Your Catch of the Day Could be Your Catch Next Week: Anglers' Interactions with the Trout Populations of Northeast Colorado

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Abstract

This research project is an analysis of catch-and-release fishing near Boulder, Colorado. Catch-and-release is a conservation practice, common among anglers, which requires anglers to return fish to the water after capture with no harm done or as little harm as possible. This study focuses on voluntary catch-and-release during fly fishing. The first research question is: What are the conservation effects of catch-and-release angling on healthy trout populations? The methods employed to answer this question involved reviewing past literature and studies on catch-and-release for various trout populations. This review showed that there are remarkable inconsistencies in research methods and results. Further investigation is needed to observe how to best practice catch-and-release for specific species. The second research questions asked, how does the angling population of Boulder, CO view and practice catch-and-release fishing, and can they identify the native trout populations in Colorado? To answer this question, a survey was conducted for the anglers in Boulder. 149 usable responses were received. The results indicated that although several respondents knew the correct practices and techniques, there is further need and desire for an increase in the dissemination of scientific findings to the public regarding the best catch-and-release practices.

Preface

Catch-and-release angling is an ethic that has been instilled in me since I was young. I grew up fishing with a spinning rod and recently took up fly fishing. My father has been fly fishing most of his life, and he wanted my brother and me to take up his passion. Even when using a spinning rod, my father always preached catch-and-release because of the conservation effects and the general fisherman's ethic that you see in many seasoned anglers. While discussing this practice with other friends and family, I noticed that there seemed to be a disconnect between people who practice catch-and-release and people who do not. I also observed that everyone had different ideas of what the best practices for catch-and-release were. This disconnect led me to inquire if catch-and-release, as a conservation practice, was being utilized to the best extent, and how policy and education were impacting this. This inquiry is where my ideas for this project initially developed.

A large number of people helped me through this project, and they all deserve the highest praise. I would like to thank both my parents for helping me through this process and giving me the opportunity to do a thesis in the first place. I also owe a lot to everyone in my life that has contributed to my interest in fly fishing and the outdoors in general. In particular, I want to thank my father for instilling in me a passion for the environment. I would like to give my sincerest gratitude to my thesis committee who were all immensely helpful in this extensive process. Daniel Sturgis, my primary advisor, helped me develop my thesis into an actual researchable project. I came to him with an undeveloped idea to research catch-and-release fly fishing, and without much hesitation, he agreed to mentor me through the process. He not only assisted me with the writing but also expanded my local knowledge of fly fishing because of his vast fly fishing experience. Dale Miller, from the Environmental Studies department, helped me to stay on track through both semesters of intense work. He also assisted me in structuring my paper and staying sane throughout the entirety of this project. I cannot thank Dale enough for the immense help and always being available for any question or concern even with his hectic schedule. Stacey Schulte has been an enormous help with the development of my survey and the initial IRB proposal. Both of these were completely new processes for me, and I would have been lost without Stacey's assistance. She also helped me develop my data into useful statistics that can be analyzed and discussed. Andrew Martin, from the Ecology and Evolutionary Biology department, has extensive knowledge about the native fish in the region. He not only provided me with key resources that aided my research, but he also offered an enthusiasm for my project that I greatly appreciated. Last but not least, I would like to acknowledge and thank all the other faculty members that met with me and helped in the progression of my thesis. I could not have successfully completed this project without the enormous amount of help from all of you.

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Introduction

I am exploring the practice of catch-and-release fishing and anglers' interactions with the conservation strategy. Although this topic is extensively researched, I observed the anglers' views along with the overall conservation effects and practices associated with catch-and-release trout fishing. I generalized this data to make a claim about the value of catch-and-release as a method of conservation after reviewing the practice in Boulder, CO. General claims are less common in this field, and there is no published research on this topic within the City of Boulder. I analyzed the current status of catch-and-release in Colorado, specifically on the trout populations. My focus is on fly fishing because fly fishing culture is associated with catch-and-release ethics more so than other forms of fishing. I also centered my attention around voluntary catch-and-release with a small emphasis on local regulations in Boulder, Colorado related to native versus non-native trout.

The scope of my research is separated into two different segments. In the first section, I analyzed the question: What are the conservation effects of catch-and-release angling on healthy trout populations? This analysis will be in the form of a review of how effective catch-and-release is as a practice, and the research methods employed to study it. Recently, there have been many studies observing biological effects of catch-and-release angling. In my research, I reviewed these studies, and make educated generalizations and recommendations. Then I collected data through a survey administered throughout the City of Boulder. This survey answers the question: How does the angling population of Boulder, CO view and practice catch-and-release fishing, and can they identify the native trout populations in Colorado? The City of Boulder is an ideal population because of the abundance of fishing opportunities within the city limits and just outside. Since Boulder is notorious for being an outdoor recreation epicenter, there are a significant number of anglers in the city. This provides an excellent opportunity for data collection. I hypothesized that different demographics will have different catch-and-release practices and ethics. The information I collected will be important for the future of catch-and-release conservation within Boulder and extended into the rest of Colorado. Government agencies, fishery managers, conservationist, and even avid anglers can use these findings to further the battle to maintain healthy trout populations in Colorado. Being informed on why, how, and by who catch-and-release is practiced, in addition to the review of the effectiveness of catch-and-release as a management tool for trout populations can be extremely useful in further dissemination of the conservation practice. This study aims to show that the current knowledge of catch-and-release is insufficient for the proper practice of the conservation method. My goal is to enhance the further understanding of catch-and-release angling in Boulder, Colorado.

Background

To comprehend the full scope of my project, there are some fundamental concepts that shape the understanding of the current state of catch-and-release fishing and anglers' acceptance. Some key themes that will be necessary for understanding are the history of fishing within the United States, specifically fly fishing, the definition of catch-and-release and how it has evolved, significant information regarding the trout populations in Colorado, and a review of the previous literature relevant to this topic.

History of Fishing

Fishing, as we know it, has a history dating back to 50,000 years ago when people first began using hooks to catch fish for food (Arlinghaus et al., 2007). Homer wrote of men "wandering with barbed hooks, in quest of game" (Goodspeed, 1939, p. 4). During this time a writer wrote, "men seldom hunted and fished for mere pleasure" (4). Although these texts indicate fishing was one of the oldest human professions, the forms and techniques that we are accustomed to today did not develop until much later. Simple recreational fishing was the first derivation towards our current fishing practices. Recreational fishing is defined as fishing that is "not motivated by personal consumption, sale, or trade" (Snyder, 2016, p. 6). The first historical evidence of recreational fishing is seen in an image of an Egyptian noble dated 3,290 years ago (Snyder, 2016). This image depicts a man sitting down while holding what looks like an earlier form of a modern fishing rod. He is overlooking a stream full of various species of fish. Recreational fishing has evolved significantly since this first depiction.

There is evidence of recreational fishing in a variety of different civilizations, but the direct line to recreational fishing in North America stems from Europe, specifically England (Arlinghaus et al., 2007). Past European writing and literature is our strongest basis to analyze the evolution of western angling. In 1307, *The County Farm* mentioned that there is a time and a season that is "fittest for the sport" (Snyder, 2016, p. 7). In this case, 'sport' is actually a derivative of the word disport, which means "to take one's ease" (Arlinghaus et al., 2007, p. 81). The term sport fishing is now typically only used when describing tournament or competitive fishing (Arlinghaus et al., 2007). The first ever recreational fishing text was the *Heidelberg Fishing Tract* "How to Catch a Fish," which was written by Jacob Koebel in 1493 (Snyder, 2016). Since then, European fishing has made its way into North America. In 1612, Alexander Whitaker wrote about the abundance of fish in the rivers of Virginia five years after the settlement of Jamestown. It is undetermined if Whitaker fished for pleasure, but he mentions fishing for a variety of fish. He also observes that the Native Americans had different methods for fishing that did not include the angling technique most common today (Goodspeed, 1939). Since this initial European arrival, angling has evolved in America, and fly fishing is one of the evolutions that we have seen grow substantially.

History of fly fishing

Fly fishing is a form of angling "where the weight of the line is used to cast a very light weight fly that would not be heavy enough to be cast with a conventional spinning or casting rod" (Fly Fishers International). Fly fishing was first reported around 1,800 years ago in Macedonia (Snyder, 2016). It came to the United States much later. Fly fishing in the United States started during the late colonial era, and the practice was brought to America by British elite. It was first established in Pennsylvania, New England, and Upstate New York. In the 1870s, fly fishing started to expand to the western United States. In the western states, the culture of fly fishing was vastly different. It was viewed as less of a gentlemen's only sport and was becoming an accessible sport for men and women of various status. Until the mid-1930s, the western hub for fly fishing was located in California and the Pacific Northwest. It began to become more common in the Rocky Mountain region when avid fly fishermen began to promote the trout-filled waters through business and guiding. In the 1970s, the sport became more accessible to the middle-class population and novices due to the increase in leisure time, better technology, and the growing interest in outdoor recreation. This period was known as the fly fishing boom. With the increase in participation, the discussion about wilderness ethic and conservation practices became more prominent. One of the key players in this rhetoric was Ted Trueblood. He was one of the first writers to promote catch-and-release fishing in the 1950s, and it was widely accepted by outdoors writers later in the 1970s. Before the Environmental Movement in the 1970s, there was very little regulation on hazardous activities such as mining, agriculture, and urban development. Many notorious fly fishers, including Dan Bailey, Bud Lilly, and Joe Brooks, began advocating for the natural environment, and this led to the implementation of regulatory practices by state and federal agencies. These regulations include "fly fishing only" areas, limited or no-take rules, and the angler's ethic of catch-and-release (Owens, 2002).

Angling Ethics

Although the historical timeline of fly fishing in the United States is extremely important for the understanding of the activity's evolution, it is also important to know how the fly fishing ethic in the US evolved to where it is now. Fly fishing has been celebrated by generations of anglers "because it refreshes, restores, and recreates the soul" (Snyder, 2016, p. 7). The famed line "there was no clear line between religion and fly fishing," from Norman Maclean's *A River Runs Through It,* is just one of many examples of the extreme beliefs that many constituents of the sport have (Maclean, 1976, p. 1). There is also a history of pretentiousness associated with fly fishing. The claim of spirituality within the fly fishing community has been linked to the "elitism, snobbery, and idolatry" often associated with the sport (Snyder, 2016, p. 7). This perception of fly fishing is imperative to the understanding of the evolution of catch-and-release, and the ethics associated with the practice.

The ethics surrounding angling have been developing over centuries. Specifically, catch-and-release has had an interesting transition through time regarding anglers' perception. There are recreational fishing areas where voluntary catch-and-release reaches 100%, and this implies that anglers practice catch-and-release for more reasons than simply to abide by the law (Cooke & Suski, 2005). Catch-and-release ethics are an extension of fly fishing ethics that surround conservation. Catch-and-release was one of the earliest environmental ethics and was touted by the "father of fish culture" Seth Green and his son along with the use of barbless hooks in the 1870s (Snyder, 2016). "In North America, many tout Lee Wulff as the father of catch-and-release for his statement in 1939 that 'game fish are too valuable to only be caught once'" (8). There is an expansive history of catch-and-release as a practice. The initial fishermen responsible for the introduction of the catch-and-release ethic in the west includes, but are not limited to, Trueblood, Lilly, Bailey, and Brooks (Owens, 2002). Since this time, the catch-and-release ethic has evolved in many ways and is a common practice among a majority of fly fisherman in the United States.

Catch-and-Release fishing

Catch-and-release is such a common fly fishing ethic that one can even observe it being preached on license-plate frames and bumper stickers. It is more complicated than the simple definition one can probably infer, and the history of catch-and-release as both a conservation practice and an angler's code has led to its status as one of the most common regulations for fishery management.

Definition

Catch-and-release fishing is the act of catching a fish and proceeding to release it back into the water it came from with no harm done to the fish or as little harm as possible. There are three different forms of catch-and-release. The first form is total catch-and-release. Total catch-and-release means that every fish caught must be released with no harm done (Arlinghaus et al., 2007). This is evident in places where there is an extreme overfishing problem or a vulnerable population of fish. Some examples of fishing areas in Colorado where all fish must be released immediately after they are caught are Los Pinos Creek, Jerry Creek Reservoirs, and a section of the South Platte River (CPW, 2017). The second form is known as regulatory catch-and-release, and this refers to releasing the fish based on regulations such as bag limits, protected season, protected species, length-based limits, etc. This form is prevalent in the United States and has been crucial in the maintenance of healthy fisheries (Arlinghaus et al., 2007). There are examples of regulatory catch-and-release within Boulder, CO. Boulder Creek requires a mandatory release of all trout immediately after the catch (CPW, 2017). This law is an example of species-specific regulatory catch-and-release. Lastly, voluntary catch-and-release is when it is the angler's decision on whether or not they want to release the fish. Often there are two mechanisms of reasoning for why people perform voluntary catch-and-release. The first is the non-consumptive method which refers to people who release the fish for conservation reasons and for the sake of the fish. The second is the consumptive method which refers to people who release the fish for the opportunity of recapture (Arlinghaus et al., 2007). These are typically the two reasons for the practice of voluntary catch-and-release, but a strict angler's ethic or code is also referenced as a contributing reason for the current practice (Rahel, 2008). The development of catch-and-release as a conservation practice, consumptive method, and ethic has a history that dates back to the fifteenth century in Europe (Snyder, 2016).

History of Catch-and-Release

The first evidence of catch-and-release fishing in writing was in the Ploughman Stories. In these stories, Dame Juliana Berners made the argument that people should be fishing a conservative harvest in order to maintain the fishery resources. Berners is a celebrated as one of fly fishing's ancestors, but it is still questioned if she is a mythical figure. Either way, she is who we attribute the beginning of conservative fishing methods to back in 1496 (Snyder, 2016). Following Berners, the next notable figure to move towards a conservative fishing approach through the lens of catch-and-release was Charles II in 1671. He enacted The Game Act of 1671 during his rule. This law restricted the amount of fish, and the size of the fish one was able to keep (Snyder, 2016). This was the first evidence of what we now call a bag limit and size restrictions. Following the Game Act, the evolution of voluntary catch-and-release became more associated with an angler's rhetoric. In 1821, Sir Humphrey Davy stated that "every good angler, as soon as his fish is landed, either destroys his life immediately, if he is wanted for food, or returns him to the water" (8). Similar to Davy's claim, "in 1913, Frederick Halford noted that 'the sportsman is not only willing to return any fish below legal limit to the water but exercises great care both in extracting the hook and returning the fish to the water'" (8). This is only a brief review of the origins of the practice. Catch-and-release is a dynamic topic that frequently evolves with the introduction of new techniques, technologies, and changes in perception. To understand the current status of catch-and-release in the United States, specifically in Boulder, one must understand how and why catch-and-release is implemented and practiced.

Current Status

"Catch-and-release regulations in recreational fisheries have evolved over the last 20 years into a key tool used by management agencies to reduce fishing mortality and help rebuild depleted stocks of both marine and freshwater sportfish species" (Pollock & Pine, 2007, p. 123). Currently, 60-65% of fish caught in the United States are believed to be released (Cooke and Schramm, 2007; Arlinghaus et al., 2007). Although these numbers indicate that the majority of fish caught are released, the lethal and sub-lethal effects of improper techniques are currently of concern. The present goal of catch-and-release is to make the practice sustainable through the education of the anglers and the application of the best angling practices (Brownscombe et al., 2017). These practices are universally agreed upon by scientist, but not by the fishery agencies publishing the guidelines (Pelletier, Hanson, & Cooke, 2007). Brownscombe et al. (2017) believe that in order for catch-and-release to be sustainable, "it is the responsibility of management agencies and the scientists to communicate and evaluate the best angling practices, while anglers need to be educated and use the correct tools and tactics to maximize the likelihood that released fish survive" (703). There are specific practices that are not universally agreed upon in the angling community.

There are four specific practices that are commonly misunderstood or improperly practiced by anglers. The first is the time one should allow the fish to be exposed to air. This is not well known among the fishing community. Scientists have stated that the fish should actually never be exposed to the air. Taking the fish out of the water can induce stress, which can lead to lethal and non-lethal effects related to population dynamics, reproductive health, and food acquisition (Pelletier, Hanson, & Cooke, 2007: Ferguson & Tufts, 1992). Many fishermen are conflicted because they want to photograph their catch, or they do not believe it ‘counts’ unless they remove the fish from the water. Another handling method that none of the state fishing agencies mentioned was the danger of holding a fish vertically. When you bring a fish out of the water, there is an immediate change in gravitational pull, and if they are held vertically, the gravity can cause permanent damage to vital organs. It is crucial to hold the fish horizontal with wet hands if there is a need for handling (Pelletier, Hanson, & Cooke, 2007). A third misconception is what to do when the hook is deeply embedded in the fish. The correct technique is to cut the line. Ninety percent of the agencies recommended taking this measure, but many anglers instinctively try to remove the hook from the fish. In a study observing fish survival, they compared fish that were dehooked to fish where the hooks were not removed. The survival rate was 18% greater in the fish whose hooks were not removed (Pelletier, Hanson, & Cooke, 2007). Overall, the understanding of proper catch-and-release techniques still needs to be diffused into the larger angling community, and the fishery agencies need to create guidelines in accordance to scientifically agreed upon procedures.

State implemented catch-and-release regulations

In Boulder and the neighboring fishing areas, there are a variety of catch-and-release regulations. Although the focus of this research is on voluntary catch-and-release, it is still necessary to understand the restrictions currently in place. These regulations give an idea of how the government agencies use catch-and-release as a conservation approach for fishery management. Figure 1 shows how these regulations are often displayed to the public. Colorado Parks and Wildlife (2017) published an angling guide for the 2017-2018 fishing season. This guide outlines all the restrictions for the different fishing destinations in Colorado. For Boulder Creek, which is the most popular fishing destination in Boulder, all trout must be returned to the water immediately when you are within the city limits. For Button Rock Reservoir, there is a bag limit of two trout, and there is a designated fishing season in the summer months. In Como Creek, which connects with Boulder Creek, fishing is strictly prohibited. There are also statewide restrictions for trout. With regard to bag limits and possession limits, there are specifications for different trout. A daily bag limit refers to the amount of fish from a particular species you are able to catch and keep each day. A possession limit is the amount of fish one angler is allowed to have at a time. This includes in the field, in transport, at home, or in storage. For all the trout species, the daily bag limit is four, and the possession limit is eight. The only outliers are the brook trout and the greenback cutthroat. Greenback cutthroat must be returned to the water immediately. For brook trout eight inches long or less, the bag limit is ten, and the possession limit is also ten (Harlan, 2017). The regulations vary between water system, but they are very important to know when fishing in Colorado.

Figure 1: Photograph of catch-and-release guidelines in Estes Park, CO

Trout Species in Colorado

Overall, there are five species of trout commonly found in Colorado water systems. This includes the rainbow trout, brook trout, brown trout, lake trout, and the cutthroat trout. The rainbow, brook, brown, and cutthroat are all found in common habitats throughout the state, while the lake trout is typically only found in mountain lakes, and in deeper water. The cutthroat trout are the only native trout species within Colorado, and there are three subspecies in the state (Colorado Parks & Wildlife (CPW)). Although there are characteristics that distinguish the trout species from one another, there are a large number of hybridizations between them that have led to subspecies and various deviations into various lineages (Behnke, 1992). This is primarily due to the trout stocking and hatchery development that began in the late 1800s (Wiltzius, 1985). In this review of the trout in Colorado, the descriptions will remain true to the species.

Rainbow trout

The rainbow trout, *Oncorhynchus mykiss,* were first introduced to Colorado in 1882 by fish culturists from California (CPW; Wiltzius, 1985). They were initially introduced by Spencer Baird, the first U.S. commissioner of Fish and Fisheries, who shipped them to Colorado applicants or culturists. Among these culturists was William Sisty, Colorado's first Fish Commissioner, and Sisty is attributed with being responsible for the initial introduction of rainbow trout to Colorado (Wiltzius, 1985). Since their initial introduction, they have been a highly sought-after sport fish in the entirety of the United States (CPW). They are cold water fish and are typically found in streams, rivers, and lakes. Their native range is from Alaska to Mexico and Northeast Asia, but they have been widely introduced all over the world (The Dorling

Kindersley encyclopedia of fishing, 2010; Cooke & Suski, 2005). This range includes British Columbia, Washington, Oregon, California, Idaho, and Nevada. The native rainbows are typically west of the Cascade Mountains (Staley & Mueller, 2000). Colorado is not within the rainbow trout's native range, but they have been in the state for over a century. Rainbow trout were introduced to Colorado for sport fishing purposes.

Brook trout

Brook trout, *Salvelinus fontinalis,* are different from the other trout species common to Colorado waters because they are from a different genus. Although they are still salmonids, they are from the genus Salvelinus. Their native range is northeastern North America (The Dorling Kindersley encyclopedia of fishing, 2010). The first evidence of brook trout in Colorado was in 1872, making them the first non-native trout to be introduced to the state of Colorado. The initial introduction was done by James Broadwell, a former Denver mayor and hotel owner, who obtained 10,000 brook trout eggs from facilities in Boscobel, Wisconsin. He proceeded to hatch them on the South Platte River. This initial introduction of brook trout opened the door for many other men in the state to do the same thing (Wiltzius, 1985). Although brook trout are invasive species in Colorado, they are highly conserved in their native range (Detar et al., 2014).

Brown trout

Brown trout, *Salmo trutta,* along with rainbow trout are the most important gamefish in the United States due to their distribution. Brown trout are not native to North America. Their native range is from Norway to North Africa and Ireland to Russia, so they span most of Europe. These carnivorous fish were introduced into Colorado in 1885, making them the last of the invasive trout species to enter Colorado waterways (The Dorling Kindersley encyclopedia of fishing, 2010). They were first introduced by General John Peirce, an ex-Surveyor General of Colorado, as eggs in the Denver area. He operated four private fish hatcheries, and he hatched the first brown trout population in his Lake Archer Fish Co. facility located in Denver (Wiltzius, 1985). Brown trout are found in various ecosystems from high mountain streams to broad rivers (CPW).

Cutthroat trout

There are three subspecies of cutthroat in the state of Colorado: the Colorado River cutthroat, the Rio Grande cutthroat, and the greenback cutthroat. These three species are the only trout that are native to the region, and because of this, they have been a target for some of the states' most intensive conservation programs. Though they all have similar ranges and characteristics, there are key distinctions we can use to decipher between them. The greenback cutthroat trout is the only one of these three species that occupies the target region of the Boulder area, but it is important to have an understanding of all the native trout of Colorado, and their interactions with the invasive trout species (Behnke, 1992).

Colorado River cutthroat

The Colorado River cutthroat trout, *Oncorhynchus clarkii pleuriticus,* were historically found in portions of the Colorado River drainage in the states of Colorado, Wyoming, and Utah.

Recently, the species was discovered to be separated into two lineages (CPW). “Colorado River cutthroat evolved in isolation from rainbow and other trout” according to Behnke (1992, p. 42). He continues to explain that because of this isolation, they proceeded to hybridize with rainbows and get outcompeted by brook and brown trout. Hybridizations are a standard issue for all the cutthroat trout in Colorado. Currently, pure populations of Colorado River cutthroat trout are extremely intermittent in their native range (Behnke, 1992). The conservation efforts for the Colorado River cutthroat began in 2006 on a state level with the 2006 Conservation Agreement for Colorado River Cutthroat (CPW). The next native trout of concern is the Rio Grande cutthroat.

Rio Grande cutthroat

The Rio Grande cutthroat trout, *Oncorhynchus clarkii virginalis,* is found in high elevation streams and lakes, which is similar the other trout species of Colorado (CPW). They differ from the other two cutthroat species in Colorado because they have fewer scales and irregular spots on the caudal peduncle (Behnke, 1992), and they have the southernmost distribution. The Rio Grande cutthroat range has been dramatically reduced because of hybridization with rainbow trout and other cutthroat species, habitat changes, and competition with alien species like brook and brown trout (CPW). In 2003, the state, federal, and tribal representatives signed the legislation for the first conservation efforts for the Rio Grande cutthroat, and the conservation of this species is still ongoing (CPW).

Greenback cutthroat

The greenback cutthroat trout, *Oncorhynchus clarkii stomias,* is the official state fish of Colorado. The conservational history of the greenback cutthroat has been unstable. In fact, in 1937, they were thought to be extinct due to habitat loss, overfishing, and invasive species introductions. However, a pure population was found by a group of students, in the 1950s, east of the Continental Divide (Coleman, 2007; Love and Martin, 2016). They were listed as endangered in 1973, and their status changed to threatened in 1978 (Coleman, 2007). Overall, the greenback cutthroats are viewed as a conservation success story (Love and Martin, 2016).

Greenbacks are found in conditions similar to other salmonid species (Coleman, 2007). Experimental stocking has provided us with information on the elevation requirements of the current populations of greenbacks. The highest productive population is at 3,402 meters, and the lowest is at 1,420 meters (Coleman, 2007). A group of scientists observing the greenbacks raised a problem when they found that many of the fish were actually hybrids or belonged to a separate lineage (Love and Martin, 2016). The conservation of the greenback cutthroat trout is still ongoing, and catch-and-release guidelines have been instrumental in preserving the species.

Literature Review

Catch-and-release fishing has been thoroughly studied by the scientific community as well as the through an ethical lens. With the evolution of the practice, more researchers have taken an interest in observing the biological impacts on fish species. According to Rahel (2008), there are three reasons for why we conserve fish. These reasons are utilitarian, ecological, and ethical and religious. The utilitarian reason refers to conserving fish because we like to eat them, the potential for a fish to be instrumental in curing a disease like cancer, or to continue the sport

(Rahel, 2008). This is a strictly anthropocentric view, but it drives a lot of the conservation efforts that go into protecting fisheries, especially trout fisheries. The ecological reason is a recognizable approach that is paramount in preservation. Many scientists have done extensive studies observing the ecological effects of conservation techniques on the fish and their ecosystems. Lastly, the ethical and religious reasons relate to the angler's ethic that many seasoned fishers abide by. All of these motives are important to consider when studying catch-and-release angling.

Previous studies on the lethal and sublethal effects of catch-and-release fishing

The effects of catch-and-release fishing on trout individuals and populations have been reviewed by many scientists through a variety of techniques. Although the consequences are not drastically different for the different trout species, it is important to acknowledge that some are more resilient than others. The lethal effects of catch-and-release are thoroughly studied, but sublethal effects are far less researched (Pope, Wilde, & Knabe, 2007). Both the lethal and sublethal impacts of catch-and-release fishing on trout are important for reviewing the effectiveness of the conservation practice as a whole.

Through a collection of numerous studies and data collection techniques, Pollock and Pine (2007) capture the various options researchers have when observing the biological impacts of catch-and-release angling. Due to the increase in catch-and-release practice and regulation, research on the potential biological effects, in particular, the mortality rates, of catch-and-release are essential in the observation of the practice as a management tool. In order to assess catch-and-release mortality, Pollock and Pine (2007) divide it into immediate mortality, short-term mortality, and long-term mortality. Immediate mortality is observed when the fish is dead upon landing, predation due to hooking, or acute injuries. Short-term mortality is within the time range of around 24-72 hours, and this category can be divided into death resulting from hooking or handling injury and death resulting from indirect effects like exposure to predators after release. Lastly, long-term mortality refers to death 72 hours or more after the initial catch. This is much harder to study and is estimated to be low. Within the parameters of these three mortality categories, Pollock and Pine (2007) compare the different research and study methods employed by scientists observing post-release mortality rates. The various methods include the basic model with and without control fish. Ideally, there is both a control and a treatment (catch-and-release) group, and these can take various forms depending on the fish species and type of mortality being observed. Another way to study fish mortality due to catch-and-release is through a generalized computer model. This method is useful when comparing different groups of fish. Containment studies are another research possibility that is commonly used. This form of study involves capturing fish, placing them in containment chambers, and then observing the impact of catch-and-release within a controlled setting. Telemetry study designs offer increasingly detailed analysis on a smaller sample size. A benefit of telemetry is that one can observe indirect effects of catch-and-release, such as predation after the fish is released. The last research method described is a long-term tag return study. This form of research involves tagging fish and then observing the individuals when they are caught in the future. Although each of these research methods has drawbacks, they seem to be the primary study designs for the biological impacts of catch-and-release on fish species (Pollock & Pine, 2007). These approaches can be observed in a variety of catch-and-release studies on trout populations.

Studies on how catch-and-release impacts rainbow trout are fairly common, and rainbow trout are among the most studied trout species. Rainbow trout are also the most susceptible to impacts from catch-and-release compared to other salmonids like brown trout, brook trout, and cutthroat trout. Pope, Wilde, and Knabe (2007) conducted the study, *Effect of catch-and-release angling on growth and survival of rainbow trout, Oncorhynchus mykiss*. It has been observed that the handling of fish can induce stress leading to higher energy demand and disrupted feeding behavior. They collected the rainbow trout from a hatchery, acclimated them to their new habitat, and then they were tagged and separated into four aquaria. This is an example of a containment study (Pollock & Pine, 2007). In one aquarium, the fish were not handled at all. This served as the negative control. The other three aquaria each had fish assigned to handling events, either one time, two times, or four times, and each event was paired with a hooking in the mouth. Though some fish did die in the handling tanks, there were no statistically significant differences in the length, weight, and survival of the fish hooked in the mouth and handled and the fish in the control group. There were some variables in this study that were not observed and could have the potential to give different results. Pope et al. (2007) only hooked the fish in the mouth, and quite often the fish is hooked in other locations that are much more damaging to the fish's health. Also, this study only looked at non-spawning, young adult trout, and the "physiological responses of salmonids to stress vary with life stage" (118). Other limitations of the study were that length and weight might not have been the best way to measure growth. The fish subjects were also born in a hatchery and may be more assimilated to handling. The results would have been more revealing if the experiment was done in the wild on wild trout, but there would be too many variables. Although Pope et al. (2007) did not find any changes in growth or survival of rainbow trout from handling, other studies do show impacts of hooking and handling incidents on rainbow trout.

Other studies done on rainbow trout populations have shown contrasting results. Campbell, Pottinger, & Sumpter (1992) found that when a population of rainbow trout was stressed by air exposure at random times over the course of 9 months, the gametes quality was affected compared to a control group of unstressed fish. There was a delay in their ovulation, reduced egg size, and lower sperm counts. The most significant finding that they observed was a lower survival rate for progeny of the stressed fish (Campbell et al., 1992). This study found more specific data focusing on reproduction. Another study surrounding hook type show more obvious impacts on trout individuals. *Evaluating Recent Innovation in Bait Fishing Tackle and Technique for Catch and Release of Rainbow Trout,* a study done by Thomas Jenkins Jr. (2003), found that when J-hooks were left in the fish after the line was cut, the growth rates were lower. It is important to know how rainbow trout's growth can be affected by different fishing techniques and practices (Jenkins, 2003). There have been similar studies surrounding other species of trout as well.

A study was done by Detar, Kristine, Wagner, and Greene in 2014. This study evaluated catch-and-release regulations on brook trout in Pennsylvanian streams. Brook trout are native to Pennsylvania, and their distribution and abundance has been significantly reduced. This is likely due to "habitat loss, the introduction of exotic species, atmospheric deposition of acidic compounds, overexploitation, and other anthropogenic influences" (Detar et al., 2014, p. 49). To evaluate the effects of catch-and-release on brook trout they used a before-after-control-impact design. They observed the abundance of brook trout for a 15-year period before the implementation of catch-and-release regulations. They compared this data to the abundance of brook trout over a 7-8 year period after restrictions were put in place. The regulations were no brook trout could be kept, but angling was permitted year-round, and there were no tackle restrictions. They did not observe any significant change in brook trout population numbers over the various stream sites. Although this study did not show catch-and-release regulation being a successful conservation tool, there are some limitations to the study that could have been the cause of these results. In the waters observed, angling rates are relatively low, and the catch-and-release rates are already high with brook trout. Also, the environmental conditions of the streams in Pennsylvania are extreme, and this can be hard to combat with angling regulations. Some other studies done to assess catch-and-release impacts on brook trout have had different results. A study done by Casey Risley and Joseph Zydlewski (2010) analyzed how the mortality rates associated with catch-and-release fishing can alter the age structure of brook trout populations. They created a deterministic population model using data from a variety of sources. They found that hooking mortality rates consistent with what is observed with catch-and-release fishing could shift the age structure of a brook trout population. The age group that is significantly affected are 4-5 years old, and these are considered trophy size (Risley & Zydlewski, 2010). Overall, the studies for brook trout differ considerably from the studies done for rainbow trout. This is consistent when observing research on other salmonid species.

There are fewer studies on the impacts of catch-and-release on cutthroat and brown trout compared to brook and rainbow trout. One study examines the post-release mortality of cutthroat trout in Yellowstone National Park. They observed the dead cutthroat by establishing snorkeling routes and counting the dead fish. They found that “3% of the population died in 1981 as a result of hooking” (Schill, Griffith, & Gresswell, 1986, p. 231). The impact of humans on cutthroat trout in this region of Yellowstone has dramatically decreased since the implementation of catch-and-release guidelines. Before 1973, when the catch-and-release restrictions were established, approximately 14,000 fish were killed annually by anglers. That number has since dropped into the hundreds and is possibly even lower now with improved education and technology (Schill, Griffith, & Gresswell, 1986). This study indicates that catch-and-release restrictions have improved the cutthroat populations in Yellowstone. A study on the hooking mortality of trout in Michigan was done in 1955. This study compared fly-hooking and worm-hooking for rainbow, brook, and brown trout. For brown trout, there were no deaths observed from fly fishing catch-and-release (Shetter & Allison, 1955). Both of these studies showed positive outcomes for catch-and-release.

All of the studies and results reviewed above show us that there is currently a lack of consistency when observing the effects of catch-and-release on trout populations. This makes it difficult to make a claim regarding if the conservation practice is being best accomplished with regards to fishery management. It is also important, when reviewing catch-and-release, to understand the relationship of the anglers to catch-and-release angling.

Anglers' relationship with catch-and-release fishing

Although less common than observing catch-and-release research through the fish species or the angling practice, there are a variety of studies that assess the anglers' outlook. These kinds of studies are seen all over the world and have been conducted by people in a variety of fields. There was a study done by Gupta et al. (2015) in India that examined the knowledge, perceptions, and attitudes of anglers towards catch-and-release fishing. In India, catch-and-release fishing has been practiced since the colonial times, but it did not gain popularity until much more recently. With this increase in popularity, India's fisheries are succumbing to ecological threats from the anthropogenic pressures. The goal of Gupta et al.'s (2015) study is to get a further understanding of the anglers practicing catch-and-release, and then to use this information to increase understanding of the status of recreational fishing in India. They gave the survey out to both domestic and international anglers in India. The population of international anglers was from the United Kingdom. In this study, they focused the survey primarily on assessing the angling experience. It has been suggested that the angler's experience while fishing can affect their conservation efforts (Bryan, 1977). Interestingly, only 16% of anglers expressed the importance of education of catch-and-release in the survey, but the 'spirit of river' educational intervention in Mongolia was successful in expanding the angler's knowledge of the best catch-and-release techniques and promoting conservation. The results of this survey varied slightly between the international and domestic anglers (Gupta et al., 2015). Overall, the most significant takeaway from this study was that the anglers were aware of the need for conservation, and they were also willing to participate in further conservation efforts.

Another published study done in Norway shows similar methods in determining the anglers' sentiment towards the practice of catch-and-release angling. This studied focused on the catch-and-release norms and sanctions for Atlantic salmon, *Salmo salar L.,* in the Lakselva River. This study done by Stensland and Aas (2014) is particularly interesting because the attitude towards catch-and-release in most parts of Europe is drastically different than in the United States and other regions where catch-and-release is regularly practiced (Arlinghaus et al., 2007). In this study, they focused on how norms motivate an individual's behavior with regards to catch-and-release angling. They conducted a web-based questionnaire, and with the results, they decided to do a cluster analysis to determine the different groups of anglers within the study. They organized the anglers into four different angler groups. These groups were trophy anglers, catch-and-release anglers, keeper anglers, and something else. Stensland and Aas (2014) compared the various dependent variables through the variation in responses between these angler segmentations. The two independent variables with the most significant impact on the results were social norm power for catch-and-release and social norm power for keep. Their findings indicated that social norm power contributed more substantially to positive implications for catch-and-release than negative impacts influencing anglers to keep the fish. Interestingly, about 50% of the anglers did not believe it was necessary to release all fish caught. Also, the views observed from the survey were not highly polarized. A vast majority of respondents did not entirely believe that catch-and-release was either “an unethical and reprehensible practice” or that it was “an ethical conservational approach to resource use” (Stensland & Aas, 2014, 297).

Another study of the social aspect of catch-and-release angling was done by Arlinghaus et al. (2007) in the article, *Understanding the Complexity of Catch-and-Release in Recreational Fishing: An Integrative Synthesis of Global Knowledge from Historical, Ethical, Social, and Biological Perspectives.* In this article, they explain that it is important to understand angler’s motives, attitudes, and preferences in order to promote catch-and-release most effectively. A variety of studies have shown that more specialized anglers are more inclined to practice catch-and-release because they are less consumption oriented. The reason that an angler practices catch-and-release is a topic that has not been thoroughly studied. Various scholars have tried to research this topic, but there have been flaws in the execution. An early study done by Grambsch and Fisher (1991) found that there was a correlation between practicing catch-and-release and income, fishing frequency, number of fish caught per year, and education level. This research was among one of the first studies done assessing angler’s participation, but it did not give insight on why the anglers participated in catch-and-release (Arlinghaus et al., 2007). The determinants of whether an angler will practice catch-and-release are "the individual's attitudes, beliefs, values, knowledge, and norms" (102). These determinants can be affected by situational variables. A study that was done in Australia elaborated on these determinants and gave more comprehensive results around why the anglers were practicing catch-and-release. In this study, 88% agreed with the statement that they don't see any benefit to releasing the fish they catch, but 29% agreed with the statement that it is more satisfying to keep the fish rather than releasing it. This study gave increasing evidence towards the understanding of why and how anglers practice catch-and-release (Roy Morgan Research, 2004). To further the understanding of why anglers practice catch-and-release fishing, I have created a survey to analyze the question of why and how anglers participate in catch-and-release in Boulder, CO.

Methods

To analyze the sentiments of the angling population of Boulder, I conducted a survey. "Research into the social aspects of fisheries management has lagged behind," so I elected to use a survey because it was the best mechanism to get answers from the angling population of Boulder, CO (Barclay et al., 2017, p. 427). I created the survey through an online program called Qualtrics. The survey was exclusively administered through this online platform, but the distribution varied. These distribution methods included reaching out to different fly fishing organizations in the region, reaching out to students, and posting on social media groups. The various distribution methods were important because it gave me a more diverse answer set. I received usable results from 149 anglers in the Boulder area.

Data Collection

The data collection methods employed were instrumental in obtaining useful information. The survey was distributed using a linked from the online program Qualtrics. The link was sent out to various fly fishing organizations including Trout Unlimited, CU Fly Fishing Team, Rocky Mountain Lady Anglers, and Colorado Women Flyfishers. The linked was also distributed personally by myself and friends to known anglers in the region. All links were distributed over email. When distributing my surveys to the fly fishing organizations, I contacted the leaders of the groups. They proceeded to send out the link to the rest of the organizations. Regarding sampling and choosing the participants, I am not worried about skewed results due to varying demographics. I assume that the anglers of Boulder all have access to the internet through some means. When deciding on forms of distribution, I chose a variety of platforms to get a varied demographic of responses. I also sent follow-up emails to further incline participants to take the survey.

Survey

My survey (Appendix A) was comprised of a set of 21 questions all focused on getting a full understanding of anglers' catch-and-release practices in Boulder, Colorado. The first question on the survey simply asked the participants for consent to participate in the survey. The consent process explains that there was minimal risk, and it was completely anonymous. The consent process was important in order to gain trust from the participant and to have the information be viable within the scientific community. If the participants consented to take the survey, they were then directed to the next set of questions. The questionnaire started with basic questions regarding the participants angling experience, the kind of fish they catch, and how often they fish. The next set of questions moved onto fish type and the respondents' ability to identify native versus non-native fish by both name and picture. Because of species-specific catch-and-release regulations in Colorado, the information regarding native species is important to see if local anglers are practicing proper catch-and-release. Then after these questions, the survey went right into the catch-and-release section. In this section, the respondents were asked if, when, and why they practiced catch-and-release. The survey also asked questions regarding what the respondents believe to be the proper techniques. The last set of questions was a series of demographic inquiries. These include age, gender, income, and whether or not you're a student. Then the final question, asking what the survey was about, was aimed to make sure the participant was paying attention and was not a bot. I also asked the participants for their emails if they would like to be entered into a raffle for one of two $20 gift cards to local fly shops, but they had the option not to. This was done in order to incentivize people to participate in the survey. When considering my survey methods and distribution, I referenced other surveys and literature on survey development to obtain the most effective data.

When creating my survey, I considered the implications of using an online survey platform, and I reviewed past surveys and literature similar to mine. Electronic surveys follow a different format than paper surveys, and the construction of them has evolved along with the population's internet use. Some of the most essential components considered were "survey design, participant privacy and confidentiality, sampling and subject solicitation, distribution methods and response rates, and survey piloting" (Andrews, Nonnecke, & Preece, 2003, p. 185). When designing my survey, I attempted to make it user-friendly by adding pictures, keeping the text uniform, and providing multiple choice answers for a majority of the questions (Andrews et al., 2003). I also made sure that all the results remain confidential and providing one's email at the end for entering the raffle was completely optional. The process of survey piloting is "conceptualizing and re-conceptualizing the key aims of the study and making preparations for the fieldwork and analysis so that not too much will go wrong, and nothing will have been left out" (193). Survey piloting involves eliminating questions bias, creating clear questions, making sure all the questions asked are relevant, and other details regarding the formulating of questions and answers. There were key determining factors that I considered when forming my questions. I made sure to keep them as short and simple as possible. When doing scientific research, it is easy to formulate questions that the participants may not be able to understand, which can make them feel uneducated and further skew their answers (Lietz, 2008). It is also important to consider the order of the questions. An improper ordering of the questions can lead to different answers. The questions in my survey start broad and get increasingly specific as the survey progresses. I also ended my survey with the demographic questions to "avoid negative feelings about the provision of personal information impacting on the answering behavior or participation" (8). All of these aspects of survey creation and distribution are important to consider and are evident in my methodology.

Method for Data Analysis

The results of the survey are analyzed in a variety of ways. First by comparing the answers for each question to one another. With the responses observed in Qualtrics, I use evidential support through visual comparisons in the form of various graphs. I use statistical analysis in the form of finding correlation coefficients (Appendix B) to compare the results that have the most trends and strongest relationships. I also make inferences about the free response options on particular questions. Using qualitative data analysis, I am able to observe trends that might not have been evident in the quantitative approach (Barclay et al., 2017). With these trends, I can make tentative conclusions about the use of catch-and-release angler in Boulder, CO.

Results

The data I collected comes from the 149 responses I received from my survey described previously. Through these responses, I am able to analyze the results through visualizations and finding correlation coefficients. I also view the qualitative data from the free response options in the survey to further understand the information acquired. The nature of my data has the potential to answer a variety of questions. Through these methods, I can observe if the data show any correlations between similar catch-and-release practices.

Data Overview

The people who took the survey come from a variety of demographic and angling backgrounds. Out of the 159 people who took the questionnaire, only 150 completed it entirely. There was also a respondent who incorrectly answered the question that was put in place to ensure the respondents were not bots and were paying proper attention to the survey. Therefore, only 149 of the 159 survey responses are used in the data analysis. Using a variety of figures, my research and analysis aims to find relationships between the data collected. The demographic distributions are important to understanding the significance of my research. Using the demographic information compared to the angling specific data, we can see if any hypothesized trends are evident.

Demographic Data

Figure 2 shows the age distributions of the survey respondents. The majority of the respondents were 40-60 years old, and the second highest age range was 60-80 years old. The age distribution of the respondents is key because it can show if any of the results are due to generational differences. I did not receive much information from younger populations. This could either be because there is less of an angling presence in these populations, or because I did not reach out to groups that include a younger demographic. The next data set reviews the gender distribution.

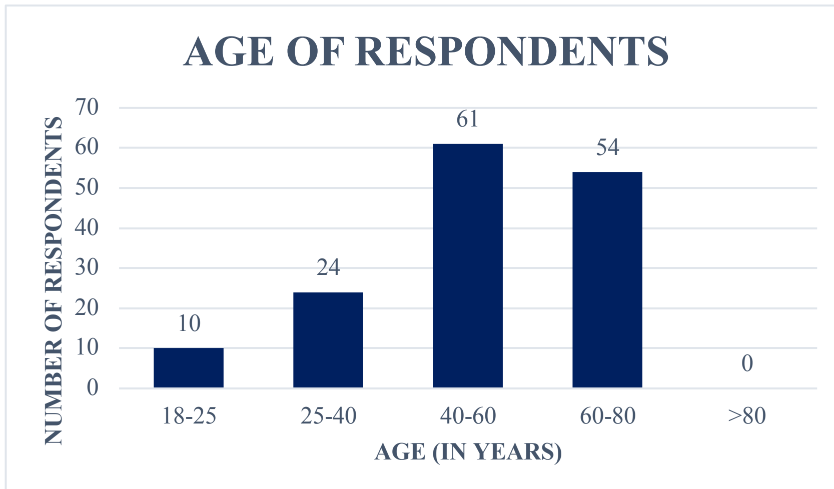


Figure 2: Age distribution of survey respondents

Figure 3 shows the gender distributions of the survey respondents. The vast majority of the respondents are male. Only 17% of the respondents were females. This information is important to consider because it shows that fly fishing could male-dominated in Boulder, CO.

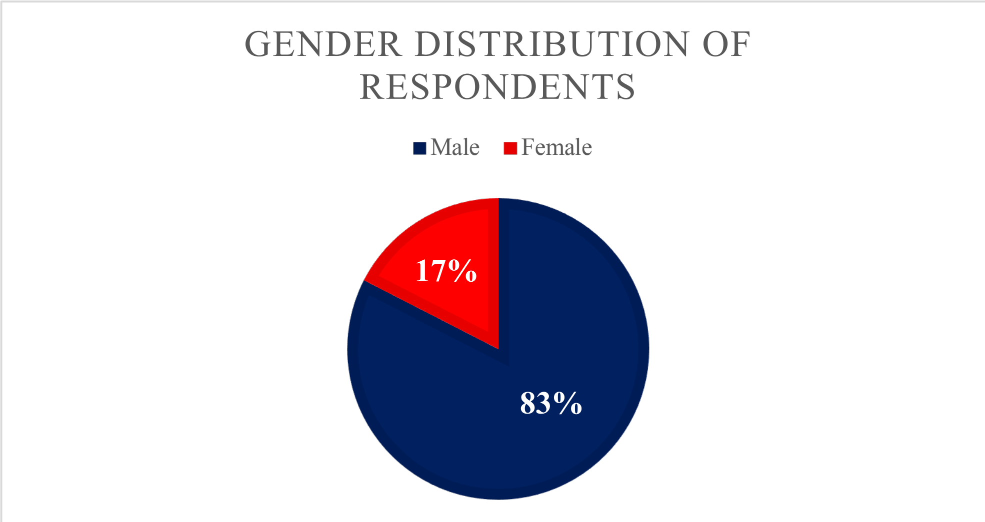


Figure 3: Percent distribution of male respondents versus female respondents

Figure 4 shows the distribution of income among the participants. Interestingly, only 139 of the survey respondents answered this particular question. The other ten participants might have been concerned about answering a question regarding how much money they make. This may skew the results slightly, but ten missing responses should not make a significant impact on the data. This data indicates that the highest percentage of participants have incomes greater than $150,000. The lowest percentage of respondents fell in the income category less than $20,000, and this category was significantly lower than any of the others.

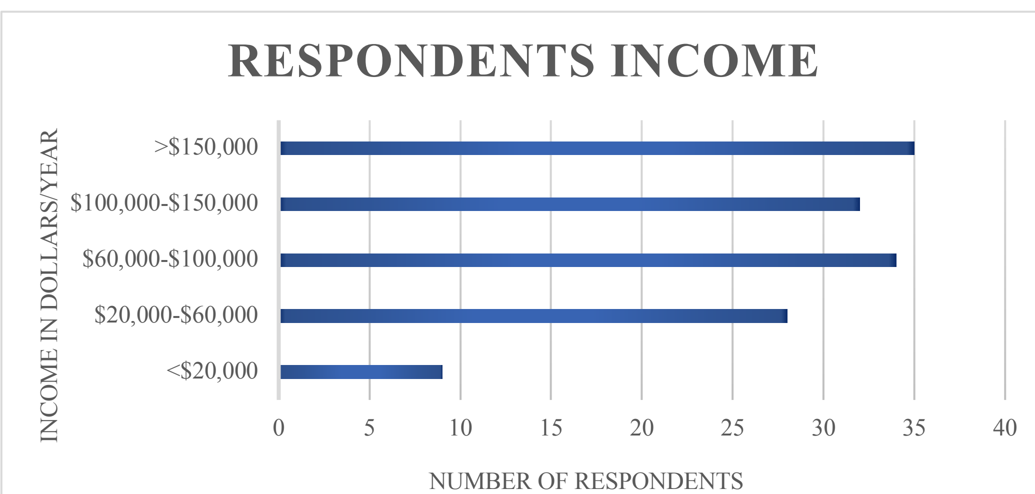


Figure 4: Income distribution of survey respondents in dollars

The last demographic question on the survey asked the participants whether or not they were students. This data was important to capture in the instance that there was a skewed number of students versus non-students. Although not many students took the survey, it is still relevant to the study and the discussion. Figure 5 shows that only eleven of the survey respondents were students. This indicates that students will not have a major impact on my findings.

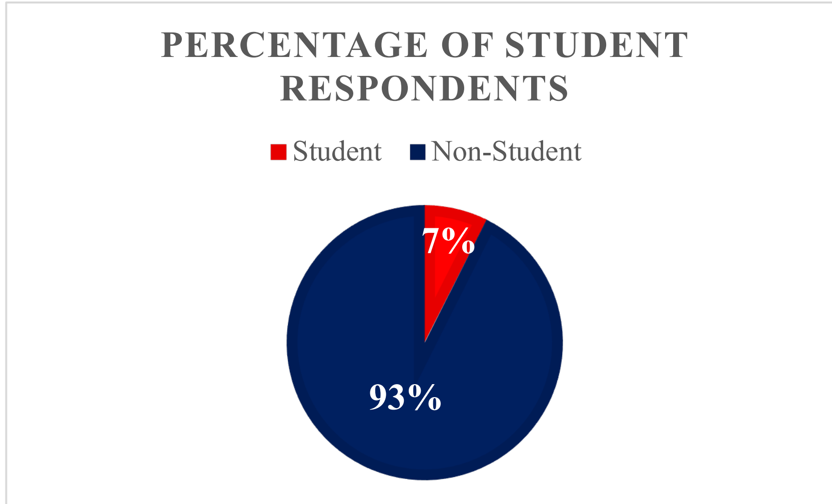


Figure 5: Distribution of students within the survey respondents

Angling and Catch-and-Release Data

In addition to the information received from the demographic data, the questions focused angling give more insight into how the population of anglers in Boulder practice fishing and catch-and-release techniques. Figure 6 displays the fishing experience of the survey respondents measured by the years they have been fishing. A vast majority of the anglers have been fishing for over twenty years. This correlates with the age demographic data showing the majority of respondents being older.

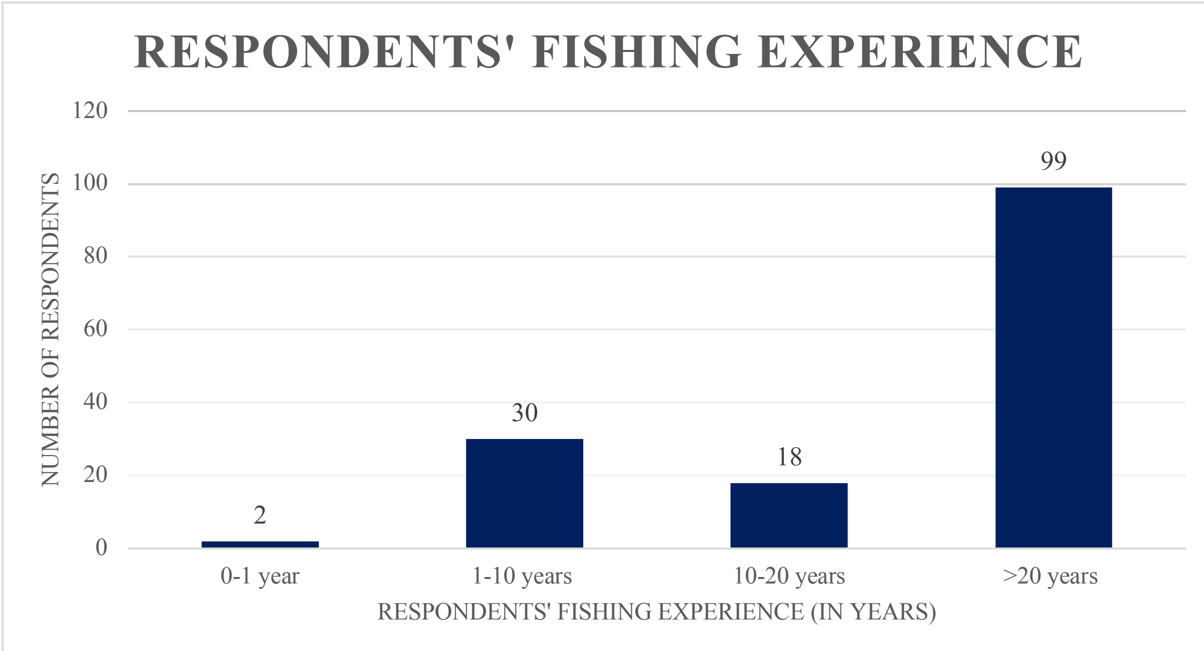


Figure 6: Respondents fishing experience measured by the years they have been fishing

Moving on to the catch-and-release data collection, the participants were asked why they practiced catch-and-release. Typical responses, according to Arlinghaus et al. (2007) and Rahel (2008), were displayed, but participants also had a free response option if their primary reason for practicing catch-and-release was not presented. Figure 7 shows the distribution of responses.

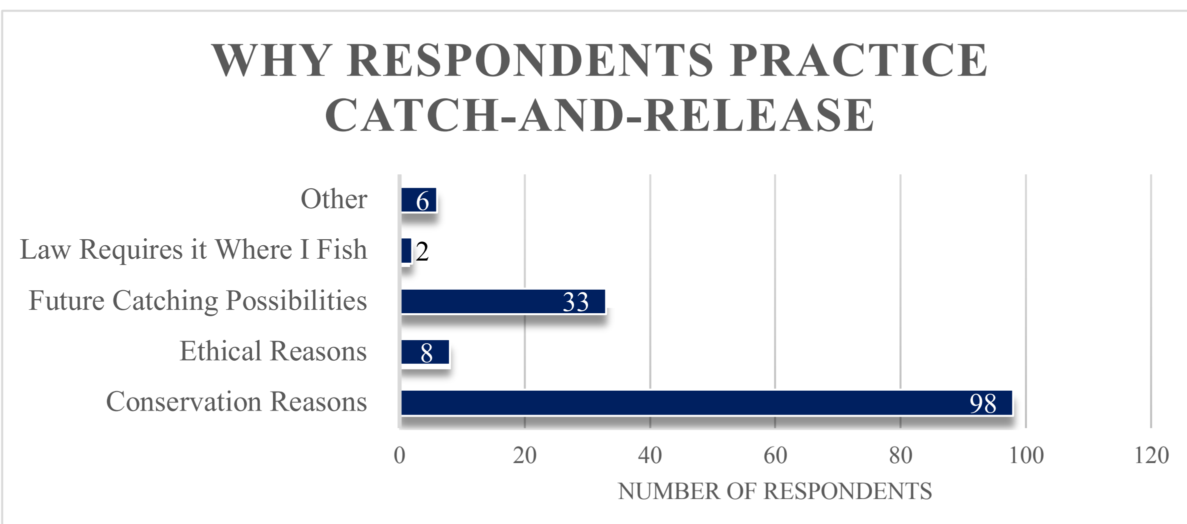


Figure 7: The reason for respondents' participation in catch-and-release

A clear majority, 66%, of the respondents practice catch-and-release for conservation reasons to protect the fishery and general ecosystem. In addition to this question, participants were asked when or in what situation they practiced catch-and-release fishing. The answer options and participants' responses are displayed in Figure 8. 74% of the survey respondents said they

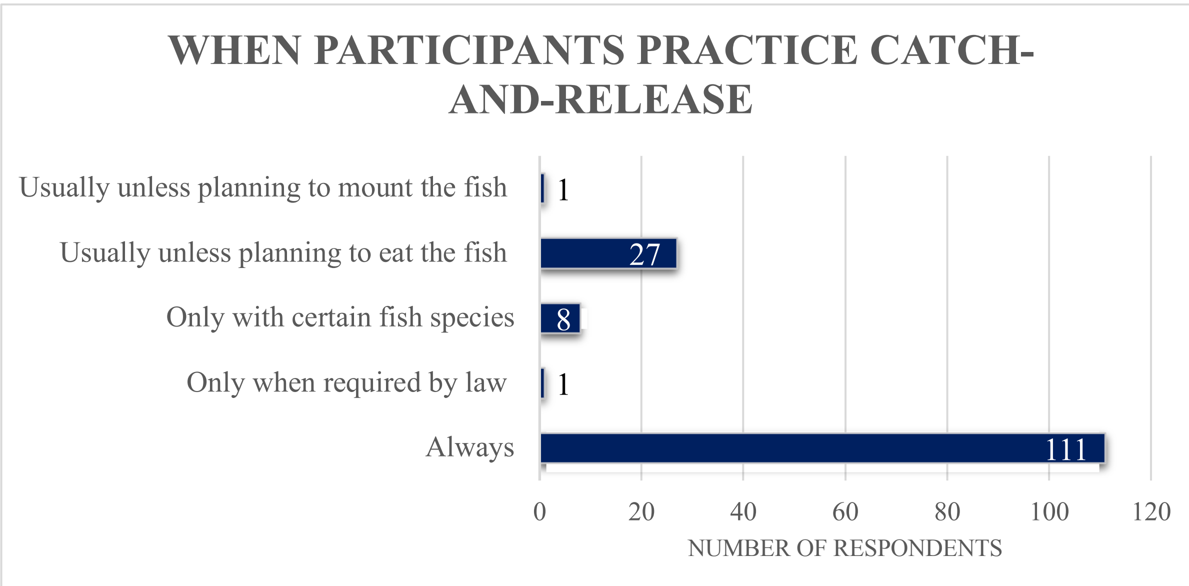


Figure 8: Respondents' explanation of when they participate in catch-and-release fishing

always practice catch-and-release. The second largest percentage was the 18% that said they practice catch-and-release unless they plan to eat the fish.

Survey participants were asked if they could identify both the pictures and the names of the native trout of Colorado. There are three native trout in Colorado; greenback cutthroat trout, Rio Grande cutthroat trout, and Colorado River cutthroat trout. The other trout that were pictured and named in these prompts were brook trout, brown trout, and rainbow trout. Figure 9 shows the distribution of the people who could identify the pictures of all the native trout versus the people who could not. Figure 10 shows the same distribution for those who could identify the names of the native trout in Colorado. It is evident that more people could identify the names of the native trout compared to the pictures, but still, only 39% of the respondents could identify all the native trout by names, and only 17% could identify the native trout by pictures. Because of species-specific catch-and-release requirements, it is important that anglers know the native trout species in order to practice effective conservation.

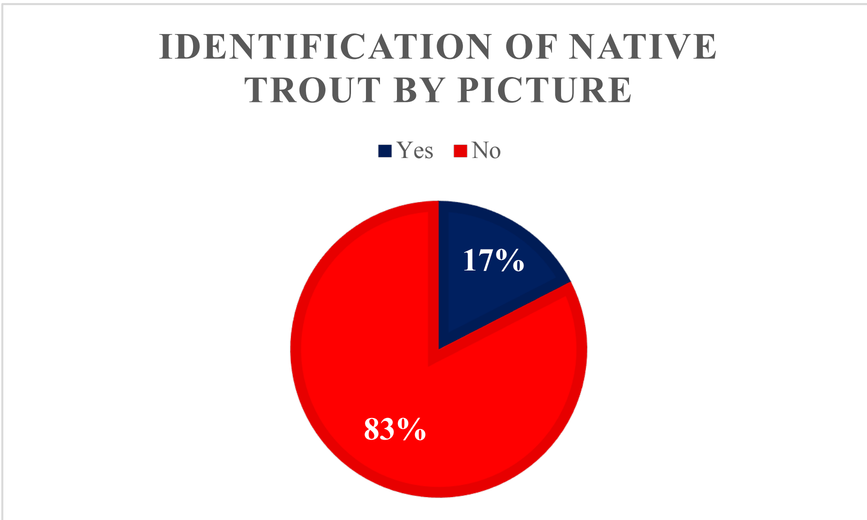


Figure 9: The distribution of respondents who could accurately identify Colorado's native trout by viewing a picture

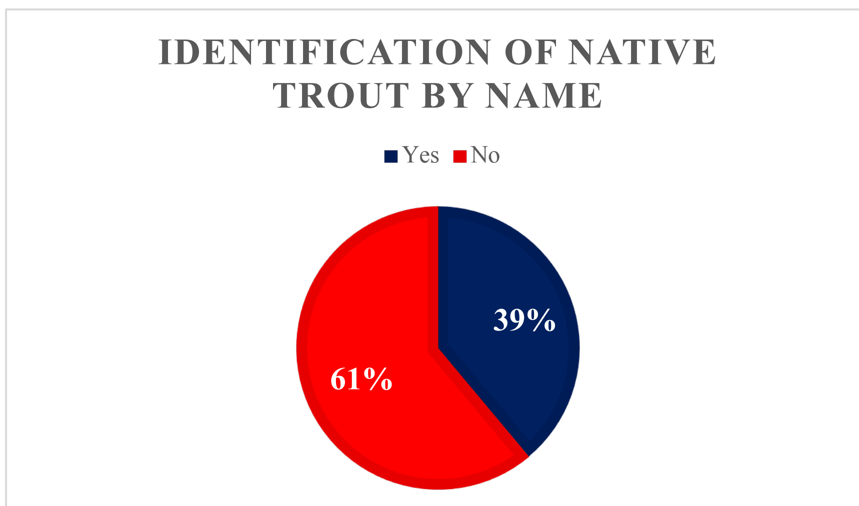


Figure 10: The distribution of respondents who could accurately identify Colorado's native trout by species name

The next set of data is a result of the questions regarding catch-and-release techniques. There are scientifically agreed upon catch-and-release practices that can seriously impact the health of individual fish as well as fish populations (Brownscombe et al., 2017). The majority of the respondents answered these questions correctly. This still provides insight to determine who is practicing correct catch-and-release, and this information can be used to further the knowledge needed for fishery management.

The first question is regarding the amount of time the angler should allow the fish to be exposed to air after the capture event. This is a contested topic among scientist and anglers. Although the ideal time is no time out of the water, many anglers believe it is alright to take the fish out of the water briefly to remove the hook or take a picture (Pelletier, Hanson, & Cooke, 2007). Figure 11 represents the answers from the angling sample in Boulder, CO. In figure 11, it is evident that many 69% of Boulder anglers in the survey sample did not believe that zero time out of the water was the appropriate exposure time for fish after capture. The majority, 44%, believed that the proper air exposure time is less than 10 seconds.

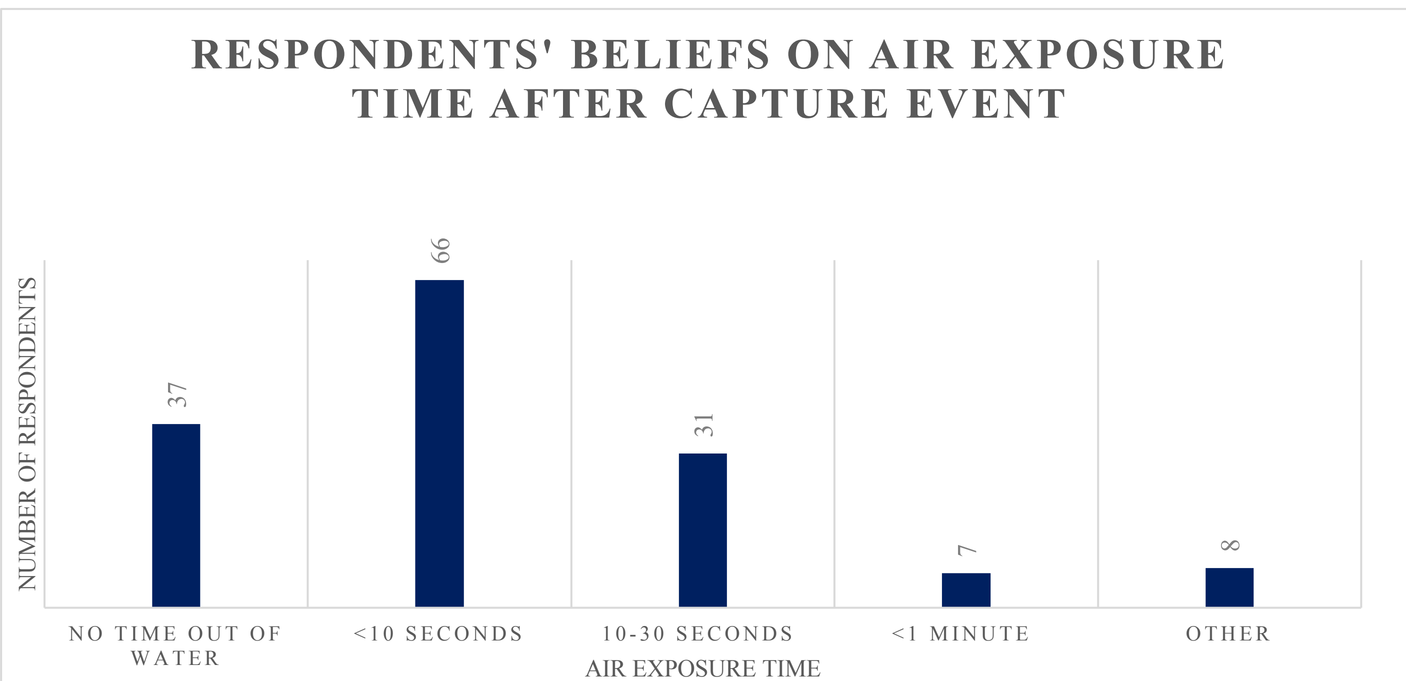


Figure 11: Respondents' beliefs on the duration of air exposure for the fish that should be allowed after a capture event

The next question regarding proper catch-and-release technique is based on how you handle the fish if needed. The scientifically agreed upon approach is to hold the fish with wet hands. This is because holding a fish with dry hands can actually lead to the removal of the protective slime on the scales of the fish. It is also important to hold large fish horizontal because if they are held vertically, their internal organs can be injured by gravitational force. Although it varies by fish species, wet hands and horizontal orientation are the most agreed upon approaches (Pelletier, Hanson, & Cooke, 2007). The majority of the respondents answered this question correctly. Only 2.5% did not answer correctly, and 8% gave a written answer. Figure 12 gives a graphic explanation of the distribution of answers regarding proper fish handling technique.

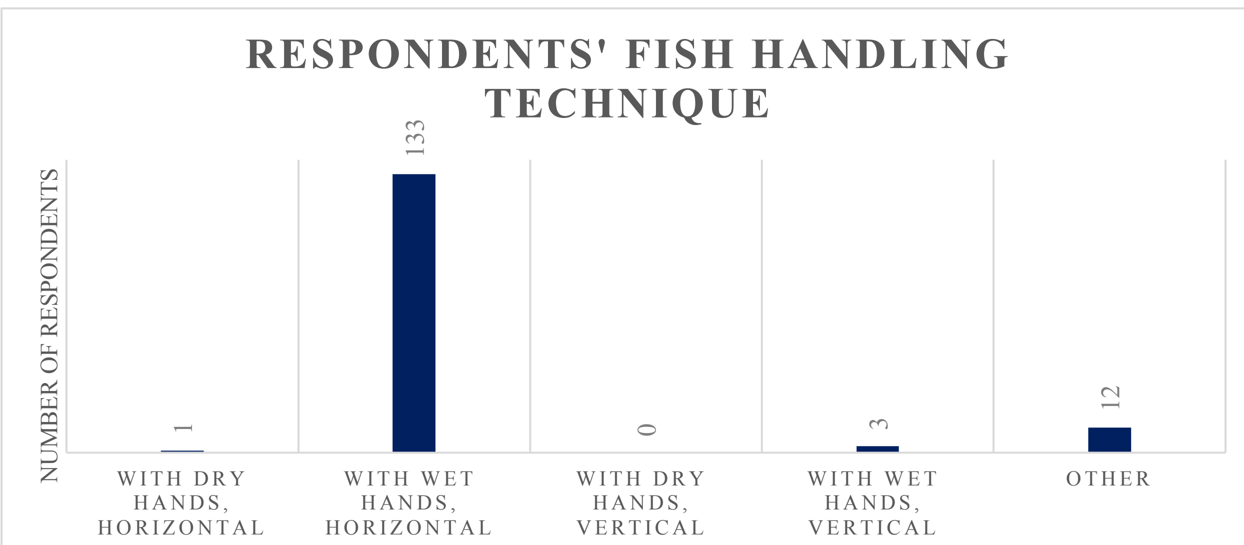


Figure 12: Respondents' perspective on proper fish handling techniques

The third survey question within this category prompted respondents to answer the question regarding how they handle a capture when the hook is deeply embedded in the fish. Figure 13 shows how the survey participants react to a situation with a deeply embedded hook. Although the majority, 61%, said they would cut the line, which is scientifically agreed to have a better turn out for the fish, 30.5% said they would do everything they could to get the hook out.

The practice of trying to get the hook out of the fish can actually be detrimental and lead to immediate injury or death. Leaving the hook in the fish and cutting the line, although not ideal, can allow the hook to disintegrate from water erosion, and this gives the fish a better chance of survival (Pelletier, Hanson, & Cooke, 2007).

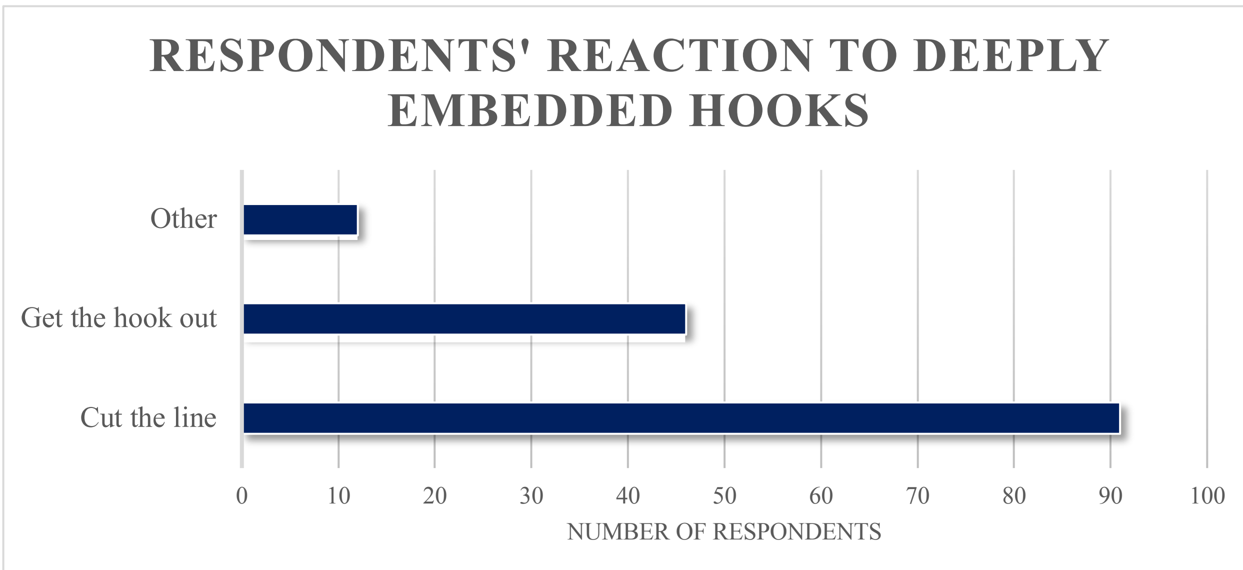


Figure 13: How respondents react to situations where a hook is deeply embedded in the fish after a capture event

The last question asked in the survey regarding proper catch-and-release practices asked respondents about the hook type they used. The two options were barbed and barbless hooks. Figure 14 shows the distribution of participants' responses. The majority of the

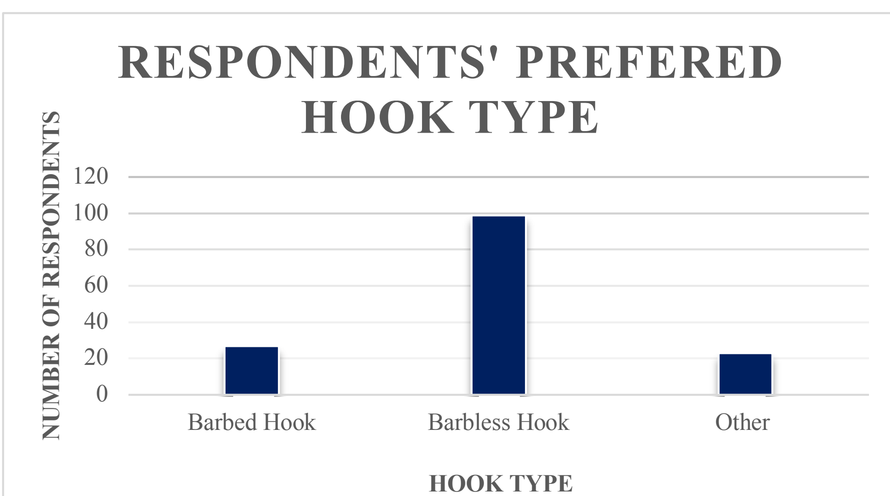


Figure 14: Respondents' response to which hook type they use between barbed and barbless hooks

participants said they used barbless hooks. Barbless hooks are hooks without the tooth on the end that helps to keep the fish on the hook after the hook is set. Figure 15 shows a comparison of a barbed J hook and a barbless J hook. It is evident in the image that barbed hooks can really harm a fish if they are hooked in a less than ideal location, meaning anywhere besides the mouth (Pelletier, Hanson, & Cooke, 2007). Studies show using barbed hooks can lead to a 10% increase chance of fish injury compared to using barbless hooks (Meka, 2004). 18% of the respondents use barbed hooks, 67% of the respondents use barbless hooks, and 15% said other. The respondents that said other wrote their answers as a free response, and that information is important qualitative data.

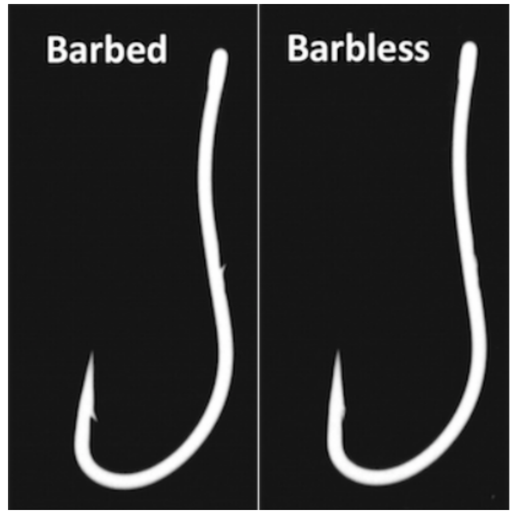


Figure 15: Comparing images of barbed versus barbless hooks (Weltersbach, 2016)

Qualitative Data

Due to the option of free response in my survey (Appendix A), the qualitative data is important to observe. Barclay et al. (2016) explain that a qualitative approach to data collection and analysis "adds a new dimension to understanding fisheries that is not possible with a focus solely on quantitative data" (426). The questions that respondents had the option to write their own response to were: which species they practiced catch-and-release for, why they practiced catch-and-release, and the various catch-and-release technique questions. The written response answers to these prompts allow for analysis and identification of different perspectives.

For the question regarding when people practice catch-and-release fishing, the free response coordinated with only practicing catch-and-release fishing with certain fish species. Around 5% of the respondents stated that they practice species-specific catch-and-release. I asked which species they were referring too, and the majority of respondents answered by saying they only keep brook trout. Invasive brook trout are notorious for their biological invasion in the native cutthroat trout habitat (Dunham et al., 2002). A smaller percentage of respondents explained that they would keep rainbow trout or brown trout, but none of the respondents mentioned keeping any native trout. There was only one respondent in this group who did not know the difference between the native and non-native trout. The rest of the participants knew that the cutthroat were the only native trout in Colorado. I also asked the participants why they practiced catch-and-release. The options were conservation reasons, future catching possibilities, ethical reasons, the law requires it, and other. The other option requested participants to explain their reasoning. A majority said that they do not want to kill the fish or they only fish for fun. One respondent said that "angling is one of the few hunting sports that does not have to end in the demise of the hunted animal" (Survey respondent). Another respondent said, "watching a healthy fish swim away is very rewarding" (Survey respondent). The only response that was not related to the others had to do with the potential of arsenic poisoning from mining contamination within the stream that could be in the fish.

The next set of free response questions referred to the proper practice of catch-and-release fishing. Initially, the respondents were prompted to answer within the confines of the most commonly agreed upon approaches, but for each question, there was the option to choose other if they explained their reasoning. The first questions asked, "how long do you believe is proper exposure time for the fish?" The prompted options were no time out of the water, <10 seconds, 10-30 seconds, <1 minute, or other. People consistently answered as little time out of the water for the fish as possible. Scientists have agreed that no time out of the water is ideal. Others commented that it should only be out of the water as long as you need to take a picture or retrieve the hook. These answers were very similar to the options given, but they included more explanation. The scientifically agreed on 'best approach' is to not take the fish out of the water at all, but if necessary, as little time out of the water as possible.

The next question asked, "what are the best handling techniques when holding a fish?" This led to a differing sample of written answers. The options given were with dry hands, horizontal; with wet hands, horizontal: with dry hands, vertical; or with wet hands, vertical. The answers given were very on par with the scientifically agreed upon approach of either not touching them at all, but if needed to hold with wet hands, horizontally (Pelletier, Hanson, & Cooke, 2007). Many people knew that they needed to use wet hands, but they were not sure about the orientation of the fish. This can make a huge difference in the fish's overall health and survival.

The next question that had a written option asked participants what they would do if there was a deeply embedded hook in the fish after a capture event. The two given answers were to cut the line or to try everything to get the hook out of the fish. Many of the respondents said that it was situational based on hook location, the difficulty of removal, and catch-and-release regulation. One respondent said, "Each situation is different. If I am in a catch-and-release only area I will try to get the hook out. If it is an area where a fish can be caught, and the fish is so badly hurt that it will die I will eat it" (Survey respondent). This indicates that some regulation may not be ideal for the fish's best interest. Many also mentioned that this was not very common with fly fishing, so they do not encounter this problem often. A large number of respondents seemed to be concerned with harming the fish and would try to take the best action that would inflict the least amount of harm.

The last question that provided qualitative data through the survey was an inquiry on the hook type used by the angling participants. The question prompted the respondents to answer whether they used barbed or barbless hooks. Figure 15 above shows the difference between these two hook types. 15% of the respondents answered other and gave written answers. Many of the respondents said they used both hook types dependent on what kind of fish they were trying to catch, the size of the hook, and the location where they are fishing. One respondent said they always use barbless hooks in National Parks but uses barbed hooks every other time. Another participant said that they use both but tries to stick to barbless hooks when fishing for greenback cutthroat trout. Many respondents also explained that they smash the barb down on barbed hooks in order to make them barbless. Overall, many participants seemed to understand how barbless hooks have a lower physical impact on the fish, but it also can decrease catch rate.

Analysis

When analyzing my data, I used correlation coefficients. Correlation coefficients are useful in data statistics because the results show how correlated the various questions are based on the respondents' answers. Correlation coefficients are important to understanding linear relationships. In each case, I had to code the responses into numerical answers in order to obtain valuable statistics that are actually testable (Fink, 1996). The correlation coefficient is a numerical value between 0 and 1, and the symbol for correlation coefficient is r. If $r = 1$, this indicates that the two variables have a perfect relationship. If $r = 0$, the two variables have no relationship. Table 1 displays how the correlation coefficients value determines the relationship of variables (36).

Correlation Coefficient Value (r)	**Degree of Relationship**
0 - ± .25	Little to no relationship
± .26 - ± .50	Fair degree of relationship
± .50 - ± .75	Moderate to good relationship
± .76 - 1	Very good to excellent relationship

Table 1: Distribution of how correlation coefficients (r value) represent the degree of relationship between variables

To determine my correlation coefficients, I conducted three different correlation tests (Appendix B). The first test (B-1) represents the comparison of all the questions with the answers coded with a numerical value for each different response. For example, if a respondent answered brook trout, brown trout, and greenback cutthroat for the native fish identification, their answer code would be 124. As evident in Appendix B-1, there was little to no correlation between any of the survey question variables. The highest correlation coefficient values were comparisons of demographic data, which does not give insight into catch-and-release practices and the implications of why people have certain ideas regarding catch-and-release.

The second correlation coefficient statistical test (B-2) included the right versus wrong analysis of the native trout picture and name identification questions. Through the use of Boolean logic, this test was done by adding a 0 to any answer that did not state all and only the native fish (greenback cutthroat trout, Rio Grande cutthroat trout, and Colorado River cutthroat trout), and adding 1 to any answer that included the three native trout. Appendix B-2 shows that the right versus wrong analysis did not make a difference in the correlation relationships. They all indicated little to no relationship.

The last correlation analysis I conducted included the catch-and-release techniques separated into the right versus wrong answers (B-3). This was done in the same manner as the previous analysis using Boolean logic. Appendix B-3 also shows no strong correlations between any significant question pairs. Overall, the comparison of questions indicated that there were no strong relationships between any questions of interest. This disproves my hypotheses surrounding the relationship of demographics to the practice of catch-and-release angling. This will be examined further in the discussion section.

Discussion

The culmination of both the data and the information displayed in the literature review aid in the answering of questions surrounding voluntary catch-and-release. Although catch-and-release is not a new focus for scientific study, there are questions that have been left unanswered in previous research, and these are the questions that I answered or attempted to answer with my project. All of these prior components helped me to reach a conclusion about whether or not education is sufficient enough for the proper practice of catch-and-release fishing.

General Review of Catch-and-Release

In my research, I came across a large number of articles outlining the effectiveness of catch-and-release on trout populations. These different studies will help answer the question: What are the conservation effects of catch-and-release angling on healthy trout populations? This question is extremely broad and does not hone in on specific regions or catching technique, but because of the nature of this review, the generalizations made will be strictly observational. Cooke and Suski (2005) made a similar claim. They presumed that "there are some generalities that can be derived from existing studies that could be broadly applied to most fish species" (1196). Although the data cannot be statistically generalized, there are evident patterns in the research that display some of the successes, and some of the shortcomings of catch-and-release as a conservation practice.

The studies done surrounding catch-and-release for trout species were largely inconsistent. Pollock and Pine (2007) mention that each of the catch-and-release research techniques they analyzed had drawbacks. This indicates there is a need for more research to discover the best study techniques for catch-and-release impacts on fish species. Evidence of this need is seen in the contradicting data results from the research found about rainbow trout. One study done by Pope, Wilde, and Knabe (2007) showed no negative impact on rainbow trout growth or survival due to catch-and-release stressors. Another study done by Campbell, Pottinger, and Sumpter (1992) showed significant data indicating that rainbow trout subjected to handling had negative impacts on reproduction and a lower survival rate for the progeny of the trout handled. Studies on brook trout had similar inconsistencies, but particularly showed the need for better research practices. The study done by Detar et al. (2014) showed no positive impact when catch-and-release was implemented for brook trout in a region of Pennsylvania. This study had so many limitations listed that it is clear there is a need for further research. Lastly, there were limited studies reviewing catch-and-release for cutthroat and brown trout. The studies reviewed for both species showed positive results from catch-and-release. For Yellowstone cutthroat, the study done by Scill, Griffith, and Gresswell (1986) indicated that with the implementation of catch-and-release restrictions and further education the number of trout killed had been significantly reduced. The study for brown trout indicated that there were no deaths observed from catch-and-release for brown trout in Michigan (Shetter & Allison, 1955). This review suggests that there is a need for increased efforts toward catch-and-release research methods, and also a need for consistencies among research for comparable species and ranges within species themselves.

Importance of Native Trout Identification

The survey conducted included two questions prompting respondents to indicate which species they could identify as native trout in Colorado. The first question asked for identification by images of the trout species, and the second question asked for identification by the species' common name. Due to the increase in species-specific guidelines surrounding cutthroat trout, it is critical that anglers in this region can identify the fish they have caught. It is also important because many times anglers are prompted to remove the brook or brown trout from cutthroat habitat for species preservation (CPW). The survey results indicated only 39% of the respondents could identify all the native trout by the name, and only 17% could identify all the native trout by the picture. This shows a lack of proper knowledge within the angling community. It may be believed that it is not important to know the different species if one always practices catch-and-release. This is not the case in areas were brown and brook trout need to be removed. Overall, preservation of native trout may seem simplified by always practicing catch-and-release, but it becomes more complicated when maintaining total fishery health.

Catch-and-Release Practice

The reason why and how often respondents practice catch-and-release is key information into understanding the best way to disseminate the knowledge to the public. In Boulder, 66% of the angling population surveyed said they practiced catch-and-release for conservation reasons. This statistic gives insight into the population's desire to protect the fisheries to their best ability. Seventy-four percent said that they always practice catch-and-release. With both of these statistics, it can be inferred that the proper practice of catch-and-release and species identification is not readily accessible to the anglers who wish to practice for conservation and maintaining healthy trout populations. Although no statistically significant data is backing this claim, evidence suggests that in Boulder, there is a desire among anglers to conserve, and scientists and regulators have a responsibility to get the proper information to the public for them to be able to practice the best catch-and-release methods.

Catch-and-Release Techniques

My survey gave increasing insight into whether or not the education of catch-and-release practices and techniques are sufficient for the proper practice of catch-and-release fishing for conservation. Some of the best insights gained from the survey came from not only the questions regarding the native trout identification but also the answers to the proper practices of catch-and-release.

The first question asked the respondents to answer what they presumed was the most appropriate air exposure time for trout species after a capture event. There is little debate among the scientific community. "No matter what the species, air exposure is harmful for fish" (Cooke & Suski, 2005, p. 1200). A study done by Ferguson and Tufts (1992) showed that when the fish was exercised and then exposed to air for 30-60 seconds, the 12-hour survival rate was 28%. The survival rate was 88% for the fish exercised and then briefly exposed to air. Only 25% of the survey participants answered this question correctly, stating no time out of the water was the proper exposure time. This data proves the importance of proper catch-and-release practices because the statistics explain that anglers in Boulder, CO may be unintentionally harming the fish. The next question asked respondents how they handled the fish. The majority, 89%, of the respondents knew that if the fish needed to be handled, it was important to use wet hands and hold the fish horizontal. It is interesting that the majority of the respondents knew the proper handling, but do not practice proper air exposure techniques. It seems that having the fish out of the water may have implications regarding the social community surrounding fly fishing and photographing one's catch. The third question asked participants how they respond to a deeply embedded hook in the fish. The correct answer is to cut the line, but it is very situational (Pelletier, Hanson, & Cooke, 2007). There was no vast majority in the responses to this question. This distribution is informative because many anglers may not know the proper practice that is ideal for the fish. One respondent even said that catch-and-release guidelines might lead him to try to get the hook out. This is an example of the improper information being distributed to the angling public. The last question prompted respondents to answer which hook type they use between barbed and barbless hooks. Although the majority said barbless, there was a significant number of respondents that declared using barbed hooks or both. This is an example of the improper use of equipment that can lead to injury or death for the fish. It is clear that there is not much uniformity over what the best catch-and-release practices are among the angling population of Boulder. It seems as though anglers may view catch-and-release as a simple response to hooking a fish, but it is much more complicated and requires further education to be the most beneficial management practice for fisheries around Colorado.

My initial research started by trying to find statistical relationships between demographic data results and catch-and-release practices. Through statistical correlation analysis, the data showed that there were very little correlations between these two categories. Although my data showed little correlation with respondents who were anglers in Boulder, other research has shown different results. Grambsch and Fisher (1991) found that there was a positive correlation between practicing catch-and-release properly and various demographic data such as income and education level. My survey may not have asked the right questions, or my set of respondents may have been skewed. This leads to the limitations of this study.

Limitations

It is important to identify the limitations of this study due to factors both within my control and outside the realm of availability. Acknowledging limitations is essential for future research within the same area of study. One of the limitations of my data collection was the population I reached for my survey. The majority of my survey respondents are involved with the conservation group Trout Unlimited. This group generally comprises a majority of middle-aged white men who care about trout conservation, so they may have more knowledge on different catch-and-release practices that the average Boulder angler may not know. There were also limitations concerning the time available, research experience, and resources available. Although eight months may seem like a long time, when conducting scientific or social research, in many cases, it is not sufficient time to obtain the kind of results desired. With more time I could have reached out and expanded my research beyond just Boulder, CO. This would have made the results increasingly diverse. Boulder does not have a diverse population. In 2016, Boulder had a population of 322,226, and 90.7% is white, 59.3% has a bachelor’s degree or higher, and the median household income is $72,282 (U.S. Census Bureau, 2017). These demographics paint a brief picture of the homogeneous population in Boulder and how they might limit a social study. Another limitation due to time constraints was that the survey could have been further developed through initial tests, and I could have done more research to find out which question would be most important to ask. Although limitations were evident, I was still able to draw useful conclusions and implications from the data and review.

Implications

A key implication found through my survey results is that the majority of the angling population in Boulder are concerned about the conservation of the fisheries and are consistently practicing catch-and-release. This led to the finding that there is a lag between the available scientific research regarding catch-and-release angling and the anglers practicing catch-and-release. Although many of my survey respondents knew the correct techniques and practices, there are so many other aspects to consider when practicing catch-and-release that go beyond the scope of my research. Other similar research indicates this gap in knowledge as well. One of the biggest struggles for the scientific community is disseminating informational research to the general public (Eagleman, 2013). Since fly fishing, and fishing in general, is practiced across the globe, it is important to keep the public up to date with the best techniques to maximize their conservation efforts. The primary implication of my study is the need to increase the dissemination of catch-and-release practices, but also to continually study the anglers' practices and techniques to ensure they match up with the scientifically agreed upon approaches.

Conclusion and Recommendations

Catch-and-release angling is a broad topic, and this study delves into the practice surrounding the angling population of Boulder, Colorado. Through a variety of study generalizations and the survey results, it seems as though catch-and-release may be understood too simplistically. There is so much to consider when practicing catch-and-release for increased conservation results. Overall, the importance of education of the anglers is key to improving the conservation practice. It is also imperative that consistent studies are done to fill the gaps in knowledge of catch-and-release impacts on various species using various practices and methods. The research I conducted regarding catch-and-release as a conservation practice has led me to a series of recommendations to further improve the conservation impact anglers have on fisheries.

One recommendation that can be made through both policy measures and overall angler education is regarding equipment. “The equipment used by anglers to capture fish can play a large role in determining the severity of injury and chance of mortality” (Cooke & Suski, 2005, p. 1202). The discussion of different equipment types is expansive and beyond the scope of this research, but an example discussed above is the use of barbless hooks. The increase of education and policy regarding mandatory use of barbless or debarbed hooks is extremely important. This need can be addressed by agencies, fly shops and fishing companies, and by anglers advocating for the proper equipment use.

Another recommendation I have after reviewing catch-and-release practices is to have an educational approach when distributing fishing licenses. This intervention could involve an incentive, in which the purchaser pays less for the license by taking a small quiz after reviewing an informational reading on proper catch-and-release practices. This could also include handing out an educational pamphlet is the participant is buying the pass over the counter as opposed to online.

A third recommendation is for researchers and scientists in the field of fishery management and catch-and-release conservation. Through the general review of catch-and-release data, it was evident that there were few consistencies within research for similar fish species. This data is very important to the complete understanding of catch-and-release, and therefore it is critical that scientist consider doing comparable research in order for claims to be made about different catch-and-releases practices.

My final recommendation is to put pictures of the native and non-native fish in each popular fishing area. This will aid in the identification of species that need to be returned to the water and the species that may be best if kept. This is a measure that state agencies would need to implement. Overall, my recommendations take the form of increasing the angler’s understanding and allowing them to do what they can with this knowledge. The dissemination of scientific knowledge is extremely important with regards to public action, and catch-and-release practices are no different.

References

Anderson, D. K., Ditton, R. B., & Hunt, K. M. (2007). Measuring Angler Attitudes Toward Catch-Related Aspects of Fishing. *Human Dimensions of Wildlife,12*(3), 181-191. doi:10.1080/10871200701323066

Andrews, D., Nonnecke, B., & Preece, J. (2003). Electronic Survey Methodology: A Case Study in Reaching Hard-to-Involve Internet Users. *International Journal of Human-Computer Interaction*, *16*(2), 185-210. doi:10.1207/s15327590ijhc1602_04

Arlinghaus, Robert, Cooke, Steven J., Lyman, Jon, Policansky, David, Schwab, Alexander, Suski, Cory, Sutton, Stephen G., and Thorstad, Eva B. (2007). 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 (1 & 2). pp. 75-167.

Barclay, K., Voyer, M., Mazur, N., Payne, A. M., Mauli, S., Kinch, J., . . . Smith, G. (2017). The importance of qualitative social research for effective fisheries management. *Fisheries Research*, 186, 426-438. doi:10.1016/j.fishres.2016.08.007

Behnke, R. J. (1992). *Native trout of western North America*. Bethesda, MD: American Fisheries Society.

Bryan, H. (1977). Leisure Value Systems and Recreational Specialization: The Case of Trout Fishermen. *Journal of Leisure Research, 9*(3), 174-187. doi:10.1080/00222216.1977.11970328

Brownscombe, J. W., Danylchuk, A. J., Chapman, J. M., Gutowsky, L. F., & Cooke, S. J. (2017). Best practices for catch-and-release recreational fisheries – angling tools and tactics. *Fisheries Research*, *186*, 693-705. doi:10.1016/j.fishres.2016.04.018

Coleman, Mark A., (2007). Life-History and Ecology of the Greenback Cutthroat Trout, 1-15

COLORADO PARKS & WILDLIFE: Fish Species Identification. (n.d.). Retrieved December 07, 2017, from http://cpw.state.co.us/learn/Pages/FishID.aspx

Campbell P.M., Pottinger T.G. & Sumpter J.P. (1992) Stress reduces the quality of gametes produced by rainbow trout. Biology of Reproduction 47, 1140–1150.

Cooke, S. J. & Schramm, H. L. (2007), Catch-and-release science and its application to conservation and management of recreational fisheries. *Fisheries Management and Ecology*, 14: 73–79. doi:10.1111/j.1365-2400.2007.00527.x

Cooke, S. J., & Suski, C. D. (2005). Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources? *Biodiversity and Conservation,14*(5), 1195-1209. doi:10.1007/s10531-004-7845-0

Crisp, D. T. (2000). *Trout and salmon: Ecology, conservation, and rehabilitation*. Oxford: Fishing News Books.

Detar, J., Kristine, D., Wagner, T., & Greene, T. (2014). Evaluation of Catch-and-Release Regulations on Brook Trout in Pennsylvania Streams. *North American Journal of Fisheries Management*, *34*(1), 49-56. doi:10.1080/02755947.2013.848251

The Dorling Kindersley encyclopedia of fishing. (2010). London: Dorling Kindersley.

Dunham, J.B., Adams, S.B., Schroeter, R.E. et al. Reviews in Fish Biology and Fisheries (2002) 12: 373. https://doi.org/10.1023/A:1025338203702

Eagleman, D. M. (2013). Why Public Dissemination of Science Matters: A Manifesto. Journal *of Neuroscience,33*(30), 12147-12149. doi:10.1523/jneurosci.2556-13.2013

Ferguson, R. A., & Tufts, B. L. (1992). Physiological Effects of Brief Air Exposure in Exhaustively Exercised Rainbow Trout (Oncorhynchus mykiss): Implications for "Catch and Release" Fisheries. *Canadian Journal of Fisheries and Aquatic Sciences,49*(6), 1157-1162. doi:10.1139/f92-129

Fink, A. (1996). *How to Analyze Survey Data*. Thousand Oaks, Calif.: Sage.

Fly Fishers International. (n.d.). Fly Fishing Glossary. Retrieved March 20, 2018, from https://flyfishersinternational.org/Resources/EducationalResources/FlyFishingGlossary/tabid/273/Default.aspx

Goodspeed, C. E. (1939). *Angling in America*. Boston: Houghton Mifflin.

Grambsch A. E., and Fisher W. L. (1991). Catch-and-release statistics for bass and trout anglers. *Am. Fish. Soc. Symp.,* 12, 390-396.

Gupta, N., Raghavan, R., Sivakumar, K., Mathur, V., & Pinder, A. C. (2015). Assessing recreational fisheries in an emerging economy: Knowledge, perceptions and attitudes of catch-and-release anglers in India. *Fisheries Research, 165*, 79-84. doi:10.1016/j.fishres.2015.01.004

Harlan, C. (2017, March). 2017 Colorado Fishing. *Colorado Parks and Wildlife.* Retrieved from http://cpw.state.co.us/Documents/RulesRegs/Brochure/fishing.pdf

Jenkins T.M. Jr (2003) Evaluating recent innovations in bait fishing tackle and technique for catch and release of rainbow trout. North American Journal of Fisheries Management 23, 1098–1107.

Lietz, P. (2008). Questionnaire Design in Attitude and Opinion Research: Current State of an Art. *Germany: Jacobs University Bremen* 655(13), 1-20

Love Stowell, S.M., and Martin, A.P. (2016). Cutthroat trout in Colorado: A case study connecting evolution and conservation. *CourseSource*. https://doi.org/10.24918/cs.2016.20

Maclean, N. (1976). *A River Runs Through It and Other Stories.* Chicago (IL): University of Chicago Press

Matthiessen, P. (1995). *Wildlife in America*. New York: Penguin Books.

Meka, J. M. (2004). The Influence of Hook Type, Angler Experience, and Fish Size on Injury Rates and the Duration of Capture in an Alaskan Catch-and-Release Rainbow Trout Fishery. *North American Journal of Fisheries Management,24*(4), 1309-1321. doi:10.1577/m03-108.1

Owens, K. (2002). Fishing the Hatch: New West Romanticism and Fly-Fishing in the High Country. *Montana: The Magazine of Western History*, *52*(No. 2), 10-19.

Pelletier, C., Hanson, K. C., & Cooke, S. J. (2007). Do catch-and-release guidelines from state and provincial fisheries agencies in north america conform to scientifically based best practices? *Environmental Management, 39*(6), 760-73. doi:http://dx.doi.org.colorado.idm.oclc.org/10.1007/s00267-006-0173-2

Pollock, K., & Pine, W. (2007). The design and analysis of field studies to estimate catch-and-release mortality. *Fisheries Management and Ecology, 14*(2), 123-130. doi:10.1111/j.1365-2400.2007.00532.x

Pope, K. L., Wilde, G. R., & Knabe, D. W. (2007). Effect of catch-and-release angling on growth and survival of rainbow trout, Oncorhynchus mykiss. *Fisheries Management and Ecology,14*(2), 115-121. doi:10.1111/j.1365-2400.2007.00531.x

Rahel, F. (2008). "Managing Fisheries and Conserving Fishes: A Difficult Balancing Act." *BioScience*, vol. 58, no. 4, pp. 354-356. *JSTOR*, www.jstor.org/stable/10.1641/b580411.

Risley, C. A., & Zydlewski, J. (2010). Assessing the Effects of Catch-and-Release Regulations on a Brook Trout Population Using an Age-Structured Model. *North American Journal of Fisheries Management*, *30*(6), 1434-1444. doi:10.1577/m09-158.1

Roy Morgan Research. (2004). Released fish survival national follow up survey report. *Infofish Services.*

Schill, D. J., Griffith, J. S., & Gresswell, R. E. (1986). Hooking Mortality of Cutthroat Trout in a

Catch-and-Release Segment of the Yellowstone River, Yellowstone National Park. *North American Journal of Fisheries Management,6*(2), 226-232. doi:10.1577/1548-8659(1986)6<226:hmocti>2.0.co;2

Shetter, D. S., & Allison, L. N. (1955). *Comparison of mortality between fly-hooked and worm-hooked trout in Michigan streams*

Snyder, S., Borgelt, B., & Tobey, E. M. (2016). *Backcasts: a global history of fly fishing and conservation*. Chicago (IL): The University of Chicago Press.

Staley, K., & Mueller, J. (2000). Rainbow Trout (Oncorhynchus mykiss). *United States Department of Agriculture*. Retrieved from https://www.fws.gov/northeast/wssnfh/pdfs/RAINBOW1.pdf.

Stensland, S., & Aas, Ø. (2014). The role of social norms and informal sanctions in catch-and-release angling. *Fisheries Management and Ecology*, *2*1(4), 288-298. doi:10.1111/fme.12078

Trotter, P. (2008). *Cutthroat, native trout of the West*. Berkley: University of California Press.

U.S. Census Bureau. (2017). QuickFacts. Retrieved March 09, 2018, from https://www.census.gov/quickfacts/fact/table/bouldercountycolorado/PST045217

Weltersbach, M. S., Ferter, K., Sambraus, F., & Strehlow, H. V. (2016). Hook shedding and post-release fate of deep-hooked European eel. *Biological Conservation, 199*, 16-24. doi:10.1016/j.biocon.2016.04.015

Wiltzius WJ. (1985). Fish culture and stocking in Colorado, 1872– 1978. Division report no. 12. Denver (CO): Colorado Division of Wildlife.

Appendix A

Catch-and-Release Thesis Survey

Consent Question

My name is Melissa Merritt, and I am conducting a study observing how anglers in Boulder practice catch-and-release angling. I am conducting this survey as part of my Senior thesis for my Environmental Studies degree at University of Colorado, Boulder.

You will be asked to answer the following questions to the best of your ability.

There are no anticipated risks to you if you participate in this study. You will have the option to enter a raffle for one of two gift cards from either Rocky Mountain Anglers or Front Range Anglers.

Taking part in this study is completely voluntary. If you choose to be in the study you can withdraw at any time without consequences of any kind. Participating in this study does not mean that you are giving up any of your legal rights.

All answers to this study will remain confidential.

If you have any questions you may contact me at melissa.merritt@colorado.edu or (847) 772-5137.

If you are 18 years of age or older, and you consent to take part in this survey, please select yes. If not, select no, and your participation will be complete.

a) Yes
b) No

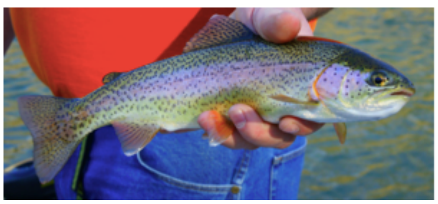
1) How many years have you been fishing?
   a. 0-1 year
   b. 1-10 years
   c. 10-20 years
   d. 20+ years
2) How often do you fish in Boulder or Northeast Colorado?
   a. Daily
   b. 2-3 times a week
   c. Once a week
   d. 2-3 times a month
   e. A couple times a year
3) Have you caught a trout in Colorado?
   a. Yes
   b. No
   c. Unknown
4) What species of trout have you caught in Colorado?
   a. Rainbow
   b. Greenback Cutthroat
   c. Brown

d. Brook
e. Rio Grande Cutthroat
f. Colorado River Cutthroat
g. Unknown
h. None

5) Below are pictures of trout species in Colorado. Please mark the species that you can identify as native.

a.


b.


c.


d.


e.


f.


   g. Do not know

6) Below are the names of trout species in Colorado. Please mark the species you can identify as native.
   a. Rainbow Trout
   b. Greenback Cutthroat Trout
   c. Rio Grande Cutthroat Trout
   d. Brook Trout
   e. Colorado River Cutthroat Trout
   f. Brown Trout
   g. Do not know
7) When do you practice catch-and-release fishing?
   a. Never
   b. Only when required by law
   c. Usually unless you plan to eat the fish
   d. Usually unless you plan to mount the fish
   e. Only with certain fish species
   f. Always
8) If you answered only with certain fish species, which species? (If you did not submit this answer, type N/A)
   a. Free response
9) If you typically do practice catch-and-release, please select the reason why that you relate with most
   a. Conservation reasons (to protect the fishery and general ecosystem)
   b. Future catching possibilities (so you or others can catch the fish again)
   c. Ethical reasons
   d. Law requires it in the places you primarily fish
   e. Other, please explain
10) The best catch-and-release practices are not universally agreed upon by government agencies. For these different categories select the technique you believe to be best. If you select other, please explain the practice you believe to be best.
11) How long do you believe is a proper air exposure time for the fish?
   a. No time out of the water
   b. <10 seconds
   c. 10-30 seconds
   d. <1 minute
   e. Other
12) What are the best handling techniques when holding a fish?
   a. With dry hands, horizontal
   b. With dry hands, vertical
   c. With wet hands, horizontal
   d. With wet hands, vertical
   e. Other
13) When a hook is deeply embedded do you cut the line or do you do everything you can to get the hook out?
   a. Cut the line
   b. Get the hook out
   c. Other
14) Do you use barbed or barbless hooks?
   a. Barbed hooks
   b. Barbless hooks
   c. Other
15) How old are you?
   a. 18-25 years old

   b. 25-40 years old
   c. 40-60 years old
   d. 60-80 years old
   e. >80 years old

16) What is your gender?
   a. Male
   b. Female
   c. Other

17) Are you a student?
   a. Yes
   b. No

18) What is your income?
   a. Less than $20,000
   b. $20,000 to $60,000
   c. $60,000 to $100,000
   d. $100,000 to $150,000
   e. Greater than $150,000

19) What was this survey about?
   a. Recycling
   b. Fishing
   c. Computer Science

20) If you would like to be entered into the raffle for one of two $20 gift cards for either Rocky Mountain Anglers or Front Range Anglers, please enter your email. If you would not like to be entered in the raffle, type N/A

Appendix B

B-1: Correlation Coefficient Table Number 1 – Correlation matrix of survey responses

	Years Fishing	*How often do you fish?*	*Trout caught*	*Native Trout (Picture)*	*Native Trout (Name)*	*When do you practice C&R*	*Why do you practice C&R*	*Air exposure*	*Handling*	*Embedded hook*	*Hook Type*	*Age*	*Gender*	*Student*	*Income*
Years Fishing	1														
How often do you fish?	0.096794451	1													
Trout caught	0.1605135	-0.0271588	1												
Native Trout (Picture)	-0.079017165	0.029782819	0.003020925	1											
Native Trout (Name)	0.095848756	0.039380346	0.01357312	0.272266197	1										
When do you practice C&R	0.11393975	0.166451458	0.185005037	0.100242723	0.035621586	1									
Why do you practice C&R	-0.055538819	-0.008013881	-0.004438894	-0.106247086	0.002360138	-0.118711325	1								
Air exposure	-0.037486065	0.02002127	0.040709388	0.08956632	0.027489949	0.116130566	0.219184539	1							
Handling	0.083477774	-0.003919314	0.26409951	0.239536894	0.119115082	0.030422972	0.191988264	0.076673885	1						
Embedded hook	-0.141584417	0.061237104	-0.075299385	0.061619824	-0.107741025	0.023726475	0.001756393	0.312058327	-0.174165767	1					
Hook Type	0.023700935	-0.114928478	0.062403025	-0.057641575	0.008988325	-0.008951658	0.129008804	-0.046184463	0.04190814	0.05214134	1				
Age	0.563647773	0.172375953	0.045094662	-0.048046807	0.044994329	-0.134467543	-0.014261083	0.020745093	0.046257151	-0.090908405	0.108069681	1			
Gender	-0.483385646	0.169278768	-0.11852927	0.135220967	-0.063895316	0.044697363	0.086835634	0.109104	-0.065001939	0.159736518	0.113005893	-0.234047098	1		
Student	-0.234408656	-0.121738439	-0.043464608	-0.050041103	-0.042214053	0.15614546	-0.018256979	-0.058308086	-0.090533298	0.073428209	-0.119965918	-0.484133356	-0.062179246	1	
Income	0.379099804	0.173423725	0.093994833	-0.017478931	0.101509904	-0.071137057	-0.09458478	-0.138117303	0.107061001	-0.051182087	0.169302202	0.509290454	-0.294155705	-0.418874185	1

B-2: Correlation Coefficient Table Number 2: Identification of Native Trout

	Identifying Native Trout by Picture (right vs wrong)	Identifying Native Trout by Name (right vs wrong)
Years Fishing	0.09645	0.17244
How often do you fish?	0.00752	0.04966
Trout caught (species)	0.02988	0.08666
Number of trout species caught	0.12902	0.35194
Native Trout (Picture)	-0.084426	-0.04385
Native Trout (Name)	-0.06875	-0.11929
When do you practice C&R	0.05920	0.11339
Why do you practice C&R	0.09020	-0.07580
Air exposure	0.00707	-0.00604
Handling	-0.00318	0.01668
Embedded hook	-0.06115	-0.02682
Hook Type	0.20468	0.06082
Age	0.06486	0.03268
Gender	-0.02501	-0.04064
Student	-0.06217	-0.12011
Income	0.05574	0.03328
Native Trout name (right vs wrong)	0.24948	1
Native Trout picture (right vs. wrong)	1	0.24948

B-3: Correlation Coefficient Table Number 3: Proper Catch-and-Release Techniques

	Air Exposure (right vs. wrong)	Handling (right vs. wrong)	Embedded Hook (right vs. wrong)	Hook Type (right vs. wrong)
Years Fishing	0.03381	-0.07667	0.14994	0.13003
How often do you fish?	0.01184	0.02142	-0.07667	0.24640
Trout caught (species)	-0.01615	-0.23881	0.07385	0.07704
Number of trout species caught	0.01039	-0.09733	0.18291	0.11273
Native Trout (Picture)	0.00008	-0.22966	-0.02596	0.03269
Native Trout (Name)	0.02459	-0.10278	0.11718	0.10153
When do you practice C&R	-0.03423	-0.01729	-0.03423	-0.15519
Why do you practice C&R	-0.10154	-0.21057	-0.02108	0.03473
Air exposure	-0.67141	-0.09513	-0.23221	-0.08558
Handling	0.03292	-0.92452	0.17580	-0.00400
Embedded hook	-0.17906	0.18673	-0.91884	-0.12228
Hook Type	0.02666	-0.05355	-0.01325	0.06528
Air Exposure (right vs. wrong)	1	-0.00134	0.14026	0.21107
Handling (right vs. wrong)	-0.00134	1	-0.18798	-0.01694
Embedded hook (right vs. wrong)	0.14026	-0.18798	1	0.10310
Hook Type (right vs. wrong)	0.21107	-0.01694	0.10310	1
Age	0.00904	-0.07148	0.12242	0.21392
Gender	0.02225	0.04523	-0.14068	0.13949
Student	0.07535	0.09792	-0.14308	-0.07113
Income	0.03943	-0.08685	0.09489	0.07582
Native Trout name (right vs wrong)	0.08274	0.01014	0.10098	0.01349
Native Trout picture (right vs. wrong)	0.10410	-0.01188	0.11318	0.02714