THESIS

# REGIONAL ECONOMIC IMPACTS OF ELK HUNTING LICENSE REDUCTIONS IN NORTHWEST COLORADO

Submitted by

Matthew Wagner

Department of Agriculture and Resource Economics

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Summer 2026

Master's Committee:

Advisor: Jude Bayham

Tim Komarek
Andy Seidl

# ABSTRACT

## REGIONAL ECONOMIC IMPACTS OF ELK HUNTING LICENSE REDUCTIONS IN NORTHWEST COLORADO

Big game hunting is a vital revenue source for state wildlife agencies and brings tourism to rural economies. The winter of 2022-2023, which drastically reduced big game populations in Northwest Colorado, took funding away from Colorado Parks and Wildlife and took revenue away from businesses in the area. As wildlife populations stand to become more variable in the future, it's critical that state managers understand the full scope of the economic consequences of hunting permit reductions. Current methods for estimating the economic impact of hunters assume limited heterogeneity in hunter spending. Which likely estimates larger impacts than are occurring.

In this study, lost economic impact was calculated from fewer elk hunters traveling to three specific herds. I quantify lost economic impact as direct payments to CPW and hunter spending in the local area. IMPLAN analysis was incorporated to estimate additional multiplier effects from tourism dollars entering the local economy. Four alternative methods of deriving hunter expenditures from survey data were evaluated against each other.

Results show that the common method of calculating total hunter spending produces inaccurate estimates when the data is heavily skewed. Total lost economic impact from the 2022-2023 winter ranged from $17 million to $1.4 million, depending on which profile of hunter spending was applied. Disaggregating spending by permit

demand allowed state managers to minimize lost economic impact by prioritizing the highest demand hunters. I also evaluated the tradeoff Colorado Parks and Wildlife made by choosing greater license reductions than were originally warned in the immediate aftermath of the winter. Based on observed elk growth rates from 2023-2025, Colorado Parks and Wildlife could have allocated more permits after the 2022-2023 winter and maintained the same elk recovery timeline. Roughly $950,000 of economic impact was lost by choosing to increase license reductions beyond what was originally warned. State managers can minimize lost impact from wildlife population shocks by prioritizing license reductions to low demand hunters and maintaining permits for high demand hunters. However, state managers account for more than economic revenue in the decision making process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

# Introduction

Hunting in America, once the primary driver of species extinction, has become a primary funder of ecosystem conservation. Most state funding for wildlife management comes from hunting and fishing license sales. Many rural communities also see substantial increases in economic activity during the hunting season. Consequently, any event that reduces the population stability of game species may reduce economic activity in the state and in rural communities. The extent of lost economic impact hinges on decisions made by state wildlife agencies. Specifically, how hunting permits are allocated for a given season.

The winter of 2022-2023 was especially harsh for the northwest corner of Colorado, and elk herds in the region declined by up to sixty percent. Colorado Parks and Wildlife (CPW) responded by reducing the license quota in these areas by up to ninety percent for certain permits (Colorado Parks and Wildlife), leading to a loss of state revenue and a decrease in local economic activity in the affected regions. However, by aggressively reducing permits, the elk population rebounded quickly.

The objective of this paper is to perform an economic impact analysis of the 2022-2023 winter in Northwest Colorado and study the implications of alternative strategies of hunting permit allocation. I use observed permit allocations to quantify the reduction of hunters visiting the region, then estimate economic losses using four unique spending profiles. I show that heterogeneity in hunter spending, associated with hunter origin and individual permit demand, has substantial effects on economic loss estimates. Then, I consider the trade off CPW took by choosing a more aggressive reduction in hunting permits than they originally warned about. I show that the aggressive permit reduction did not cause the elk population to reach target management levels any faster than what was originally considered.

In America, wildlife is managed in accordance with the North American Model of Wildlife Conservation. Under this system, wildlife is a public resource held in trust by the government and managed for the benefit of all citizens (Organ et al. 2012). Making government issued permits the only legitimate way to recreationally hunt. Landowners can sell hunting opportunities on their land at premium prices, but they or their clients must obtain a hunting permit from the government. Throughout Colorado, hunting permits are either sold over the counter or allocated via a lottery. Over the counter permits have no quantity restriction and are sold at a fixed price. This allows all hunters who wish to hunt an opportunity to do so, but can reduce hunter satisfaction due to overcrowding. Permits with set quantity restrictions imposed are typically allocated via a lottery system. This can be a purely random lottery in which each applicant has the same chance of receiving a permit, but more commonly involves a preference point system. Where hunters have a greater chance to receive a permit, the more consecutive lotteries they have been unsuccessful. In both instances, state agencies charge hunters below market clearing prices to obtain a permit, which increases hunter satisfaction. The lottery system allows more dedicated hunters to receive licenses through preference points, but doesn't guarantee that the hunters who most value hunting monetarily receive permits. Allocating permits at market prices would overcome this issue, but would exclude less wealthy hunters from ever participating. A lottery system is overall more equitable, but provides less revenue for CPW and local businesses.

Revenue collected from the permit system is a vital source of funding for wildlife management. State agencies determine the total number of permits awarded and the method of take for each permit, but their decisions are heavily influenced by public opinion. Making game species, especially big game species, an important resource to manage for ecological wellbeing, government revenue, and public enjoyment. It is critical that state managers understand how policy and climate events will alter game populations and the economic flows associated with them.

In Colorado, elk permits are allocated based on a semi-random lottery system. Hunters can apply to multiple hunts, ranked by choice, and can collect a preference point if they did not receive their first choice. CPW allocates permits to hunters with the highest preference point totals first. If the number of hunters with preference points exceeds the number of available permits, then the draw becomes a lottery at a specific point level. For example, if there were five permits and ten hunters with one preference point, each hunter would have a 50% chance of getting a permit. When a hunter receives their first choice permit, their preference points for the species reset. I used preference points as an analog for permit demand. Total preference points display how many years a hunter decided against receiving a more desirable hunt to get a specific permit in the future. This imposes a cost to receive a permit beyond the fees paid to CPW. Unclaimed permits from the initial or “primary draw” are allocated via the “secondary draw” which is a purely random lottery. CPW also sells unlimited over the counter elk archery and rifle licenses that are valid in select locations. In this study, only hunters from the primary draw are considered, as their total numbers and demand are observable.

# Literature Review

Many studies have been conducted relating to the economic value of outdoor recreation. The Bureau of Economic Analysis (BEA) maintains the Outdoor Recreation Satellite Accounts (ORSA), which quantify the size of the outdoor recreation economy in America. In their accounts, “a complete measure of the outdoor recreation economy includes the value of goods and services directly related to outdoor recreation, plus the value of goods and services that support access to outdoor recreation” (Highfill and Smith-Nelson, 2018). BEA defines outdoor recreation as an activity for pleasure that involves intentional physical exertion and occurs outdoors. They use a very broad definition of outdoor recreation and measure its economic value based on the sale of associated goods and services. Southwick and Associates measured the economic contribution of outdoor recreation in Colorado by taking surveys of recreation expenditures. Outdoor recreation was more selectively defined than BEA’s definition. Only including traditional recreation activities such as hiking, camping, hunting, etc. Direct expenditures were input into IMPALAN to estimate state wide impacts (Southwick, 2024). In 2018, Southwick estimated the annual economic contributions of wildlife recreation on BLM lands across the United States stratified by state. To get expenditures, state spending proportions were applied to the National Survey of Hunting, Fishing, and Wildlife Recreation’s average hunter spending estimates. In these studies, the value of recreation comes from government revenue and spending on goods and services.

Other studies on outdoor recreation expand economic measurements to nonuse values and ecosystem services. Pelletier, Heagney, and Kovac (2021) defined outdoor recreation services as all biotic and abiotic characteristics of open space that enable outdoor activities. They then compared eight different valuation methods against each other and found that the value of annual recreation services varies from $228 million to $7 billion in New South Wales,

Australia, based on methodology. BenDor et al. (2015) examined the economic value of ecological restoration by comparing property values in areas near ecological restoration sites before and after their completion. While it's more common for researchers and government agencies to quantify the economic impact of outdoor recreation by only including direct expenditures and measurable goods and services, it has been shown that the true value of outdoor recreation extends to nonuse values as well. Kirkland et al. (2024) attempted to measure the value of a herd of elk, including all nonuse and use values. The researchers defined the full value of a herd of elk as a welfare function including surplus from hunters and wildlife viewers, government and business revenue, ecosystem services, and other nonuse values. In all the studies listed above, hunting has been included as a type of outdoor recreation and contributed a fraction of value to the final estimate. Literature investigating the economic contribution or impact of hunting exclusively is more limited.

Previous studies on the economic contribution of hunting focused on the total impact of hunters over one season. Researchers from the University of Nevada surveyed Nevada resident and nonresident hunter expenditures in 2020 (Bowman, Taylor, and Borden 2022) and disaggregated spending between 10 different types of hunts (antlerless elk, antlered elk, bear, mountain goat, etc.). Estimates were multiplied by the total number of hunters by species to estimate total expenditures. Koontz and Loomis (2005) surveyed hunters in Jackson Hole on their spending habits. These results were averaged for the entire area and multiplied by the number of hunters to estimate economic impacts for the season. North Dakota frequently estimates the impact hunters have in the state (Gakpetor, Bangsund, and Hodur 2025). To get their data, the North Dakota Game and Fish Department conducts an online survey of licensed hunters. Spending is separated into two categories: direct and secondary effects. Direct effects are the literal payments made by hunters as expressed in the survey, and secondary effects are the results of that money being further spent in the region. Koontz, Loomis, and Gakpetor, Bangsund, and Hodur used IMPLAN software to further estimate the economic contribution of

hunters for the season based on their expenditures. Bowman, Taylor, and Borden estimated expenditures for only one season, not any secondary effects.

As consistent with Koontz and Loomis (2005) and Gakpetor, Bangsund, and Hodur (2025) input output analysis was conducted using the IMPLAN software to estimate multiplier effects that arise from direct spending. Additional economic impact is only generated from an influx of funds to the region (United States Department of Agriculture 2014). Dollars already within the region do not generate additional economic impact. This is because dollars already in the economy do not generate any additional demand in their respective industries. An influx of new dollars into the economy will require industries to increase output to meet the new demand. Regional coefficients and social accounting matrix multipliers are utilized to ground economic simulations. Where many county level multipliers are derived from the state wide multipliers when they are not individually measured. Burkard and Hill (2023) used IMPLAN analysis to quantify the economic contribution of river based recreation in the Yampa Valley, contained in Moffat County. Burkard and Hill made no adjustments to regional coefficients or multipliers for this study. As I also lack data on industry spending in the study area, I made no adjustments to regional coefficients or social accounting matrix multipliers. My multipliers, therefore, reflect those used in Burkard and Hill (2023), which are IMPLAN's default regional multipliers.

Ideally, the final model of economic valuation directly relates the economic values to the size of the wildlife population. Something which is encouraged in wildlife management literature but seldom done in ecological valuation. Gren et al. (2018) conducted an exploratory overview of the available literature associated with the determination of population sizes and policy design for wildlife management. Their main argument is that regardless of the valuation method or the scope of analysis, economic valuations should be attributed to wildlife populations. But it is not common practice. Relating economic values to population size is useful for state managers for implementing management policy.

In North America and the western United States, wildlife populations are managed to be relatively stable across time. Colorado Parks and Wildlife manages its big game populations to be within target ranges. Management decisions are made to attempt to maintain or return to these population targets (Northwest Elk Herd Management Plans, 2025). Because hunting is the primary mechanism state managers have to control wildlife populations, hunting permits are increased or decreased based on population measurements relative to CPWs' set objectives.

Large population shocks are uncommon, so no studies have been conducted investigating how hunters respond to a large immediate decrease in licenses. However, chronic wasting disease has gradually decreased select wildlife populations across America. Needham et al. (2007) investigated the hunter response to chronic wasting disease based on hunter characteristics. Hunters were categorized into four categories, ranging from casual to veteran hunters. Classification was performed based on hunter skill, centrality, equipment, and experience. They found that hunter response to the prevalence of chronic wasting disease varied by residency and experience category. Veteran hunters were least likely to quit hunting but were more inclined to hunt in another state. This shows that hunter response is not uniform for all hunters and varies based on certain hunter characteristics.

Hogan (2016) investigated elk permit demand in Colorado based on several permit characteristics, including method of take and location. He found that demand is correlated with many of these factors. Resident hunters were categorized as "meat hunters" who value hunts with high success rates, and nonresidents as "trophy hunters" who value opportunities to hunt large bull elk. Milon and Clemons (1991) applied household production theory to hunting. They not only investigated demand across species but also how species diversity affects hunter utility. These papers suggest that hunter demand varies by game, animal gender, method of take, location, species, and many other factors. If hunters have a higher demand for specific permits and are willing to pay or spend more time to receive them, they likely will spend more money on the hunting trip overall. Estimates of hunter spending and economic values are

typically separated by residents and nonresidents. Reinforcing the idea that heterogeneity exists among hunters and can be elicited by categorizing hunters. North Dakota reinforces this idea by separating hunter spending for deer and by method of take. While the relationship between hunter preferences and permit type has been observed, it has not been applied to estimates of the total economic impact of hunters.

I contribute to the current literature by estimating the total economic impact resulting from reduced hunting licenses in the wake of the 2022-2023 winter. It is understood that permit reductions hurt the local economy, but the total economic effect has not been quantified. Furthermore, I investigate the implications of the current method of quantifying hunter spending by multiplying average hunter spending by the total number of hunters. Studies have separated spending based on residency and permit type before, but not based on permit demand or hunter investment. I highlight how heterogeneity in hunter spending can lead to inaccurate economic estimates when the average is taken, and that this can be overcome by separating hunter spending by hunter characteristics. Finally, I investigate the economic trade offs related to alternative management decisions based on the wildlife population. Similar methods have been presented in McEachran et al. (2025). Researchers used survey data from Koontz and Loomis to estimate the social and economic consequences of five alternative management plans in Jackson Hole. I expand on this work by applying their methods to gauge the impact of an observed population event and management decision, rather than to project potential decisions. This provides state managers with a framework to more accurately evaluate the economic impact of past management decisions. It also highlights how climate and biological variability obscure economic outcomes associated with permit allocation.

# Data

The data for this project comes from yearly estimates and reports posted by CPW and from a survey of hunters' spending profiles in Jackson Hole. CPW estimates hunter harvest from a voluntary survey of hunters from specific hunt codes (2025 Elk Statewide Harvest Final). CPW uses the collected survey results to estimate total harvest and participation. Estimates of total yearly harvest per herd and total yearly hunters per herd are found in the annual harvest report posted by CPW. CPW publishes yearly estimates of elk population per herd. The total number of elk per herd is estimated from aerial counts and population models (Elk Herd Management Plan – E-2). CPW also publishes an annual draw report. This shows how many Colorado resident and nonresident hunters applied for and received each individual permit, as well as the total quota for each permit. The report shows how many permits were awarded by preference point and the minimum point level required to be considered in the draw. Yearly reports are compared across time to determine how the elk population, harvest, permit quota, total hunters, and permit allocation changed in response to the 2022-2023 winter.

I create hunter spending profiles from a 2001 survey conducted in Jackson Hole by Koontz and Loomis (2005). It is the best available data for this research because the researchers surveyed elk hunters specifically, and Jackson Hole resembles the study area. Both Jackson Hole and Northwest Colorado are known for having the largest elk herds in the nation, and for high quality trophy elk. In both regions, many hunts are offered that require few preference points to obtain, and a select number of hunts are offered that are considered "once in a lifetime" opportunities.

The cost for a guided elk hunt in both Jackson Hole and the study area ranges from eight to twelve thousand dollars. Jackson Hole's chamber of commerce lists 26 outfitters operating in the area, while CPW only lists 15 registered ranches in the study area. However,

unlike Jackson Hole, not every outfitter needs to be a registered ranch to operate in the study area. Jackson Hole is a smaller area covering 1,200 square miles, whereas the study area is 7,105 square miles. Jackson Hole offered about 3 permits per square mile in 2001. Where the study area offered 2.6 permits per square mile before the 2022-2023 winter and 1.2 permits per square mile after the winter. The Jackson Hole airport is 8 miles away from the town of Jackson, WY. In the study area, the Yampa Valley airport is 20 miles from Craig, CO, and 24 miles from Steamboat Springs, CO. The largest towns in Moffat and Routt respectively. There are 9,177 available rooms in Jackson Hole, comprising 15,491 beds. Steamboat has 3,390 available units comprising 11,411 beds, and Craig has an estimated 500 rooms available. Jackson Hole had a population of 10,680 and did $723,703,000 in retail sales in 2025. Steamboat's population was 13,620 with $581,417,000 in retail sales, and Crag had a population of 8,874 with $223,297,000 in retail sales in 2025 (US Census). Jackson Hole is a wealthier area in general and offers more luxurious accommodations. Many visitors come to Jackson Hole for the elk, but many more come due to its proximity to Yellowstone and the Grand Teton National Parks (Jackson Hole Visitor & Tourism Board). Jackson Hole also has its own ski resort near the town. Northwest Colorado is also known for its outdoor recreation and offers the same opportunities as Jackson Hole, but its opportunities are overall less renowned and more dispersed.

Another reason the Jackson Hole survey is the best available is that I have the raw survey results, not just the reported averages. This is beneficial because it allows additional complexity to be incorporated into the model. The study area is known for its high demand trophy elk, but not all elk hunters in the area are pursuing these types of hunts (2025 Elk Draw Recap Report). Allowing spending to differ given permit demand alters the results when elk permits are not reduced proportionally by demand. As was observed after the 2022-2023 winter.

## Spending Profiles

I assigned permits to one of five categories based on the minimum preference points required to receive them. Permit categories by preference points are shown in Table 1.

*Table 1: Permit Demand Category by Preference Points*

| | Run Off | Low | Medium | High | Outfitter |
|---|---|---|---|---|---|
| **Preference Points** | 2nd-4th Choice | 0-5 | 6-10 | > 10 | Landowner Tags |

Low to high demand permits are categorized by the minimum level of preference points required to receive them. Hunters can also choose permits as a second, third, or fourth choice hunt. If all first choice hunters receive a permit then it gets allocated to second, third, or fourth choice applicants. Permits allocated beyond first choice applicants are categorized as runoff permits. Outfitter permits originate from landowner tags. CPW has a special program for landowners with over 40 acres to obtain permits. These permits can be sold by the landowner and transferred to one other hunter, but not resold by that hunter. It is assumed that every landowner permit gets sold to a guide or outfitter. With these distinctions, each permit can be classified and then grouped by herd.

Elk hunting is divided into game management units (GMUs). Multiple management areas are combined to form data analysis units (DAUs). DAUs are drawn to approximate the year round range where elk are born, raised, and die with minimal interchange between other herds (Northwest Colorado Herd Management Plans Draft 2024). More commonly, a DAU is referred to as a herd of elk and is denoted with an “E-“ before the herd number. I investigate permits in herds E-1, E-2, and E-47 in this study. Total permit allocation by type and herd over time is shown in Figures 1-a through 1-d.


*Figure 1-a: E-1 Permits Over Time.*

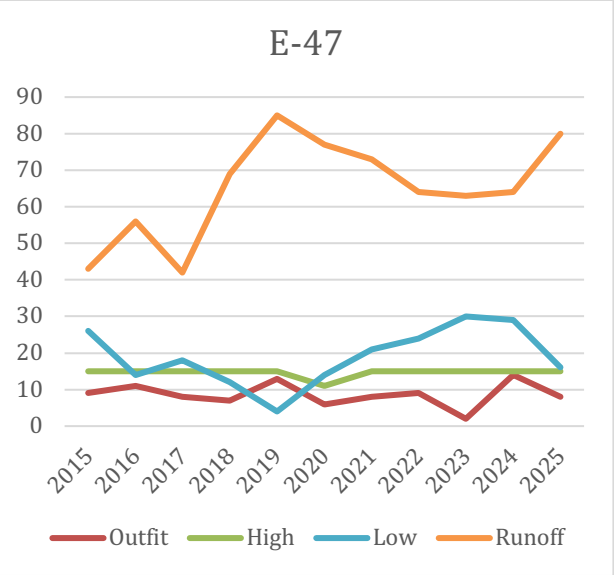


*Figure 1-b: E-47 Permits Over Time*

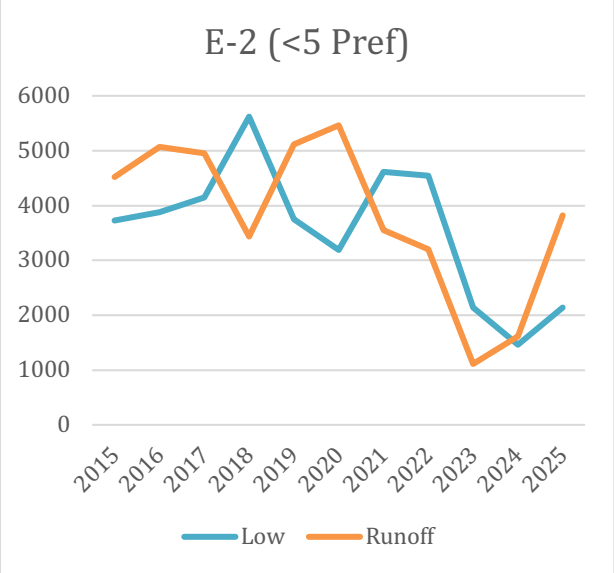


*Figure 1-c: E-2 Low Demand Permits Over Time*

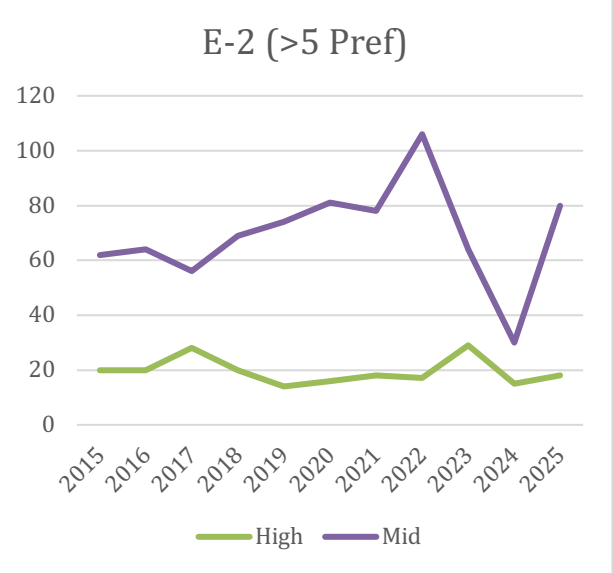


*Figure 1-d: E-2 High Demand Permits Over Time*

Low demand and runoff permits are the most common permit types across all three herds. Noticeable reductions were not observed in herds E-1 and E-47 after the 2022-2023 winter. The impact may not be observed because both herds cross state lines and are not fully captured in Colorado. Outfitters saw a decrease in E-47 following the bad winter and were subsequently restored to slightly above average in 2024. Runoff, low and medium demand

permit allocation all declined sharply in E-2 following the bad winter. This is due to cows and calves experiencing higher winter mortality than bulls. Note that in 2025, CPW restored E-2 medium demand permits close to historical levels. This suggests that CPW prioritized restoring higher demand permits before lower demand ones.

A critical assumption I make in this paper is that hunter expenditures are positively correlated to the number of preference points required to obtain a permit. To accumulate a high number of preference points, hunters have to wait as many years as they have points and forgo obtaining any first choice hunts until they use their preference points. High demand hunts require waiting for more than 10 years to receive a permit, and for many nonresidents, these hunts can only be experienced once or twice in a lifetime. Given the time investment and opportunity cost of forgoing hunts drawn out to first choice applicants, I assume these hunters will spend comparatively more on a trip. The assumption forms a critical relationship used in this paper. Past literature (Needham et al. 2007; Hogan 2016; Gakpetor, Bangsund, and Hodur 2025) has characterized hunters into separate categories and has assigned spending based on hunter categories. I impose a relationship between hunter spending and demand to highlight how heterogeneity in spending among hunters can influence results. Hunter spending may better correlate with other hunter characteristics, but the impact on results of stratifying spending by those characteristics will be similar to the impact of stratifying spending by demand. Low demand hunters follow the same logic, whereby investing less time in a trip, they will spend less on it.

These assumptions impose heterogeneity in hunter spending based on observable characteristics, but spending may deviate from this assumption. For example, committed, high spending hunters could obtain runoff permits while they bank points for a high demand hunt. These individuals could still spend more than the average hunter despite investing very little to obtain a runoff permit.

Three alternative spending profiles were allocated to each demand category, and another was constructed using the average spending by Colorado and out of state residents. In total, there are four separate spending profiles: low, high, adjusted, and benchmark. All spending profiles separate hunter spending between Colorado residents and nonresidents. I assume there are no hunters that originate from the study area. All profiles, except the benchmark, further split hunter spending into the five demand categories shown in Table 1. Here, outfitter spending is not separated by residency. Outfitter spending was calculated by filtering the survey data to only include observations where hunters spent more than $1,000 on guides. To represent that outfitters are spending outliers on the high end, outfitter spending for each industry was found by adding one standard deviation to the mean of this subset. This specification was chosen as it matched hunter expenditures on guides and outfitters to be within the observed range of prices outfitters charge in this area. Outfitter prices in the study area range from $8,000 to $12,000. I specify each outfitter hunter as spending about $9,200 on an outfitter. This calculation for the outfitter spending was used in both the low and high spending profiles.

To calculate runoff through high demand permit spending, a subset of the data was created for all hunters who spent less than a thousand dollars on guides and outfitters. Runoff spending is the $25^{th}$ percentile in the low spending profile and the mean minus half a standard deviation in the high spending profile. Low demand is the $50^{th}$ percentile of hunter spending in the low spending profile and the mean in the high spending profile. Medium demand is the $75^{th}$ percentile in the low spending profile and the mean plus one standard deviation in the high spending profile. High demand is the $95^{th}$ percentile in the low spending profile and the mean plus four standard deviations in the high spending profile.

There is no empirical evidence suggesting that hunters waiting for certain lengths of time for a permit will spend a certain amount in Colorado. I assigned spending to permit demand categories to reflect trends in hunter spending surveys (Koontz and Loomis 2005; Bowman,

Taylor, and Borden 2022), which show spending as being heavily right skewed. Assigning spending based on permit demand resembles surveyed hunter spending distributions, where demand categories are also right skewed. The assumption is that the longer a hunter waits to receive a permit they more they invest in the trip when it's taken.

Finally, a profile was created using estimates from both the high and low spending profiles, and values were adjusted based on the researcher's assumptions. I assumed that not all individual expenditures are correlated to total spending, and that hunters substitute between similar commodities, such as lodging. For example, high demand hunters are more likely to stay in hotels, so their camping expenditures were proportionally lower. No studies were found that estimate hunters' expenditure elasticity based on the cost of obtaining a permit, so I inferred plausible substitution between expenditures. Values from the adjusted estimate show how substitution would impact results compared to cases where substitution was not considered, but are not reflective of known hunter behavior. Figure 2 shows total spending per trip by resident category in each profile except the benchmark. Expenditure spending by profile is available in Appendix A.

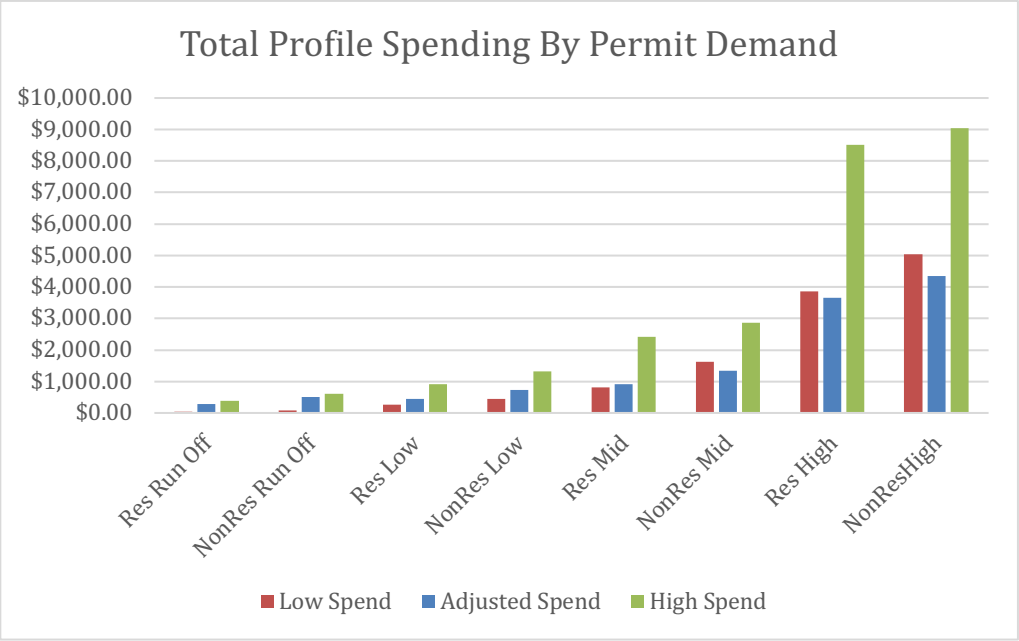


*Figure 2: Total Spending By Category*

Average spending per trip (benchmark profile) for Colorado resident and nonresident hunters is $1,117 and $2,750, respectively. Among the profiles that separate spending by demand, the high spending profile produces the highest estimates, and the low spending profile the lowest. This arises because some level of spending is imposed for each expenditure type at the lowest demand levels in the high spending profile. While low demand and runoff hunters spend no money on certain expenditures in the low spending profile. For example, in the low spending profile, resident runoff hunters only purchase gas. These impositions on spending cause the low spending profile to underestimate low demand hunter values, and the high spending profile to overestimate low demand values. True low demand hunter spending would be found between these two profiles. Therefore, the adjusted spending profile best estimates low demand hunter spending as being greater than the low profile but less than the high profile.

# Methods

A complete estimate of the economic impact from a reduction in hunting permits captures direct payments to CPW, hunter spending at local businesses, and the secondary effects from new money being introduced to the region's economy. Population and harvest are observed in yearly counts published by CPW. License reductions are observed from CPW draw reports. Direct CPW payments and hunter spending can be found by multiplying the number of hunters by associated permit fees or spending profiles. CPW revenue is measured as exogenous to the system as revenue is pooled into a general fund, and does not generate any multiplier effects in this study. Secondary effects are derived by inputting direct hunter spending into IMPLAN. Figure 3 illustrates the structure of the model.

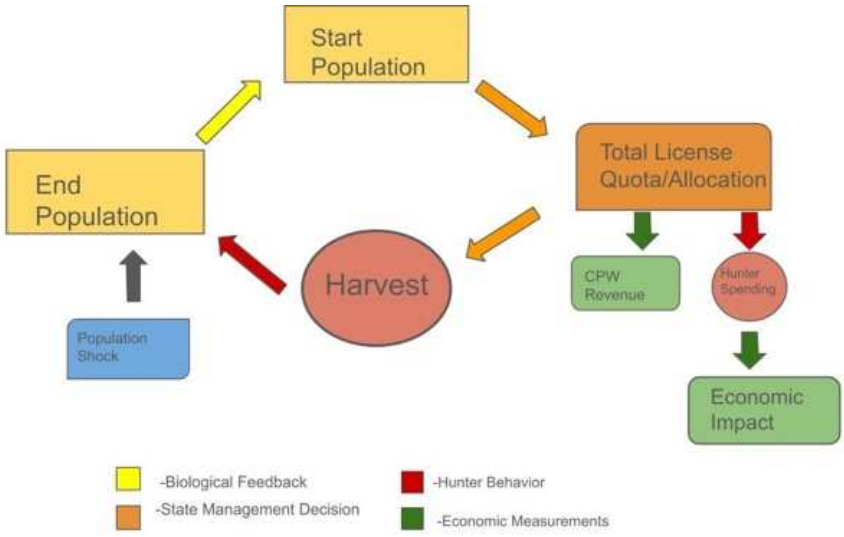


*Figure 3: System Overview*

Economic impacts are simulated one season at a time. In Figure 3, “Total License Quota/Allocation” represents the total number of licenses awarded by CPW and the demand types of those licenses as shown in Table 1. CPW determines the total permit allocation and the proportional permit demand type based on the starting population. Total licenses awarded and how many went to Colorado residents are taken from CPW annual draw reports. Permits are

further assigned a demand type based on the number of preference points required to get them. “Hunter Spending” refers to direct spending by hunters at local businesses. Hunter expenditures are taken from Koontz and Loomis (2005). Four alternative calculations of hunter spending are derived from this data. One separates hunters between Colorado and out of state residents, and the other three further separate spending based on permit demand. I calculate lost direct hunter spending by multiplying a spending profile by the difference between the observed total hunters and the historical average of total hunters. “Economic Impact” is the total additional effect of new dollars being introduced into the region’s economy. These dollars are hunter expenditures brought in by hunter tourists. I assume all hunters originate from outside of the study area, so all direct hunter expenditures are new dollars being introduced into the regional economy. Colorado residents generate no secondary effects in the rest of the state. Secondary effects are found by inputting lost hunter spending into IMPLAN, which estimates the impact of new dollars being spent throughout the economy. “Harvest” is the number of elk killed by hunters in a given season. This value is estimated to be proportionally equal to the observed harvest when permit allocation is altered, and is taken from CPW’s harvest report when the observed permit allocation is used. I estimate the elk population response if CPW allocated more permits than observed after the 2022-2023 winter. A simple elk growth model is incorporated, where the end population after a harvest grows to the starting population for the next season. Figure 3 displays one hunting season for one herd. The region of interest for this study consists of 3 herds.

## Study Area

Analysis is conducted around three herds of elk in the northwest corner of Colorado. These being herd E-1 (Cold Springs), E-2 (Bear’s Ears), and E-47 (Green River) or GMUs 1, 2, 3, 4, 5, 14, 201, 214, and 441. These herds range from Colorado's northwest border with Wyoming to the eastern border of Routt County and comprise the northern half of Moffat and Routt County (Figure 4).

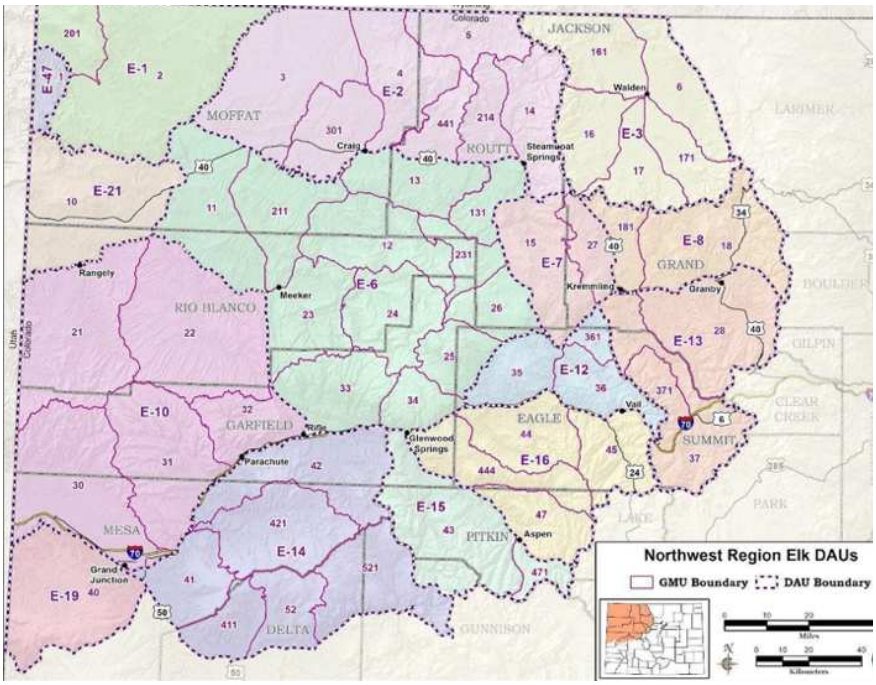


*Figure 4: Northwest Colorado Herds*[1]

For IMPLAN analysis, Routt and Moffat were combined into one economic region. Economic estimates show how changes in elk permits allocated through the primary draw impact both counties, represented as one region. I chose this region due to the observed reduction in elk licenses after the 2022-2023 winter (Figure 5). The 2023 quota was reduced by 5,600 permits from the year prior (Figure 5), marking a reduction of 63% compared to the region's average quota. The region is also known for its unique elk hunting. E-2 is well known as one of the largest elk herds in the nation. Herds E-1 and E-47 are known for their high density, high quality trophy elk, which attract specific hunters who bank up to 20 preference points to hunt these GMUs.

[1] Retrieved from: DRAFT Northwest Colorado Elk Herd Management Plans

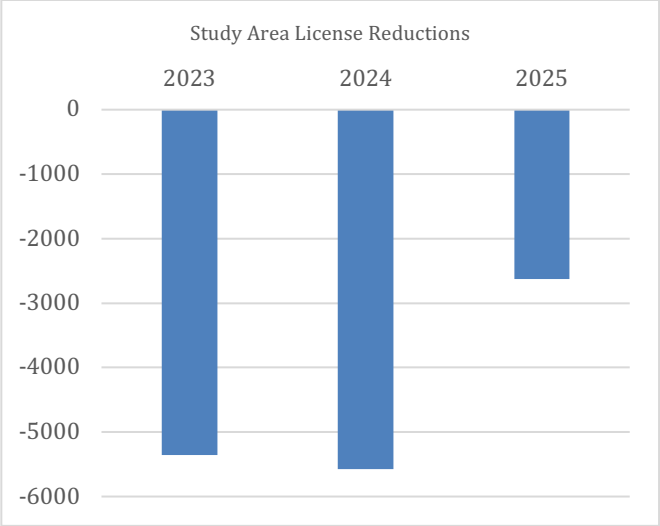


*Figure 5: Study Area License Reductions*

## Spillovers

A concern with economic impact analysis is the prevalence of spillover effects. Spillover effects are of concern when hunters have permits within the study area but stay or spend elsewhere. I did not incorporate spillover effects into the study. While there is no formal research to support this assumption, the infrastructure in and around the study has very little for hunters to take advantage of. Land ownership in the study area is shown in Figure 6.

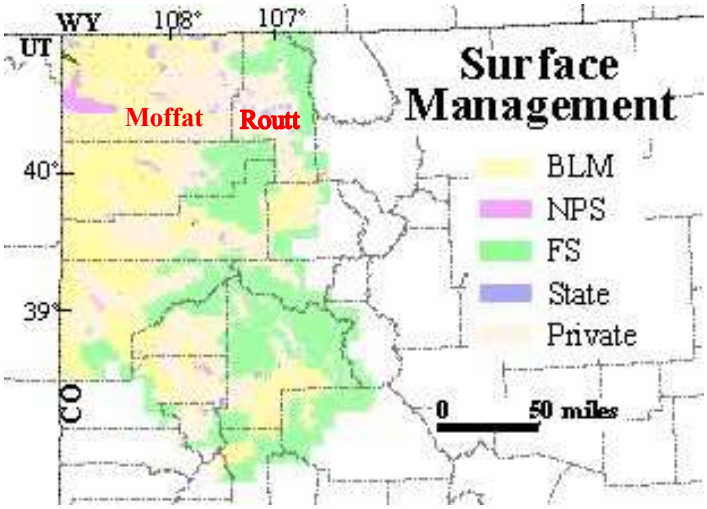


*Figure 6: Northwest Colorado Land Use*[2]

[2] Source: USDA, "Land and Federal mineral ownership coverage for northwestern Colorado"

Moffat and Routt counties (study area) have been labeled in Figure 6. Recall from Figure 4 that the hunting units of interest comprise the top half of both counties. Most of the study area is public land, and counties adjacent to the study area have little development except for on the eastern end of Routt County. It's unlikely a hunter would stay east of Routt and travel in, as the hunting is primarily west of Steamboat Springs where there is significant infrastructure. Development is also sparse across the Utah and Wyoming border. Towns in Utah close to the study area are Dutch John, population 139, and Jensen, population 331. Vernal Regional Airport, Utah, is close to these towns and about 30 miles west of the Colorado border. Baggs, population 407, is the most significant town close to the study area on the Wyoming side. Southwest Regional Airport is the closest airport to the study area in Wyoming and is roughly 130 miles from Baggs. Due to the lack of infrastructure in adjacent Corado counties, as well as across the state border, spill over effects appear to be minimal. No adjustments were made to account for hunters spending outside of the study area beyond what was reported in the survey from Koontz and Loomis, 2005. Furthermore, no adjustments were made to the regional purchaser coefficients. This determines what proportion of inputs businesses purchase from inside and outside of the study area. Due to the lack of information about business habits in the area, and the lack of surrounding infrastructure, regional purchaser coefficients were not altered from IMPLANS original estimate.

## Government Revenue

Government revenue comprises payments made directly to CPW. Colorado Parks and Wildlife collects revenue from fees to apply for and receive a hunting license. To apply for a permit, all hunters are required to purchase a habitat stamp and a qualifying license. An additional fee is paid if they receive a permit. Direct revenue to CPW from licenses and fees is pooled with other funding sources (federal grants, Colorado lottery, etc.) and spent where deemed most necessary. I do not model government revenue from permits and fees as being

spent in the study area. This would result in a greater loss in economic impact when permits are reduced. Undoubtedly, CPW spends on wildlife management in the study area, which generates economic impact, but that spending is irrelevant to the number of permits sold in the area. According to CPW's chief financial officer, "License reductions do not automatically reduce funding spent managing a particular herd and, depending on the circumstances, might indicate that increased investment in managing that herd may be warranted" (Justin Rutter).

Permit prices vary for resident and nonresident hunters, and further if they are youth or adult permits. This study does not distinguish between youth and adult hunters. Youth hunters pay less to apply for and receive permits, but were assumed to identically resemble adult hunters both in application and local spending. Youth hunters are small in number, so this assumption is unlikely to significantly change the results. Direct CPW revenue is calculated by multiplying the number of permit applicants and recipients by their associated fees. Note that equations 1 and 2 are not simplified with the application variable appearing twice. This is to highlight the disparity in resident and nonresident prices. The first coefficient represents the habitat stamp, whereas the second represents the cheapest available qualifying license[3]. The third coefficient is the price paid to receive a permit if a hunter is successful in the draw.

*(1) Resident Gov Rev = 21.69*(∑resident apps) + 38.49*(∑resident apps) + 70.4*(∑res success)*

*(2) NonResident Gov Rev = 24.25(∑nonres apps) + 104.86*(∑nonres apps) + 845.16*(∑nonres success)*

## IMPLAN

Total economic impact is a combination of direct and secondary effects. Direct effects come from hunter expenditures, and secondary effects were estimated using the IMPLAN modeling software. An important distinction in the IMPLAN model is whether you are conducting a contribution or an impact analysis. A contribution analysis examines a specific industry and

[3] Hunters can purchase a lifetime habitat stamp for $374.17 - $384.16 in 2026. To reflect the general trend of application revenue it was assumed all hunters need to purchase yearly stamp.

estimates the effect it has on the rest of the economy. Importantly, this excludes secondary effects occurring within the industry. This measures the gross impact of the industry. I want to measure lost secondary impacts within the industries being shocked, and I am conducting analysis over multiple industries. I perform an economic impact analysis, measuring the total loss across all industries resulting from reduced demand in the study area. Or the net impact of a reduction in industry demand. Rather than a contribution analysis, where I would compare an industry's gross impact before and after the demand shock.

IMPLAN modeling is commonly applied to regional economies and has been frequently used to estimate impacts of hunting and fishing (Gakpetor, Bangsund and Hodur 2025; Southwick 2018; Southwick 2023). Direct hunter spending was calculated by multiplying the reduction in hunters by one of the four spending profiles. Reported hunter expenditures from Koonz and Loomis (2005) were mapped to their respective industries in IMPLAN using the 546 level of industry aggregation. Hotel, restaurant, grocery, and gasoline expenditures were mapped to their own respective industries. Guide spending, game processing, and access fees were mapped to other amusement and recreation. While hunting supplies, taxidermy, and camping were mapped to sporting goods stores. Horse related expenditures and rental vehicles were excluded as they were not relevant to the study area or were under sampled. Fully mapped spending profiles are available in Appendix A.

Dollars brought in from outside the region expand the size of the economy and carry multiplier effects through additional business to business transactions (indirect effects) and labor income (induced effects). Lost multiplier effects were estimated by inputting the decrease in direct spending into IMPLAN. Indirect and induced effects are found via the social accounting matrix (SAM). Social accounting matrices are constructed using the Bureau of Economic Analysis’s input output tables as benchmarks and are adjusted to the county level by IMPLAN’s economists. A SAM displays the fraction of purchases and sales each industry makes from every other industry in the region of interest.

The IMPLAN model utilizes the Leontief production function to estimate total economic impacts. Leontief production assumes that inputs are perfect complements that scale linearly with output. As output decreases from a reduction in demand, production inputs will decrease proportionally to output with no substitution. For example, a 40% reduction in output results in a 40% reduction in inputs. Prices and economic flows will all stay the same. In reality, markets adjust to demand shocks by altering prices or substituting for other production inputs. A larger economic shock would trigger a stronger market response.

Leontief production is acceptable here because the observed economic shock is relatively small compared to the output of the study area. Outdoor recreation comprises 12.4% of GDP in the Colorado (Southwick, 2024), and elk hunting comprises a fraction of outdoor recreation. Routt and Moffat are well known for elk hunting, but also for many other kinds of outdoor recreation. Many businesses patronized by elk hunters don't exclusively service hunters. All expenditures surveyed, except taxidermy, game processing, and hunting guides, cater to a larger clientele than hunters. The demand shock resulting from fewer elk hunters would also be a fraction of these industries' revenue and, therefore, would not drastically change their business models. The true economic inputs and flows of the market after the winter of 2022-2023 likely resemble pre-shock levels, which is in line with the assumptions of Leontief production.

## Hunter Participation

Multiplier effects only arise from hunters coming from outside the study area or state. CPW reports how many resident and nonresident hunters received licenses, but not how many of those residents originate from the study area. There is minimal information on the number of local hunters in the area, and what type of permits local hunters typically buy, so I assumed that no hunters are from the local area. This is unrealistic, but likely will not have major implications on results, as previous surveys show locals tend to spend less than residents (Koontz and

Loomis, 2005). Based on the assumptions of this paper, most local hunters would pursue runoff or low demand licenses. A significant number of low demand hunters can be removed without drastically altering estimates, so no hunters were removed for being locals.

Another concern is hunter participation. I assumed that every hunter who received a tag to hunt in the region traveled to and spent money in the study area. Realistically, not every hunter who received a tag generates impact in the study area. CPW publishes estimates of the total number of hunters in a DAU each year. For DAUs E-1 and E-47, hunters can only receive permits from the primary and secondary draws. Total permits awarded always exceed the total number of hunters in these herds, but not by a large margin (Table 2, Table 3).

*Table 2: E-1 Licenses by Draw*

E-1

| Year | Primary Draw | Secondary Draw | CPW Estimate |
|---|---|---|---|
| 2015 | 403 | 0 | 374 |
| 2016 | 405 | 0 | 388 |
| 2017 | 405 | 0 | 395 |
| 2018 | 405 | 0 | 374 |
| 2019 | 405 | 0 | 389 |
| 2020 | 405 | 0 | 388 |
| 2021 | 405 | 0 | 414 |
| 2022 | 405 | 0 | 365 |
| 2023 | 390 | 0 | 357 |
| 2024 | 390 | 0 | 373 |
| 2025 | 345 | 0 | 369 |

*Table 3: E-47 Licenses by Draw*

E-47

| Year | Primary Draw | Secondary Draw | CPW Estimate |
|---|---|---|---|
| 2015 | 93 | 0 | 79 |
| 2016 | 96 | 0 | 92 |
| 2017 | 83 | 0 | 84 |
| 2018 | 103 | 0 | 89 |
| 2019 | 117 | 0 | 90 |
| 2020 | 112 | 10 | 105 |
| 2021 | 117 | 5 | 81 |
| 2022 | 112 | 10 | 79 |
| 2023 | 115 | 7 | 106 |
| 2024 | 122 | 0 | 82 |
| 2025 | 122 | 0 | 107 |

"Primary Draw" shows how many permits were allocated in the primary draw. "Secondary Draw" is the total number of unallocated first draw permits left for the secondary draw. The secondary draw was introduced in 2020, so no permits were allocated via the secondary draw before then. "CPW Estimate" is the total number of hunters that traveled to the

DAU that year, obtained from CPW's annual harvest survey. Primary and secondary draw permits typically exceed CPWs' estimate, but not by a large margin. E-47 occasionally captures 40% more hunters than CPW estimates, but CPW's estimate is based on a small sample size and is voluntarily reported. It's expected that if a hunter received a permit in this region but chose not to hunt, the permit was low demand, and the hunter was a low spender. Many low spenders can be removed or added without significantly altering results, so no considerations were made for hunter participation.

In herd E-2 not all permits are allocated in the primary draw. Typically, about eight thousand permits are awarded from the primary draw, and about two thousand are left over for the secondary draw. Unlimited over the counter (OTC) licenses are also available for purchase that allow hunting in many elk herds including E-2. The primary draw typically captures about 45% of all hunters in this DAU. Once again, I assumed participation was 100% in this DAU as well. Table 4 shows the number of first and secondary draw permits and the estimated over the counter (OTC) hunters in herd E-2.

*Table 4: E-2 Licenses by Draw*

**E-2**

| Year | Primary Draw | Secondary Draw | OTC |
|---|---|---|---|
| 2015 | 8334 | 0 | 7645 |
| 2016 | 9033 | 0 | 8525 |
| 2017 | 9180 | 0 | 8091 |
| 2018 | 9140 | 0 | 8478 |
| 2019 | 8959 | 0 | 8719 |
| 2020 | 8789 | 1835 | 9520 |
| 2021 | 8276 | 1086 | 9779 |
| 2022 | 7877 | 1237 | 9333 |
| 2023 | 3346 | 199 | 6152 |
| 2024 | 3119 | 532 | 3257 |
| 2025 | 6064 | 1642 | 1140 |

"OTC" was estimated by subtracting primary and secondary permits from CPWs' estimate of total hunters. Total over the counter license sales, as reported by CPW, do not reflect the number of OTC hunters in E-2 as these permits are valid in over 100 game management units. CPW issued multiple regulations for OTC hunters over the three year period after the winter causing the number of OTC hunters to decline. Although no quantity restriction was set. These restrictions had a significant impact on the heterogeneity of OTC hunters in the study area over the three year period. As this heterogeneity is not observable, OTC hunters were excluded from analysis. More context on OTC heterogeneity is found in Appendix C.

I only considered hunters from the primary draw in my analysis. This has little impact of results from herds E-1 and E-47, as they have few to no permits allocated outside of the primary draw, but has a large impact on the results from E-2. Because roughly 55% of permits are not allocated by the primary draw. I exclude secondary draw and over the counter licensees because I cannot observe demand for these permits. The secondary draw is a random lottery, and OTC permits are sold in infinite quantity. The secondary draw was introduced in 2020, and total permits awarded via the secondary draw varied considerably from 2020 to 2022. There is no observable stable historical average of secondary draw permits to compare the 2023 to 2025 decrease against, so secondary draw permits were excluded from impact analysis.

Over the counter license are characteristically unique, and are not easily assigned demand. They are less desirable than an equivalent permit from the draw, but many OTC licenses have characteristics that relate to higher demand permits. For example, a bull or archery hunt. In this study I want to highlight how heterogeneity in hunter spending based on hunter permit demand can significancy alter economic impact results from hunting tourism. Because OTC and secondary draw permit demand is unobservable, I exclude them as they obscure the relationship I form between demand and permit spending. Appendix C shows how

including OTC and secondary draw permits impacts total results and the assumptions that are required to include them.

Hunter participation was assumed to be 100% for all herds, so final results are an overestimate of the impact of hunters from the selected herds in the primary draw. However, because secondary draw and over the counter hunters are excluded, final results will underestimate the total impact elk hunters in E-1, E-2, and E-47 have in the study area.

## Elk Growth Function

Actual permit reductions in the study area were 63%, but CPW originally warned hunters of a 40% decrease in licenses due to the harsh winter. After monitoring the recovery of the elk population and receiving feedback from the hunting community, license reductions were increased in the study area. By choosing larger reductions than originally warned, CPW lost additional revenue, and the region lost additional impact. I estimate the economic trade off CPW made by choosing greater permit reductions.

To estimate economic impacts from CPW choosing greater reductions, a simple elk growth model was incorporated using birth and survival rates from Raithel et al. (2007). A static birth and calf survival rate was chosen within the reports' estimated confidence intervals that best fit the observed population change in Colorado post 2023, with observed harvest values. Total bull, cow, and calf harvest is assumed to be proportionally equal to the observed values post 2022-2023. I also assumed that permit type, as displayed in Table 1, was proportionally equal to the permit type from the observed license reductions. Chosen growth and birth rates were applied to estimate elk growth after harvest each season. A detailed description of the elk population model and its assumptions is found in Appendix B.

# Results

Results are first calculated for the lost economic impact of the 2022-2023 winter. Then I estimate the trade off of CPWs decision to increase license reductions. Lost CPW revenue resulting from reduced license sales is estimated for residents and nonresidents across the recovery period. Licenses are grouped by demand and compared to the historical average allocation. Lost hunter spending was informed by the reduction in permit demand types, and input into IMPLAN to estimate secondary effects. Lost impact from the 2022-2023 winter is calculated and compared across four alternative spending profiles. After results are found for the 2022-2023 winter, an elk growth model is utilized to estimate lost impacts from CPW's decision to impose aggressive license restrictions. Observed license reductions after the 2022-2023 winter, compared to historical averages by permit demand, are shown in Table 5.

*Table 5: License Reductions by Permit Demand*

| Year | Run Off | Low | Medium | High | Outfit | Total |
|---|---|---|---|---|---|---|
| 2023 | -72.85% | -46.43% | -12.61% | 8.50% | -13.69% | -58.21% |
| 2024 | -61.13% | -62.54% | -59.66% | -2.69% | 14.52% | -60.56% |
| 2025 | -12.78% | -46.43% | 11.60% | -0.97% | -3.73% | -28.60% |

Roughly ninety nine percent of license reductions in the study area came from herd E-2. E-2 saw license reductions greater than 5,000 in 2023 and 2024. License reductions came overwhelmingly from antlerless (cow/calf) hunts, which required five or less permit points to obtain. Antlerless reductions are reflected in the runoff and low damage categories in Table 5. Permit demand is highly correlated with elk gender, where high spenders almost exclusively hunt bull elk. Reductions to hunts that required more than five preference points were more variable. Variability in reductions arises due to state managers prioritizing high demand hunts, and because the winter disproportionately affected cows and calves.

2025 reductions in E-2 were about half of the previous year's because the population rebounded. The elk population after the 24-25 season was 15,840, which is 840 over the minimum target population. Still, CPW chose to reduce licenses by 2,630. A majority of licenses made available again were low demand antlerless rifle hunts, corresponding to a majority of the reductions in previous years. The 2025-2026 post hunt population estimate was 17,000 which is well within the objective threshold (15-18 thousand elk), and 2026 licenses will be awarded near historic levels. The entire impact of the 2022-2023 harsh winter is captured over the period spanning spring 2023 to spring 2026.

## CPW Revenue

CPW revenue from hunting licenses and fees from the primary draw in the study area is shown below in Table 6. Revenue from the three years prior to the license reduction is shown to display typical revenue. 2023 is revenue for the 2023-2024 season, and is the first season in which license reductions were imposed.

*Table 6: Direct CPW Revenue Over Time*

| Year | Resident Applications | Nonresident Applications | Resident Success | Nonresidents Success |
|---|---|---|---|---|
| 2020 | $727,937 | $695,515 | $465,062 | $2,232,041 |
| 2021 | $832,530 | $858,452 | $427,046 | $2,259,085 |
| 2022 | $741,537 | $817,653 | $402,899 | $2,206,686 |
| 2023 | $682,681 | $783,955 | $179,379 | $1,057,282 |
| 2024 | $495,883 | $585,384 | $167,833 | $995,586 |
| 2025 | $580,075 | $724,048 | $283,500 | $2,105,268 |

Application revenue did not change drastically despite large license reductions between 2022 and 2023 (Table 6). Hunters may still apply for licenses, despite limited permit supply, to bank preference points for future permits. However, the delayed response in applications is more likely caused by hunters having incomplete information. CPW released the finalized license reductions for the 2023-2024 season in late May of 2023. More than a month after the deadline to apply. Hunters applied based on last year's draw report, so applications still

resemble historical trends. Revenue collected for license sales decreased dramatically from 2022 to 2023. Both resident and nonresident permit sales declined by approximately 50%. This is expected as total licenses allocated declined by close to 50% as well.

Elk populations rebounded close to target levels after the 2024-2025 season, causing CPW to increase licenses for the 2025-2026 season. Overall, license reductions were less than half the magnitude of previous seasons. Of the 2,940 licenses reallocated in 2025-2026, 1,643 were resident permits, and 1,297 were nonresident permits. The disproportionate restoration of permits, compared to the original reductions, brings nonresident application and license revenue close to prewinter levels.

CPW allocates permits to residents and nonresidents based on permit demand. 80% of permits are awarded to residents if that license is drawn out at more than 6 preference points for three consecutive years. In the study area, residents received 68% of available permits on average. Despite receiving 32% of permits, nonresidents comprise about 73% of CPW revenue from primary draw elk permits in the area. Nonresidents express much higher willingness to pay to hunt in Colorado and are a vital revenue source for CPW. Average annual CPW revenue from 2018 to 2022 was $4,216,630.  Compared to the average permit allocation, CPW lost $4,009,011 in direct revenue due to the harsh winter of 2022-2023.

## Direct Hunter Spending

Lost direct hunter spending in the region and state, resulting from the 2022-2023 winter, by spending profile, is provided in Tables 7 and 8.

*Table 7:  Study Area Hunter Spending*

**Direct Spending Region**

| Year | Benchmark | High | Low | Adjusted |
|---|---|---|---|---|
| 2023 | -$4,584,353 | -$1,092,801 | -$353,300 | -$479,334 |
| 2024 | -$5,218,460 | -$1,196,463 | -$232,178 | -$390,761 |
| 2025 | -$1,532,456 | -$685,640 | -$204,395 | -$237,673 |

*Table 8: Rest of State Hunter Spending*

**Direct Spending State**

| Year | Benchmark | High | Low | Adjusted |
|---|---|---|---|---|
| 2023 | -$303,639 | -$190,728 | -$68,954 | -$106,253 |
| 2024 | -$321,946 | -$229,282 | -$59,465 | -$112,879 |
| 2025 | -$44,029 | -$106,376 | -$35,397 | -$36,953 |

The benchmark profile uses the total average spending of residents and nonresidents. All other profiles assigned varying levels of spending based on permit demand. Spending reductions were greatest using the benchmark spending profile. 2024 had the largest estimated decline in spending when the benchmark and high spending profiles were implemented. The low and adjusted spending profiles estimated the largest reduction for the region in 2023, but 2024 was still the worst for the state.

Discrepancies in magnitude between years in the profiles arise from high demand for permits and outfitter permits in 2024. CPW allocated about 15 more outfitter permits than the previous year, despite larger overall reductions. Outfitter permits were made available by reallocating high demand permits. High demand hunters spend significantly more in the rest of the state compared to low demand hunters. Outfitters spend significantly more in all categories, especially in the local region. For the low and adjusted spending profiles, an influx of outfitter hunters in 2024 offset some of the impact in the study area from the decrease in total licenses. However, the decrease in high demand permits led to lower state spending compared to 2023. Depending on how hunter spending is calculated, CPW was able to mitigate economic losses in 2024 by prioritizing permits to outfitters.

Statewide spending was almost entirely restored in 2025. Corresponding with CPW almost entirely restoring nonresident permits. The high spending profile produces the largest loss statewide impact in 2025, as most of the restricted permits this year were low demand.

Because economic impact only originates from new dollars entering the economy, resident spending was excluded for statewide estimates. Statewide impacts are entirely dependent on nonresident permit allocation.

The highest total spending estimates came from the benchmark profile, and the lowest spending estimates came from the low spending profile. Variability in spending estimates originates from the distribution of the data and the biological impact of the 2022-2023 winter. Hunter spending is heavily skewed right (Figure 7, Figure 8) and a majority of the reductions were from low demand permits. Which are primarily permits to hunt female elk.

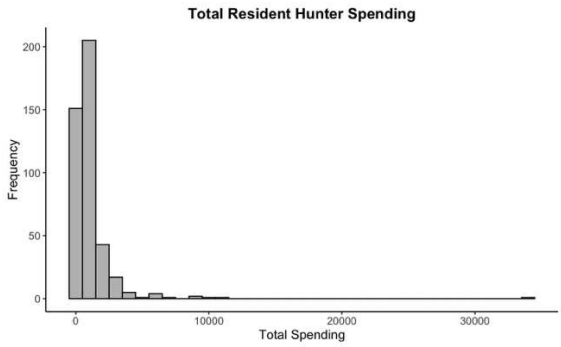


*Figure 7: Total Resident Spending by Hunter*

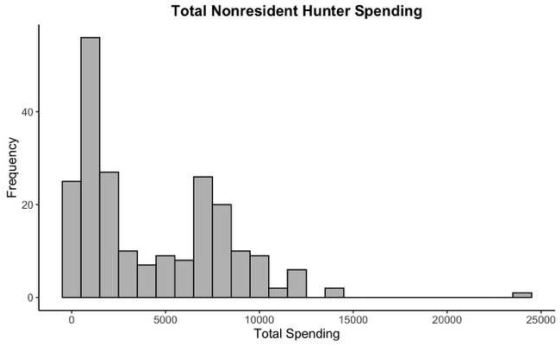


*Figure 8: Total Nonresident Spending by Hunter*

Nonresident spending is overall greater and much more variable compared to resident spending. Both distributions are heavily skewed right with large outliers. Causing the benchmark spending profile to overestimate total spending. Because state impacts are only derived from nonresident hunters, the benchmark profile estimates are closer to the other profiles statewide. As the distribution is less skewed, outliers have less of an effect. However, dropping the outliers would not be appropriate in this situation. High spending, high demand hunters are always present in the study area and are important revenue streams, particularly for local outfitters.

## Secondary Effects

IMPLAN estimates additional economic impacts from direct spending as indirect and induced effects. Indirect effects represent additional business to business transactions

originating from hunter spending. Induced effects represent additional household spending resulting from increased labor income generated by hunter spending. Figure 9 displays induced and indirect impacts by profile, except the benchmark, for the study area. Figure 10 shows indirect and induced effects by profile for the state.

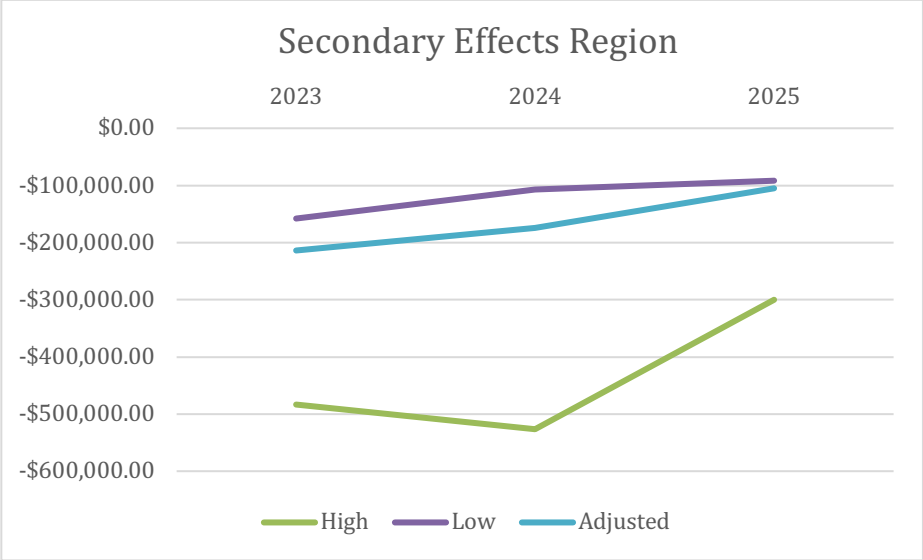


*Figure 9: Lost Regional Impact*

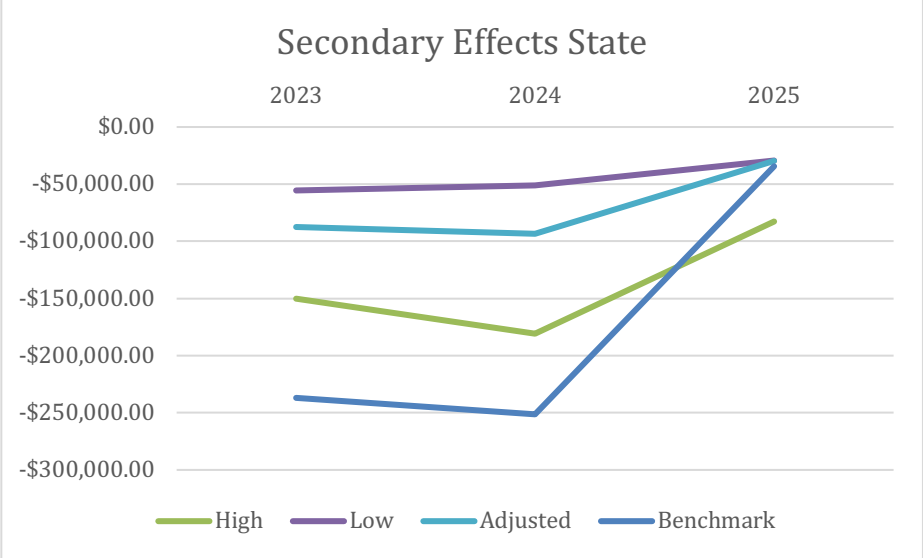


*Figure 10: Lost State Impact*

Estimated effects from the benchmark profile are removed from Figure 9 due to their large magnitude. Regional effects from the benchmark profile follow the shape of the high

spending profile, except they are roughly four times larger. Because indirect and induced effects are derived from direct spending, the trend in this data follows that of direct spending. 2023 had the largest regional reductions for the low and adjusted spending profiles, and 2024 had the largest regional reductions for the average and standard deviation profiles. Secondary effects are almost entirely recovered statewide in 2025 through the restoration of nonresident permits. Indirect and induced effects are about 1/4th of direct spending estimates across the board.

IMPLAN estimates lost tax revenue generated from reduced business transactions at the state and local level. As well as an estimate of the loss in employment. I only estimated the employment for the study area, and didn't include statewide effects. The results for each spending profile are shown in Tables 9 and 10.

*Table 9: Tax and Employment (Benchmark and High Profiles)*

| Year | Bench Tax State | Bench Tax Region | Bench FTE | High Tax State | High Tax Region | High FTE |
|---|---|---|---|---|---|---|
| 2023 | -$297,177 | -$177,654 | -32.08 | -$65,174 | -$38,811 | -7.72 |
| 2024 | -$327,620 | -$197,027 | -36.74 | -$64,287 | -$37,470 | -8.51 |
| 2025 | -$87,639 | -$51,891 | -10.66 | -$36,874 | -$21,492 | -4.81 |

*Table 10: Tax and Employment (Low and Adjusted Profiles)*

| Year | Low Tax State | Low Tax Region | Low FTE | Adjusted Tax State | Adjusted Tax Region | Adjusted FTE |
|---|---|---|---|---|---|---|
| 2023 | -$19,717 | -$11,565 | -2.42 | -$25,009 | -$14,440 | -3.4 |
| 2024 | -$7,292 | -$3,611 | -1.61 | -$13,951 | -$7,185 | -2.85 |
| 2025 | -$9,990 | -$5,698 | -1.44 | -$11,276 | -$6,354 | -1.67 |

Here employment isn't a number that can be aggregated. It should be interpreted only for an individual year. Tax revenue and employment are derived from secondary effects, so the trend matches direct spending. Different spending profiles alter employment estimates significantly. The benchmark profile estimated that 26 jobs were restored by increasing permits in 2025, while the low spending profile estimated that increasing permits had almost no impact on employment.

## Total Impact

Total lost economic impact from the 2022-2023 winter (Direct effects, Secondary Effects, and Taxes) is displayed in Table 11.

*Table 11: Lost Total Impact by Spending Profile*

**Total Impact**

| | Benchmark | High | Low | Adjusted |
|---|---|---|---|---|
| Total Impact | -$17,591,267 | -$5,145,428 | -$1,411,458 | -$1,947,348 |

The benchmark profile had the largest total impact, about three times the magnitude of the second highest estimate. These results highlight why multiplying total hunters by average spending yields inaccurate estimates. Assuming hunter spending is correlated with hunter demand a model that utilizes average spending will grossly overestimate spending for low demand hunters. Because most elk hunters are in the low demand category, this creates a large error. Especially if permits are disproportionately increased or reduced across hunt types. Stratifying spending by hunter demand better represents individual regions. With the average, you need to assume the composition of hunters is constant across all areas or well captured in your survey. Due to the extreme outliers in the data, hunter spending surveys are likely to take unrepresentative averages even with large sample sizes. Mapping hunter spending to hunter characteristics creates a method that could elicit heterogeneity in hunter expenditures across location and species with limited survey data.

## Alternative Recovery

CPW warned hunters to expect a license reduction of at least 40% prior to the 2023-2024 season. After receiving feedback from their biologists and the community, CPW reduced licenses by about 63% in herd E-2. Alternatively, CPW could have reduced licenses by less than observed to dampen the immediate economic impact following the harsh winter. Reductions had to be imposed, as a 0% reduction in licenses would cause the population to

shrink each year. Oversimplification of the elk growth function leaves uncertainty as to the validity of the estimated maximum harvest that would allow yearly growth. So, the original 40% warning was chosen to represent the potential minimum level of license reductions.

The growth model predicts that, given a 40% reduction in licenses, E-2 would reach the target population in the same time period as with the observed reductions. The estimated population is smaller compared to the observed one, but still within the herd population objective. Appendix B displays the estimated population from 2023-2025 compared to the observed population. Total state and region impacts for the observed and proposed license reductions are calculated using the adjusted spending profile. The adjusted profile was chosen as the best fit for hunter spending data as it provided a middle ground between the low and the high spending profiles. Which underestimate and overestimate low demand hunters respectively. Lost regional and statewide impacts are presented in Figures 11 and 12.

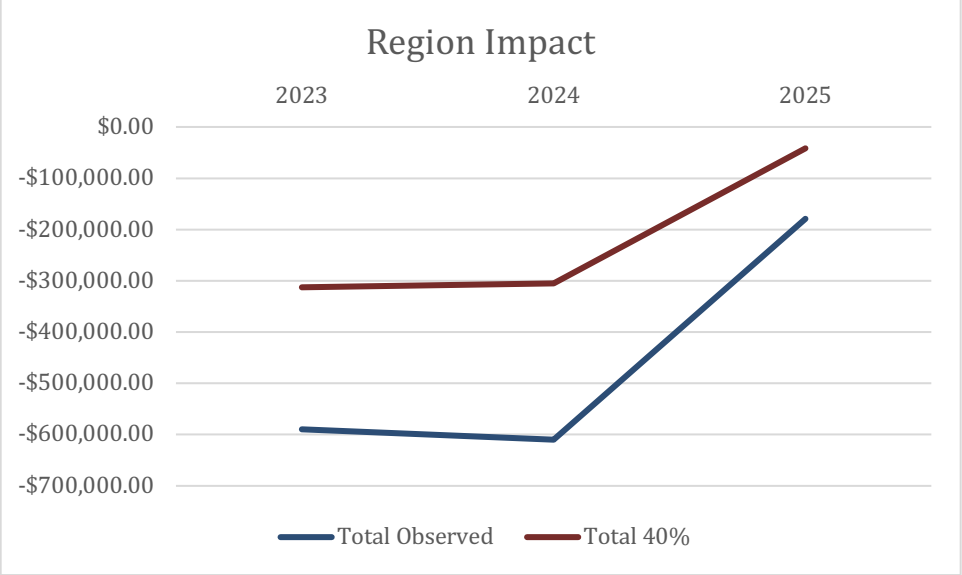


*Figure 11: Alternative Recovery Lost Impact, Study Area*

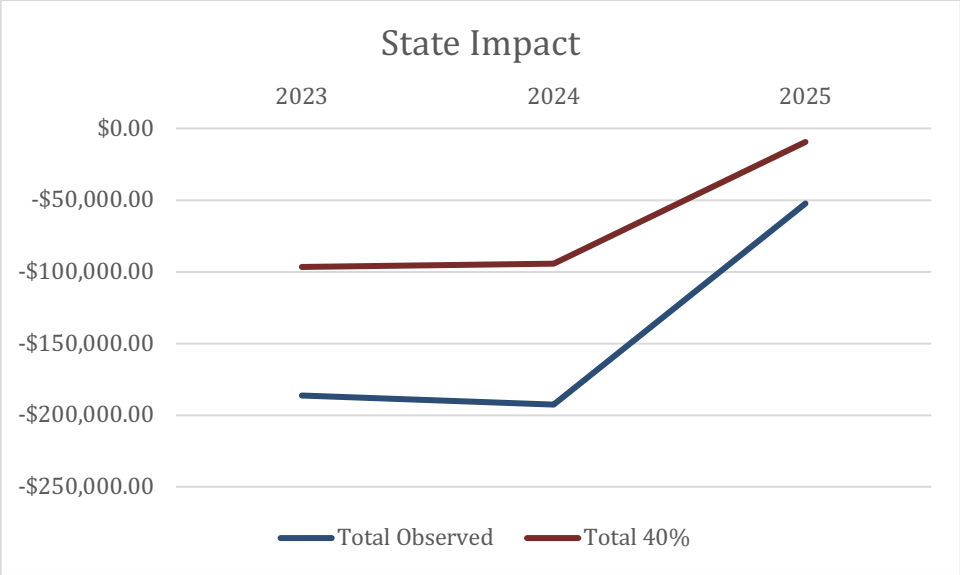


*Figure 12: Alternative Recovery Lost Impact, Rest of State*

Estimates are presented in 2025 dollars and discounted with 2023 as period 1. Total statewide and regional impacts are about half of what was observed when licenses were reduced by 60%. Roughly $950,000 in total impacts was lost across Colorado when CPW chose to reduce licenses by more than its original suggestion. Estimates use an elk growth rate chosen to fit observed population change from 2023-2025. Following the harsh winter of 2022-2023 Colorado experienced three mild winters in a row, resulting in higher growth rates than normal.

While it appears that CPW could have made a Pareto improvement by increasing elk permits allocated from 2023 to 2025, its important to state that CPW's objective function is not fully defined in this paper. I only estimate economic impacts and population size, but CPW manages wildlife based on local concerns, hunter satisfaction, nonuse values, and more complex measures of herd wellbeing. It's possible that, given perfect information on future elk growth rates after the harsh winter, CPW would still decide to maintain larger license reductions. CPW may not value the recuperated economic impact more than hunter satisfaction, local opinion, or any other metric or factor considered in wildlife management.

# Discussion

In this study, I highlight limitations and potential errors when estimating hunter impacts using average spending. If the data is right skewed with large outliers, calculating total spending by multiplying the total number of hunters by the average spending provides an overestimation.

Interestingly, when the nonresident permit allocation was restored, the benchmark profile's estimated impact was very close to two of the other spending profiles. This is explained by nonresident spending being distributed more evenly than resident spending, and an increased ratio of high demand to low demand permits in 2025. If hunter demand is similar across permits, disaggregating the average spending profile by demand might be irrelevant to results. However, demand for all species in Colorado is highly variable. Some hunts are sold over the counter, and others require more than a 15 year wait. A survey of all Colorado hunters spending would likely yield a distribution even more skewed than a survey of elk hunters. Resulting in economic impacts with even greater variability than elk hunting estimates, depending on the method of calculating total hunter spending.

A modern survey of elk hunters in the study area would greatly improve the model's results. An expenditure survey similar to the one conducted by Bowman, Taylor, and Borden (2022) could achieve this. Where expenditures are disaggregated by state residency and permit type. However, the sample would need to be large and comprehensive. There may be unique spending patterns associated with permit type in this location compared to the rest of Colorado or the country. Hunters are shown to be willing to spend more money and time to receive permits, but there has been no formal study correlating permit demand to hunter spending. Formalizing the relationship between hunter spending and permit demand would improve results considerably and provide a method for mapping hunter spending across all permit types. A formal investigation of hunter characteristics could allow for more in depth grouping of hunters

beyond permit demand. A researcher could then classify each individual permit as attracting a certain group or combination of hunters. This method can provide more accurate measurements of the economic impact of hunting while keeping data collection feasible. If hunter spending can be categorized by permit demand across species, then surveys of hunter spending could be applicable nationwide rather than being restricted by species or study area. This would reduce the number and scope of surveys required when applying this methodology to different species or study areas and would have the same effect when updating expenditure data in the future.

This study made many assumptions to simplify the system. Elk populations were assumed to be homogenous were permits give hunters the right to harvest one elk. Permits were separated based on demand, but a successful high demand hunt had the same impact on the elk herd as a successful low demand hunt. Permit demand is heavily correlated to location and elk sex, and their total allocation relies on the herd's ecological composition. No spillover effects were considered, and it was assumed that every hunter who received a permit hunted in the region that season.

A study into spillover effects and hunter participation could improve results as here they are not considered. Furthermore, this study did not consider the impact from the secondary draw and over the counter sales which comprise more than half of all hunters yearly in E-2. Over the counter sales capture all hunting outfitters in E-2. Outfitter hunters are consistently surveyed as the highest spenders by a very large margin, and if economic impact depends on the highest spenders, this omission is a vital one. Outfitters in E-2 may comprise a majority of the total economic impact elk hunting has in the region, and economic losses from large permit reductions from the primary draw could be mitigated by these hunters.

Estimating elk population recovery, given an alternative permit reduction of 40%, resulted in populations reaching the target range in the same time period as observed post 2022-2023. This quick rebound was caused by unusually large growth rates during this period. These originate due to increased available winter forage resulting from mild winters over the

recovery period. An advanced elk model in 2023 would likely project a lower growth rate than what was actually observed, and a state manager would likely not project populations rebounding in the same time period as observed with a 40% reduction. These results highlight how economic impacts rely on the biological response of elk. Weather and climate conditions are the primary factors that inform elk growth rates, making them highly variable. This obscures the “optimal response” of state managers in the current period, so the allocation that minimizes lost impact can only be found post ante. As climate conditions become more variable, so do elk populations, increasing the likelihood that the observed permit allocation is a “nonoptimal” one. Where the same ecological results could be achieved at a lower cost to the state or community.

It's important to remember that CPW manages wildlife populations based on more factors than just revenue from permits and fees or regional and state economic activity. State managers also consider ecological well being, hunter satisfaction, nonuse values of wildlife, and community opinion. Economic impact can be mitigated by prioritizing specific high demand permits. However, this may not align with other CPW objectives such as ecological stability. If state managers were attempting to maximize economic measures, permits would not be allocated in a lottery primarily to residents. CPW may choose a permit allocation that yields less revenue or economic impact based on ecological factors or community input. As observed in the 2022-2023 winter, most license reductions were for antlerless elk, as they were disproportionately impacted by the winter. Economic incentives aligned with ecological incentives, but the decision was not primarily based on economic impact. CPW determined the final license reductions in response to the local community advocating for drastic reductions because they value herd health. Rather than CPW trying to shorten the recovery period to minimize lost economic impact.

# Conclusion

The harsh winter of 2022-23 significantly reduced the elk population in Northwest Colorado. CPW reacted by reducing licenses by a combined 60% in herds E-1, E-2, and E-47. CPW lost an estimated $4,009,011 in direct revenue due to license reductions. The total economic impact of license reductions in the study area and state varies depending on how the researcher calculates hunter spending and the presence of heterogeneity in permit demand. The common method of calculating total hunter spending provides an overestimate when the data is right skewed with large outliers. The total lost economic impact using average spending estimates was $17,591,267. When spending was adjusted based on permit demand, the total lost economic impact ranged from $5,145,428 to $1,411,458. Yearly impacts also varied by spending profile as the composition of permit demand changed over the time period. This is most pronounced when high demand permits are prioritized to offset low demand reductions.

Loss in economic impact and direct revenue from license reductions can be minimized if the state manager maintains a supply of high demand permits. Direct CPW revenue was close to historical levels in 2025 despite about 2,500 fewer permits being made available. CPW was able to recuperate lost revenue by restoring nonresident permits to historical levels, which comprise a majority of direct revenue from license sales.

The alternative growth model, based on observed elk growth rates from 2023-2025, estimated that Colorado lost roughly $950,000 in economic impacts by reducing permits by more than 40%. CPW could have allocated more permits and reached the target population in the same period as with the current management plans, given the observed winter severity from 2023-2025. However, elk population growth was significantly above average over the time period.

Hunting permits are the primary revenue source for state wildlife agencies and support local communities through hunting tourism. Economic and ecological impacts depend not only on the total number of hunting permits allocated but on the composition of those permits. To maintain economic revenues, CPW should maintain total permit levels at the highest demand and enforce permit reductions at the lowest demand if needed. State managers' ability to prioritize high demand hunts is dependent on the health and composition of the herd. Ecological incentives align with economic ones when bull elk populations are plentiful compared to cows and become misaligned if bull elk are scarce. Given a reduction in hunting licenses, state managers can minimize lost economic impacts if the future elk growth rate is known. Increased climate variability has further obscured future population growth, making it more difficult for state managers to maximize economic impacts and manage elk populations.

# References


BenDor, T.K., Livengood, A., Lester, T.W., Davis, A. and Yonavjak, L. (2015), Defining and evaluating the ecological restoration economy. Restor Ecol, 23: 209-219. https://doi.org/10.1111/rec.12206

Bowman, Taylor, and Borden. (2022). Hunter Expenditure in Nevada, A Comprehensive Analysis of Big Game and Upland Game Hunting-Related Expenditures in 2020. Nevada Economic Assessment Project.

Burkard. M. (2023). The Economic Contribution of River Recreation and Tourism in the Little Yampa Canyon, Colorado. [Masters Thesis, Colorado State University] Mountain Scholar, Dissertations and Theses.

Dogbey-Gakpetor, J., Bangsund, D. A., & Hodur, N. M. (2025). Resident and Nonresident Hunter and Angler Expenditures, Characteristics, and Economic Effects, North Dakota, 2023-2024. Unknown. https://doi.org/10.22004/AG.ECON.356766

Finley, Bruce. (2023). CPW plans to cut NW Colorado hunting licenses by more than 40% to protect challenged herds. *Denver Post.* 28 March.

Gren, IM., Häggmark-Svensson, T., Elofsson, K. *et al.* Economics of wildlife management—an overview. *Eur J Wildl Res* 64, 22 (2018). https://doi.org/10.1007/s10344-018-1180-3

Highfill, and Smith-Nelson. (2018). Outdoor Recreation Satellite Account Methodology. *U.S. Bureau of Economic Analysis*

Hogan, P. H. (2016). Evaluating the homogeneity of preferences across resident and nonresident elk hunters in Colorado (Publication NO. 10149936) [Masters Thesis, Colorado State University] ProQuest Dissertations and Theses Global.

Koontz, L., and Loomis, J.B., (2005), Economic importance of elk hunting in Jackson Hole, Wyoming: U.S. Geological Survey, Open-File Report 2005-1183, 21 p.

Lindall, S. A., & Olson, D. C. (1996). The IMPLAN input-output system. *MIG Inc., Stillwater, MN et www.implan.com*.

McEachran, M.C., Don Carlos, A., Cotterill, G.G., Cole, E.K., and Cook, J.D., (2025), Estimating the social and economic consequences of proposed management alternatives at the National Elk Refuge, chap. E of Cook, J.D., and Cross, P.C., eds., *Decision analysis in support of the National Elk Refuge bison and elk management plan: U.S. Geological Survey Scientific Investigations Report* 2025–5076, 11 p., https://doi.org/10.3133/sir20255076E. [Supersedes USGS Scientific Investigations Report 2024–5119.]

Milon, J. W., & Clemmons, R. (1991). Hunters' Demand for Species Variety. *Land Economics*, *67*(4), 401–412. https://doi.org/10.2307/3146547

Natural Resources Conservation Service. 2014. *Guidelines for Economic Impact Analysis with IMPLAN.* United States Department of Agriculture, Technical Note

Raithel, J.D., Kauffman, M.J. and Pletcher, D.H. (2007), Impact of Spatial and Temporal Variation in Calf Survival on the Growth of Elk Populations. *The Journal of Wildlife Management*, 71: 795-803. https://doi.org/10.2193/2005-608

Southwick Associates, "Quantifying the Economic Contributions of Wildlife-Related Recreation on BLM Lands" (2018). *All Publications.* Paper 2. https://digitalcommons.usu.edu/public_land-recreation-all/2

Southwick Associates, “The 2023 Economic Contributions of Outdoor Recreation in Colorado” (2024). Prepared for Colorado Parks and Wildlife, in collaboration with Colorado State University. https://hermes.cde.state.co.us/islandora/object/co%3A40628

Vaske, Jerry & Donnelly, Maureen & Manfredo, Michael. (2007). Hunting Specialization and its Relationship to Participation in Response to Chronic Wasting Disease. Journal of Leisure Research. 39. 413-437. 10.1080/00222216.2007.11950115.

# Appendix A

Spending profiles are presented as in Koontz and Loomis (2005). Horse and car rentals were excluded for being irrelevant to the study area or under sampled. Spending was adjusted to 2025 dollars. Jackson Hole spending was assigned to the study region, and Wyoming was assigned to the rest of Colorado. Average spending (benchmark profile) is displayed below.

*Table 12: Benchmark Spending by Expenditure*

| | Jackson Hole | | Wyoming | |
|---|---|---|---|---|
| **Variable** | **Resident** | **NonResident** | **Resident** | **NonResident** |
| Gasoline Stores | $144.79 | $201.64 | $123.44 | $171.28 |
| Full Service Restaurants | $138.40 | $301.15 | $39.67 | $71.89 |
| Food and Beverage Stores | $96.66 | $156.71 | $81.59 | $34.57 |
| Hotels and Motels | $194.63 | $411.05 | $6.64 | $45.57 |
| Other Amusement and Retail | $48.70 | $1,130.83 | $56.12 | $33.28 |
| Sporting Goods, hobby, ….. | $59.78 | $143.65 | $127.45 | $48.95 |
| Total | $682.96 | $2,345.03 | $434.91 | $405.54 |

High Spending Profile:

*Table 13: High Spending in Study Area*

| | SD Profile Jackson Hole | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Res Run Off** | **NonRes Run Off** | **Res Low** | **NonRes Low** | **Res Mid** | **NonRes Mid** | **Res High** | **NonRes High** | **Outfitter** |
| Gasoline Stores | $99.41 | $143.29 | $99.41 | $143.29 | $99.41 | $143.29 | $99.41 | $143.29 | $138.66 |
| Full Service Restruants | $2.42 | $91.40 | $87.37 | $198.95 | $257.27 | $414.04 | $766.97 | $1,059.30 | $465.37 |
| Food and Beverage Stores | $0.00 | $56.20 | $69.86 | $175.66 | $210.26 | $414.59 | $631.44 | $1,131.36 | $246.02 |
| Hotels and Motels | $0.00 | $31.65 | $74.03 | $162.31 | $307.89 | $423.62 | $1,009.47 | $1,207.57 | $551.68 |
| Other Amusment and Retail | $29.13 | $94.39 | $31.79 | $107.81 | $76.45 | $195.89 | $210.46 | $460.11 | $9,040.51 |
| Sporting Goods, hobby, ….. | $0.00 | $0.00 | $47.10 | $92.34 | $269.76 | $381.46 | $1,284.73 | $1,978.60 | $1,498.60 |
| | | | | | | | | | |
| Total | $130.96 | $416.92 | $409.56 | $880.36 | $1,221.04 | $1,972.87 | $4,002.48 | $5,980.23 | $11,940.84 |

*Table 14: High Spending in the Rest of Colorado*

| Spending Profile Wyoming | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Res Run Off | NonRes Run Off | Res Low | NonRes Low | Res Mid | NonRes Mid | Res High | NonResHigh | Outfitter |
| Gasoline Stores | $141.09 | $141.09 | $141.09 | $183.86 | $141.09 | $141.09 | $141.09 | $141.09 | $108.93 |
| Full Service Restruants | $9.60 | $24.91 | $47.04 | $75.78 | $121.92 | $177.53 | $346.56 | $482.77 | $144.18 |
| Food and Beverage Stores | $31.14 | $0.00 | $120.79 | $59.85 | $300.08 | $186.10 | $837.94 | $564.84 | $96.34 |
| Hotels and Motels | $0.00 | $0.00 | $10.16 | $48.23 | $56.90 | $180.66 | $197.11 | $577.96 | $93.43 |
| Other Amusment and Retail | $62.68 | $34.16 | $62.68 | $37.15 | $62.68 | $70.10 | $62.68 | $168.97 | $285.25 |
| Sporting Goods, hobby, ..... | $0.00 | $0.00 | $114.48 | $35.46 | $511.84 | $140.06 | $2,927.82 | $1,127.87 | $457.81 |
| | | | | | | | | | |
| Total | $244.50 | $200.16 | $496.23 | $440.34 | $1,194.50 | $895.54 | $4,513.20 | $3,063.49 | $1,185.94 |

For all profiles, gas was the mean value, as that wouldn't change given demand. Run off was found by subtracting half of a standard deviation from the mean. Negative values were rounded to zero. Originally, one standard deviation was subtracted, but nearly all categories were zero. Low is the mean, Medium is the mean plus one standard deviation, and High is the mean plus four standard deviations. Four standard deviations were chosen as they output results close to the maximum spending, and I wanted high spenders to spend close to the maximum. The data is so right skewed that it takes 4 deviations to actually get spending within one standard deviation of most maximum values. Outfitter spending adds one standard deviation to the outfitter subset means.

Low Spending Profile:

*Table 15: Low Spending in Study Area*

| Spending Profile Jackson Hole | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Res Run Off | NonRes Run Off | Res Low | NonRes Low | Res Mid | NonRes Mid | Res High | NonResHigh | Outfitter |
| Gasoline Stores | $99.41 | $143.29 | $99.41 | $143.29 | $99.41 | $143.29 | $99.41 | $143.29 | $138.66 |
| Full Service Restruants | $0.00 | $36.40 | $36.40 | $109.20 | $109.20 | $352.63 | $364.00 | $546.00 | $465.37 |
| Food and Beverage Stores | $0.00 | $0.00 | $0.00 | $91.00 | $72.80 | $273.00 | $364.00 | $546.00 | $246.02 |
| Hotels and Motels | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $273.00 | $364.00 | $682.50 | $551.68 |
| Other Amusment and Retail | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $227.50 | $511.24 | $9,040.51 |
| Sporting Goods, hobby, ..... | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $86.45 | $197.02 | $429.97 | $1,498.60 |
| Total | $99.41 | $81.90 | $109.20 | $291.20 | $291.20 | $1,167.08 | $1,880.52 | $3,079.71 | $11,940.84 |

*Table 16: Low Spending in the Rest of Colorado*

| Spending Profile Wyoming | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Res Run Off | NonRes Run Off | Res Low | NonRes Low | Res Mid | NonRes Mid | Res High | NonResHigh | Outfitter |
| Gasoline Stores | $141.09 | $141.09 | $141.09 | $183.86 | $141.09 | $141.09 | $141.09 | $141.09 | $108.93 |
| Full Service Restruants | $0.00 | $0.00 | $21.84 | $36.40 | $72.80 | $116.03 | $182.00 | $273.00 | $144.18 |
| Food and Beverage Stores | $0.00 | $0.00 | $36.40 | $0.00 | $182.00 | $61.43 | $455.00 | $273.00 | $96.34 |
| Hotels and Motels | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $91.00 | $273.00 | $93.43 |
| Other Amusment and Retail | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $0.00 | $357.63 | $244.34 | $285.25 |
| Sporting Goods, hobby, ..... | $0.00 | $0.00 | $0.00 | $0.00 | $91.00 | $0.00 | $531.89 | $182.00 | $1,832.38 |
| Total | $36.40 | $0.00 | $149.24 | $145.60 | $527.80 | $450.45 | $1,981.53 | $1,964.24 | $2,560.51 |

runoff is the 25th percentile, low in the median, medium is the 75th percentile, and high is the 95th percentile. Outfitter is the same as in the standard deviation

Adjusted Spending Profile:

*Table 17: Adjusted Spending in Study Area*

| Spending Profile Jackson Hole | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Res Run Off | NonRes Run Off | Res Low | NonRes Low | Res Mid | NonRes Mid | Res High | NonResHigh | Outfitter |
| Gasoline Store | $99.41 | $143.29 | $99.41 | $143.29 | $99.41 | $143.29 | $99.41 | $143.29 | $138.66 |
| Full Service Re | $2.42 | $91.40 | $44.89 | $145.17 | $44.89 | $145.17 | $364.00 | $546.00 | $364.00 |
| Food and Bev | $0.00 | $56.20 | $34.76 | $115.93 | $72.80 | $273.00 | $210.26 | $414.59 | $138.78 |
| Hotels and M | $0.00 | $0.00 | $0.00 | $0.00 | $74.03 | $162.31 | $364.00 | $682.50 | $364.00 |
| Other Amusm | $0.30 | $0.15 | $0.30 | $0.15 | $0.30 | $0.15 | $230.46 | $524.81 | $9,205.92 |
| Sporting Goo | $0.00 | $0.00 | $6.35 | $41.97 | $90.17 | $220.86 | $241.37 | $506.73 | $1,342.06 |

*Table 18: Adjusted Spending in the Rest of Colorado*

| Spending Profile Wyoming | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Res Run Off | NonRes Run Off | Res Low | NonRes Low | Res Mid | NonRes Mid | Res High | NonResHigh | Outfitter |
| Gasoline Store | $141.09 | $183.86 | $141.09 | $183.86 | $141.09 | $183.86 | $141.09 | $183.86 | $108.93 |
| Full Service Re | $9.60 | $24.91 | $28.32 | $50.35 | $28.32 | $50.35 | $182.00 | $273.00 | $72.80 |
| Food and Bev | $31.14 | $0.00 | $75.97 | $28.29 | $182.00 | $61.43 | $300.08 | $186.10 | $0.00 |
| Hotels and M | $0.00 | $0.00 | $0.00 | $0.00 | $10.16 | $48.23 | $455.00 | $273.00 | $0.00 |
| Other Amusm | $0.02 | $0.00 | $0.02 | $0.00 | $0.02 | $0.00 | $357.65 | $247.32 | $280.70 |
| Sporting Goo | $0.00 | $0.00 | $20.88 | $12.21 | $171.74 | $60.05 | $717.60 | $364.75 | $328.42 |

Run off is the same as the standard deviation. Low subtracts 25% of the standard deviation except for camping, which is only 10%. This is to impose that a low-demand hunter is more likely to camp. Medium is 75th percentile except for camping, which is the mean plus half a standard deviation. High is the 95th percentile except camping is the mean and grocery is the mean plus a standard deviation. Outfitter is the 95th percentile. Assumptions were made to find a middle ground between the low and high spending profiles as they overestimate and underestimate, respectively. Values were chosen to reflect substitution between expenditures. While there is no basis for the raw numbers of this data, the assumed profile was altered such that results would reflect the general impact these assumptions would have if true.

# Appendix B

To estimate elk recovery, if CPW instead reduced licenses by 40%, measures were taken from Raithel et al. (2007). In their paper, Table 1 presents summary statistics on calf and cow survival rates and the pregnancy rate for multiple age groups of cows. The researchers produced estimates by summarizing the results of 37 different studies conducted between 1935 and 2005 (Raithel et al. 2007). For my growth model, I would like these estimates to represent the climate and biological impacts on elk survival exclusively. Harvest is known for testing the observed case and for the 40% reduction. I assumed harvest proportionally increased given additional licenses. Studies on elk survival typically track elk from year to year and capture the survival rates, which include hunting mortality. In this instance, it was assumed that all cow and bull elk mortality comes from the harvest. Winter survival was very high post 2022-23 due to mild winters, and as seen in Raithel et al. (2007), cow survival is already above 80% with harvests incorporated. Calf survival was chosen to be the maximum reported (72%). This was chosen to fit the observed population rebound. The population over time was estimated based on the observed harvest and a proportionally increased harvest. Estimates are shown below, as well as the population number reported by CPW.

*Table 19: Population Model Results*

| Year | CPW Reported | Obs Harvest Estimated | 40% Estimated |
|---|---|---|---|
| 2023 | 10570 | 12661 | 12402 |
| 2024 | 15840 | 15419 | 14721 |
| 2025 | 17070 | 18709 | 17395 |

"Obs Harvest Estimated" displays the elk model output using the observed elk harvest. It can be compared against the CPW reported figures to show where there may be an error in the model. There is no official report of the population in E-2 after the 2022-23 winter. CPW reports

the post harvest 2022 and 2023 population; however, those estimates are before winter mortality. It was assumed that the post winter population was 9,984, which grew over the summer to be harvested in the 2023 season. The reported population estimates are post hunt populations. The estimated population recovery given the observed harvest overestimated population in 2023 and 2025, but underestimates population in 2024. Because CPW reported estimates are not precise and are only to be used as trend lines, estimates from the simple growth model are believable. Because recovery was similar between the 40% and observed allocation, it was assumed CPW made the same decision in 2025 to restore half of the reduced licenses.

# Appendix C

Three types of OTC licenses are valid in E-2. These are antlerless elk archery, any elk archery, and bull elk rifle hunts. Before the 2022-23 winter, rifle hunters could hunt in all game management units in E-2. Archery hunters could hunt in most game management units, with a select few only allowing hunting on private land. In 2023, after the winter, CPW reduced the timeframe OTC rifle hunters were allowed to hunt in E-2 from 16 to 10 days. In 2024, CPW restored the time frame to its original length for rifle hunters but only allowed hunting on private lands. In 2025, no OTC antlerless archery hunts were issued in E-2, and no either sex archery hunts were issued in GMUs that previously were private land only. Either sex archery hunts in E-2 GMUs that allowed hunting on public lands were restricted to residents only. Table 4 shows that as these restrictions mounted, OTC hunters in E-2 declined. I expect spending to vary by each of the 3 OTC permit types available, and to further vary if these hunters were on public or private land. However, it is unobservable which type of hunters stopped frequenting the DAU and which ones stayed after the restrictions.

Each of these hunt types has characteristics that might lead a hunter to spend more on a trip. Permit demand from the primary draw was heavily correlated to method of take, location, and gender of the animal. Given that no time investment is required for OTC permits, I expect hunters to spend comparatively less than a hunter with an equivalent permit from the primary draw. Furthermore, I expect there to be significant heterogeneity within OTC permits. All outfitters receive permits from the OTC license in this area. Anyone of the OTC permits could be a hunter who will invest very little and casually hunt during the busiest time of the year on public land, or it could be a high spending hunter who hires an expensive guide and pays to hunt on private land. However, with OTC permits I cant observe how many rifle or archery OTC hunters were in the DAU. Nevertheless, their demand/willingness to pay or spending habits. A study that

correlates hunter spending to hunt characteristics could allow spending to be mapped across all elk permits and possibly all species permits in Colorado.

Differences in secondary draw and OTC licenses in E-2 compared to their averages are shown below. OTC is compared against the 10 year average while secondary draw is compared against the 2021 and 2022 data as that's all that's available pre 2022-2023 winter.

*Table 20: E-2 Secondary Draw and Over the Counter Permits vs. Historical Average*

| Year | Secondary Draw | OTC |
|---|---|---|
| 2023 | -69.44 | -29.78% |
| 2024 | -36.59% | -62.82% |
| 2025 | 13.98% | -86.99% |

Both residents and nonresidents can purchase permits over the counter or apply to the secondary draw. Resident and nonresident totals are available for the secondary draw but not OTC permits. I assumed that 60% of OTC permits went to residents, as that's the average split from the primary draw. I categorize all secondary draw permits as run off demand and all OTC permits as low demand. Total impact using the adjusted spending profile results, which are shown below.

*Table 21: Secondary Darw and OTC Impact in Study Area*

OTC and 2nd Draw Study Area

| Year | RunRes | RunNonRes | LowRes | LowNonRes |
|---|---|---|---|---|
| 2023 | -$21,875.53 | -$11,349.53 | -$161,977.61 | -$259,620.41 |
| 2024 | -$13,512.19 | -$324.27 | -$341,694.08 | -$547,672.94 |
| 2025 | -$5,148.86 | $29,508.79 | -$473,113.68 | -$758,314.47 |
| Total | -$40,536.57 | $17,834.98 | -$976,785.37 | -$1,565,607.81 |

*Table 22: : Secondary Darw and OTC Impact in Rest of Colorado*

OTC and 2nd Draw State

| Year | RunRes | RunNonRes | LowRes | LowNonRes |
|---|---|---|---|---|
| 2023 | $0.00 | -$8,083.72 | $0.00 | -$158,596.25 |
| 2024 | $0.00 | -$230.96 | $0.00 | -$334,561.05 |
| 2025 | $0.00 | $21,017.68 | $0.00 | -$463,237.20 |
| Total | $0.00 | $12,702.99 | $0.00 | -$956,394.50 |

Secondary draw permits are represented in the “run” categories, and OTC permits are represented in the low categories. Including permits from the secondary draw adds $40,536.59 of lost economic impact to the study area, or 1.7% of the estimated regional impacts from the primary draw. Sitewide, including the secondary draw, results in an additional $12,702.99 of economic impact gained, or 2.9% of the estimated statewide impacts lost from the primary draw. Nonresident secondary draw permits were higher than the average for 2021-2022, causing CPW to earn more revenue compared to the past. However, this is a very limited sample and may not reflect the historical average. Ultimately, the secondary draw represents less than 3% of final results, so its exclusion has almost no impact on final results.

Including OTC licenses had a drastic impact on results. In the region, an additional $2,542,392 of lost impact was generated. This is greater than the entirety of lost impact from the primary draw. With restrictions placed on OTC hunts by 2025, 90% less permits were being claimed than the average in previous years. OTC permits comprise more than 50% of the study area, so these reductions are drastic. Sitewide it’s the same story. Here over $1,000,000 of lost impact is estimated, which greatly exceeds the primary draw estimate. Again, with the distribution of resident to nonresident permits being unknown this number could vary drastically across years. OTC permits undeniably have a large influence on the overall economic impact of hunting, but this study was not concerned with the overall impact and was more interested in how current methods of spending aggregation output inaccurate results. The impact OTC hunters have on the economy will vary drastically depending on the proportion of hunter types pursuing OTC hunts. For the primary draw, I found that significant impact could be regained by focusing on high demand hunters and outfitters. All E-2 outfitters use OTC permits which could drive the majority of economic impact in the study area. Ultimately, too little is known about OTC hunters composition to try to understand how the restrictions altered economic impact, and how alternative restrictions could have worsened or improved economic measurements.