invasive species, and overfishing. Decades of biologists have recognized that these cumulative effects are the roots of the problem, however, lack of quantitative data on degrees of effects, and where, and what mitigation is necessary all have stymied recovery. As a first step in quantifying and solving these threats, Alberta has developed a framework of hypothesis modelling called Joe Modelling. The output of these models are testable hypotheses based on best-available data, and should easily facilitate landscape-level adaptive management learning. None-the-less, two major problems appear to prevent these solutions; 1) the blame game: stakeholders refuse to reduce their footprint without an equally shared reduction by other stakeholders, and 2) the uncertainty cloud: with even only 2 or 3 cumulative threats, a large reduction in one individual threat can have a small or insignificant effect on the whole problem, resulting in decision-makers being unwilling to act based on uncertainty of outcomes. These two human-behaviour-based factors (blame and uncertainty) may be insurmountable obstacles to fishery agency cultures that value consensus and evidence-based management actions.

Athabasca rainbow trout from the Tri Creeks area, Alberta (credit: Ryan Cox).

Appendix A – Workshop Agenda

Wednesday, February 1st, 2023

11:30 am - 12:30 pm	**Lunch**	Dining room
12:30 pm - 1:00 pm	BGI orientation talk (for in-person attendees)	Lecture hall
1:00 pm - 1:10 pm	**Introduction, land acknowledgement and opening remarks** Dr. Jonathan Thompson (Chief Scientist, AEPA)	Lecture hall and Teams meeting
1:10 pm - 1:30 pm	Provincial and federal perspectives on native trout recovery	Peter Rodger (DFO) and Jessica Reilly (AEPA)
1:30 pm - 2:40 pm	**Alberta research** 11 talks (5-minute presentations)	Lecture hall and Teams meeting
	Monitoring	
1:30 pm	Monitoring bull trout in the upper Ghost River, Alberta	Paul Christensen (AEPA)
1:36 pm	Westslope cutthroat trout population monitoring in the upper Oldman watershed	Brad Hurkett (ACA)
1:42 pm	But I would walk 500 miles - 15 years of bull trout redd surveys on Fall Creek	Chad Judd (ACA)
1:48 pm	Status of native trout populations at the margins of their range: a baseline assessment of the bull trout population in the Little Red Deer River watershed	Lindsay Dowbush (ACA)
1:54 pm	Updating our understanding of aquatic health within the Traditional Land Use area of the Aseniwuche Winewak nation near Grande Cache, Alberta	Nathan Medinski* (AWN)
2:00 pm	Assessing the impacts of warming stream temperatures on Athabasca rainbow trout	Tyana Rudolfsen* (DFO)
2:06 pm	Questions	
	Threats	
2:12 pm	Pilot application of a flexible cumulative effects modeling tool for managing species at risk: plains sucker case study	Dr. Lauren Jarvis* (DFO)

2:18 pm	Task-based approach to prioritize bioremediation sites	Abigail Robinson (AJM Env. Inc.)
2:24 pm	Habitat vulnerability assessment of bull trout populations across Alberta East Slopes	Dr. Neil Mochnacz (DFO)
2:30 pm	A friendly introduction to statistical stream temperature modelling for conservation practitioners	Dan Struthers (Parks Canada)
2:36 pm	Web-based stream temperature modelling for Alberta's Eastern Slopes	Dr. Ryan MacDonald (MacHydro)
2:42 pm	Whirling disease confirmed as a significant threat to pure westslope cutthroat trout populations in the upper Bow River, AB	Chloe Christenson (UofA)
2:48 pm	Questions	
2:55 pm - 3:15 pm	**Break**	Dining room
3:15 pm - 5:00 pm	**Alberta research** (Threats cont'd) 14 talks (5-minute presentations)	
	Threats (continued)	
3:15 pm	Spatial delineation of genetic information of westslope cutthroat trout within their historic native range in Alberta watersheds	Jennifer Earle (AEPA)
3:21 pm	Investigating the extent of hybridization between native bull trout and introduced brook trout in Alberta	Emily Franks (UofC)
3:27 pm	An assessment of the effects of changes in brook trout (*Salvelinus fontinalis*) stocking practices in Alberta	Dr. Benjamin Kissinger (UofC)
3:33 pm	Can smartphones kill trout? Mortality of memorable-sized bull trout (*Salvelinus confluentus)*	Dr. Brian Joubert (AEPA)
3:39 pm	Evaluation of catch-and-release sport fishing regulations for westslope cutthroat trout in Picklejar Lakes, Kananaskis, Alberta	Sara Bumstead (AEPA)
3:45 pm	Estimating angler effort at high mountain lakes in Alberta: a native westslope cutthroat trout case study	Kevin Fitsimmons (ACA)
3:51 pm	Questions	
	Recovery	

3:57 pm	A synopsis of five-years of ACA-led westslope cutthroat trout conservation activities	Jason Blackburn (ACA)
4:03 pm	Returning rotenone to the restoration tool box in Banff, NP. Reflections on public engagement and communication tools to address public interest in a National Park context	Shelley Humphries (Parks Canada)
4:09 pm	Restoration stocking for westslope cutthroat trout	Brian Meagher (AEPA)
4:15 pm	Development of a westslope cutthroat throat composite brood stock population in Alberta	Dr. Andreas Luek (AEPA)
4:21 pm	An experimental test of the potential for bull trout conservation translocations, via instream incubation capsules, in Alberta.	Tara Lepine (UofC)
4:27 pm	No evidence of recovery of native trout in response to sustained angling suppression of invasive brook trout	Dr. Nilo Sinnatamby (Miistakis)
4:33 pm	Restoring hydro-regulated waters to support native trout species at risk recovery in Banff National Park	Helen Irwin (Parks Canada)
4:39 pm	Bull trout recovery through OHV trail remediation at Rocky Creek, Alberta	Kenton Neufeld (AEPA)
4:45 pm	Native trout restoration in the mountain National Parks	Bradley Stitt (Parks Canada)
4:51 pm	Questions	
5:00 pm - 6:00 pm	**Free time - outdoor activities**	Snowshoes available for use - other outdoor activities nearby with personal/rental equipment
6:00 pm – 7:30 pm	**Dinner**	Dining room
7:30 pm - 9:00 pm	**Evening entertainment**	Dining room

*Virtual

Thursday, February 2nd, 2023

7:15 am - 8:15 am	**Breakfast**	Dining room
8:30 am - 8:45 am	**Welcome**	Lecture hall (Teams for invited speakers only)
	Land acknowledgement	Dr. Steven Vamosi (UofC)

	Introduction	Dr. Barry White (fRI Research)
8:45 am - 10:15 am	**Research into species at risk and cumulative effects**	Lecture Hall (Teams for invited speakers only)
8:45 am	The role of science in species conservation: reviewing research progress and gaps for SARA-listed species	Dr. Andrew Drake* (DFO)
9:15 am	Key uncertainties for bull trout status in the Saskatchewan-Nelson drainage	Dr. John Post (UofC)
9:25 am	General considerations for cumulative effects modelling and species at risk	Dr. Jordan Rosenfeld (UBC & BC Env.)
9:55 am	Is mitigating cumulative effects the most difficult problem in trout recovery?	Dr. Michael Sullivan and Laura MacPherson (AEPA)
10:15 am - 10:45 am	**Break**	Dining room
10:45 am - 12:00 pm	**Climate and native trout recovery**	
10:45 am	Climate change risks and big data opportunities for native trout conservation and management	Dr. Dan Isaak* (USFS)
11:05 am	Climate warming effects on a cold-water stenothermal fish occurring near a northern geographical range boundary	Dr. Neil Mochnacz (DFO)
11:25 am	Climate research priorities - panel discussion	Facilitators - Dr. Andy Paul (AEPA) & Lesley Peterson (TUC)
12:00 pm - 1:30 pm	**Lunch**	Dining room
1:30 pm - 3:00 pm	**Non-native removal and native trout recovery**	
1:30 pm	Rotenone and the development of Montana's native species recovery program	Don Skaar (retired MFWP & PC)
2:00 pm	Westslope cutthroat trout restoration in Montana with emphasis on the Cherry Creek Project in the Madison River drainage	Pat Clancey (retired MFWP)
2:30 pm	Non-native removal research priorities - panel discussion	Facilitator – Shelley Humphries (PC)
3:00 pm - 3:15 pm	**Break**	Dining room
3:15 pm - 4:45 pm	**Angling and native trout recovery**	
3:15 pm	Characterizing and managing recreational angling impacts on native trout in Alberta	Dr. Jacob Brownscombe (DFO)

3:45 pm	Idaho's experience with catch and release angling on trout	Joe Kozkkay (IDFG)
4:15 pm	Angling research priorities - panel discussion	Facilitator - Dr. Michael Sullivan (AEPA)
4:45 pm – 6:00 pm	**Free time - outdoor activities**	Snowshoes available for use - other outdoor activities nearby with personal/rental equipment
6:00 pm – 7:30 pm	**Dinner**	Dining room
7:30 pm - 9:00 pm	**Evening entertainment**	Dining room

*Virtual

Friday, February 3rd, 2023

7:15 am - 8:15 am	**Breakfast**	Dining room
8:30 am - 8:40 am	**Welcome**	Lecture hall (Teams for invited speakers only)
	Land acknowledgement and introduction	Dr. Steven Vamosi (UofC)
8:40 am - 10:10 am	**Genetics and native trout recovery**	Lecture hall (Teams for invited speakers only)
8:40 am	How four decades of genetic data informs native species conservation in Montana	Dr. Ryan Kovach (MFWP)
9:30 am	Genetic research priorities - panel discussion	Facilitator - Dr. Benjamin Kissinger (UofC)
10:10 am - 10:40 am	**Break**	Dining room
10:40 am - 12:00 pm	**Habitat and native trout recovery**	Lecture hall (Teams for invited speakers only)
10:40 am	Working with people to create and apply science in bull trout conservation	Dr. Jason Dunham* (USGS)
11:25 am	Habitat research priorities - panel discussion	Facilitators – Michael Rodtka (ACA), Jessica Reilly (AEPA) & Elliot Lindsey (TUC)
12:00 pm - 1:00 pm	**Lunch**	Dining room

* Virtual

Appendix B – Planning Committee

Name	Organization
Dr. Andy Paul	Office of the Chief Scientist
Maddie Bemrose	Office of the Chief Scientist
Dr. John Post	University of Calgary
Mike Rodtka	Alberta Conservation Association
Peter Rodger	Fisheries and Oceans Canada
Shelley Humphries	Parks Canada
Jessica Reilly	Alberta Environment and Protected Areas
Lesley Peterson	Trout Unlimited Canada
Dr. Steven Vamosi	University of Calgary
Dr. Benjamin Kissinger	University of Calgary
Elliot Lindsay	Trout Unlimited Canada
Dr. Barry White	fRI Research
Dr. Mark Poesch	University of Alberta
Dr. Michael Sullivan	Alberta Environment and Protected Areas
Nicole Pilgrim	Alberta Environment and Protected Areas