TROUT STOCKING IN COLORADO (1885-2013): SPECIFICALLY OBSERVING VARIABLES CONTRIBUTING TO ANGLER LICENSE SALES

A THESIS

Presented to

The Faculty of the Department of Economics and Business

The Colorado College

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Arts

By

Kevin James Coleman

April 2015

TROUT STOCKING IN COLORADO 1885-2013: SPECIFICALLY OBSERVING VARIABLES CONTRIBUTING TO ANGLER LICENSE SALES

Kevin James Coleman

April 2015

Economics

Abstract

This study analyzes the various trends in Colorado's historical angler license sales from the conception of hatchery and licensing programs within the state. The analyses illustrate how the historic supply and demand for hatchery trout greatly determined how Colorado's stocking programs developed over time. The results show that as Colorado stocks more fish, there is an expected decline in total angler licenses bought three years down the line.

KEYWORDS: (Trout Stocking, Fishing, Salmonid, Colorado, Angler, License)

ON MY HONOR, I HAVE NEITHER GIVEN NOR RECEIVED
UNAUTHORIZED AID ON THIS THESIS

_____

Signature

TABLE OF CONTENTS

Introduction

Colorado's trout stocking programs have greatly fluctuated and evolved over time. In the early history of Colorado's statehood and the evolvement of its conservational orient, two persistent themes rise to the surface: (1) A need for strict budgeting, and (2) a creative outlet for profit. Early financial constraints were tied to Colorado's stocking programs because of limited funding from Congress. These constraints are what tragically led the state to lose sight of protecting its only native trout species, the Greenback Cutthroat. Leaning towards profit and business expansion inevitably sacrificed integral aspects of conservation.

As stocking programs developed, it became apparent that angler license sales reflected the success of the fishing culture in Colorado. Originally, the state of Colorado assumed that fishing productivity was the result of how many fish were being stocked each year. In aims to sell more licenses and expand its fishing industry, Colorado committed to stocking more fish in its waters. As a result, mass production plans for stocking non-native trout were established, and this had deep contributions towards some of the problems Colorado Parks and Wildlife (CPW) are backtracking to fix today. CPW is in a difficult situation where they are trying to increase angler licenses sales to where peak totals were twenty years ago, while also making the attempt to restore native fish species, like Colorado's state fish, the Greenback Cutthroat. An effective way to restore the native fish populations would be to decrease the stocking volumes of the non-native fish species that replaced them.

CPW fears that stocking less non-native hatchery trout per year will result in decreased fishing productivity, thus ruining their ability to return licenses sales to what they used to be.

Through extensive research, I have found that Colorado state's assumption that fishing productivity is the result of how many fish are being stocked each year is incorrect. In actuality, higher stocking volumes have proven to result in lower angler license sales. This study will explain the structures of the state and federal stocking programs in Colorado, and how their individual factors of production influenced angler license sales over time.

Background

History of Colorado Salmonids

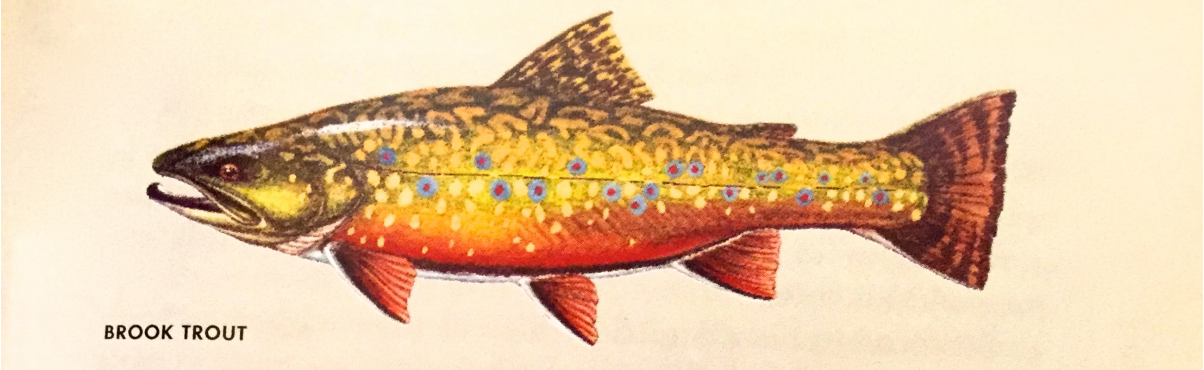
The Rainbow trout (*Oncorhynchus mykiss*) and Brown trout (*Salmo trutta*) are the two fish species that dominate the Rocky Mountain drainages. Both the Rainbow trout and the Brown trout have proved to thrive in the rivers of Colorado, despite neither one of them being native to the state. The trout species fall under the same family as the salmon, *Salmonidae*, hence their similarity in shape, fin location, and bone structure. Salmonids are historically rooted as a valuable food source, and have recently become the center of a growing recreational sport and profitable tourist attraction across the many countries in which they live. While the Brook trout (*Salvelinus fontinalis*) and Cutthroat trout (*Oncorhynchus clarkii*) are also abundant throughout the state, they are generally perceived as having lesser socioeconomic value than the Rainbow and Brown trout (Ficke, Peterson, & Janowsky, 2009).

Early on, Coloradans acknowledged the great economic importance of the trout, and they did not hesitate to make organized attempts to optimize its resource potential (Wiltzius, 1985). This prompt recognition of economic opportunity ultimately steered Colorado towards becoming the trout mecca for the stocking and hatchery endeavors of the United States in the years to come. Following its recognition as the trout-rearing icon in the late 19th century, Colorado began artificially stocking non-native trout species among its waters (Wiltzius, 1985). However, it was before that time when Colorado's formerly untouched rivers belonged to the Greenback Cutthroat trout (*Oncorhynchus clarkia stomias*). Due to

the excessive stocking of non-native trout, the Greenback's presence was diluted almost to the point of extinction by the 1930's ("Colorado State Fish," 2015).

In addition to the Rainbow trout, Brown trout, and Brook trout, Colorado's hatchery programs were involved in the stocking of a wide variety of other non-native *Salmonidae* species. This secondary list of non-natives includes the Mackinaw trout (lake trout), Bullhead trout, Steelhead trout, Yellow-fin trout, and Golden trout. Contrary to popular belief, Colorado also stocked various salmon species, including the Chinook salmon (King), Atlantic salmon, Coho salmon, and Kokanee salmon (landlocked Sockeye). The costly endeavor of stocking these non-natives taught Colorado that its lakes and rivers were too small for what the bigger species, such as the Chinook salmon or Steelhead trout, needed to survive. After being stocked, the bigger Salmonids would exceed their carrying capacity, deplete their food source, and eventually die out (Wiltzius, 1985).

Following many decades of trial and error with experimental species, Colorado discovered its permanent, most well adapted list of Salmonids: the Mackinaw trout, Brook trout, Brown trout, Cutthroat trout, Rainbow trout, and Kokanee salmon. Colorado's stocking endeavors became much more efficient once these six species were selected for large-scale hatchery production. For the purposes of this study, I decided to not access the stocking records of both the Mackinaw trout and Kokanee salmon because of great inconsistencies in their historical stocking entries. Due to the availability of much more consistent data, the Salmonid species analyzed in this study have been narrowed down to the Brook, Brown, Cutthroat, and Rainbow trout.



Brook trout (Salvelinus fontinalis) were introduced to Colorado in 1872, and are native to eastern North America. They are most commonly found in small streams and high mountain lakes. Known for their exceptional ability to reproduce two years after hatching, they are often considered as a nuisance species because they threaten populations of more desirable trout species (Christopherson, 2015).

Brown trout (*Salmo trutta*) *were introduced to Colorado in 1890, and are native to Central Europe and Asia. Its heightened ability to detect movement in water allows it to hunt more proficiently in low light conditions. While a river never sleeps, this advantage makes the Brown the top predator of the night* (Christopherson, 2015).

The Cutthroat (*Oncorhynchus clarkii*) *is the only native trout to Colorado. Nearly 22,000 years ago, a subspecies of Cutthroat crossed the Continental Divide when the last Ice Age began to melt, and later found itself in the drainages of Colorado. Having reached its destination, the Greenback Cutthroat* (*O. clarkia stomias*) *became Colorado's only native trout species and was named the Colorado State Fish in 1994* (Christopherson, 2015).

The Rainbow (*Oncorhynchus mykiss*) *was introduced to Colorado in the 1880's, and is native to the Pacific drainages along the West Coast of North America. By earning the reputation for being a hard-fighting game fish, it became the most commonly stocked fish in Colorado* (Christopherson, 2015).

Pictures Source: (Bitton & Walinchus, 2004)

State Stocking Programs

Over time there has been much discourse among Colorado anglers about the "right" way to successfully sustain Colorado's stocking programs. Some consider it tragic that non-native hatchery fish, like the Rainbow and Brown trout, wiped out Colorado's native fish species, like the Greenback Cutthroat. Others believe that although many native fish were lost along the way, Colorado's stocked fisheries support the enormous amount of fishing pressure the state receives each year. With that said, a majority of the fishermen are indifferent to the specific origins of the fish they catch.

Colorado Parks and Wildlife's (CPW) state stocking efforts are reliant upon how active Colorado fishermen are, how much revenue angler license sales produce annually, and the amount in which Congress gives to the state annually in the form of Sport Fish Restoration Apportionments. Colorado's stocking and hatchery programs largely function as a collective business. CPW manage the state's stocking and hatchery programs, and their successes bring in significant amounts of revenue to the economy. With that said, the output of stocking programs is mutually dependent upon the productivity of the fishing industry.

State stocking programs aim to maximize revenue by increasing the amount of fishing licenses that are bought each year. If more licenses are sold in a year, then their business expands. An increase in licenses typically calls for more fish to be raised and stocked to account for anticipated increases in angling pressure. Next to license revenue, federal-aid apportionments are the second greatest source of funds

for state stocking programs. Better known as the Sport Fish Restoration Apportionments (SFRP), the amount in which Congress gives to Colorado's state stocking programs is calculated by the expected economic benefits of the fishing industry from year to year, including secondary impacts from industry employees (P. Nicholas, personal communication, February 25, 2015). The state of Colorado makes use of its Salmonid populations to ensure that its resident and non-resident fishermen are reasonability satisfied with the availability of fish to catch.

Revenue generated from angler license sales stand as the primary source of funds contributing to how many fish are stocked annually. The analyses in this study prove that the correlation between licensed anglers and stocking volumes in Colorado was most significant during the earlier parts of the 20th century. The shift in correlation between the two occurred in the late 1960s, when federal stocking programs increased their level of involvement in Colorado.

Federal Stocking Programs

Federal stocking programs began in 1871, when President Ulysses S. Grant nominated Spencer Baird as the first U.S. Fish Commissioner (Osborne & Gerencser, 2003). The initial goals of the U.S. Fish Commission were to increase the populations of desirable food fishes across America. By this time, the Fish Commission had been given limited funding, and Baird requested additional resources to establish the country's first hatchery units and stocking programs. Due to the increased demands for fish in the 1870s, Congress gave the Commissioner $15,000 to build fish breeding and hatchery stations across the country (Wiltzius, 1985).

The Colorado River Storage Act of 1956 drove this great demand for dams to be built Colorado ("Facilities by State - Bureau of Reclamation," 2007). The Colorado River Storage Project (CRSP) was designed to regulate the flows of rivers in the Upper Colorado River Basin, while providing for reclamation of arid and semi-arid lands, providing flood control, and generating hydropower for the state ("Colorado River Storage Project Home Page," 2008). The United States Bureau of Reclamation manages water resource distribution in the U.S., and was in charge of designing the major hydropower dams built for this project ("Colorado River Storage Project," 2015). The Bureau of Reclamation has listed a total of 60 major dams in Colorado, more than half of which were built in accordance with the CRSP ("Facilities by State - Bureau of Reclamation," 2007). Due to the increase of dams built in Colorado during the 1960's and 70's, many miles of river were being extracted for the physical construction space of each dam. When a dam is built into a flowing river, miles of habitat are transformed into reservoirs that naturally pool above and, in some cases, below each site. This habitat withdrawal was severely decreasing the fish populations in major Colorado rivers, and this became a great threat to fisheries in the 1960s. Dam construction processes regularly cloud river water, and this repeated flush of sediment suffocates the delicate gill structures of Colorado Salmonids. The extreme transformation of the river habitats restructured the goals of federal stocking programs. In the 1950's their main objective became reviving fish populations rather than stocking them for recreational use (E. Stege, personal communication, February 16, 2015).

There have been many attempts to avoid the negative environmental impacts associated with dams. For example, most dams have built in fish ladders, which give fish the opportunity to cross into the upper or bottom sections of a river. Fish ladders are a series of ascending pools that fish can jump through to access the river on the other side of the dam. These ladders are essential to the upstream migration of many adult trout ("National Ocean Service," 2014). Dams are a great source of hydroelectric energy for the state, and when the reservoir above a dam is drained, it creates immense amounts of power. It is estimated that the CRSP dams have capabilities to provide over five billion kilowatt-hours of energy annually ("Colorado River Storage Project," 2008). In order for dams to generate maximum amounts of hydroelectricity, water must be drained through the dams at great volumes and speed. By draining top reservoirs, major increases in the height and flow of a river below the dam are very hard on the fish occupying that water. These harsh fluctuations stress the fish out, as they are suddenly required to exert huge amounts of energy to keep up with the increased speed of water.

A strategy used to lessen this stress put on fish is to build a second dam downstream, which is called an afterbay dam (T. Flanagan, personal communication, February 25, 2015). An afterbay dam is designed to catch the immense speed and rush of water flowing from the draining dam, and is pooled in between the two dams. Over time, the afterbay dam releases the water pooled in this area to prevent major shifts in the aquatic habitat. Unlike the one above it, afterbay dams are not used for hydroelectric power, so the slow trickle and release of water overtime is beneficial to creating a homeostatic environment for river organisms. Occasionally during the

construction of a dam, a river will be diverted around the construction site so that flowing water can continue to pass through and not completely disrupt the river life below, resulting in what Colorado calls "divergent dams" ("Bureau of Reclamation: Lower Colorado Region," 2009).

There are now two national hatcheries located within Colorado, the Leadville National Hatchery and the Hotchkiss National Hatchery. The Leadville National Hatchery was established in 1888, and its initial roles were assisting the Commission by increasing populations of game fish and restoring the declining populations of food fishes (E. Stege, personal communication, February 16, 2015). The Hotchkiss National Hatchery was later established in 1967, and was primarily in charge of mitigating losses in fish populations due to federal development projects ("COLORADO PARKS & WILDLIFE," 2015). In the late 1950's, the Leadville National Hatchery was in charge of stocking fish across the western front of the United States and maintaining species even outside of Colorado (E. Stege, personal communication, February 16, 2015). In the years following of CRSP dam construction, there was an increase in demand for trout to be stocked in rivers that had suffered greatly from declining fish populations (A. Mendoza, personal communication, February 12, 2015), and the Leadville hatchery could not possibly produce enough fish at the time. The solution to supply the increase in demand for trout was to establish the second national hatchery in Hotchkiss, Colorado, to take on the mitigation efforts of the federal stocking programs (A. Mendoza, personal communication, February 12, 2015).

This study observes the implementation of dam projects across Colorado because after the CRSP was put into action, the increase in dams wiped out millions of Salmonids. Environmentalists blamed the major losses in fish populations on the construction of these CRSP dams. It then became the responsibility of the federal stocking programs to make up for these losses in fish. In addition to assessing the connection between state stocking volumes and angler license sales, this study will also evaluate how CRSP dams influenced both total license sales and the yearly demands for stocked hatchery trout.

Data and Methods

This study examines historical data for Salmonid stocking volumes, angler license sales and revenue, federal aid apportionments, and dams in Colorado. A portion of research for the background section of this study was collected qualitatively in the form of interviews, and this was to help further the relevancy of historical data that was collected and analyzed quantitatively.

Collection of Data

The following section explores the collection process and significance of data belonging to the variables that influenced the historical volumes of annual license sales in Colorado.

Salmonidae Stocking I contacted the Pueblo State Hatchery and spoke to one of their employees, David Harris, explaining my plans to research historic trout stocking levels in Colorado. I wanted to discover what variables influenced the fluctuating volumes of how many fish get stocked in Colorado each year. I originally believed that different stocking volumes were related certain annual weather variable trends, such as river water flows, rainfall, snowpack, days of sunshine, humidity levels, etc. Harris forward me to his boss, Jim McKissick, CPW's Asst. Chief of Hatcheries.

I contacted McKissick on December 10, 2014, asking about hatcheries, influential weather variables, and if he could help me access some of Colorado's trout stocking data. McKissick explained that the CPW fish-stocking database only covered stocking data back to the early 1970s. He recommended the book, *Fish*

Culture and Stocking in Colorado, 1872-1978 by William J. Wiltzius, to access the early Salmonid stocking records of both the state and federal stocking programs from 1885 to 1978. McKissick sent me his own personal copy of Wiltzius' report, and I transferred all of the early annual Salmonid stocking records by species onto an Excel spreadsheet. Jim then introduced me to John Alves, CPW Senior Aquatic Biologist SW Region of Gunnison Colorado, to discuss the influence that weather variables may have on historic trout stocking volumes in Colorado.

I interviewed Alves, on February 17, 2015. Alves explained how hard it would be to pinpoint the effects of weather variables and their direct correlation to how many fish would be stocked in Colorado each year. He advised that although CPW Biologists account for water pH and water flows when deciding how many trout to stock, he said that it would be too hard to collect all the data, for each year, at all the different stocking locations around Colorado (personal communication, February 17, 2015). I asked Alves how I could acquire the data for annual trout stocking volumes from the beginning of their electronic records in the 1970s up until 2014. He sent me the CPW aquatic data request form, explaining that it was my only ticket to acquire the electronic data of recent state stocking programs. He told me to complete the form, and then send it to Andrew Treble, CPW Aquatic Research Data Analyst.

I completed the aquatic data request form and sent it to Treble. He said that he forwarded my form to the CPW data request review committee for approval. He explained that if the committee approved my data request form, I would be required

to sign a data sharing agreement and a data disclaimer before he could actually send me the data.

After the CPW review committee approved my data request form, I signed the data sharing agreement and data disclaimer, and Treble sent me the data I had requested on March 2, 2015. This data contained the total amount stocked per year for each Salmonid species (specific to each genetic strain) in Colorado from 1973 to 2014. There were a total of 925 stocking entries in and I decided to add up all the similar strains of trout to categorize them into the four species of trout I was planning on analyzing in the study. I formatted the CPW stocking totals from 1973 to 2014 in the same way that I had formatted the earlier annual stocking totals from the Wiltzius' report.

I asked Treble how I could request electronic stocking data records from the federal stocking programs. He recommended that I get in contact with both the Leadville and Hotchkiss National Hatcheries, but warned me that it would be a much more lengthy process, that could take up to months, to get access to those federal data stocking records. He explained that it would be much harder to go through the federal databases and get approval from much larger agencies with many more hoops to jump through, but he reassured me and saying that federal stocking levels are not as significant as state stocking levels in Colorado (personal communication, February 17, 2015).

Although I was not successful in acquiring electronic 1973-2014 data from the federal stocking programs, getting in contact with the national fish hatcheries gave me the great opportunity to interview the hatchery managers at both the Hotchkiss

and Leadville national hatcheries. Both hatchery managers gave me great insights on the historical roles that their national hatcheries played as federal stocking programs evolved over the 20th century. Ed Stege, Hatchery Manager at Leadville, explained the roles that the Leadville National Hatchery was responsible for even before the Hotchkiss National Hatchery was established (personal communication, February 16, 2015). Adam Mendoza, Hatchery Manager at Hotchkiss, described how the Hotchkiss National Hatchery was established to supply the state with Rainbow trout to mitigate the fish population losses due to CRSP dams (personal communication, February 12, 2015).

At this point in my search for Salmonid stocking data, I had acquired the state and federal annual stocking totals for each species of trout from 1885 to 1978, as well as the annual state stocking totals for each species of trout from 1978 to 2014. I combined all of my stocking data to a collective fish data Excel sheet. I had categorized the data by trout species, year, federal stocking program, and state stocking program. For the years that did not included stocking entries for certain trout species in the Wiltzius' report, I either left it blank or wrote down "NR" for not recorded.

While Wiltzius' report was incredibly helpful, there were inconsistencies with state stocking data records. Many stocking entries were not recorded between 1885 and 1902, and there are no state stocking records between the years of 1937 and 1943 during WWII. Federal stocking records proved to be more consistent than state stocking records throughout the first few decades of hatchery program establishment. Jim McKissick believes this is most likely due to greater availability of funds that

federal stocking programs had at the time, and this is especially applicable to the years of WWII (J. McKissick, personal communication, December 15, 2014). McKissick clarified that these additional funds for federal stocking programs had come from the U.S. Fish Commission, and this explains why early state stocking records are less consistent than federal stocking records (personal communication, December 15, 2014).

I consolidated the data to enter years are both state and federal stocking levels for all four trout species overlapped. By isolating the years that overlapped with full entries for each trout species on both the federal and state side of stocking programs, I was able to include that in my regressions and also add up a collective calling of grand total stocking levels between the early parts of the 20th century up until 1978, when my federal stocking program data reached it's limit.

License Sales and Revenue Angler license sales and revenue throughout Colorado's history from the beginning of the program's creation is so important because they shed light upon is the productivity of Colorado fishing. A spike of license sales, for example, reflects positive increases in fishing productivity in recent years. Another key component on license sales and revenue is the effect that natural disasters have on the fishing industry in Colorado. Wild fires, floods, and droughts in Colorado are detrimental not only to the river habitat conditions but also decrease the amount of non-residents fishermen that serve as a powerful asset to Colorado's annual fishing revenues. For example, the section of the South Platte River, known among local fishermen as "Deckers," was originally one of the most productive trout fisheries in the United States. In the summer of 2002, the Hayman Fire burned

150,000 acres of Colorado land, including the vegetation along the river at Deckers (Mayer, 2011). After trees had burnt and roots were destroyed, the framework holding the soil and riverbanks together collapsed, resulting in filling the river with sediment. This erosion ruined the deep pockets of water and pools along the river in which trout feed, and ultimately transformed Deckers into a habitat that was unappealing and life threatening to trout. The decline of Deckers trout populations eventually developed into a steep decrease in the ability to successfully catch fish. The Hayman Fire is one example where an event, such as a natural disaster, can cause decreases in fishing productivity and further add to decreases in angler license sales of both residents and non-residents. I wanted to acquire the angling license and revenue data to gain a better sense of how well Colorado's fishing productivity was doing throughout the years.

The historical license sales and revenue that I collected came from the CPW licenses offices in Denver. Henrietta Turner, head of CPW license management, sent me the electronic spreadsheets of license and revenue data from 1982 to 2013. It was incredibly helpful that these electronic spreadsheet records from recent decades because in the 1990s, so many alternative options were added to the licenses anglers could buy which would have taken forever to copy by hand. The 1990s provided the options of 1-day, 2-day, 5-day, 10-day, mixed hunting/fishing 1-day combo licenses, etc. The revenue columns for each license option were also provided in these records. Since the historical records before the 1990s were not included in the electronic copies that Turner sent to me, I ask her if I could have access to the CPW license office's historical records. When she approved my request, she allowed me have time

with these only historic physical recordings of early Colorado license data. On March 6, 2015, I visited Turner's office to record as much historical license data as I could. Sifting through these documents revealed that the first records of fishing licenses sold in Colorado began in 1919. Having hand recorded these historical physical copies in my own notes; I was able to sum up all of the columns to create total license and revenue figures for both residents and non-residents annually. The revenue of each column was added up to reveal the amount of funds that were redirected to Colorado's state stocking programs each year. The summed up totals of non-resident license was a great indicator for understanding how productive the tourism industry of fishing was doing within Colorado, and the total resident licenses were a great indicator for explaining how productive the Colorado rivers and reservoirs were fishing year round.

Figure 1

Total Licensed Anglers in Colorado 1919-2013

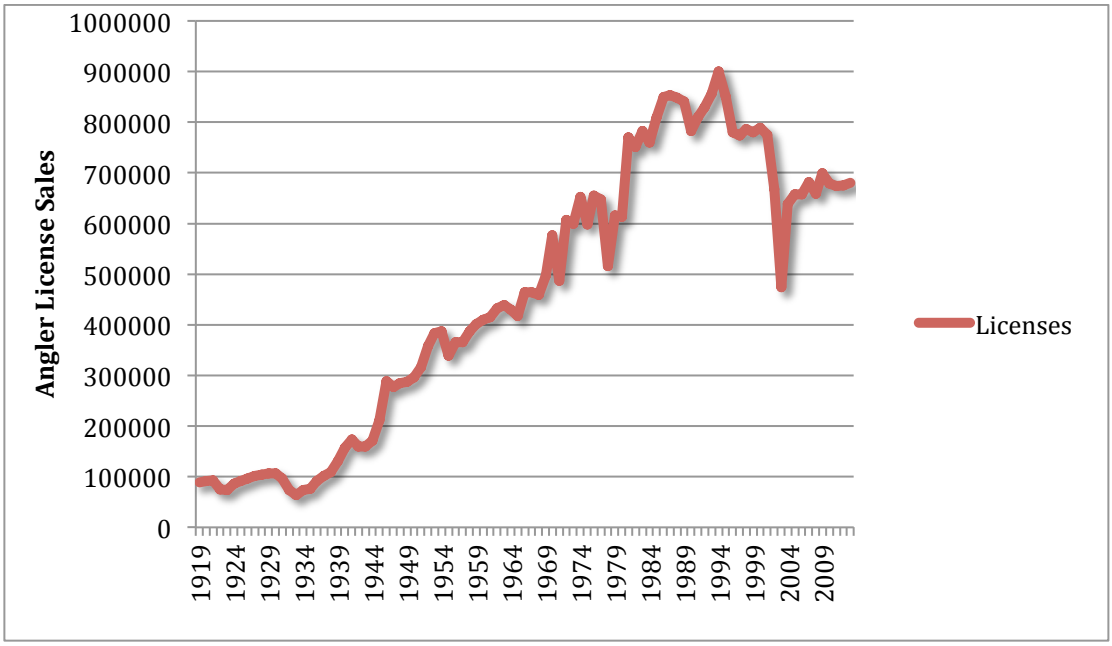


Figure 1 displays the complete view of the annual totals for angler license sales, which include every angler license transaction ever recorded in Colorado from 1919 to 2013. Having generated the sums of both resident and non-resident license sales between 1919 and 2013, I gained a much broader understanding in how the fishing industry was doing throughout different time periods. For example, in a stretch of years, when the amount of licensed resident anglers was in a constant decline, it showed that at that time it may have possibly been more difficult for fisherman to decide whether or not to buy a license or whether it was worth it to spend their hours of leisure time fishing. On the other hand, when there were great increases in licenses bought during a certain time period, it reflected the possibility that rivers in Colorado were offering more productive fishing conditions, and in a time like this, it must have become more appealing for people to spend more time fishing and buy a license that year. It is so important that Colorado's historical angler license records, which were previously only documented in physical copy form, have now been documented in electronically. Not only does this reduce the risk of losing such precious information, but it also allows others to use these historical records in a much more efficient manner.

Federal Aid I contacted CPW Federal Aid Coordinator, Paula Nicholas, on March 3, 2015, and interviewed her two days later. Nicholas directed me to the federal aid apportionments for state stocking programs on the CPW website. The data listed on the website archives started in 1952 and continued through 2014. These federal funds came from Sport Fish Restoration (SFR) grants, which are sent to every state annually. The amount of SFR funds is determined annually based on fishing

licenses sold, the size of the state, and the number of water bodies in the state (P. Nicholas, personal communication, February 25, 2015)

I transferred Colorado's annual SFR apportionments from each year into an Excel sheet, and the line graph I generated show great oscillations within the data at the start of the 1990s through 2014. I planned to combine Colorado's annual SFR apportionments with total license revenue from each year to get a more accurate sense for how much money was being put towards state stocking programs.

Colorado Dams In search of information on the major dam projects of Colorado, I reached out to four major offices in the Great Plains Regional division of the U.S. Bureau of Reclamation (USBR). I interviewed Timothy Flanagan, Manager of Infrastructure and Engineering Services for the Great Planes Region of the USBR, on February 2, 2015. Flanagan touched upon the environmental precautions taken by USBR engineers to protect fish populations while CRSP dams were being constructed. By the end of the discussion, he pointed me towards the "Projects and Facilities" tab of the USBR website to attain the relevant facts about the Colorado dams I used in my analyses ("Facilities by State - Bureau of Reclamation," 2015). After selecting the Colorado region on the "Projects and Facilities" interactive map, a list of the 60 Colorado USBR dams with separate links to webpages that provided overview stories, general facts, dimensional measurements, hydraulics and hydrology details, and contact information for each dam site ("Facilities in State of Colorado," 2007).

I focused on the general facts tab for each of the 60 dams, and transferred the original construction years and name of each dam to an excel sheet. I organized my

dam datasheet in two columns. The first was in chronological order from the dates in which each dam was built, and the second included the quantity of dams that were established in each year from 1935 to 1983. The data column containing the quantity of total dams built each year allowed me to create a cumulative running total of Colorado dams, which was later used as one of my five variables included in my final multivariable regression.

Variables and Methods

In this study, the graphical projections of Colorado's annual license sales were used as a determinant for gauging the economic condition of the state's fishing industry throughout the years. Variations in total license sales would either reflect periods of growth or economic stagnation for the industry. The annual amount of licensed anglers not only dictates how much revenue state stocking programs will receive, but also drive the retail and guiding sectors of the Colorado fishing economy.

Colorado's annual license totals are used as the independent variables in the bivariate regressions of this report. The bivariate regressions assess the relationship between license totals and the annual stocking totals of state programs, which is the dependent variable. The results of my bivariate regressions are presented with dual vertical axis line graphs, generated by Microsoft Excel '11, and with summarized regression figures, computed in Stata 13.1.

Bivariate and multiple variable regressions are used to highlight correlations shared among variables in this study. The correlations drawn from multiple variable analyses are tested with the use of robust regressions. The dependent variable used in

this study's multiple variable regressions is Colorado's annual license totals. There are five independent variables used in the multiple variable regressions in this study:

(1) Total_Stocked_Fish: *The collective total volume of fish stocked by state and federal programs annually.*

(2) Total_License_Revenue: *The total revenue generated from angler license sales annually.*

(3) Total_Dams: *The cumulative sum of dams present in Colorado as each year passes.*

(4) Federal_Aid_Dummy: *The amount of federal aid that is received by state stocking programs each year in the form of Sport Fish Restoration Apportionments.*

(5) Year: *Interval of time.*

The results of my multiple variable regressions are presented with tables containing summarized regression figures, generated by Microsoft Excel '11 and Stata 13.1.

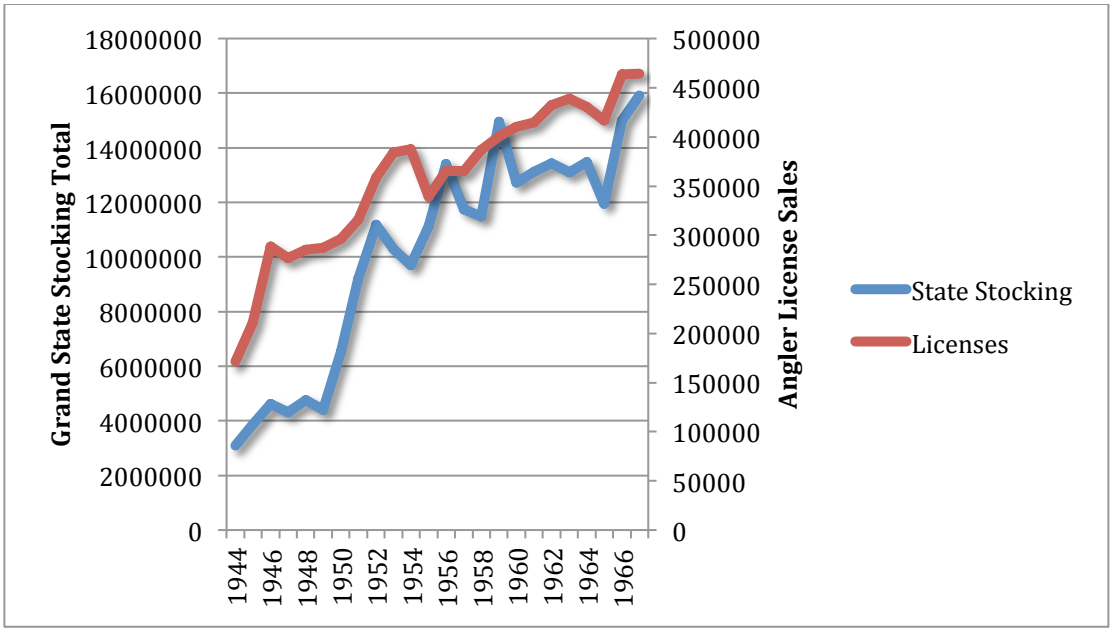
At a certain point in this study, an independent variable (annual license totals) is projected years into the future. Running regressions with an independent variable casted years into the future is an attempt to find the multivariable regression model with the best fitting and strongest correlating results. This study uses the Akaike Information Criterion (AIC) for the selection of how many years the independent variable (annual license totals) should be projected into the future to find the regression model with the strongest correlating results (Kaike, 1974). It turns out the model with the strongest correlating results has the lowest AIC value when testing for information criterion on Stata 13.1. The results of my multiple variable regressions that use the AIC for this reason are presented with tables containing summarized regression figures, generated by Stata 13.1.

Results and Conclusions

Bivariate Regressions

Figure 2

State Stocking Volumes and License Sales 1944-1967



Observations	R^2	Adj R^2
24	0.8598	0.8534

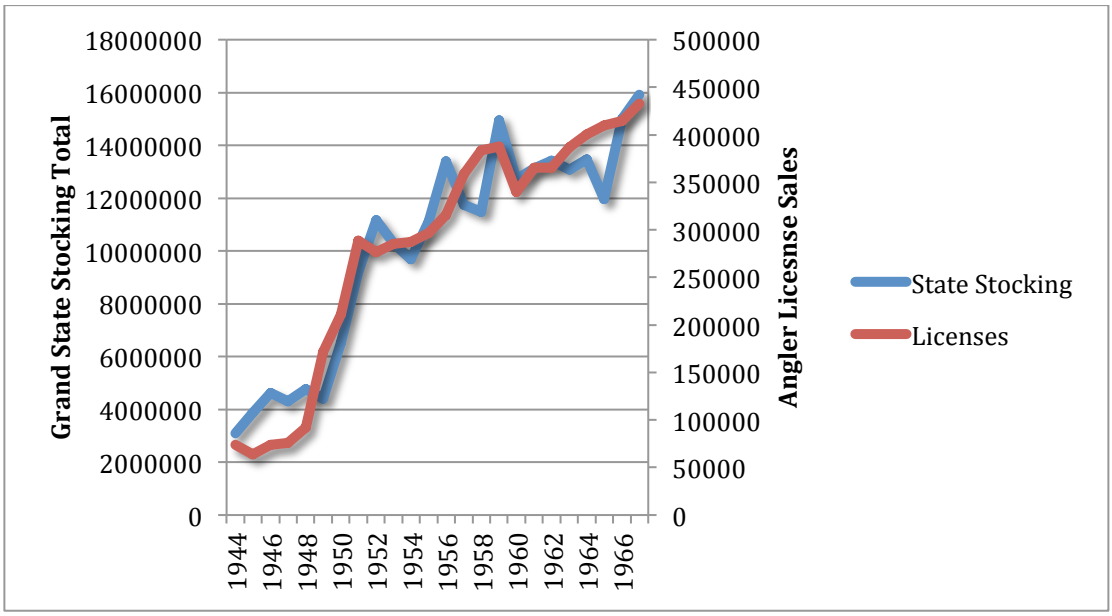
Figure 2 shows the relationship between state stocking totals and total licenses sales through 1944 and 1967. The correlation between the two variables is significant with an Adjusted R^2 value of 0.8534. The graph shows that state stocking volumes have a mirroring response to the growth trends of license sales. However there appears to be a delayed response, of approximately five years, that it takes for state stocking programs to react to when there are significant increases or decreases in annual licenses sales.

The years between 1944 and 1967 are a very unique. In 1944, six years following the absence of state stocking records during the years of World War II, the state stocking

programs began to record of their stocking volumes again. After 1967, there was a major shift in the balance of the Colorado hatchery fish supply. Following 1967, the federal stocking programs increased their level of involvement in Colorado because they were asked to mitigate the fish population losses due to the construction of new CRSP dams. The second national hatchery started stocking fish for the first time in 1967, and as that started, Coloraoed entered a new era of stocking production that ultimately changed the previous relationship that state stocking volumes and license sale shared between the years of 1944 and 1967.

Figure 3

State Stocking Volumes and License Sales (Projected 5 Years Ahead) 1944-1967



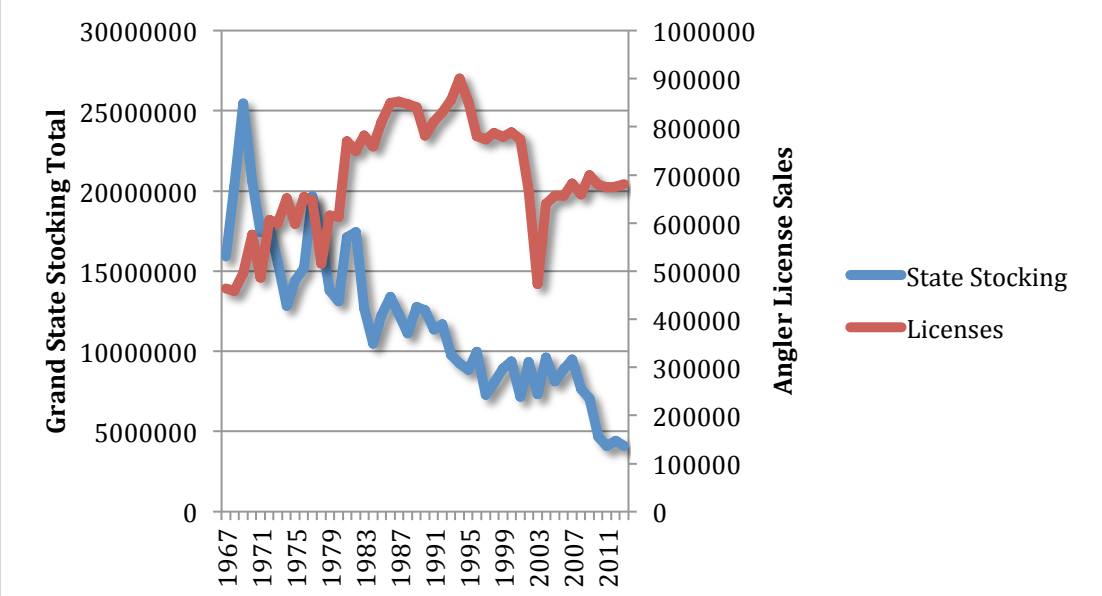
Observations	R^2	Adj R^2
24	0.9217	0.9182

In Figure 3, I projected license sales five years ahead in the future to make up for the lagging response that states stocking programs took when responding to significant changes in license sales. The relationship between state stocking volumes and license sales can be seen more clearly with this theoretical shift in the

licenses. This shows how the state stocking programs truly mirrored the changes that license sales experienced throughout this time period. The adjusted R^2 value of 0.9182 reveals how state stocking programs responded to increases or decreases in license sales. This is the only set of years in which the relationship between state stocking totals and license sales can be evaluated without the introduction of many extra variables, contributing to the cloudiness direct correlation. As we entered the 1970s and 80s, and as the federal stocking programs got more involved in Colorado, the state stocking and license relationship was completely ruined. The previous equation that state stocking programs used to fuel increases in licensed anglers was obsolete by the 1970s

Figure 4

State Stocking Volumes and License Sales 1967-2013



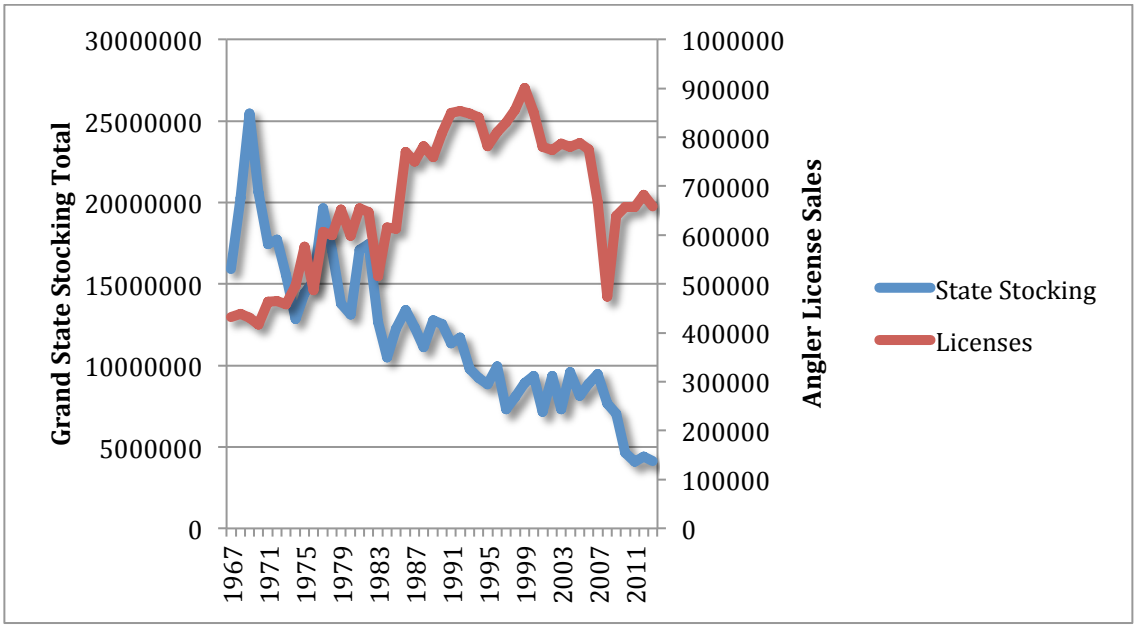
Observations	R^2	Adj R^2
47	0.1682	0.1497

Figure 4 shows the relationship between state stocking volumes and total license sales from 1967 to 2013. The Adjusted R^2 value of 0.1497 shows that the new relationship between state stocking volumes and licenses during the years of 1967 and 2013, were nothing alike to the relationship that used to exist during the years of 1944 to 1967.Between the years 1967 and 2013 the amount of licenses that were bought were no longer being fueled by state stocking volumes like it was between the years between 1944 and

1967. Between 1967 and 2013, there are many more variables involved that were influencing the amount of licenses that would be bought in Colorado each year. This made the sales of angler licenses it much harder to understand.

Figure 5

State Stocking Volumes and License Sales (Projected 5 Years Ahead) 1967-2013



Observations	R^2	Adj R^2
24	0.3586	0.344

Figure 5 displays that even with license sales being projected five years ahead into the future to make up for the state stocking programs lag in response, the correlation between the two variables are still insignificant.

Multiple Variable Regressions

Table I

AIC for Total Licenses with Future Year Projections

Variable	Observations	AIC	R^2	Adj R^2
F0.Total_Licenses	51	1199.178	0.9791	0.9767
F1.Total_Licenses	48	1157.775	0.9634	0.9590
F2.Total_Licenses	48	1157.066	0.9649	0.9607
F3.Total_Licenses	47	1136.077	0.9654	0.9612
F4.Total_Licenses	47	1136.714	0.9662	0.9621

Table I shows the AIC values that chose the projection of Total Licenses to be shifted 3 years into the future for the best results. The Stata regression results below show total licenses connection to dependent variables included in the multiple variable regressions.

Akaike's information criterion and Bayesian information criterion

Model	Obs	ll(null)	ll(model)	df	AIC	BIC
.	47	-641.1025	-562.0387	6	1136.077	1147.178

Linear regression

Number of obs = 47
F(5, 41) = 252.61
Prob > F = 0.0000
R-squared = 0.9654
Root MSE = 40442

F3.Total_Licenses	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
Total_Stocked_Fish	-.0025875	.0011026	-2.35	0.024	-.0048142	-.0003608
Total_License_Rev	-.0043065	.0352571	-0.12	0.903	-.0755098	.0668967
Total_Dams	6231.003	2409.321	2.59	0.013	1365.281	11096.73
Federal_Aid_Dummy	-26296.98	18528.23	-1.42	0.163	-63715.51	11121.55
Year	6796.811	1107.313	6.14	0.000	4560.546	9033.076
_cons	-1.29e+07	2148483	-6.02	0.000	-1.73e+07	-8601237

The multiple regressions assess the correlation strength that each of independent variables shares with actual and future projections of annual license totals. The results from this multiple variable regression shows the for with this overall encompassing view of stocking programs in Colorado, the overall most significant finding is that when more fish are stocked each year there is an expected decline in total licenses that will be bought three years into the future.

References

Alves, J. (2015, February 17). Advice on Thesis Direction with CPW Senior Aquatic Biologist for the SW Region of Gunnison Colorado [Telephone interview].

Bitton, D., & Walinchus, R. (2004). Trout. In *A field guide to fly fishing*. Guilford, CT: Lyon's Press.

Bureau of Reclamation: Lower Colorado Region - Hoover Dam Tunnel FAQs. (2009, January 1). Retrieved January 30, 2015, from http://www.usbr.gov/lc/hooverdam/faqs/tunlfaqs.html

Christopherson, K. (n.d.). Colorado Fishing Network: Species of Fish in Colorado. Retrieved March 5, 2015, from http://www.coloradofishing.net/species.htm#brook

COLORADO PARKS & WILDLIFE. (n.d.). Retrieved March 4, 2015, from http://cpw.state.co.us/learn/Pages/Hatcheries.aspx

Colorado River Storage Project. (n.d.). Retrieved March 22, 2015, from http://web.archive.org/web/20080317064511/http://www.usbr.gov/dataweb/html/crsp.html

Colorado River Storage Project Home Page - Reclamation, Upper Colorado Region. (2008, November 25). Retrieved March 21, 2015, from http://www.usbr.gov/uc/rm/crsp/

Colorado State Fish - Greenback Cutthroat Trout. (n.d.). Retrieved February 19, 2015, from http://www.statesymbolsusa.org/Colorado/fish_greenback_cut.html

Facilities by state - Bureau of Reclamation. (2007, May 1). Retrieved February 19, 2015, from http://www.usbr.gov/projects/FacilitiesByState.jsp?StateID=CO

Ficke, A., Peterson, D., & Janowsky, B. (2009). Brook Trout (Salvelinus fontinalis): A Technical Conservation Assessment. *USDA Forest Service, Rocky Mountain Region*. Retrieved February 27, 2015, www.fs.fed.us/r2/projects/scp/assessments/brooktrout.pdf

Kaike, H. (1974). A New Look at the Statistical Model Identification. *Three Transactions of Automatic Control, 19*(6), 716-723. Retrieved April 5, 2015.

Mayer, L. (2011). *Colorado's best fly fishing: Flies, access, and guides' advice for the state's premier rivers*. Mechanicsburg, PA: Headwater Books/Stackpole Books.

National Ocean Service (2014, November 14). Retrieved March 8, 2015, from http://oceanservice.noaa.gov/facts/fish-ladder.html

Nicholas, P. (2015, February 25). Talk with CPW Federal Aid Coordinator on Sport Fish Restoration Federal Aid to State Stocking Programs [Telephone interview].

Osborne, J., & Gerencser, A. (2003, July 9). Spencer Fullerton Baird - Biography. Retrieved March 2, 2015, from http://deila.dickinson.edu/theirownwords/author/BairdS.htm

Stege, E. (2015, February 16). Talk with Hatchery Manager of Leadville National Hatchery on the Historical Responsibilities of Colorado's Federal Stocking Programs [Telephone interview].

Wiltzius, W. (1985). *Fish culture and stocking in Colorado, 1872-1978*. Fort Collins, CO: Colorado Division of Wildlife.