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The Salmonidae Solution: An analysis of Catch and Release as a Sustainable Management Practice for Climate Threatened Trout and Related Species in Colorado

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Fishing is an important industry and recreational activity for many people. As climate change continues on its projected path, cold-water fish will encounter problems that will certainly threaten their future survival. Salmonidae are one such family of fish predicted to be greatly impacted due to numerous climatic and anthropogenic impacts. The Salmonidae family contains Salmon, Trout, Char, Whitefish and Graylings, all of which are prized gamefish and are essential in many ecosystem functions. Impacts harming these fish species include habitat loss, degradation and fragmentation; introduction of invasive species; and changes in temperature and precipitation, all of which are predicted to become more frequent and severe in current climate models.[1] In addition to their struggles to adapt to a changing climate, members of the Salmonidae family are often fished for sport and thus have to deal with the extra anthropogenic stressor of both commercial and recreational fishing. Because of their value as game fish, Catch and Release has often been portrayed as the silver bullet solution. Anglers can continue to fish for these species and promote the economy and fish conservation, while also having little to no impact on their populations due to low mortality rates. The purpose of this research paper is to determine if Catch and Release is a sustainable conservation method for Colorado trout species as threatening anthropogenic and climate factors continue to increase.

Materials and Methods

This study is limited mainly to species within the Salmonidae family in the state of Colorado, with a particular focus on trout. Because of the limited research on Catch and Release with trout species in Colorado, research on other Salmonidae species will be included due to the

[1] Isaak, D. J. e. a. The Past as Prelude to the Future for Understanding 21st-Century Climate Effects on Rocky Mountain Trout. In (Vol.37, pp.542–556): Fisheries.

physiological similarities between trout other species contained within the Salmonidae family.[2] The state of Colorado was chosen due to its diversity in landscapes and biomes, as well as the state identity that incorporates the importance of fish both economically and culturally.

Research in this study is broken down into two parts. The first part of the research presents a synthesized analysis on Catch and Release as a conservation strategy. This involves determining fish mortality post release, examining beneficial and non-beneficial practices involved in Catch and Release, and comparing Catch and Release to a few proposed alternative conservation strategies. Material for this section was collected mostly from books, scholarly journals, government sources, and conservation websites addressing the benefits and negatives of these conservation strategies. The second part of this research analyzes case studies of trout species and whether Catch and Release has benefited their overall conservation within Colorado. Additionally, interviews of government fish and wildlife officials and recreational fishermen were conducted to compare their Catch and Release habits and understand their opinions on the successes or failures within each case study. In addition to scholarly journals, magazines, books, etc., existing statistics will be used as the methodology for analysis. Interviews will be analyzed through re-listening to recorded interviews and categorizing themes within questions. The body of literature I will be working with focuses on Catch and Release strategies, angler incorporated and non-incorporated conservation efforts, invasive species, climate change impacts, and viewpoints from anglers, fishery and government professionals.

[2] Kraft, C.E et. al. "Inland Fishes of New York (Online)." 2006. Accessed feb 5, 2020. http://www2.dnr.cornell.edu/cek7/nyfish/Salmonidae/salmonidae.html.

Threats to Salmonidae

The changing climate is undoubtably one of the biggest threats to Salmonidae. As climatic patterns begin to change, thermal and precipitation patterns will too.[3] Increased temperatures result in problems such as sex ratio changes, temperature related fallback and increased mortality rates when caught.[4] The ratio of male to female sex is temperature sensitive process: in developmental periods, higher water temperatures have been found to have higher ratios of male fish.[5] Additionally, increased temperatures have been shown to reverse the movement of fish from upstream to downstream, likely due to exhaustion or seeking out cold water areas/refugia.[6] Changes in precipitation will also likely affect these fish species. Occasionally occurring droughts are predicted to become more normalized. This means that small trout streams where endangered species of cutthroat trout are often found will have little capacity to deal with these changes, and in some cases the entire population of trout within a stream will be wiped out as the stream dries up.[7] Habitat loss, degradation and fragmentation are also predicted to become more severe within the future. Increasing temperature and less precipitation are anticipated to increase wildfire frequency and intensity. While wildfires are a natural ecosystem event in Colorado, they can severely degrade river ecosystems through increasing water temperatures, and changes in water chemistry and sediment inputs.[8] Depending

[3] Henson, Robert. "*The Thinking Person's Guide to Climate Change*." Massachusetts: American Meteorogical Society, 2014.
[4] Bartholomew, Aaron, and James A. Bohnsack. "A Review of Catch-and-Release Angling Mortality with Implications for No-Take Reserves." *Reviews in Fish Biology and Fisheries* 15, no. 1 (February 01 2005): 129-54; Crozier, Lisa. Dechant, Delaney. Sullivan, Kile. "Impacts of Climate Change on Columbia River Salmon." edited by Impacts of Climate Change on and Columbia River Salmon. Seattle, Washington: NOAA, 2014.; Magerhans, Andreas, Andreas Müller-Belecke, and Gabriele Hörstgen-Schwark. "Effect of Rearing Temperatures Post Hatching on Sex Ratios of Rainbow Trout (Oncorhynchus Mykiss) Populations." *Aquaculture* 294, no. 1 (2009/09/01/ 2009): 25-29.
[5] Crozier, Lisa. Dechant, Delaney. Sullivan, Kile. "Impacts of Climate Change on Columbia River Salmon." edited by Impacts of Climate Change on and Columbia River Salmon. Seattle, Washington: NOAA, 2014.
[6] Ibid.
[7] Isaak, D. J. *et al.* "The Past as Prelude", Fisheries.
[8] Ibid.

on how close wildfires burn along the riverbanks, entire populations could be destroyed if there is a lack of cold water refugia. Natural recolonization also unlikely in many scenarios due to severe habitat fragmentation in many rivers.[9]

Figure 1. A poorly fit culvert blocking the migration of Kokanee salmon[10]

In addition to these climatic factors, many anthropogenic barriers further degrade habitat, block fish migration and increasingly fragment suitable habitat. These barriers include diversion of water for agricultural purposes, development of riparian zones for housing, livestock, and agriculture and poor construction practices on rivers (such as poorly fit culverts, see Figure 1) which block fish movement and migration.[11] Continuing development of areas is likely to increase the frequency of these negative effects from these anthropogenic barriers. All of the above-mentioned threats make habitats less suitable for native fish populations and increase opportunities for their replacement by invasive species.[12] One such example in Colorado includes brook trout overtaking native cutthroat. The introduction of brook trout often leads to the replacement of native cutthroat.[13] Furthermore, introduced species such as Rainbow trout have the potential to breed out native populations through hybridization, thus destroying the true population of native

[9] Isaak, D. J. *et al.* "The Past as Prelude", Fisheries.
[10] Ibid
[11] Ibid.
[12] Boddy, Nixie C., and Angus R. McIntosh. "Temperature, Invaders and Patchy Habitat Interact to Limit the Distribution of a Vulnerable Freshwater Fish." *Austral Ecology* 42, no. 4 (2017): 456-67.
[13] Peterson, Douglas P, Kurt D Fausch, and Gary C White. "Population Ecology of an Invasion: Effects of Brook Trout on Native Cutthroat Trout." *Ecological Applications* 14, no. 3 (2004): 754-72.

cutthroats.[14] With these impacts taking the largest toll on the Salmonidae family, it will be critical to analyze how Catch and Release magnifies or minimizes each impact.

Why We Should Preserve Salmonidae

When it comes to the importance of preserving any fish species, the most obvious reasons often come from the instrumental values they provide us. Fishing has been a commodity since the beginning of humanity and still shows its value through the money it generates. Together in the U.S., recreational and commercial fishing generated over 200 billion dollars in 2015.[15] In addition, fish conservation helps pay for itself. In 1950, the United States government passed the Dingell-Johnson Act which took a tax on fishing equipment to go directly to conservation; since then, the act has raised more than $9 billion toward fish related conservation efforts around the country alone.[16] Ecosystem services fish provide also play a role in our economic welfare. Fish are a vital part in nutrient cycling and often bring nutrients from further downstream, or from the ocean, upstream to areas of the river that are less nutrient rich.[17] These nutrients feed megafauna (such as bears, wolves, etc.). invertebrates, and even help the growth of trees.[18] These environmental benefits that are a direct result of fish populations increase property values through increased production of these environmental services; they also increase the quality and quantity of natural resources.

[14] Muhlfeld, Clint C., Thomas E. McMahon, Matthew C. Boyer, and Robert E. Gresswell. "Local Habitat, Watershed, and Biotic Factors Influencing the Spread of Hybridization between Native Westslope Cutthroat Trout and Introduced Rainbow Trout." *Transactions of the American Fisheries Society* 138, no. 5 (2009/09/01 2009): 1036-51.
[15] "U.S. Fishing Generated More Than $200b in Sales in 2015, Two Stocks Rebuilt in 2016." U.S. Department of Commerce, 2017.
[16] "Fishing Funds Conservation." Department of the Interior 2018.
[17] Department of the Interior. "Catch and Release Fishing." 2018. 2020. https://www.nps.gov/subjects/fishing/catch-and-release-fishing.htm; Department of the Interior "Fishing." Department of the Interior, 2016.
[18] Post, Anne. "Why Fish Need Trees and Trees Need Fish." Alaska Department of Fish and Game, 2008.

While the instrumental values are undoubtably important, many would argue that fish provide more value through their non-instrumental values. Cultural value related to fish must be considered. For centuries Native Americans placed huge importance on fish species. Not only were they valued for their sustenance, they are incorporated into religious ceremonies and traditional teachings to pass down stories of creation and life.[19] To protect these cultures, we must protect the fish which they grew upon. In addition to culture, many attribute life lessons, core values and the creation of principles from how fishing has impacted their life. Whether it involves spending time with a loved one, or just an opportunity to get away, protecting fish means protecting the core values and special moments many people experience. Lastly, all fish are aesthetically beautiful. Whether it be their form, colors, or behavior, we should want to preserve fish for the same reason we would a beautiful painting; their intrinsic values lie within themselves. It is through looking at both the intrinsic and instrumental value of fish species we find good reasons to promote and protect them.

History of Catch and Release

The idea and practice of Catch and Release dates back to medieval England but became well known in the early 20th century.[20] Catch and release was first introduced in the United States as a conservation method in the Great Smokey Mountains National Park in 1954, with the ultimate goal of Catch and Release being to reduce the pressures on game fish by allowing them to be caught multiple times.[21] As Lee Wulff, a legendary recreationalist and fisherman explained,

[19] Colombia River Inter-Tribal Fish Commission. "Tribal Salmon Culture." 2020.
[20] Arlinghaus, Robert, Steven J. Cooke, Jon Lyman, David Policansky, Alexander Schwab, Cory Suski, StephenG Sutton, and EvaB Thorstad. "Understanding the Complexity of Catch-and-Release in Recreational Fishing: An Integrative Synthesis of Global Knowledge from Historical, Ethical, Social, and Biological Perspectives." *Reviews in Fisheries Science* 15, no. 1/2 (2007): 75-167.
[21] Barnhart, Roger A. "Symposium Review: Catch-and-Release Fishing, a Decade of Experience." *North American Journal of Fisheries Management* 9, no. 1 (1989): 74-80.

"There is a growing tendency among anglers to release their fish. Game fish are too valuable to be caught only once."[22] As Catch and Release became more popular among recreational anglers, it began to be implemented in many national parks and forests for the purpose of conservation and preservation. The Department of the Interior and Department of Agriculture have implemented 6 techniques as an umbrella guide for all fish species to be released.[23] In more recent times, questions have been brought up regarding both what the true mortality rate of Catch and Release is as well as the ethics behind Catch and Release culture.[24] The practice of Catch and Release is most closely related with recreational fishing. Instead of fish being caught and killed for food or other instrumental values, they are released instead; the fight is only enjoyed for sport. Often this involves landing the fish (getting the fish out of the water), a quick measurement of size, and potentially a photograph if the angler deems the fish as a rewarding catch. While both commercial fishing and recreational fishing share many management strategies, the main difference is that recreational fishing does not necessarily depend on high catch rates; however, the enjoyment of the experience is nevertheless often based on the number of fish caught.[25]

Previous Research on Catch and Release

Perhaps the largest question around Catch and Release research is the mortality rate of fish and the different variables that affect it. To name some of the variables studied: air exposure, equipment type, cutting the line on deeply hooked fish, artificial vs live bait use, fight time,

[22] Arlinghaus."Understanding the Complexity of Catch-and-Release in Recreational Fishing", 2007.
[23] Department of the Interior. "Catch and Release Fishing." 2018.; Department of the Interior. "How to Safely Catch and Release." 2017.
[24] Arlinghaus. "Understanding the Complexity of Catch-and-Release in Recreational Fishing", 2007.
[25] Ibid.

water temperature, and active vs passive fishing. One of the most important factors regarding Catch and Release was found to be temperature. Temperature can play a huge role in fish mortality due to it being a key component in many physiological processes within Salmonidae. A meta-analysis showed that higher temperatures have been shown to increase either stress or mortality factors in 70% of reported studies of fish species.[26] Often, it is a combination of air exposure, fight time, and water temperatures that yield the highest mortality rates. Even in studies where temperatures showed little effect on mortality, high survival rates are attributed to fish with access to cold water refugia or cooler nighttime temperatures.[27] Air exposure has also been a consistent research topic within the Catch and Release realm of fishing. One study found that air exposure up to 60 seconds has negligible effects on Yellowstone cutthroat trout, a good predictor for the capacity of other trout species.[28] This being said, other studies have found that there is correlation between air exposure and mortality rate. For example, air exposure paired with handling techniques were found to affect the mortality rate of Rainbow trout depending on time out of water.[29] It was argued that the Rainbow trout sampled in these experiments often were not a product of true environmental conditions and were exercised to exhaustion.[30] While fish should always be released as quickly as possible, the average fisherman takes 30 seconds to release a fish with less than 5% keeping the fish exposed for over 60 seconds, making air exposure negligible.[31]

[26] Twardek, W. M., T. O. Gagne, L. K. Elmer, S. J. Cooke, M. C. Beere, and A. J. Danylchuk. "Consequences of Catch-and-Release Angling on the Physiology, Behaviour and Survival of Wild Steelhead Oncorhynchus Mykiss in the Bulkley River, British Columbia." *Fisheries Research* 206 (2018): 235-46.
[27] McCarrick, Darcy K., Curtis J. Roth, Daniel J. Schill, Brett High, and Michael C. Quist. "Effects of Air Exposure on Survival of Yellowstone Cutthroat Trout Angled from a Stream with Warm Water Temperatures." *Journal of Fish & Wildlife Management* 10, no. 2 (2019): 509-16.
[28] Ibid.
[29] Bartholomew, Aaron, and James A. Bohnsack. "A Review of Catch-and-Release Angling Mortality", 2005.
[30] McCarrick, et al. "Effects of Air Exposure on Yellowstone Cutthroat" *Journal of Fish & Wildlife Management*, (2019).
[31] Ibid.

Equipment type is yet another variable that has been studied to see how mortality rates are impacted, especially in regard to hooks (Figure 2). During the event of capturing a fish via hook and rod, internally hooking a fish was consistently found to have higher chances of bleeding and thus higher chances of mortality; however, when comparing the rate of internal hooking, bleeding, impairment or mortality between treble hooks and siwash hooks (single hooks), there was no statistically significant difference.[33] Treble hooks did, however, increase the handling time and air exposure of fish which could increase the rate of mortality.[34] With respect to hook modifications, barbless hooks were also found to have lower mortality rates in non-anadromous trout than those that contained barbs.[35] This again, was likely due to the increased time needed to remove the fish from the hook, thus increasing air exposure and handling time.

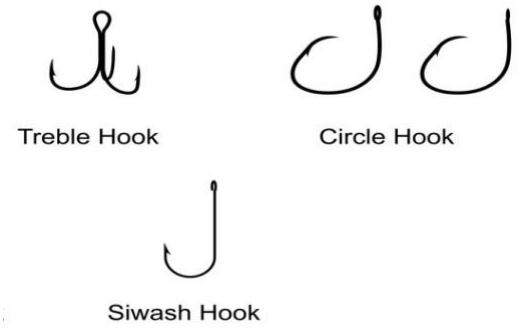

Figure 2. Diagram of hook types addressed. These hooks can vary in material and make (size, thickness, etc.).[32]

A relatively new hook design, the circle hook, has begun to be used as a means for conservation due to the lower rates of mortality it was found to have in some fish species. When compared to siwash (single hooks), circle hooks had lower potential for hooking into vital organs as well as for deep hooking fish.[36] This being said, there were instances of circle hooks causing increased tissue damage to the eye regions of some fish species and because of this, species

[32] VectorStock. 2020. https://www.vectorstock.com/royalty-free-vector/types-fishing-hooks-isolated-on-white-vector-26672926.
[33] Kerr, S. M. *et al.* "Influence of Hook Type and Live Bait on the Hooking Performance of Inline Spinners in the Context of Catch-and-Release Brook Trout Salvelinus Fontinalis Fishing in Lakes.", 642–47: Fisheries Research, 2017.
[34] Ibid.
[35] Bartholomew, Aaron, and James A. Bohnsack. "A Review of Catch-and-Release Angling Mortality", 2005.
[36] Cooke, S. and Suski, C. "Are Circle Hooks an Effective Tool for Conserving Marine and Freshwater Recreational Catch-and-Release Fisheries?": Aquatic Conserv: Mar. Freshw. Ecosyst., 2004.

specific guidelines should be researched before encouraging the use of circle hooks for any particular species.[37] Subtle differences in these hook sizes could also have impacts on mortality depending on fish species and size of the hook compared to the fish.[38] Equipment used for bait has also shown some impacts relating to fish mortality. Artificial bait (lures, and tied flies, etc.) has been found to have less impact on mortality when compared to the use of live bait (worms, leaches, etc.) for non-anadromous trout.[39] This is likely due to fish being more likely to swallow live bait more quickly due to the attractive smell and taste, rather than hesitating when smelling/tasting artificial bait.

Regarding fishing techniques that impact mortality, cutting the line of deeply swallowed hooks has been shown to benefit fish more than harming them. One study found white spotted char that were deeply hooked saw extremely low mortality rates when the line was cut and the hook was left in place.[40] These hooks usually become dislodged eventually due to rusting and gastric digestion of the fish, but the time taken to dislodge the hook can vary.[41] It should be noted that while the hooks are still imbedded, the growth of fish usually slows due to problems associated with foraging for food and its digestion, but hooks can dislodge very quickly depending on the material and its make (hook size, thickness, shape, etc.).[42] Ultimately, leaving a deeply imbedded hook in place (as shown in Figure 3) may slow down growth and feeding habits for a few days, but there is a very high chance the hook will dislodge, and the fish will continue to live. Attempting to remove a deeply imbedded hook can not only increase air exposure and

[37] Cooke, S. and Suski, C. "Are Circle Hooks an Effective Tool for Recreational Catch-and-Release Fisheries?", 2004.
[38] Ibid
[39] Bartholomew, Aaron, and James A. Bohnsack. "A Review of Catch-and-Release Angling Mortality", 2005.
[40] Tsuboi, Jun-ichi, Kentaro Morita, and Hisatoshi Ikeda. "Fate of Deep-Hooked White-Spotted Charr after Cutting the Line in a Catch-and-Release Fishery." *Fisheries Research* 79, no. 1/2 (2006): 226-30.
[41] Ibid.
[42] Ibid.

handling time but can also lead to detrimental tissue damage, impairment, and bleeding, all of which significantly increase the rate of mortality.

Figure 3. image of a deeply hooked fish. This fish would likely benefit from cutting the line and leaving the hook in place.[43]

Fight time is another factor that can negatively impact the mortality rate of members within the Salmonidae family. Longer durations of angling activity showed increases in blood lactate levels when compared to baseline levels. It is possible that a variable such as fight time could have lethal and sub lethal effects such as exhaustion, decreased feeding, and increased post catch predation on steelhead (which are the same species Rainbow trout) and related fish.[44]

Temperature is another variable that must be considered when fighting a fish due to temperature having a strong positive correlation with blood lactate levels and strong negative correlation with blood pH.[45] Ultimately, longer fight times with Salmonidae species contribute to a higher possibility of exercising the fish to death due to increased blood lactate levels and acidification of the blood in warmer water. This stresses the importance of anglers being aware of water temperature. Fish caught in warmer water temperatures are at a much higher risk of dying from exhaustion; and thus, fight time should be minimized or in extreme cases, fish should not be caught at all.

[43] Wired2Fish. “Remove Hooks from Deep-Hooked Fish with Minimal Harm" Youtube, 2018.
[44] Twardek, *et al*. "Consequences of Catch-and-Release Angling on Wild Steelhead in British Columbia.", 2018.
[45] Ibid.

Lastly, active fishing has been shown to have reduced mortality rates when compared to passive fishing. Active fishing, sometimes referred to as "tight line" fishing, is when the angler is present and attentive throughout the angling event, whereas in passive fishing the angler is not present/attentive, has his rod set in a holding device, etc. Passive fishing is often shown to have greater probabilities of deep hooking fish when compared to active "tight line" fishing.[46] Passive fishing allows for fish to swallow or become tangled around the line, likely leading to a hook in a vital area, whereas active fishing has a higher chance of hooking only the jaw due to the angler's ability for a quicker hook set.

Despite the large amounts of research on Catch and Release variables pertaining to Salmonidae, many areas of research support contradicting results. While some hypotheses are more supported than others, the fact remains that species within the Salmonidae family have different thresholds and sensitivities to different environmental and extrinsic factors. The idea of implementing species specific guidelines has been proposed to further lessen mortality rates involved with Catch and Release. While having general guidelines to Catch and Release fishing is important, there is a lot of variability in response to Catch and Release related to physiology, morphology, ecology and behavior.[47] With the various differences between species within the Salmonidae family, providing new suggestions on Catch and Release techniques may improve mortality rates when compared to umbrella regulations given by the government.[48]

One of the newer categories of research involving Catch and Release revolves around the ethics of practicing Catch and Release. Both anglers and animal activists have raised concerns of whether Catch and Release is truly ethical due to questions of perceived pain, increased

[46] Tsuboi, et al. "Fate of Deep-Hooked White-Spotted Charr after Cutting the Line in a Catch-and-Release Fishery.", 2006.
[47] Cooke, S.J., Suski, C.D. "Do We Need Species-Specific Guidelines?": *Biodivers Conserv* 14, 2005.
[48] Department of the Interior. "How to Safely Catch and Release." 2017.

mortality, and a potentially unhealthy view of fish as simply a means for human enjoyment. Some anglers have found that the potential to kill or maim a fish simply for enjoyment is not an honorable profession or activity, while others maintain the stance that fishing brings one closer to nature and, if done correctly, fish dying from Catch and Release should be very rare.[49] Questions regarding the extent to which fish experience pain have also been a key part of the discussion, but it is impossible to know whether fishing causes excruciating pain or slight discomfort.[50] These perceptions bring into question the importance of anglers in conservation efforts. Does an angler's interest in a fish from sport help benefit its conservation? And if not, is the pain and possible death of a fish worth an angler's enjoyment?

Analysis of Alternative strategies

Although not as well-known as Catch and Release, there are some alternative conservation strategies involving fish management. Two alternatives to Catch and Release as a conservation effort include catch and kill regulations and No Take Reserves, both of which are used to control fish populations. To start, catch and kill (where all caught fish of a given species are to be killed) or the use of bag limits (where a designated number of fish to take is allowed to ensure a sustainable harvest) do not really apply to struggling fish species as they are only permitted when a fish species has a population size that will allow for a sustainable harvest. This being said, bag limit regulations help ensure that the population is not overfished or overpopulated. The other way catch and kill regulations are used is through protecting native species by minimizing predator populations or populations that could outcompete protected

[49] Kerasote, Ted. "Catch and Deny." 2003.
[50] Rose, James D. "The Neurobehavioral Nature of Fishes and the Question of Awareness and Pain." *Reviews in Fisheries Science* 10, no. 1 (2002): 1.

species. This strategy is often employed through a section of river or water body where everything caught must be killed. Usually the species desired for protection is not present in these areas and it is simply a measure to prevent the upstream migration of predator/competitor species. There can also be implementation of catch and kill where the desired protected population and their competitors both are present, but this relies heavily on angler's ability to identify the target species correctly. The issues associated with catch and kill are mainly due to the fact that areas that meet the conditions to employ the strategy of "kill everything that is caught" are rare, and areas where catch and kill is used where both competitor and desired species are may result in more deaths of desired species due to angler mis-identification.

The implementation of No Take Reserves is another possible strategy. This has been used mainly in marine ecosystems and has had little to no use in freshwater ecosystems.[51] No Take Reserves call for prohibition of angler events and only scientific activities are allowed within the designated area. While this method is useful for small populations of struggling species due to it not adding possible mortality increases through Catch and Release, it has met heavy resistance from anglers who are often instrumental in employing and supporting conservation efforts. Studies have also found that often NTRs increase fishing pressures directly outside of reserves which transfers the problem to areas outside of the reserve.[52]

Analysis of Catch and Release as a Conservation Strategy

As mentioned before, Catch and Release is most closely related with recreational fishing but does have some associations with commercial fishing. Fish are not caught and killed for food

[51] Pitman, Kara J., Samantha M. Wilson, Elissa Sweeney-Bergen, Paddy Hirshfield, Mark C. Beere, and Jonathan W. Moore. "Linking Anglers, Fish, and Management in a Catch-and-Release Steelhead Trout Fishery." *Canadian Journal of Fisheries & Aquatic Sciences* 76, no. 7 (2019): 1060-72.
[52] Ibid.

or any other instrumental value, they are simply released after enjoying the process of hooking, fighting and landing the fish. As enjoyable and good natured as Catch and Release sounds, there are certainly some issues when considering possible implications that could develop. For example, the rate of mortality is never zero during Catch and Release events. There is always the possibility of Catch and Release killing individuals within the population, especially when considering the more sensitive species within the Salmonidae family. While death can result directly from Catch and Release through impacts such as tissue damage, air exposure, fight time, etc., it can also occur indirectly through events after release due to death by exhaustion from a lack of cold water refugia or increased rates of predation due to impaired physiological processes.[53]

Another problem stems from the effectiveness of Catch and Release relying heavily on anglers having and maintaining good Catch and Release practices. While there are some benefits to universal rules for Catch and Release strategies, their success varies from species to species.[54] Fisheries management should thus continue research and inform anglers on best management practices for targeted fish species. Anglers are usually happy to follow new regulations if the management agencies can establish trust through use of providing professional expertise to anglers, as well as providing understandable evidence for implementing new regulations.[55] Additional evidence supporting this claim comes from the interviews conducted with recreational fisherman in Colorado. Both interviewees stated that they did follow Catch and Release guidelines as best as they could, including using artificial flies and lures, minimizing

[53] Bartholomew, Aaron, and James A. Bohnsack. "A Review of Catch-and-Release Angling Mortality", 2005; Raby, Graham D., Jessica R. Packer, Andy J. Danylchuk, and Steven J. Cooke. "The Understudied and Underappreciated Role of Predation in the Mortality of Fish Released from Fishing Gears." *Fish & Fisheries* 15, no. 3 (2014): 489-505.
[54] Bartholomew, Aaron, and James A. Bohnsack. "A Review of Catch-and-Release Angling Mortality", 2005.
[55] Barnhart, Roger A. "Symposium Review: Catch-and-Release Fishing, a Decade of Experience.", 1989.

time the fish spends out of the water and fight time, and cutting the line on deeply embedded hooks.[56] There is certainly the need for more research in many areas involving Catch and Release. While there are many aspects of Catch and Release thoroughly researched, experts are far from reaching a general consensus on proper technique or equipment to use. To name a few examples, air exposure, hook type, and overall angling impacts on Salmonidae physiology are have found contradicting results.[57] With so many studies contradicting of one another, continued research on current and future practices involving Catch and Release will be essential. Lastly, Catch and Release regulations can alter fish sizes due to increased competition between fish species.

> *There is a perception among the angling community that when a catch and release regulation is implemented that the fishery will become outstanding. This simply is not the case, nor the intent of the implementation of a catch and release regulation on a fishery…There are examples where a catch and release regulation was repealed due to the fishery becoming stunted from the lack of harvest. Some fisheries and fish species should have some level of harvest on them for them to continue to produce fish of a desirable size for anglers.*[58]
>
> *-Tyler Swarr, Aquatic Biologist for Colorado Parks and Wildlife*

[56] Croteau, Joe. "Recreational Angler Interview." By Nathan Stone (2020); West, Benjamin. "Recreational Angler Interview." By Nathan Stone (2020).
[57] Cooke, S. and Suski, C. "Are Circle Hooks an Effective Tool for Recreational Catch-and-Release Fisheries?", 2004; McCarrick, et al. "Effects of Air Exposure on Yellowstone Cutthroat" *Journal of Fish & Wildlife Management*.
[58] Swarr, Tyler. "Parks and Wildlife Interview." By Nathan Stone (2020).

While Catch and Release is certainly not a perfect management strategy its benefits are undeniable. At its core, Catch and Release maintains angler involvement, which greatly contributes to both economic development and conservation work. Anglers undoubtably play a huge part in the conservation of fish species. Often, conservation efforts are hard to enforce and depend upon the angling community's acceptance of implemented regulations. Overfishing has been cited as one of the main reasons for global fish declines; thus, strategies must be employed that consider both the human and ecological aspects surrounding fisheries management to ensure the best chance of success.[59] Anglers are also useful for conservation through both scientific and economic contributions. Anglers can help analyze conservation progress through data collected on their observations of abundances, populations sizes, average catches, etc.[60] Recreational fishing also supplies revenue for conservation and provides resources for raising concerns about environmental issues and the need for conservation of local habitats.[61]

In addition to involving anglers, a majority of scientific literature is in consensus that the relative rate of mortality for Catch and Release is low. Although there is some dispute regarding the actual mortality rates of fish post release, many studies have found that the relative rates are well below statistically significant levels. These studies have found mortality rates to be less than 10 percent, and suggest that Catch and Release has no statistically significant effect on Salmonidae populations.[62] This being said, there is general acceptance that Catch and Release

[59] Pitman, Kara J. *et al.* "Linking Anglers, Fish, and Management in a Catch-and-Release Steelhead Trout Fishery." 2019.
[60] Brownscombe, Jacob W., Kieran Hyder, Warren Potts, Kyle L. Wilson, Kevin L. Pope, Andy J. Danylchuk, Steven J. Cooke, *et al.* "The Future of Recreational Fisheries: Advances in Science, Monitoring, Management, and Practice." *Fisheries Research* 211 (2019/03/01/ 2019): 247-55.
[61] Ibid.
[62] Adams , Pauline, Christopher James, and Clay Speas. "Rainbow Trout (Oncorhynchus Mykiss) Species and Conservation Assessment.", 2008; McCarrick, et al. "Effects of Air Exposure on Yellowstone Cutthroat" *Journal of Fish & Wildlife Management*, (2019).; Tsuboi, et al. "Fate of Deep-Hooked White-Spotted Charr after Cutting the Line in a Catch-and-Release Fishery.", 2006; Young, Michael K. "Greenback Cutthroat Trout (Oncorhynchus Clarkii Stomias): A Technical Conservation Assessment." 39-40: Department of Agriculture, 2009.

techniques can continue to be modified with further research to continually lessen rates of mortality.

In some cases, Catch and Release has been shown to improve the quality and quantity of ecosystem services. Maintaining more fish within an environment means that there are more individuals carrying out their roles within the given ecosystem. Fish are often compared to living nutrient transporters and bring rich nutrients from oceans or lower stretches of rivers to nutrient deficient areas and overall play a monumental role in nutrient cycling. Releasing fish essentially keeps the nutrients they provide within the local ecosystem to which megafauna (Figure 4), vegetation, and so many other organisms can use and prosper from.[64] Lastly, Catch and Release allows for increased economic generation. As mentioned before, recreational fishing generates money on many fronts. Directly, commercial and recreational fishing grossed over 200 billion dollars in the United States alone.[65] Fishing conservation essentially pays for itself through taxes on fishing equipment.[66] Indirectly, fishing also bring increases to local economies through spending by tourist anglers. This encompasses housing, food, local fishing guides, equipment from tackle

Figure 4. A wolf that has managed to pull a salmon from a river for a meal.[63]

[63] Wagner, Nancy J. "Wolf with Salmon." 2017. 2020. http://nancywagnerphotography.com/2017/11/16/wolf-with-salmon-alaska/.
[64] Post, Anne. "Why Fish Need Trees and Trees Need Fish." Alaska Department of Fish and Game, 2008.
[65] "U.S. Fishing Generated More Than $200b" U.S. Department of Commerce, 2017.
[66] "Fishing Funds Conservation." Department of the Interior 2018.

shops, etc. These are all benefits that are the direct result of involving and maintaining anglers, of which a large part is encompassed with Catch and Release practices.

The Ethics of Catch and Release

As previously mentioned, a newer issue within Catch and Release involves the ethics of the actions and motives behind Catch and Release. Animal rights activists and organizations have called foul play on Catch and Release under the context of its potential death for fish in addition to the observation and hypothesis that fish feel pain.[67] Others argue that mortality rates are extremely low if anglers take care in releasing their fish, and theorize that the pain fish feel isn't too extreme as often fish will be caught twice within the same hour of fishing (interviews will be added).[68] Reports regarding the neural processes of fish and perceived pain have been generally described as a response to aggravating stimuli rather than a physiological response to perceived pain. To simplify, the response of fish to "painful stimuli" is a sort of reflex rather than a perception of pain followed by an action to stop it. While fish do have responses to what humans would consider "painful", human pain depends on activation of certain areas of our brain that are not comparable/do not exist within fish.[69] Although this response may not be a "pleasant" experience for fish, their brains are not complex enough to exhibit a physiological pain response, or fear to such stimuli that is comparable to that of human understanding.[70] In Ted Kerasote's *Catch and Deny*, one individual claims that the potential death of the fish solely for enjoyment of the angler is unbearable. To catch a fish to eat is one thing, but to play with it for our own enjoyment is another. He also believed that science only cares about the group

[67] PETA. "Animal Rights Uncompromised: Catch-and-Release Fishing." 2020.
[68] Kerasote, Ted. "Catch and Deny." 2003.
[69] Rose, James D. "The Neurobehavioral Nature of Fishes and the Question of Awareness and Pain.", 2002.
[70] Ibid.

prosperity but neglects the individuals within populations, something he believes to be morally wrong and unethical.[71] While the possibility of death is a largely shared dislike of Catch and Release, many take the opposite viewpoint and view it as an opportunity to appreciate the hunt of a fish while maintaining a high chance of letting the fish live.

> *Of course Catch and Release is ethical, the thought of killing every fish you catch is actually the unethical part. Knowing that trout that are caught are able to go back and live and thrive and possibly grow smarter and more adaptive to their environment seems right.*[72]
> *-Joe Croteau, Colorado recreational angler*

Some believe fishing is a way to get closer, enjoy and respect nature. While many Catch and Release anglers want the fish to survive, death is a part of life and happens every day.[73] The justification of the morality or ethics of Catch and Release lies within the eye of the beholder. To some, the knowledge and experiences associated with the traditions of fishing while giving the fish a high chance to live are more than enough to continue the sport. Other find they should not hold themselves as having more value to the life of a living creature and thus cannot align their moral compass with the act of Catch and Release.

> *I think that when fished for properly, fish can be hooked in the part of their jaw that contains a lot of hard bone marrow / tough cartilage, and that there aren't a*

[71] Kerasote, Ted. "Catch and Deny." 2003.
[72] Croteau, Joe. "Recreational Angler Interview." By Nathan Stone (2020).
[73] Kerasote, Ted. "Catch and Deny." 2003.

lot of nerves there. Once the fish is brought to the net, it is important to wet your hand, keep the fish near the water and carefully remove the hook while minimizing the exposure the fish has to air. Following the correct procedures, catch and release is certainly ethical. The fish may feel some pain, but the sport of fishing isn't going anywhere anytime soon, so educating the public on how important proper catch and release techniques are to the longevity of the sport, and to the environment is going to be key.[74]

-Ben West, Colorado recreational angler

Either way, these values depend on the complex nature and experiences of individual human beings and thus cannot be give a definitive right or wrong answer**.**

Improving Catch and Release

One of the few things the scientific community had agreed upon with Catch and Release is that it can continue to be improved upon through more research, education and incorporation of future technologies. With varying rates of mortality between fish species, assuring anglers know how to give species within the Salmonidae family the best chance of survival is instrumental in Catch and Release success as a conservation method. Different fish ultimately have been found to have different tolerances to different variables such as air exposure, fight time, hook types, bait, etc.[75] Continued research followed by extensive educational outreach seems to be the best way to further lower mortality associated with Catch and Release. Continued research on the subcategories of Catch and Release such as hook type, air exposure,

[74] West, Benjamin. "Recreational Angler Interview." By Nathan Stone (2020).
[75] Bartholomew, Aaron, and James A. Bohnsack. "A Review of Catch-and-Release Angling Mortality", 2005.

etc. will also be needed for the many contradictory findings within different research projects. One potential yet seldomly explored potential is that of species-specific guidelines. Proposed regulations backed by research on certain species should be implemented within management plans to see if they are successful. Upon the analysis of the small-scale outcomes, regulations can be transitioned to large scale fisheries with the hope of further reducing the mortality of fish species that struggle under the "umbrella" guideline imposed by national government.[76]

Case Studies

The use of conservation assessments has been an instrumental part in stringing together many different and specific research topics involving the Salmonidae family. These assessments have been performed on many species to document and analyze their relative populations, conditions and security. Colorado was selected for this study due to its diverse landscapes and ecosystems as well as a state identity that incorporates the importance of fish both economically and culturally. The diversity of Colorado allows for findings to be applied in similar areas and with recreational fishing totaling over 800 million dollars through sales, licenses, and taxes fishing is undoubtably an important aspect of Colorado's culture.[77] Popular game fish in Colorado include Cutthroat trout (Greenback, Rio Grande, Colorado River), Rainbow trout, Brown trout, Brook trout, Lake trout, Kokanee Salmon, and Mountain Whitefish.[78] In this study, Conservation assessments of interest will be the Greenback Cutthroat and Rainbow trout. Greenback Cutthroat are an important fish to assess regarding the effectiveness of Catch and Release as a management plan due to their environmentally sensitive nature in addition to their

[76] Cooke, S.J., Suski, C.D. "Do We Need Species-Specific Guidelines?": *Biodivers Conserv* 14, 2005.
[77] Southwick Associates. "Economic Contributions of [illegible] Recreational Fishing: U.S. Congressional Districts." American Sportfishing Association, 2015.
[78] Colorado Fishing Network. "Species of Fish in Colorado.", 2020.

status as a threatened species.[79] Assessments on the Greenback Cutthroat includes background, threats, management techniques, and impacts of recreational fishing and harvest.[80] Rainbow trout were selected as another species of interest due to their popularity as a sportfish and their potential to reduce the numbers of native Greenback Cutthroat trout through hybridization. Similarly to the Greenback Cutthroat, conservation assessments for Rainbow Trout address background, threats, management techniques, and impacts of recreational fishing and harvest.[81]

Greenback Cutthroat

Figure 5. An illustration of a Greenback Cutthroat.[82]

The Greenback Cutthroat, the state fish of Colorado, was once distributed widely throughout Colorado and southeastern Wyoming.[83] These trout underwent a huge population decline throughout the 1800s with the arrival of Euro-American settlers due to commercial harvest, pollution from mining, redirected stream water for habitat, and introducing species of

[79] Young, Michael K. "Greenback Cutthroat Trout: A Technical Conservation Assessment.", 2009.
[80] Dare, Matthew, Michael Carrillo, and Clay Speas. "Cutthroat Trout (Oncorhynchus Clarkii) Species and Conservation Assessment for the Grand Mesa, Uncompahgre, and Gunnison National Forests." US Department of Agriculture, 2011; Young, Michael K. "Greenback Cutthroat Trout: A Technical Conservation Assessment.", 2009.
[81] Adams, Pauline, Christopher James, and Clay Speas. "Rainbow Trout" Department of Agriculture, 2008.
[82] Young, Michael K. "Greenback Cutthroat Trout: A Technical Conservation Assessment.", 2009.
[83] Ibid.

non-native gamefish, such as Rainbow, Brook, and Brown trout.[84] Because Greenback Cutthroat are a relatively understudied species compared to other members within the Salmonidae family, and because of past mistakes in conservation efforts (where Colorado River Cutthroat and Greenback Cutthroat were hybridized due to mis-identification of species), the true conservation status of these fish is under much debate.[85]

One of the largest threats to Greenback Cutthroat remains the introduction of non-native species. These non-native fish species can outcompete, prey on, or hybridize with Greenback populations.[86] Brook trout have been known to severely reduce the populations of Greenbacks in ecosystems where both reside, although the mechanism is unknown, and Rainbow trout are known to hybridize with Greenback Cutthroat leaving some populations unusable for breeding efforts relating to conservation due to genetic impurities.[87]

Along with non-native species, ecosystem disturbances both natural and anthropogenic are also cited as a huge threat for Greenback Cutthroat populations. Fragmented habitats due to thermal barriers, pollution, poorly fitted culverts, water diversion etc. have all contributed to the fragmented smaller populations of Greenback Cutthroat. The fragmentation of small populations leads to less adaptability to disturbance events as well as inbreeding which can lead to reductions of fitness and lack of genetic variability, both essential to the continued survival of the species.[88] Fires, droughts and floods will also impact habitat quality where Greenback cutthroat reside. Fires can lead directly to mortality through changes in water temperature and chemistry, however, post fire effects may be a bigger issue due to excess floods due to lack of vegetation,

[84] Ibid.
[85] Ibid.
[86] Ibid.
[87] Ibid.
[88] Ibid.

black water events, and debris torrents.[89] Because Greenback Cutthroat reside in smaller streams, droughts and variability in snowmelt could reduce streams and completely wipe out small populations.[90] These events will also increase in intensity and frequency as climate change events continue.[91]

Although overharvest was a huge part in the original decline of Greenback trout populations, there is no evidence that angling is contributing to population declines of Greenback Cutthroat.[92] Regulations, along with hard to reach populations and the smaller size of these fish, undoubtably lead to less mortality from angling.[93] Similar subspecies such as Yellowstone cutthroat have been caught an average of 9 times with no impacts on population sizes.[94] High angler activity can lead to habitat degradation, but these impacts are localized and also have little effect on population. The largest impact of anglers is likely the introduction of non-native species through illegal release to stock water with desired fish.[95]

While populations of Greenback Cutthroat have overall been increasing, leading to their status change from endangered to threatened, the distribution and migratory life that was once present before

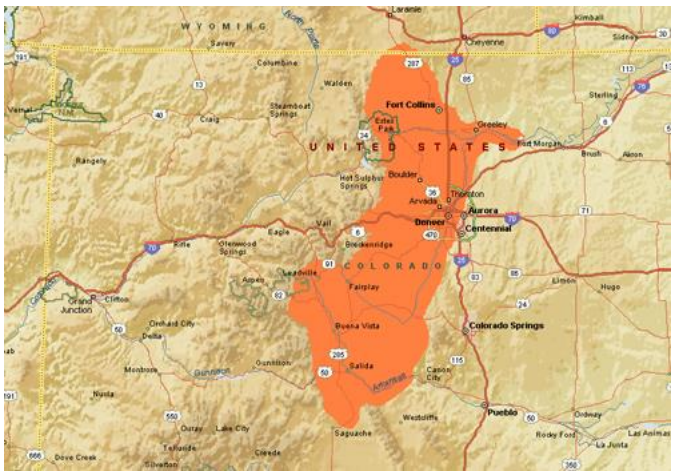

Figure 6.The native range of Greenback Cutthroat[96]

[89] Isaak, D. J. *et al.* "The Past as Prelude", Fisheries; Young, Michael K. "Greenback Cutthroat Trout: A Technical Conservation Assessment.", 2009.
[90] Ibid.
[91] Ibid.
[92] Young, Michael K. "Greenback Cutthroat Trout: A Technical Conservation Assessment.", 2009.
[93] Ibid.
[94] Ibid.
[95] Ibid.
[96] Native Trout Fly-Fishing. "Greenback Cutthroat." 2019. http://www.nativetroutflyfishing.com/greenbackcutthroat.htm.

the 1800's is impossible to restore due to severely fragmented habitats (Figure 6).[97] The status of Greenback Cutthroat is still at risk from non-native species and human activities allowing nonnative trout to invade, in addition to catastrophic environmental events that will only be increased with climate change.[98]

Regarding regulations and policy for fishing Greenback Cutthroat, Catch and Release is allowed for Greenback Cutthroat populations within the state of Colorado. All Greenback Cutthroat must be released using recommended Catch and Release practices, all hooks must be de-barbed, and the use of bait is forbidden regardless of age. Only artificial lures and flies can be used.[99] Allowing Greenback Cutthroat to be fished using Catch and Release has shown no effect on Greenback cutthroat populations. Ultimately, this allows for the increases in economic and conservation benefits mentioned earlier in this study that anglers provide for fisheries.[100]

> *Anglers play the most important role in conservation efforts. Purchasing a fishing or hunting license is what funds these conservation efforts and management of our natural resources. Colorado Parks and Wildlife for example, is almost entirely funded through the sale of fishing and hunting licenses and receives zero general tax dollars from the state government. Many other state natural resource management agencies are set up this way. Without these license dollars we could not pay for the conservation of imperiled species such as the*

[97] Ibid.
[98] Ibid.
[99] Colorado Secretary of State. "Code of Colorado Regulations." Colorado Secretary of State.
[100] Brownscombe, Jacob W. *et al.* "The Future of Recreational Fisheries" 2019; Pitman, Kara J. *et al.* "Linking Anglers, Fish, and Management in a Catch-and-Release Steelhead Trout Fishery." 2019.

Greenback Cutthroat Trout, nor could we operate our 19 state hatcheries that produce the fish anglers catch[101]

-Tyler Swarr, Aquatic Biologist for Colorado Parks and Wildlife

However, extensive educational outreach should aim to reduce angler impacts contributing to habitat degradation and introduction of non-native species, as these are the largest contributing factors of anglers to reduction of Greenback Cutthroat populations.[102]

To summarize, the main goals of conservation should be to continue increasing population sizes, favoring conservation of larger migratory populations as well as wild populations, and continuing to reduce habitat fragmentation and provide Greenback Cutthroat access to larger river networks as these will increase genetic variability and allow for more adaptability to changing climate/environmental events through continued evolution and access to refugia.[103] Additionally, incorporating educational outreach to anglers will allow continued economic gain and conservation efforts while maintaining Greenback Cutthroat populations. Lastly, maintaining the native species within certain relatively static water basins and lakes will allow for less possibility for losing the genome of Greenback Cutthroats as they are less affected by threats due to their isolation and static nature when compared to upper reaches of rivers.[104]

[101] Swarr, Tyler. "Parks and Wildlife Interview." By Nathan Stone (2020).
[102] Young, Michael K. "Greenback Cutthroat Trout: A Technical Conservation Assessment.", 2009.
[103] Ibid.
[104] Ibid.

Rainbow Trout

Figure 7. An illustration of a Rainbow trout.[105]

Rainbow trout are a popular game fish throughout the world. They are native to the Pacific Ocean tributaries along the west coast of Canada, the United States and Mexico as well as along the eastern coats of Asia.[106] They have since been introduced around the world and have proliferated with great success across the United States, making them one of the most successful game fish species of trout within the US.

The main threats to Rainbow trout are anthropogenic activities and Whirling disease.[108] Humans contribute greatly to reductions of Rainbow trout through habitat fragmentation and degradation through water development and diversion, man-made barriers such as culverts and dams, and livestock waste and trampling in riparian areas.[109] Angling pressure has also been cited as an activity the reduces Rainbow trout populations through angler stress and harvest; however stocking efforts can often

Figure 8. A Rainbow Trout with Whirling disease.[107]

[105] Iowa Department of Natural Resources. "Rainbow Trout." 2020.
[106] Adams, Pauline, Christopher James, and Clay Speas. "Rainbow Trout" Department of Agriculture, 2008.
[107] SunCruiser Media. "Trout Whirling Disease Found in Alberta." 2016.
[108] Ibid.
[109] Ibid.

largely reduce these impacts.[110] Whirling disease is a parasite that causes deformities of bones in the tail region and disrupts neurological activity causing the fish to be unable to swim properly and eventually leading to death (Figure 8), where the parasite is then released and spreads to other fish.[111] This is a prominent disease in hatcheries and the potential to transfer the disease to wild populations has been recognized as a significant threat. Reduced flows, increased water temperatures and increased sediment are all positively correlated with infection of Whirling disease and could become more prevalent as issues with habitat fragmentation and degradation become more prevalent.[112] Preventing infected fisheries from stocking Rainbow trout fry with Whirling disease should be of utmost importance to preserving Rainbow trout populations.

While Rainbow trout do face some problems regarding their conservation, there are many populations of self-sustaining Rainbow trout populations. These populations are often resistant to environmental fluctuations, and although populations of Rainbow trout can fluctuate due to environmental events, the general trend of Rainbow trout population is maintaining or increasing.[113] In more localized areas where populations declines are great, stocking fish, so long as they don't have Whirling disease, has been shown to be an effective measure to re-establishing healthy populations.[114]

Regulations for Rainbow trout within the state of Colorado include a daily bag limit of 4 fish; Catch and Release fishing is not required and completely dependent on anglers voluntarily doing so. There are no regulations on hook use or use of bait.[115] Catch and Release, in a sense,

[110] Ibid.
[111] Department of the Interior. "Whirling Disease." Department of the Interior, 2020.
[112] Adams, Pauline, Christopher James, and Clay Speas. "Rainbow Trout" Department of Agriculture, 2008.
[113] Ibid.
[114] Ibid.
[115] Colorado Secretary of State. "Code of Colorado Regulations." Colorado Secretary of State.

does not contribute largely to the management of Rainbow trout unless regulations are put on local areas where population levels are trying to be recovered.

Overall, populations of Rainbow trout are largely viable and self-sustaining largely due to management of fisheries and widespread populations (Figure 9), angling provide a very minimal threat to the resource.[117] However, Rainbow Trout do face some serious threats from anthropogenic activities that will require continued surveying and management. Additionally, Rainbow trout will need to be managed due to their hybridization with native populations of Greenback Cutthroat.[118] Outreach for education and incorporation of anglers to raise awareness around environmental problems that pose a threat to Rainbow trout populations could provide less dependence on fishery stocking through increasing self-sustainable populations of Rainbow trout. Because some populations of Rainbow trout will continue to rely on stocking efforts, increased surveying and testing for whirling disease will be needed.[119] Further educating anglers to prevent release of Rainbow trout within native Greenback ecosystems, and perhaps mandating catch and kill regulations for non-native species (such as Rainbow Trout) in lower segments of rivers where Greenbacks are present, could help

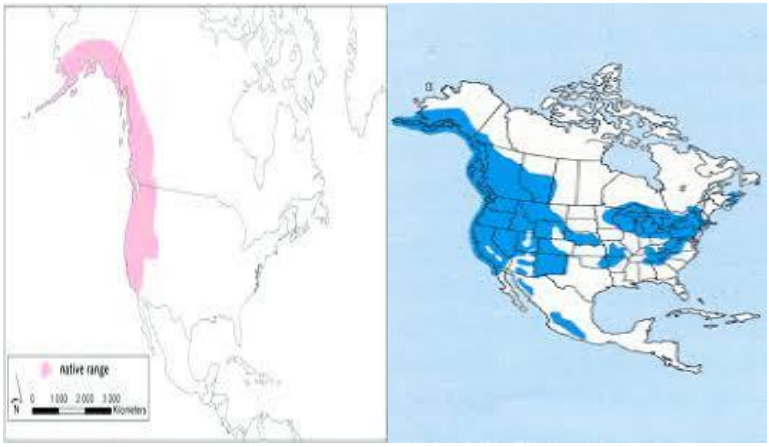

Figure 9. The native range of Rainbow Trout in North America (left) compared to their native AND introduced range in North America (right).[116]

[116] Missouri Scenic Rivers. "Rainbow Trout Facts."; Soes, Menno. "The Native Range of the Rainbow Trout within North America.", ResearchGate.
[117] Adams, Pauline, Christopher James, and Clay Speas. "Rainbow Trout" Department of Agriculture, 2008.
[118] Young, Michael K. "Greenback Cutthroat Trout: A Technical Conservation Assessment.", 2009.
[119] Adams, Pauline, Christopher James, and Clay Speas. "Rainbow Trout" Department of Agriculture, 2008.

prevent the hybridization between the two species. This is likely a good strategy as catch and kill regulations will have little impact on the overall populations and conservation of Rainbow trout.

Comparison of Case Studies

Catch and Release appeared to have little impact on Greenback populations, associated with the relatively low mortality rates of Catch and Release. These mortality rates were also hypothesized to be lower due to the geographic isolation of areas in which Greenback Cutthroat reside, relative size of the species, and regulations imposed for Catch and Release techniques.[120] Rainbow trout are less often managed with Catch and Release due to relatively high and prosperous populations across the United States. In terms of management, a daily bag limit of four has been considered to be a sustainable harvest and thus an effective management practice for Rainbow trout if the angler chooses to keep fish. This being said, Catch and Release only regulations could always be implemented in local areas where populations are low, and fisheries want to try to move away from stocking efforts. As mentioned within the case studies, Rainbow trout can negatively impact native Greenback Cutthroat Populations within Colorado through hybridizing with them. One proposed strategy for management could include mandatory catch and kill regulations for Rainbow trout in water bodies where both species are found. This could help Native populations while ultimately having little impacts on the overall populations of Rainbow trout.

Overall, Catch and Release angling was described as having minimal to no impact on populations for both Rainbow trout and Greenback Cutthroat. Incorporating the ability for

[120] Young, Michael K. "Greenback Cutthroat Trout: A Technical Conservation Assessment.", 2009.

anglers to fish for a species can lead to both economic benefits and increased resources for conservation.

> *The ability for anglers to capture and interact with an imperiled species most definitely increases public appreciation and understanding of these imperiled species. Furthered appreciation, whether it is through angling, documentaries, environmental interpretation, etc. of/on imperiled species is paramount to garnering support for conservation actions in the political arena and on the ground with local communities.*[121]
> *-Tyler Swarr, Aquatic Biologist for Colorado Parks and Wildlife*

Rainbow trout populations, despite natural fluctuations, have been documented to be increasing or at minimum sustained. Greenback Cutthroat, on the other hand, have had some success in increasing populations due to management strategies but are still in isolated and fragmented populations that still have a high chance of decreasing in the future. Both case studies addressed angling as has having minimal impacts to both Rainbow and Greenback trout populations. For the conservation of the native Greenback Cutthroat, the continuation of Catch and Release regulations in addition to implementation of catch and kill for Rainbow (or other non-native) trout within the area may be a more beneficial conservation strategy as the population of Rainbow trout will not be greatly impacted while the populations of Greenback Cutthroat will likely improve upon removal of its competition and possibility of hybridizing.

[121] Swarr, Tyler. "Parks and Wildlife Interview." By Nathan Stone (2020).

The benefits provided by anglers as an economic driver and tool for conservation strategies outweigh the very low chance of mortality that is associated with Catch and Release fishing. Continued research on reducing mortality rates from Catch and Release fishing in addition to continued educational outreach will further improve the benefits Catch and Release has as a conservation method.

Conclusion

In summary, for the species of Salmonidae studied within Colorado, it is supported that Catch and Release acts as a successful conservation method for struggling fish species. With native Greenback Cutthroat serving as a comparison, Catch and Release benefits conservation processes and implementation while having minimum impact to fish species. This being said, Catch and Release must be used in tandem with other conservation efforts such as land management, habitat restoration, educational outreach, and further research to continually minimize mortality rates on struggling population. Additionally, catch and kill regulations are suggested to be implemented in areas where they could reduce native populations due to the positive impact it would have on the native species and the low impact it would have on invading species, assuming that their populations do not have a massive decrease in the future and maintain self-sufficient. No Take Reserves could also become an implemented strategy to maintain and protect areas where genetic variability of a threatened population is high and used as a means to repopulate other ecosystems. My personal suggestions for improvement on Catch and Release fishing involves further education and research on Catch and Release techniques to further reduce fish mortality, implementing catch and kill regulations for species that effect threatened or native species, so long as they have sufficient populations elsewhere, and creating

species specific practices for struggling fish species where mortality is higher under the general Catch and Release protocols.

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