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Wildlife Economics in the American West

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Wildlife Economics in the American West - Summary

James Caudill, Guest Editor[1]

Dana Hoag: Western Economic Forum Editor

Scarcely a day goes by that each of us is not affected by wildlife in one way or another, sometimes routinely, sometimes profoundly, sometimes to our detriment but most often to our benefit. The complex relationship between humans and wildlife is sometimes misunderstood or even neglected in laws, policies, programs, and other human-centric approaches to defining the sphere of possibilities for the relationship between wildlife and humans. Economics can help strip away some of the cobwebs to better understand this relationship. The focus of this special edition of the Western Economics Forum is **Wildlife Economics in the American West**. The eight manuscripts address a variety of issues in the context of human-wildlife interactions with a focus on a number of species including wild pigs, brown bears, livestock guardian dogs, wolves, migratory birds and migratory ungulates. The focus of the papers can be classified into four categories: (1) economic damages; (2) economic benefits; (3) economic assessments; and (4) migratory species. An abstract for each paper follows:

Economic Damages

Economic Damages of Wild Pigs in Non-Traditional Areas: From the Fairway to the After Life

Authors: **Sophie McKee, Julie Elser, Maryfrances Miller, Lirong Lui, Ryan Miller, Steven S. Shwiff, and Stephanie A. Shwiff**. Invasive wild pigs are widely known to cause damage to agricultural properties and commodities, but less has been reported about damages to other types of property. A survey was distributed to golf courses and cemeteries across Texas to explore the extent of damage these properties experience. While both property types reported significant damages, golf courses were found to experience more damage than cemeteries. Using average reported costs and predicted county-level damage, total costs for all golf courses and cemeteries across the state were estimated to exceed $1.6 million USD per year.

Economic Benefits

The Economic Benefits of Wildlife: The Case of Brown Bears in Alaska

Author**: Leslie Richardson.** Wildlife is an important resource protected by public lands and waters in the West, a resource that supports locally important tourism and provides significant public value. Economic information can be used to not only document the range of benefits supported by wildlife resources, but to evaluate complex tradeoffs and guide policy and management decisions in a manner that improves social well-being. This paper presents a typology of the various economic aspects of wildlife, discussing relevant uses of the information, challenges, and opportunities for future research. An example of each component is presented within the context of Katmai National Park and Preserve, a prime wildlife viewing destination in Alaska that protects one of the world's largest concentrations of brown bears ever documented.

Economic Benefits Supported by Surface Water in Eastern Oregon's Harney Basin

Authors: **Christopher Huber, Matthew Flyr & Lucas S. Bair**. The Harney Basin is a closed river basin in southeastern Oregon. Surface water in the basin is used for a variety of social, economic, and ecological

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benefits. While some surface water uses compete with one another, others are complementary or jointly produce multiple beneficial outcomes. The objective of this study is to conduct a baseline economic assessment of surface water in the Basin as it relates to wet meadow pasture production and outdoor recreation. Given the complex interactions between surface water management on public and private land, identifying and quantifying these economic outcomes can be used to assist future decision making in the Basin.

Economic Assessments

Are These Big White Dogs Worth the Expense? The Challenge of Determining the Costs and Benefits of Livestock Guardian Dogs

Authors: **Dan Macon and Carolyn Whitesell**. Livestock guardian dogs are used by sheep and goat producers throughout the West to protect livestock from predators. Recent analysis of data from the UC Hopland Research and Extension Center suggests that the costs of keeping dogs may outweigh the benefits of death loss prevention. However, this analysis omits several key economic benefits associated with using livestock guardian dogs. We offer an alternative framework for evaluating benefits, as well as for identifying potential cost savings. We also suggest a framework for incorporating simple economic analyses into an objective case study approach. We identify key drivers (economic and management) that may increase the economic efficiency of using livestock guardian dogs. Finally, we suggest future needs for research into the economics of nonlethal livestock protection tools, including livestock guardian dogs.

Integration of Wildlife Economics with Land Use and Management Policies

Authors: **Bengt 'Skip' Hyberg and Don English**. We examine the effects of incomplete economic wildlife assessments in analyses of land use management strategies. We demonstrate that the use of a single important charismatic species or a single wildlife-based activity to capture the wildlife effects can result in a substantial understatement of the economic contributions and economic benefits resulting from land use management. We further examine the potential errors that may be introduced by using benefits transfer techniques to estimate wildlife benefits, even in areas considered to have similar characteristics.

Economic Consequences of the Wolf Comeback in the Western United States

Authors: **Dana Hoag, Stewart Breck, Kevin Crooks & Becky Niemiec**. Gray wolves were eradicated from most of the United States in the 1940's but have made a comeback in parts of their historic range over the last two decades. First reintroduced into the Greater Yellowstone Ecosystem and central Idaho in the mid-1990's, wolves have subsequently dispersed into at least 7 western states. Coloradoans became the latest state to take interest in bolstering wolf populations, as residents passed a ballot initiative in November 2020 to reintroduce a self-sustaining population of gray wolves by the end of 2023. Conflicts between people in rural areas that might incur costs (such as livestock loss) and people in urban areas geographically removed from direct contact with wolves suggest that the distribution of benefits may not align uniformly with the distribution of costs. Given that Colorado will imminently make many policy decisions that have an impact on costs and benefits, we review available literature to better understand the magnitude of gainers and losers from wolf reintroduction in western states. Although no single study has included all possible economic values, the magnitude of impacts can be inferred by assembling a broad range of estimates for different types of values into a single space. Our review of existing valuation literature from western states indicates that the magnitude of economic benefits of wolves is many times higher than what it costs to manage wolves and to reduce or compensate for losses to livestock producers and others.

Migratory Species

Economic Approaches for Managing Migratory Bird Habitat Across Multi-Owner Landscapes

Authors: **Sonja H. Kolstoe, Jeffrey D. Kline, Luanne Lohr**. Migratory bird populations rely on a continuum of habitat along their migratory path. Along the Pacific Flyway in the United States, this habitat consists of land under a mix of different management entities and landownerships including federal, state, and local land management agencies, Tribes, and private landowners. Effective management of migratory bird habitat relies on coordination among these different entities to ensure both sustained flyway continuity and habitat quality sufficient to maintain healthy migratory bird populations. We consider the challenges involved in the conservation planning problem in managing migratory bird habitat and suggest how economics can inform developing and facilitating coordinated strategies.

Incorporating Landowner Preferences into Successful Migratory Species Conservation Policy

Authors: **Chian Jones Ritten, Amy Nagler, Kristiana M. Hansen, Drew E. Bennett, and Benjamin S. Rashford**. Migratory species present a unique challenge in formulating conservation polices with different types of land uses, different private and public landowners with different objectives frequently resulting in a difficult and complex path to successful conservation measures for migratory ungulates (or any migratory species). This paper looks at the importance of addressing landowner preferences in developing successful spatial conservation policies for migratory ungulates in Wyoming.

We wish to thank all of the authors for their time and effort in exploring what economics can bring to the table in dealing with complex and sometimes contentious issues. We hope that readers find these papers both interesting and useful.

James Caudill and Dana Hoag, editors.

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Economic Damages of Wild Pigs in Non-Traditional Areas: From the Fairway to the After Life

By Sophie McKee[1], Julie Elser[2], Maryfrances Miller[3], Lirong Liu[4], Ryan Miller[5], Steven S. Shwiff[6], and Stephanie A. Shwiff[7]

Abstract
Invasive wild pigs are widely known to cause damage to agricultural properties and commodities, but less has been reported about damages to other types of property. A survey was distributed to golf courses and cemeteries across Texas to explore the extent of damage these properties experience. While both property types reported significant damages, golf courses were found to experience more damage than cemeteries. Using average reported costs and predicted county-level damage, total costs for all golf courses and cemeteries across the state were estimated to exceed $1.6 million USD per year.

Key words: cemetery, damage estimates, feral swine, golf course, invasive species, property damage

Introduction

Invasive species are one of the leading threats to ecosystems in the United States (U.S.) causing damage and economic losses to many sectors of the U.S. economy. They are responsible for over $120 billion in damage and control costs annually and these losses are expected to increase (Pimental 2007, Early et al. 2016). An important aspect of invasive species control and management is understanding economic losses and control costs. Understanding these impacts allows managers to weigh control costs and damage mitigation results to inform damage mitigation decisions improving prioritization of control resources.

One of the most important invasive species in the U.S. are wild pigs (*Sus scrofa* Linneaus), also known as feral swine, feral hogs, wild hogs, and wild boar (Keiter et al., 2016). Over $1.5 billion in annual damage is attributed to invasive wild pigs in the U.S. and has resulted in significant policy activity to mitigate damages to natural ecosystems, residential developments, agriculture, and rangelands (Miller et al., 2018). To date, most existing damage estimates have been for agricultural resources. Annual damage to six crops across ten U.S. states with large wild pig populations was

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estimated to be $200 million (Anderson et al., 2016) and $272 million for another set of six crops across 12 states (McKee et al., 2020). In Florida, one of the largest cattle production states in the U.S., damage to pasture by feral swine was estimated to result in losses greater than $2 million annually in five counties (Bankovich et al., 2016).

Little is known about damages caused by feral swine to non-traditional sectors of U.S. agriculture such as the turfgrass industry, of which golf courses and cemeteries are an important component. Cemeteries and, to a larger extent, golf courses, represent a very high category of land development and require the use of many high value horticultural products and services. The golf sector is the largest component of the turfgrass industry, representing nearly half (44%) of the industry (Haydu et al., 2006). Golf courses generate $33.2 billion in gross output and employ nearly 500,000 people on nearly 16,000 courses nationwide (Haydu et al., 2008). Four states - Florida, California, Texas, and Illinois – disproportionately contribute to golf course output. One of these states, Texas, has over 800 golf courses and 80 stand-alone driving ranges that generated over $6 billion in annual revenue employing more than 80,000 people that accounts for wage income of over $2 billion (Haydu et al., 2008). Areas that remain moist throughout the year – such as golf courses and cemeteries, which are commonly irrigated - are essential to good wild pig habitat (Graves 1984). Typically reported feral swine damages include rooting, compacting soil, wallowing, and trampling. In golf courses and cemeteries, this expands to include damage to physical structures like toppling headstones and irrigation systems. The juxtaposition of feral swine and well-to-do golfers has generated some clever headlines and snickers. However, despite the economic importance of the turfgrass industry, particularly for golf courses and cemeteries, there are no studies currently available describing the frequency of damage or the total costs associated with damage from wild pigs.

Our objectives in this study were to characterize the economic impact of wild pigs to Texas golf courses and cemeteries and to identify those areas of Texas with a greater likelihood of damage. Specifically, we sought to understand the seasonality of damages, changes in frequency and severity of impacts, and factors associated with damage. To accomplish these objectives, we conducted a survey of golf courses and cemeteries in Texas. Then, we developed a statistical model which predicted the probability of damage to cemeteries and golf courses in every Texas county. We further estimated the total cost for the golf course and cemetery based on the predicted probability and the number of properties. Our results provide the first estimates of damage to an important sector of the turf grass industry.

Methods

Survey Instrument and Implementation

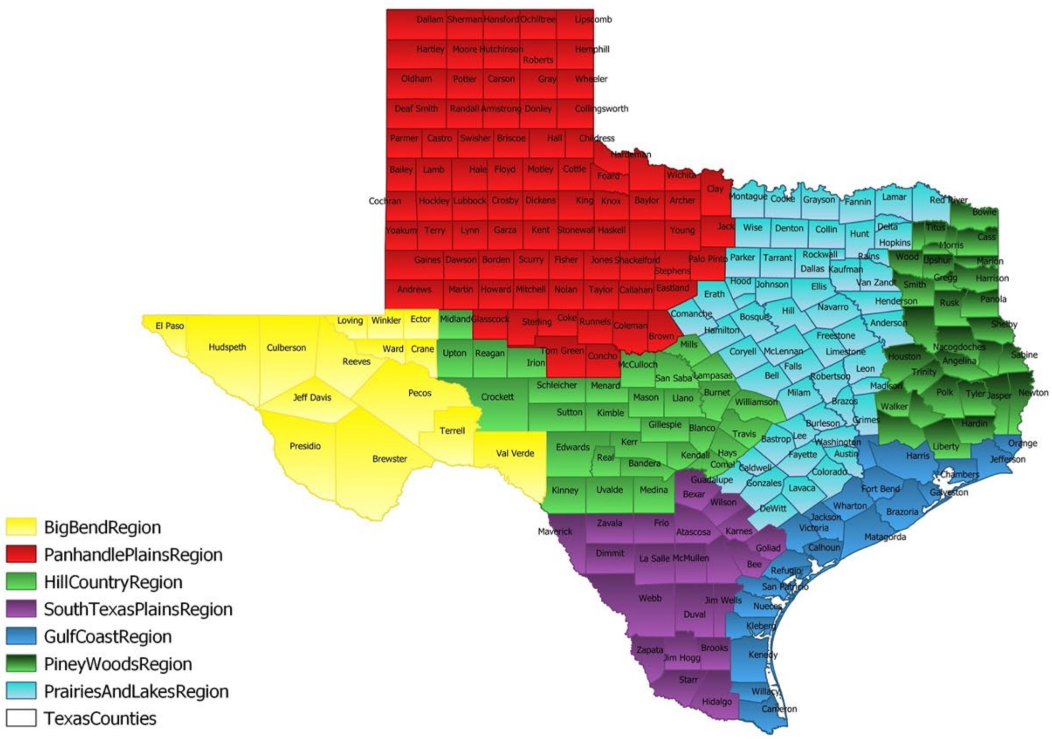
A survey was implemented by Texas A&M University-Commerce and New Mexico State University. Links to the questionnaires are available are https://tinyurl.com/feralswine for cemeteries and https://tinyurl.com/GolfandSwine for golf courses. The Texas A&M University-Commerce Institutional Review Board (IRB) reviewed all survey materials and approved the survey[8]. Cemetery listings were obtained through the Texas Cemeteries and Crematories Association. Their membership list included 175 cemeteries. The Texas Golf Association provided a list of member golf courses. Surveys were sent to 389 golf courses or associations. Member golf courses and cemeteries were

[8] IRB ID number 1822

contacted through a mailed letter which included a web address to take the survey online, or a paper survey to return. After the responses were received, non-responses were contacted by phone with a final request to complete the survey online. The surveys were initially mailed in October 2019 and non-respondents were contacted by phone during the summer of 2020.

Texas was divided into seven regions (Fig 1) and respondents were asked to select the location of their property. Additionally, the physical location of the properties was estimated using the latitude/longitude point from the location of the computer that was used to complete the online survey, or from the centroid of the zip code of the mailed survey.

Figure 1: Survey Regions



Survey Questions and Analysis

Respondents were asked whether they had ever observed damage from feral swine on the property they manage, and their level of concern about potential damage. Analysis of subsequent questions related to damage were restricted to respondents who had observed damage. Respondents who reported concern were asked what types of damage were caused (or possibly caused) by feral swine and what measure(s) they took to repair feral swine damage. They were asked to report the quarterly costs of feral swine damage from October 2018 to September 2019, the frequency of damage events, and how the frequency of damages has changed in recent years. Analysis of variance (ANOVA) was used to analyze the differences among mean reported quarterly costs. Respondents who reported concern were also asked what preventative measures they take, the annual costs of those measures for the past three years, and their effectiveness. They were offered the opportunity to write in any management advice they had for other landowners dealing with feral swine and any other information they would like to share. The questionnaire is provided in Appendix A, and responses to the survey in Appendices B and C.

Logistic regression analysis was performed to determine relationships between reported damage observations and possible influencing factors. (Eq. 1). The dependent variable was observed damage (binary responses). We expected the probability of damage in a county to increase with the density of feral swine[9], and with extreme temperatures (expressed as the number of months in a county above the average temperature plus one standard deviation (NOAA 2021))[10], as wild pigs thermo-regulate by accessing shade and water resources (Choquenot & Ruscoe, 2003).

We also hypothesized that the type of property (modeled as a binary variable golf or cemetery) would be an influencing factor, due to differences in management, average sizes and layout.

$$Observed\ Damage = \alpha + \beta_1 * Density + \beta_2 * Temperature + \beta_3 * Property\ Type + \epsilon \qquad (Equation\ 1)$$

To generate measures of feral swine density, data describing the nationwide distribution (presence/absence) of feral swine at the county level were compiled from APHIS-Wildlife Services and the Southeastern Cooperative Wildlife Disease Study (SCWDS) (Corn and Jordan 2017). These data represent the known nationwide distribution of feral swine over the past 38 years and have been used to forecast the spread of feral swine (Snow et al., 2017), estimate the probability of occurrence (McClure et al., 2015), determine agricultural producers at risk of damage from wild pigs (Miller et al., 2017), and predict corresponding policy activity (Miller et al., 2018). These occurrence data were used with county level predictions of feral swine density produced using a Bayesian Catch-Effort Model (Miller et al. Unpublished data). The catch-effort model is similar to that described by Davis et al. (2016) and uses feral swine removal data collected as part of the APHIS National Feral Swine Damage Management Program to generate predictions of feral swine density for each county at monthly scale while accounting for differing removal methods, habitat, climate, and other factors effecting either population growth or probability of capture.

Regression results were used to predict potential damage by county across the state using the total number of cemeteries and golf courses in each county. Regression analysis was performed using R version 3.5.3 (R Core Team 2019). The model's accuracy was evaluated using Area Under Curve (AUC). Predicted probability (risk) of damage was mapped by county.

Results

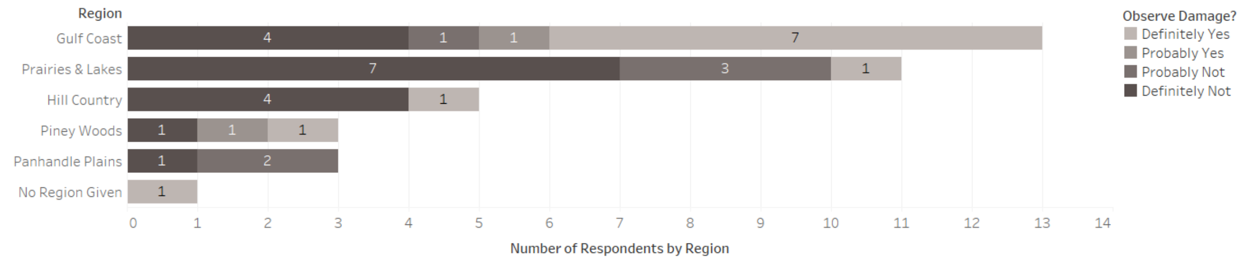
Surveys were returned from 38 cemeteries and from 85 golf courses for a respective response rate of 20.6 percent and 21.9 percent. Most surveys were returned from the Gulf Coast (n=30) and Prairies and Lakes (n=32) Regions. The most frequent reports of observed damage came from the Gulf Coast Region (Figs 2 & 3).

[9] Mean feral swine density: 0.897 head/km^2 – standard deviation 0.673 head/km^2

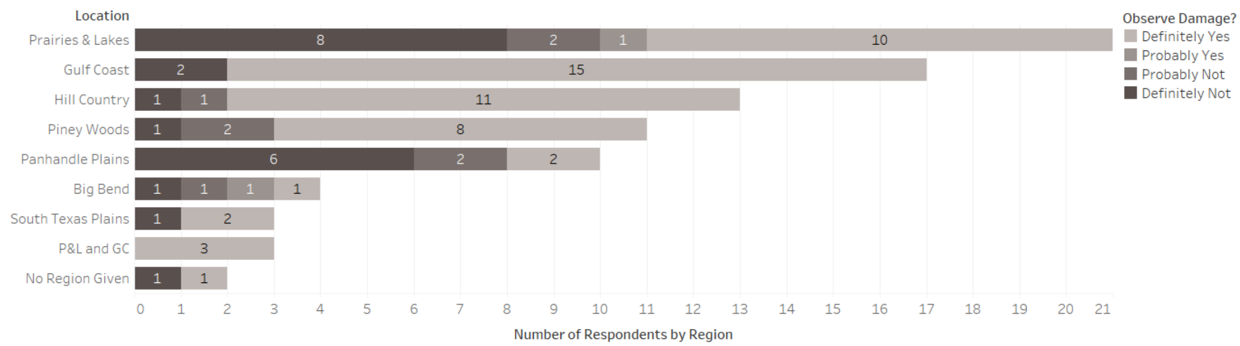
[10] Threshold temperature: 80.24°F

Figure 2: Damage Observation

Have you ever observed any damage to the cemetery property you manage that was caused by feral swine?



Have you ever observed any damage to the golf course property you manage that was caused by feral swine?

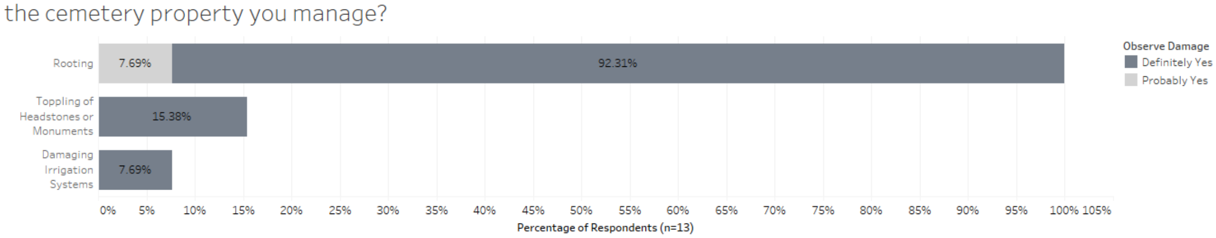


The majority of golf course respondents had observed damage (64.7%) and were concerned about potential damage (72.9%). A minority of cemetery respondents had observed damage (38.9%), but half were concerned about potential damage (50.0%).

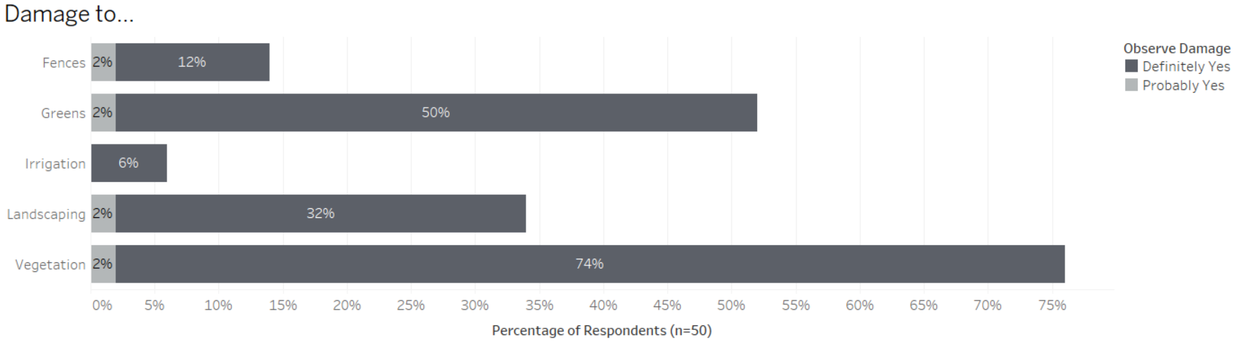
Respondents overwhelmingly reported damage to vegetation on their properties, including damage to greens and landscaping (Fig 3).

Figure 3: Types of Damages

Based on your observation, what are the types of damages caused (or possibly caused) by feral swine on the cemetery property you manage?

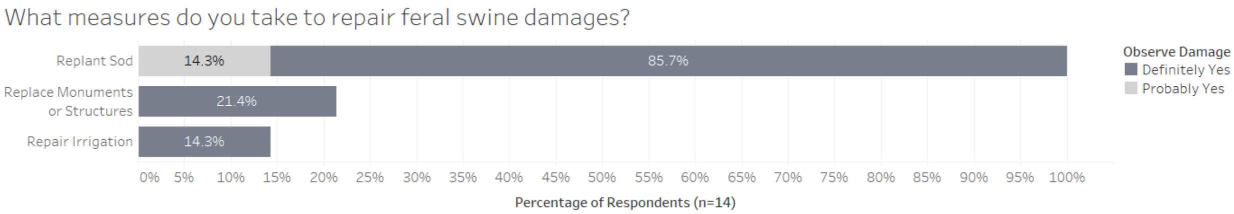


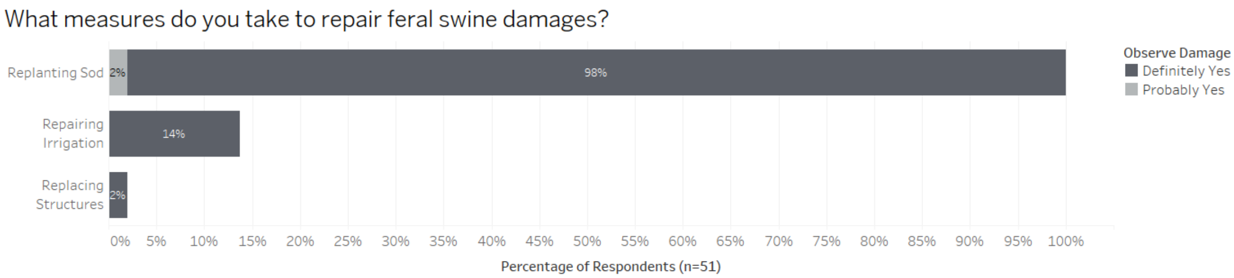
Based on your observation, what are the types of damages caused (or possibly caused) by feral swine on the golf course property you manage?
Damage to...



Fewer respondents reported damage to irrigation and other structures. Consequently, almost all reported repairs were for greenery (sod) and very few repairs were for irrigation or structures (Fig 4).

Figure 4: Repair Measures





Reported damage costs appeared mostly uniform over the year for both property types, except for the April – June 2019 quarter for cemeteries, which had lower damage (Table 1).

Table 1. Damage Costs

		Oct-18	Jan-19	Apr-19	Jul-19
Cemetery	Mean	$1,704.17	$1,566.67	$466.67	$1,433.33
n=12	Std Error	$1,137.06	$1,177.59	$255.94	$1,034.87
	Median	$350.00	$0	$0	$0
Golf Course	Mean	$1,513.68	$1,458.96	$1,191.98	$1,404.25
n=53	Std Error	$315.58	$344.72	$337.45	$380.55
	Median	$500.00	$200.00	$125.00	$500.00

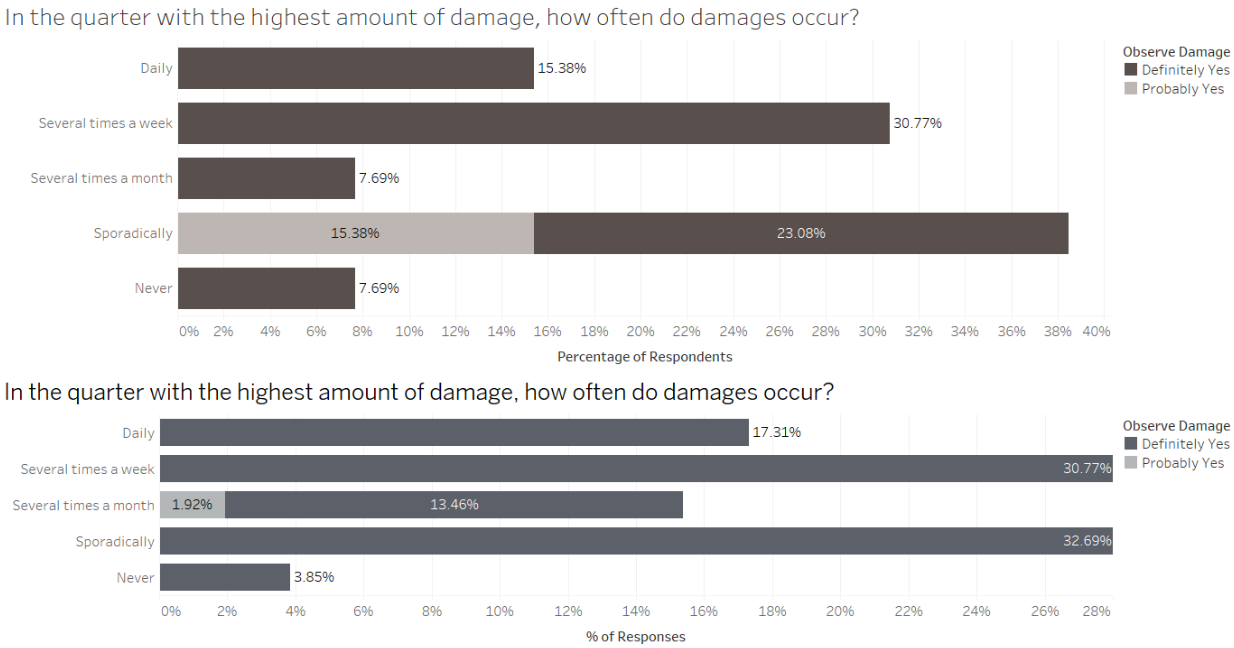
However, ANOVA analysis did not reveal significant differences among the annual quarters. Both cemetery and golf course respondents reported using trapping for mitigation most frequently (Table 2).

Table 2. Costs of Mitigation Methods

		Fencing	Trapping	Hunting	Guard Dogs	Other
Cemetery	Average	$4,325	$1,825	$2,067	$2,000	$367
	Median	$650	$1,125	$2,000	$2,000	$400
	n	4	8	3	1	3
Golf Course	Average	$5,037	$5,415	$5,990	$125	$16,575
	Median	$2,000	$2,500	$300	$0	$0
	n	19	36	30	12	16

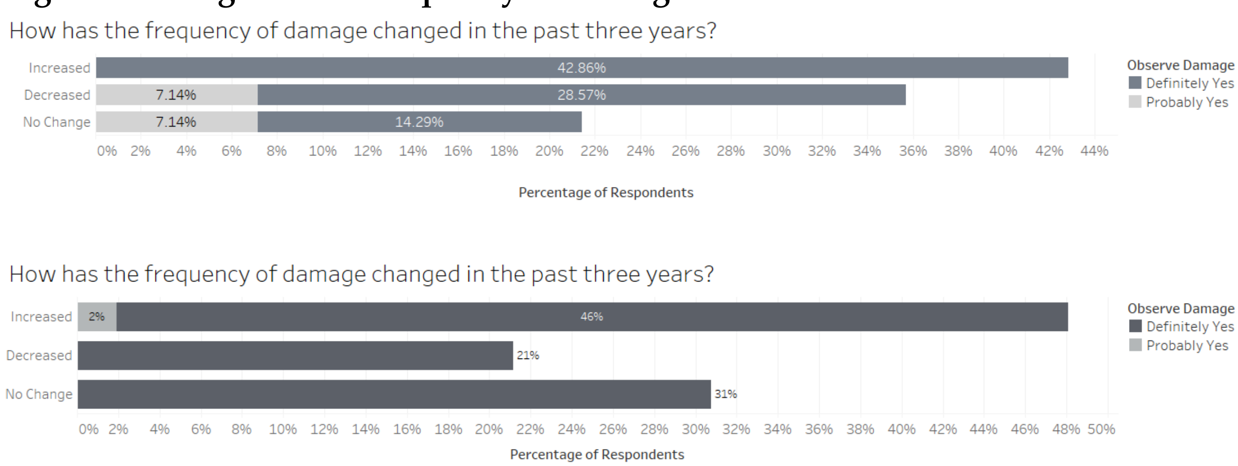
For both property types, damage frequency was most often reported as "sporadic" (Fig 5).

Figure 5: Highest Amount of Damage



A plurality of both golf course and cemetery respondents reported that damages had increased over the past three years (Fig 6).

Figure 6: Changes in the Frequency of Damage



Golf course respondents perceived more of their property at risk of feral swine damage than cemetery respondents (Fig 7).

Regression analysis (AUC: 0.798) revealed significant positive relationships between observed damage and feral swine density and average temperature (Table 3).

Table 3. Logistic regression results.

	Coefficients			Marginal Effects		
	Estimate	Std. Error	p-value	dF/dx	Std. Error	p-value
Intercept	-4.965	1.451	0.001			
Feral Swine Density	1.359	0.403	0.001	0.334	0.099	0.001
Golf Course	1.408	0.519	0.007	0.338	0.115	0.003
Temperature	0.325	0.147	0.027	0.080	0.037	0.030

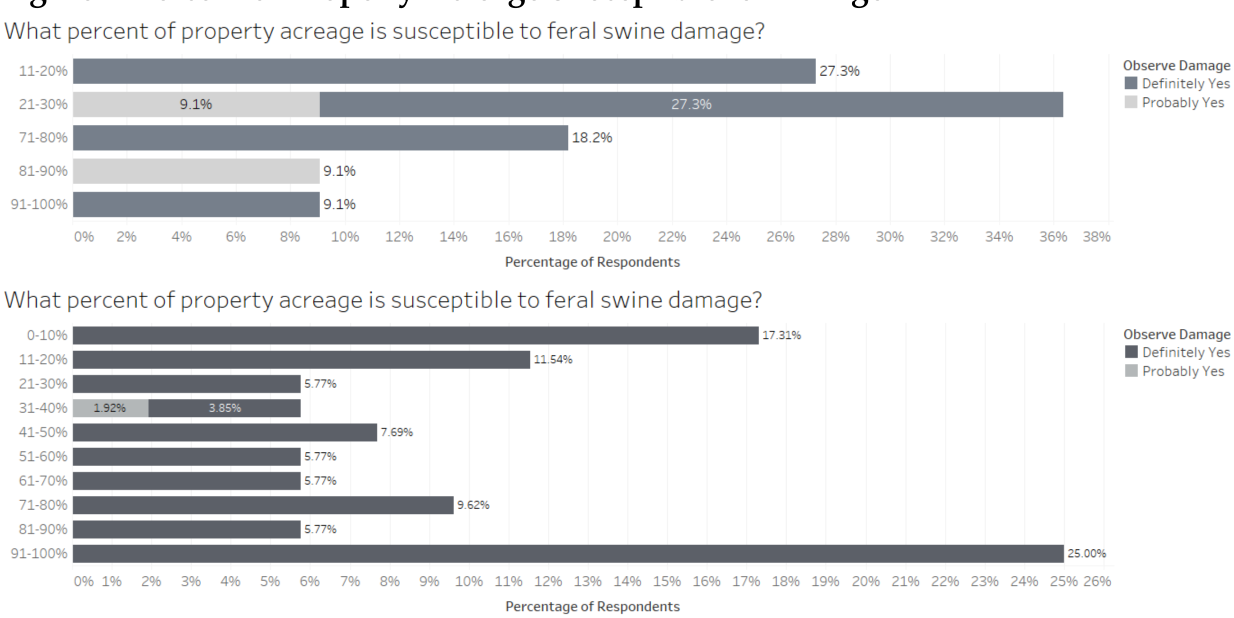
Golf courses are more likely to experience damage than cemeteries. Regression results were used to predict damage probability for each county using the complete golf and cemetery listings. For each county and each property type, the predicted probability was multiplied by the total number of properties in that county and the average cost of feral swine damage. These estimates were then aggregated to estimate the total costs of feral swine damage to all golf courses and cemeteries in Texas (Table 4).

Table 4. Predicted Total Cost of Feral Swine Damage Across TX.

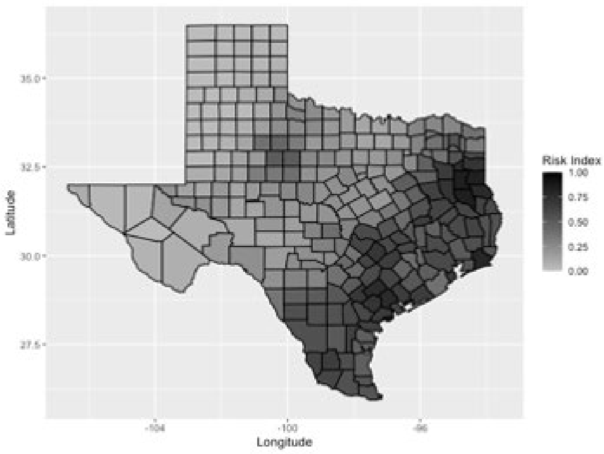
Total Costs	Average	Statewide	Count
Cemeteries	$5,171	$282,523	133
Golf Courses	$5,569	$1,389,683	389
Total		**$1,672,206**	522

Total predicted costs for cemeteries were $282,500 for 133 properties. Golf courses had predicted cost of $1,390,000 for 389 properties. Maps illustrating probability of feral swine damage indicated the greatest risk was on the southeast side of the state (Fig 7).

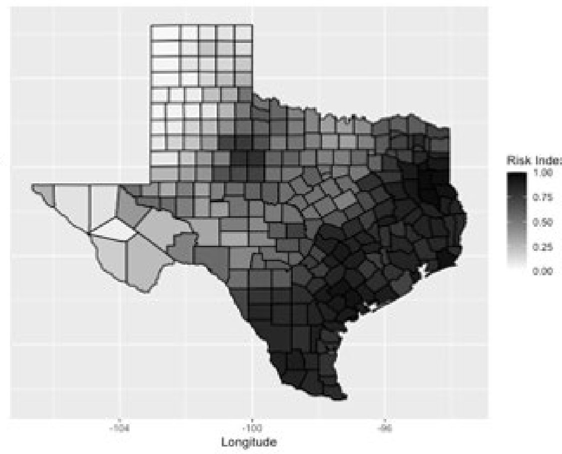
Figure 7: Percent of Property Acreage Susceptible to Damage



Risk Index



Cemeteries



Golf Courses

Discussion

While feral swine are increasingly recognized as a serious threat to agricultural land and wildlife habitat, this paper provides the first estimate of damages to two types of land uses that are not commonly recognized as at-risk by this invasive species. Respondents reported most damage to vegetation, greens, and other landscaping, and less damage to structures. As a result, most repair costs accrued to repairing or replanting sod. Regression analysis revealed the expected positive relationship between damage and feral swine density. The analysis also showed that counties with more months of above average temperatures were more likely to experience damage, perhaps because feral swine seek out the irrigated grounds of these properties when temperature rises. Cemeteries are less likely to experience damage than golf courses possibly because they are almost always fenced and are typically smaller. Possibly for the same reasons, more golf course respondents reported 91-100 percent of their property at risk from feral swine than cemetery respondents. Golf courses may also report damage more often than cemeteries because they are more consistently managed so damage is more likely to be noticed.

The total cost of damage to these property types is estimated to exceed $1.6 million annually in Texas. This is a conservative estimate, since it does not include damage mitigation costs. Certainly, there are more golf course and cemetery properties in Texas than were in our mailing list. The estimate also omits the diminished visitor experience to golfers and cemetery visitors, which could translate into loss of revenues for golf courses. Moreover, because Texas' future climate is likely to feature drier summers and decreasing water supplies for much of the state for the remainder of the 21st century (Nielsen-Gammon et al. 2020), we can expect damages to increase over time.

This work should be followed by further research into other non-traditional areas in the United States, such as roadways and parks, including the estimation of willingness to pay for mitigation strategies aimed at reducing wild pig damages. Special attention should be given to the areas that receive extra run-off or irrigation and create green spots in arid climates. The work supports efforts to broaden the interest groups involved in funding the removal of wild pigs and changing policies to limit their spread.

Funding

This research was supported by the U.S. Department of Agriculture, Animal and Plant Health Inspection Service and the National Feral Swine Program.

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	Appendix A. What management advice do you have for other land managers dealing with feral swine?
Cemetery	Trapping is by far the best.
	Once we put up a commercial 6" chain link around the back of our cemetery they never came back in. So fencing is what I would say is the best.
	Take measures ASAP because they get bad quickly.
	We were about to call in some hunters to help, but then trapped 17 hogs in one corral trap with a guillotine trap door. The box trap has only caught a couple. Game cameras are a must.
	Hunt & kill. Do not use poison, trap & kill.
	Use game cameras to help learn their patterns to make it easier to hunt/trap.
	Get a reputable trapper/hunter on the property overnight during peak season. Remove as many as possible before the sows deliver.
	Keep areas of brush and high grass well-trimmed. Maintain exterior fencing as well as possible.
Golf Course	Remove/exterminate as quick as possible they multiply fast.
	Try to use every tool available to pattern them as much as you can. Patience and persistence are key because hogs do whatever they want. They are also intelligent and trainable.
	If possible control moisture level in soil. Treat for grubs if possible, observe surrounding areas and talk to other surrounding properties to see if they have observed any feral swine and what they are doing about it.
	Nutsedge+Grub control.
	Rake up all acorns if possible. Kill all grubs if possible. Spray herbicides to eradicate nutgrasses + kylenga.
	Kill them all.
	Hunting + Trapping
	Keep them out of property at all costs.
	Hunting with fogs and killing the feral swine has been our best action taken at this time. Trapping has not been as successful. Don’t wait to take an action.
	Eliminate access to creek and river bottoms.
	As soon as you see damage, have someone out there the next night to hunt. Eventually, the hogs will be trained to avoid your property.
	The best way to disrupt wild hogs is to continually have hunters or trappers be present.
	Food source provided in acceptable area, add traps, then hunt.
	Stay active and constant. Help your adjoining properties.
	Trapping tends to be very effective.
	Hunting with dogs has been more effective than any other method.
	Treat your property for the insects and weeds that the hogs are seeking.
	Be proactive and persistent in trapping, hunting, or other measures.

	Identify what feral swine are food sources they are rooting for and take preventative steps to control those food sources. Such as grubs, nutsedge tubbers. In rural areas without topography challenges, a 2-strand electric fence can work with high success rate. In populated city areas using dogs to catch feral swine would be best yet the trained dog owners have told me it is to high risk for the safety of the dogs because they could pursue the feral swine into private property.
	Dogs seem to be the most effective in keeping them off the golf course, but you have to almost have hunters every night, which is not cost effective.
	Our facility is on an Air Force Base. Obviously, the entire base is protected by various types of fencing that is constantly monitored and well maintained. While we do have unexplained damage to the course, I do not believe this to be swine due to the fence. I have yet to see any swine on the base. If possible, I'd recommend protecting the property with fencing.
	Keep a trap available and managed.
	For us, fencing and a trapping service with remote monitoring has been successful in our urban environment. when using fence, leave open a portion of the fence to create a pinch point in which you can direct them towards the trap. Be quick to relocate traps when activity is present elsewhere. I also find it peculiar that they have not disturbed greens, tees or fairways. I was told several years ago by a biologist/trapper that this would be the case. So far it's true.
	Use of insecticides to control food source is highly recommended to reduce amount of food available to swine.
	Dogs seem to be the most effective, but to be effective, they would need to hunt daily non-stop, which is not feasible. Our property is 3500 acres and fenced but it would take a game fence to keep them out which is to cost prohibitive.
	It must be addressed in Texas. Our Ownership and Property Owners Association do a very good job planning each year on feral hog hunting and trapping. We have had only nominal damage to the course over the last 6 years. However, some owners out on the further, more rural edges of the ranch have had massive landscape damage. The plan is to keep them as far away from the course as possible. Basically, trap and hunt the lowlands and congregation points in the less residential areas of the property.
	Act quickly as soon as you see evidence of hog damage.
	Cameras on the course. When the hogs arrive, the camera sends a picture to an experienced hunter who goes immediately and shoots the hogs.
	Be diligent in finding where they sleep during the day. If you can afford it, hire a helicopter hunter to eradicate the herds. We cannot afford this measure.
	Traps seem to be the best, but homeowners complain about the cruelty of animals. Most of the complaints come from non-golfers.
	Shoot them all.
	Hire a night hunter.
	Shoot them.
	Dogs are the most effective measure to hunt.

	Fence inside the tree line, and call wildlife authorities to inform them you are having issues. They may come to assist. They may also have recommendations for your particular area and can inform you on why occurrences may be increasing in your area.
	Start eradication measures as early as possible. Do not wait on the problem to come to you, expect it to come and take action even before it does.
	Deal with the issue as soon as possible. Find the most suitable way to eradicate or deter the population from the course.
	Haven't done enough to give advice.
	Get them early!! Don't wait.

	Appendix B. Do you have any additional information on feral swine or suggestions on the survey that you would like to share?
Cemetery	Our damage took place in 2015 at our cemetery. We do see feral rooting near our basketball complex.
	No damage so far at my cemetery.
	If there is any help you can give on eradicating or info would be great.
	Qs #8 I answered several times a week. It may be 2 months before they come back, but they seem to stay for a week or so. Summer is worst when it is very dry because we irrigate so much.
	City owned cemeteries have not looked into any costs yet.
	We're within the city limits inside the loop. No feral swine reported.
	Our property damage happened only once in the spring of 2018, which was not one of the time periods on the survey.
Golf Course	I am a hunter and I understand hunting but until there is no value in feral hog hunting, we will not be able to win the war. It is amazing how those without hog knowledge think it's a "silly game" until they witness the damage and stress these animals cause.
	Local farmers have used helicopter hunting.
	On and around green spray a chemical that will kill grubs. Grubs attract feral swine.
	Eliminating the need for a hunting license is a good start but it's an access problem. No one is going to pay a landowner hundreds of dollars to help them with their so-called "problem". If landowners really wanted them gone, hunts would be free.
	The golf course I manage is in an urban area with lots of housing. I have not seen any swine in 9 years, but I would not be surprised if they show up at some point.
	Please develop/approve a poison that can be used. No present methods will ever eradicate this epidemic.
	Armadillos cause similar damage as far as cost goes.
	Amount of acreage damaged would be good to know.
	Consideration should be given to legalizing the poison used in Australia.
	Control the food source and never let them get comfortable being on the property.
	Drastically impacts the value of the course... lower the property taxes.
	Thank you for doing this. The dry weather and new construction have them on the move. They have nowhere to go and they need water. Golf courses have water!

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The Economic Benefits of Wildlife: The Case of Brown Bears in Alaska

By Leslie Richardson[1]

Abstract
Wildlife is an important resource protected by public lands and waters in the West, a resource that supports locally important tourism and provides significant public value. Economic information can be used to not only document the range of benefits supported by wildlife resources, but to evaluate complex tradeoffs and guide policy and management decisions in a manner that improves social well-being. This paper presents a typology of the various economic aspects of wildlife, discussing relevant uses of the information, challenges, and opportunities for future research. An example of each component is presented within the context of Katmai National Park and Preserve, a prime wildlife viewing destination in Alaska that protects one of the world's largest concentrations of brown bears ever documented.

Disclaimer: Views and conclusions in this report are those of the author and do not necessarily reflect policies of the National Park Service. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

Introduction
Bears. Wolves. Bison. Images of iconic wildlife often come to mind when thinking of public lands and waters in the West. The National Park Service (NPS) logo features a bison to reflect that wildlife is one of the key attributes of the National Park System, while the fish and migratory bird placed on the U.S. Fish and Wildlife Service's (USFWS) logo is indicative of their role as the principal federal

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agency dedicated to fish and wildlife conservation. Wildlife is an important natural resource protected by our national parks, national wildlife refuges, and other protected areas. These lands and waters draw hundreds of millions of recreational visitors each year. Many of these visitors engage in consumptive uses of wildlife, such as hunting and fishing, and non-consumptive uses, such as wildlife viewing and photography. Wildlife observation is one of the primary reasons people visit national wildlife refuges and many national parks (Brown and Carpenter; Otak, Inc., RRC Associates, University of Montana, 2019; RSG, 2017; Manni et al., 2012; Sexton et al, 2012). Such tourism has important economic implications, benefitting local economies and providing valued visitor experiences.

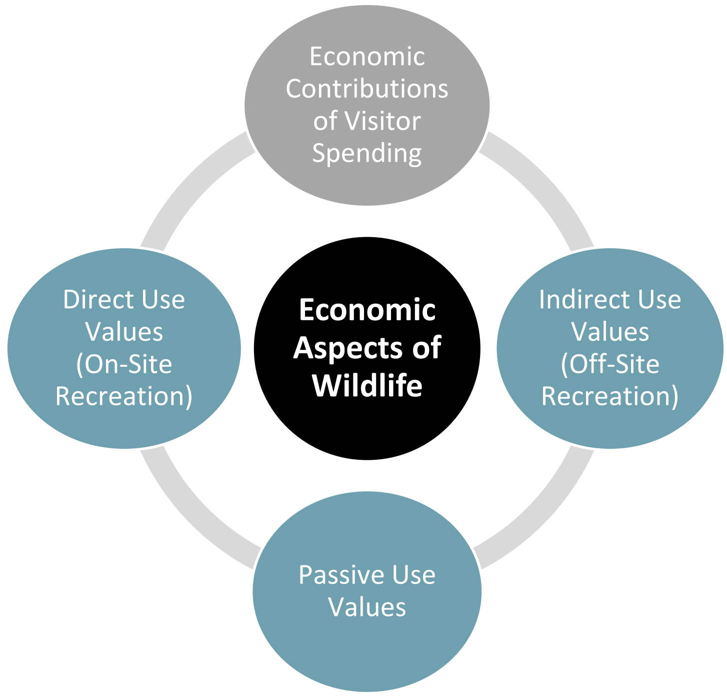
Further, many people are experiencing wildlife in new and unique ways, viewing animals virtually through the hundreds of webcams placed throughout parks, refuges, and other protected areas. By providing instant access to unparalleled wildlife viewing opportunities, webcams are becoming an increasingly popular way to connect with wildlife, allowing viewers to get up close and personal with animals without causing any negative disturbance. Virtual recreational opportunities help expand the reach of public lands and have the potential to engage sectors of the public that face constraints to visiting (Skibins and Sharp, 2018). Compared to on-site recreation, off-site virtual wildlife viewing is more characteristic of a pure public good, being both non-excludable (anyone with a computer and an internet connection has access) and non-rival (one person viewing a webcam does not displace other people from doing so) (Loomis et al., 2018). Many people spend their valuable leisure time watching wildlife webcams, thus revealing an economic value for this type of indirect use.

Beyond supporting direct and indirect recreational "uses" of wildlife, public lands and waters in the West play a critical role in preserving wildlife resources for future generations, protecting some of the last remaining habitats for certain species. The conservation of wildlife resources is central to the mission of land management agencies such as the NPS and USFWS. From an economic perspective, the general public may value the preservation of healthy populations of wildlife or the habitats that support them, regardless of any recreational use. Indeed, such passive use values are especially important for wildlife resources, where they likely play a relatively larger role compared to many other environmental goods and services (Jacobsen, Lundhede, and Thorsen, 2012).

Economics provides a powerful tool to not only communicate the importance of wildlife-related tourism and the societal value supported by wildlife resources, but also to inform policy and management decisions. For instance, regulations affecting wildlife resources on public lands often require analyzing the societal benefits and costs expected from the proposed action. Measures of net economic value are a critical input to such analyses. These values are also used to determine damages to the public from incidents such as habitat destruction and wildlife poaching. The resulting compensation is used for restoration activities intended to make the public "whole" for the injury to natural resources and the services provided by those resources. Economic analyses can also be used to inform visitor use management decisions that affect wildlife-related recreation or involve tradeoffs between recreational access and environmental protection. In general, economic information can guide complex resource allocation decisions, helping managers objectively balance the needs of both visitors and non-visitors, while recognizing that public lands cannot simultaneously meet all the demands placed upon them.

Figure 1 presents a typology of the various economic aspects of wildlife as it relates to public lands and waters. Below, each component is discussed in turn, with a summary of approaches that can be used to quantify the economic information, uses of this information, and some of the challenges and opportunities for future research. An example of each is presented within the context of Katmai National Park and Preserve, a prime wildlife viewing destination in Alaska that protects one of the world's largest concentrations of brown bears ever documented.

Figure 1. Economic Aspects of Wildlife on Public Lands.



Note: Economic contributions of visitor spending do not provide a measure of social welfare (i.e., changes in producer and consumer surplus) and cannot be compared to or added to the other three measures, which are based on the concept of net benefits.

Economic Contributions of Visitor Spending

When policymakers consider tourism's economic implications, they often think of the effect that tourism has on businesses in local communities. Recreational visitors to public lands and waters frequently spend money at the recreation site and in gateway communities. These expenditures support jobs and local economic activity. By gathering information on the amount of money that visitors spend on different items (e.g., lodging, food, guides), input-output models can track how this money gets cycled throughout the economy. The resulting metrics, including economic output, employment, labor income, and value added, are referred to as the *economic impacts* or *economic contributions* of visitor spending (Caudill and Carver, 2019; Loomis and Walsh, 1997).

For example, each year tens of thousands of visitors travel to Katmai National Park and Preserve, located on the Western Alaska Peninsula. Originally established in 1918 to protect a volcanically devastated region, today the four-million-acre park is best known for its large population of brown bears. While some visitors come to Katmai to hike and fish, most come primarily to view bears (Strawn and Le, 2015). Visitors can watch brown bears in their natural habitat from elevated boardwalks and viewing platforms placed along the Brooks River and at Brooks Falls, where bears congregate to feed on sockeye salmon in late summer and fall. In 2020, visitors to Katmai National Park and Preserve spent a combined $79 million in local gateway communities, generating 975 jobs, more than $37 million in labor income, and nearly $70 million in value added, which measures the contribution of visitor spending to the gross domestic product (GDP) of a regional economy (Cullinane Thomas and Koontz, 2021).

These types of economic contributions are reported regularly for public lands (see DOI, 2020). However, estimates are often aggregated across all recreation activities. While a park such as Katmai is primarily visited for wildlife viewing, for many other recreation sites, only a subset of visitors come primarily for wildlife-based recreation. Reporting economic contributions estimates by recreation activity (e.g., fishing, hunting, wildlife viewing) is an important avenue for future research.

Net Economic Values

Direct Use Values for On-Site Recreation

The economic contributions discussed above are often highly informative for federal land managers, local and state tourism boards, and the general public, in demonstrating the role that public land tourism plays in regional economies. Importantly, however, such measures often reflect a transfer of economic activity (a decrease in visitor spending at one recreation site may be offset by an increase in spending at another site), and do not capture the net societal value, or worth, of a recreation opportunity such as wildlife viewing. Because publicly provided goods and services are not priced in conventional markets, it can be challenging to determine their value to society. Agencies have recognized the need to quantify the economic value of recreation since at least the 1940s (NPS, 1949). By the early 1960s, Congress required that recreation be considered in benefit-cost analyses (Banzhaf, 2010). Throughout the 1950s and 1960s significant developments were made in the valuation of nonmarket goods and services.

Today, the concepts and methods used to quantify the economic value of recreation opportunities are well established. Referred to as *net economic value*, or *consumer surplus*, this measure captures the value people derive when they enjoy a recreation experience at a price less than they are willing to pay for it. For on-site recreation opportunities, such as hunting, fishing, and wildlife viewing, values are often referred to as *direct use values* since people are directly "using" a resource. Direct use values for recreation can be estimated through a variety of nonmarket valuation techniques, including: 1) stated preference methods, where individuals are asked directly about their willingness to pay to maintain or improve a recreation experience based on a hypothetical market scenario; or 2) revealed preference methods, where values are inferred based on observations of recreationist's behavior. Visitor surveys are often used to gather the necessary information.

The travel cost method is a revealed preference approach commonly used to determine the value of recreational opportunities on public lands and waters. Travel cost models rely on the basic assumption that the effective "price" of recreating at a site is the trip cost of reaching that site, and individuals reveal their value through the number of trips taken and/or the sites they choose to visit (Parsons, 2013). In a single-site model, a demand function is estimated that relates the number of trips taken to the site over some time period to the trip cost, including travel and time costs. Similar to any demand function, an inverse relationship between price and quantity demanded is expected – visitors living farther from the site will face a higher cost of reaching it, resulting in fewer trips taken, all else constant. Such models can present challenges for remote recreation sites such as Katmai National Park and Preserve, however. Many people visit Katmai infrequently, which results in a lack of variation in the dependent variable. One solution is to ask visitors about their trips taken to the site over a longer timeframe, such as the past five years. Another solution is to use a "persontrips" approach, where the dependent variable is the number of visits multiplied by the size of the visitor group. For example, Richardson, Huber, and Loomis (2017) use data from a 2014 visitor survey at Katmai National Park and apply the latter approach. They estimate a consumer surplus value of $287 per person for a day of bear viewing at the park ($619 for a bear viewing trip) and an aggregate annual benefit of nearly $8 million based on 2014 visitation.

Such measures of consumer surplus capture the net societal value of recreation opportunities on public lands and waters, providing a consistent economic metric to understand the benefits to visitors from wildlife-based recreation. Consumer surplus values can be used to inform visitor use management strategies, evaluate tradeoffs associated with conflicting recreation uses, and facilitate a more objective evaluation of management decisions that affect recreationists. While there has been some progress in estimating values for wildlife-based recreation opportunities, significant data gaps still exist. For instance, according to a comprehensive database of consumer surplus values for recreation activities in the U.S. and Canada, only a handful of studies have valued wildlife viewing opportunities in national parks and national wildlife refuges (Rosenberger, 2016). Considerable opportunity exists for public agencies to gather the necessary information from visitors to determine wildlife-related recreation values across a variety of sites.

Indirect Use Values for Virtual (Off-Site) Recreation

Increasingly, people are experiencing public lands and wildlife resources virtually through the hundreds of webcams placed throughout national parks and refuges. There are webcams in more than 60 national parks, and one of the most popular is the Katmai National Park brown bear webcam. Katmai is a remote park that can be challenging to visit in-person, accessible only by boat or floatplane with limited on-site lodging. Further, during the peak visitation season in July, there are often large crowds of visitors, resulting in wait times of an hour or more to access prime viewing platforms. In 2012, the park partnered with explore.org to establish a series of webcams placed throughout the main bear viewing locations in the park. Live streaming of the Brooks River and surrounding area occurs from late June through early October, providing a unique opportunity to view the bears anytime and from anywhere with an internet connection. Compared to the approximately 50,000 people who visit the park annually, this webcam technology has brought the bears of Katmai to millions of viewers across the globe, with around 15 million pageviews over the course of a year.

Recent surveys of these webcam viewers find that most respondents watch several times per day in the live viewing season and have been watching for more than a year (Fitz et al., 2021). Online interpretive programs and interactive elements, such as live chats with rangers, are also featured. Most viewers believe that these interpretive programs make them value conservation more and increase their confidence in wildlife conservation efforts by the NPS (Fitz et al., 2021). Webcams also provide a means to reach new and more diverse audiences, creating the opportunity to virtually travel to destinations such as Katmai that many people cannot afford or otherwise access (Loomis et al., 2018). Perhaps unsurprisingly, the average income of Katmai webcam viewers is lower than that of on-site viewers (Skibins and Sharp, 2018). This provides evidence that webcams reach audiences of different socioeconomic backgrounds compared to on-site visitation to a recreation site.

Similar to other recreation experiences, people derive value from virtual wildlife viewing opportunities. This value can be categorized as an *indirect* or *off-site use value* in that people are using the resource, albeit off-site or indirectly.[2] However, unlike on-site recreation, people do not spend money nor incur travel expenses to access webcams. To quantify the value of virtual use, stated preference methods could be used to ask viewers directly about their willingness to pay to access webcams (similar to the approach taken by Loomis et al. [2015] to value Landsat satellite imagery). Another valuation approach relies on the fact that while viewers are not spending money to access webcams, they are spending their valuable leisure time, and there is an opportunity cost. Goolsbee and Klenow (2006a; 2006b) develop an approach to value internet use using an individual's wage rate as a proxy for the "price of time" and estimating a demand function that relates the relative time spent on the internet to the user's wage rate. From the estimated demand curve, the net willingness to pay for internet use is calculated. Loomis et al. (2018) apply this same approach to determine the value derived from virtual use of the Katmai brown bear webcams. Using survey data on viewers' wage rates and the amount of time viewers spend watching the webcams, they estimate a net economic value of $11 per hour. Aggregating to the overall number of viewer hours results in a total benefit of more than $27 million annually.

Valuing virtual wildlife viewing opportunities is a relatively new research area. There are many other popular wildlife webcams for which this same valuation approach could be applied, such as the popular Channel Islands National Park bald eagle cams and the Seal Island National Wildlife Refuge puffin cams. Given the magnitude of virtual use, in many cases the aggregate benefits derived from it may be larger than aggregate on-site benefits. Failing to account for such indirect use values underestimates the total economic value associated with the preservation of wildlife and the habitats on which they depend.

Passive Use Values

The discussion thus far has focused on economic activity and societal values derived from recreational uses of wildlife. Beyond supporting recreational opportunities, public lands and waters play a critical role in preserving natural resources, such as wildlife habitats. Many people value the mere existence of healthy populations of wildlife and their preservation for future generations,

[2] Randall and Stoll (1983) referred to the value derived from watching nature television programs as a type of use value called 'vicarious consumption' in their Total Economic Value (TEV) typology.

independent of any "use." The concept of such *passive use values* (also called *nonuse values*) was articulated by economist John Krutilla in his seminal paper *Conservation Reconsidered* (1967), where he made the case that the preservation of scenic wonders, unique ecosystems, and certain wildlife species and their habitats, is a significant part of the real income of many individuals. That is, many people are willing to pay for the protection of these resources. Indeed, preservationists such as John Muir who were central to the early movement to designate national parks did not promote any particular use of such lands, but rather, believed that scenic preservation had value in and of itself. This idea is inherent in the mission of land management agencies such as the NPS.
Passive use values, which can only be estimated through stated preference valuation methods, are a key component of the total economic value associated with wildlife resources and habitats. These values have been used to inform various management decisions, such as the reintroduction of wolves in Yellowstone National Park (Duffield, Neher, and Patterson, 2006) and grizzly bears in the Bitterroot Ecosystem (DOI, 2000). They can also be used to evaluate complex tradeoffs between recreational access and preservation of wildlife habitat by putting affected values in commensurate units (dollars). For instance, at Cape Hatteras National Seashore, coastal areas used largely by off-road vehicles (ORV) also support important nesting sites for endangered sea turtle and bird species. To inform this issue of competing land uses, Dundas, von Haefen, and Mansfield (2018) compared the economic benefits of biodiversity and habitat preservation to the costs resulting from ORV restrictions. Their results provide support for the park's ORV management plan. Such analyses provide important insight into efforts to balance recreational access with environmental protection based on public preferences. Ultimately, they can be used to determine whether particular management actions are "worth it" – i.e., do the benefits to society outweigh the costs?

A number of studies have quantified the total economic value, including passive use values, associated with the preservation of threatened, endangered, or rare species (see Subroy et al. [2019] and Richardson and Loomis [2009] for a summary). Most of these studies have quantified values for entire populations of wildlife species or substantial changes in populations. However, some policy questions require information on values associated with the preservation, or avoided loss, of a single animal or small number of animals. To inform this question, Richardson and Lewis (2021) designed a contingent valuation study focused on the preservation of brown bears in Katmai National Park and Preserve. Surveying a large sample of webcam viewers, results indicate a value ranging from $70-$140 per person per year for the avoided loss of a single brown bear. Using a conservative approach and aggregating to the sample of respondents results in a lower-bound aggregate value of more than $260,000 for preservation of an individual brown bear. Results indicate significant passive use motivations. The valuation approach illustrated by Richardson and Lewis (2021) has broad applicability to other wildlife species and is especially relevant for assessing damages from incidents of poaching or destruction of small areas of habitat, and for evaluating the costs and benefits of regulations that affect a small number of animals as opposed to population-level changes. In certain national parks such as Katmai, Yellowstone, and Denali, many of the commonly seen bears and wolves are given ID numbers or nicknames and receive considerable public attention. Evaluating the effect of this "charisma" on values for individual animals is being explored by Costello et al. (2022) and represents an interesting area for future research.

Conclusion

Wildlife is an important resource protected by public lands and waters in the West, a resource that supports local economic activity from tourism and is valued by the public for a variety of reasons. While economics is just one tool that can be used to better understand the public's preferences and values for wildlife resources, a strength of economic valuation is its ability to objectively evaluate tradeoffs in the allocation of scarce resources, without relying solely on the most vocal stakeholders. Economics offers a systematic approach to help inform planning and management decisions, using a consistent metric to quantify the value of both recreational and passive uses, such as the preservation of wildlife resources and habitats for future generations. Measures of net economic value are central to the assessment of damages from incidents such as poaching and habitat destruction, as well as to cost-benefit analyses of proposed regulations that affect wildlife resources. Such measures of social welfare play a vital role in determining whether wildlife-related policies and management actions provide net benefits to the public.

The economic aspects of wildlife discussed here are relevant to a wide variety of protected areas and wildlife species. There are numerous examples of such information being used to inform policies and management decisions. However, considerable opportunity exists to incorporate economic values and analyses more regularly into the decision-making process. Looking forward, the demand for recreation opportunities will likely continue to grow and competing demands placed upon our public lands and waters will persist. Further, as technologies such as webcams continue to evolve, the public may choose to engage with wildlife in new and unique ways. Virtual wildlife viewing is a highly valued experience in and of itself, and may also lead to deeper connections with wildlife, greater support for wildlife conservation, and enhanced passive use values. Systematically accounting for the full range of benefits provided by wildlife resources, including those derived from new off-site uses, those based on shifting public preferences, and those not associated with any particular "use," can better inform complex management decisions that affect wildlife and their habitats.

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Economic Benefits Supported by Surface Water in Eastern Oregon's Harney Basin

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Abstract

The Harney Basin is a closed river basin in southeastern Oregon. Surface water in the basin is used for a variety of social, economic, and ecological benefits. While some surface water uses compete with one another, others are complementary or jointly produce multiple beneficial outcomes. The objective of this study is to conduct a baseline economic assessment of surface water in the Basin as it relates to wet meadow pasture production and outdoor recreation. Given the complex interactions between surface water management on public and private land, identifying and quantifying these economic outcomes can be used to assist future decision making in the Basin.

Keywords: Economic benefits, surface water, irrigation, outdoor recreation, migratory birds

Introduction

The Harney Basin is a closed river system in rural southeast Oregon that sits primarily within Harney County, which had a population of 7,495 in 2020 (U.S. Census Bureau, 2020). One of the region's main economic sectors is agriculture, which is largely driven by cattle, calves, and hay crop production (National Agricultural Statistics Service, 2019). Surface water used by agricultural producers in the Harney Basin is formed from melting snowpack and is seasonally diverted from rivers and creeks to inundate wide flood plains for irrigated pasture which, at the same time, provides high quality migratory bird habitat (U.S. Fish and Wildlife Service, 2013). Also situated in the Harney Basin is Malheur National Wildlife Refuge (MNWR) managed by the U.S. Fish and Wildlife Service (FWS). The MNWR protects habitat for migratory birds, fish, and wildlife that rely on surface water for survival, while also allowing compatible outdoor recreation, such as birdwatching and angling, and other uses, such as permitted haying of MNWR's irrigated pastures (U.S. Fish and Wildlife Service, 2013). MNWR's flood-irrigated pastures were established in the 1870s when uplands, marshes, and irrigated meadows were converted to provide livestock forage. These were later expanded in the 1940s when the Civilian Conservation Corps improved the irrigation infrastructure (U.S. Fish and Wildlife Service, 2013).

Today, irrigated pastures on the MNWR are distinguished from private lands in that they are managed with the primary goal of providing habitat for nesting birds and not necessarily for forage

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output or quality. Irrigation on the MNWR typically lasts into early August, well after private land irrigation has ended for the growing season, to ensure habitat is provided for breeding greater sandhill cranes (*Grus canadensis tabida*), Canada geese (*Branta canadensis*), early nesting mallards (*Anas platyrhynchos*) early in the season, and crane broods later in the season (U.S. Fish and Wildlife Service, 2013). Haying of irrigated pasture at the MNWR is delayed for nesting consideration for migratory birds, which increases tonnage hayed but reduces forage quality (Sneva, 1982).

Some surface water uses in the Harney Basin are jointly produced. As discussed previously, flood irrigation is a widespread agricultural practice that also maintains irrigated meadow habitat necessary for migrating birds. There is some concern that future time periods with prolonged drought conditions could result in cow-calf operations no longer being economically viable, and without privately flooded irrigation lands, there may be less habitat for migratory birds. Other surface water uses compete with one another. For instance, redband trout (*Oncorhynchus mykiss gairdnerii*) is a native fish that is known to occur or is likely to occur on the MNWR (U.S. Fish and Wildlife Service, 2013). FWS considers redband trout to be a species of concern (i.e., declining or in need of conservation) (U.S. Fish and Wildlife Service, 2013). While there is currently limited geographic overlap between native fish habitat and irrigation, there is concern that future surface water withdrawals for irrigation may reduce or compete with the availability of instream flow for habitat for redband trout and other native fish. With the potential increased variability in future surface water availability, there is interest among stakeholders in the Harney Basin to explore solutions to support cow-calf and haying operations while also meeting migratory bird conservation goals and minimizing any future impact to native fish habitat. Given these complexities, documenting the baseline economic benefits of surface water in Harney Basin helps to identify future tradeoffs and opportunities for water management aimed at supporting these conservation objectives.

Surface Water Benefits Categories

Similar to other locations in the Western United States, surface water in Harney Basin is a scarce resource. From an economic perspective, understanding the benefits and opportunity costs of water in commensurate units (dollars) can be helpful when making comparisons across alternative management strategies and can allow for more informed consideration of the pros and cons of different management options (Brown, Bergstrom, and Loomis, 2007). Measuring these tradeoffs in monetary terms can be useful but doing so can be challenging for goods and services that are not traded in traditional markets (e.g., wildlife habitat) and are therefore considered nonmarket resources (Habb and McConnell, 2002).

The total economic valuation (TEV) framework serves as a guide for identifying the benefits categories supported by surface water in the Harney Basin and appropriate economic valuation methods available to estimate benefits (Figure 1). The TEV of a natural resource is divided into use values and passive use (or non-use) values (Young and Loomis, 2014). Use values are further divided into direct uses (e.g., drinking water) and indirect uses (e.g., irrigation to produce hay, habitat for fish used by anglers). Components of passive use values supported by surface water include existence values (the value in maintaining a resource regardless of use), bequest values (the value in maintaining a resource for future generations), and option values (maintaining a resource for potential future use) (Patterson, 2014).

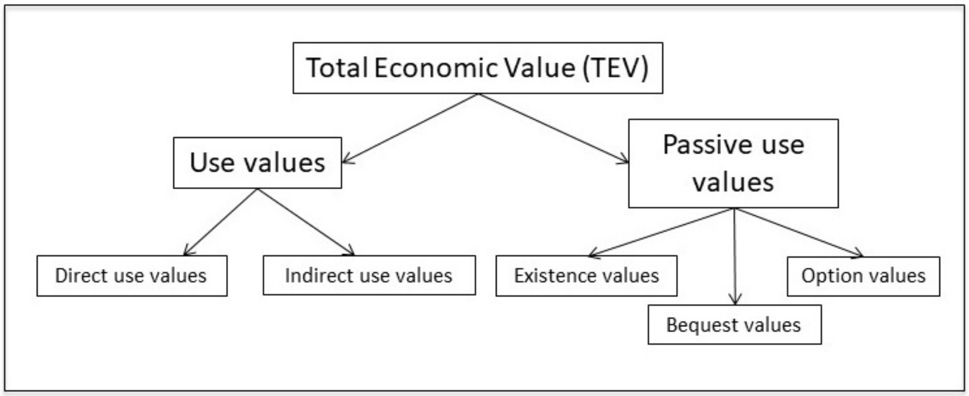

Figure 1. Components of total economic value (adapted from Patterson [2014]).

Available economic methods to monetize the value of both market and nonmarket goods and services are complex and vary depending on the context (see Young and Loomis [2014] for a complete discussion on the economics of water; Champ, Boyle, and Brown [2017] provide a primer on valuing nonmarket goods and services). For the economic analyses discussed here, we focus on 1) market-based producer surplus of flood-irrigated pasture production using crop budgets and the residual valuation method, 2) nonmarket benefits of birdwatching using the contingent valuation method, and 3) nonmarket benefits of recreational fishing using the benefit transfer method. We also qualitatively discuss passive use values and other indirect use values that arise from surface water and highlight opportunities for conservation incentives on privately owned lands that provide public benefits.

Flood-Irrigated Pasture Benefits

Estimates of the short-run economic benefits of surface water for flood-irrigated pasture were constructed using individual crop enterprise budgets representing the anticipated economic returns and costs on a per acre basis (Bair, Flyr, and Huber, 2021). This method is referred to as the residual value method (Young and Loomis, 2014) where the net farm income is identified as the producer surplus, or economic benefit, of surface water. Forage produced from irrigated pastures is used to supplement winter feed for cow-calf operations, and without the production on flood-irrigated pasture, operators would need to supplement with off-ranch sources of forage on the open market.

The first step is to estimate the average number of acres in irrigated pasture based on total consumptive use for irrigation and consumptive use per acre as reported in the Oregon Water Resources Department's Water Availability Reporting System (Oregon Water Resources Department, 2020) (note: this system follows the methods outlined in Cooper [2002]). In an average water year starting on October 1 and ending the following September 30, the total area of flood-irrigated pasture is 106,530 acres, and the annual consumptive use is 165,197 acre-feet of water (Table 1). Cooper (2002) notes that there is considerable variation in the amount of flood-irrigated pastureland and surface water available and used from year to year.

Table 1. Flood-irrigated pasture water use and area in the Harney Basin, OR., at the 50-percent exceedance level.

[Consumptive use and estimated consumptive use per acre at the 50-percent exceedance level are reported by the Oregon Water Resources Department in the Water Availability Reporting System (Oregon Water Resources Department, 2020).]

Subbasin	Annual consumptive use (acre-ft)	Consumptive use per acre (acre-ft)	Estimated flood-irrigated pasture (acres)
Silvies	89,068	1.56	57,095
Donner Und Blitzen	17,394	1.54	11,295
Silver	22,409	1.54	14,551
Malheur Lake	13,227	1.54	8,589
Malheur National Wildlife Refuge[1]	23,100	1.54	15,000
Harney Basin Total	**165,197**	**1.55**	**106,530**

[1]Flood-irrigated pasture acreage for the Malheur National Wildlife Refuge (15,000 per year) is drawn from the U.S. Fish and Fish and Wildlife (2013). This acreage is separated from the Donner Und Blitzen subbasin's total acreage (where the refuge is located) to account for different hay practices

The next step is to construct crop enterprise budgets for each of the subbasins in the Harney Basin (see the first column in Table 1 for a list). It is assumed that the similarities in topography, climate, and soil lead to costs and returns (yield and prices) that are consistent across subbasins outside the MNWR. In Harney Basin, flood-irrigated pasture is a relatively simple production process with small amounts of production inputs, and the area of production has been stable over time. Therefore, surface water represents a significant input that contributes to the value of production. Prices for all inputs have been stable over time, and interviews with Harney Basin producers confirmed that all costs were being adequately captured (Bair, Flyr, and Huber, 2021).

The four subbasins (except for the MNWR) have equivalent gross returns ranging from $100-$300 per acre when assuming hay prices range from $100-$150 per ton with a one-to-two-ton yield per acre (Bair, Flyr, and Huber, 2021). Variable costs, which include pre-harvest costs (such as fertilizer, herbicide, supplies) and post-harvest costs (such as cutting, raking, bunching, and sometimes hauling) range from $60-$138 per acre depending on water availability each year.[4] Taking the difference between per acre gross returns and variable costs equals the net return, or producer surplus, which ranges from $40-$162 per acre for the four subbasins (again, excluding the MNWR) (Table 2).

As discussed previously, the MNWR manages flood-irrigated production differently than private landowners. The forage is cut later in the season to provide for nesting habitat, and some areas are not cut, which increases the variable costs to $70-$163 per acre due to higher harvest costs. The delay in harvest decreases the protein content in the forage, which may reduce its nutritional and market value. The crop budget for MNWR accounts for this by increasing the yield to two-to-four tons per acre, and with a lower hay price at $80 per ton, the gross returns on the MNWR range from

[4] Relatively low total volume water years lead to lower per acre yields and reduced inputs (e.g., fertilizer), holding the total acres constant. The converse is true for relatively high-water years.

$160-$320 per acre. The net return for MNWR is $90-$157 per acre (Table 2) after taking the difference between gross returns and variable costs.

The consumptive use per acre attributed to each subbasin varies, which leads to a different economic benefit of an acre-foot of surface water in each subbasin. The net return per acre-foot of water is calculated by dividing the net return per acre (Table 2) by the consumptive use per acre (Table 1) (Oregon Water Resources Department, 2020). Then, the total economic return is estimated by applying the net return per acre-foot of water to the average annual consumptive use for each subbasin and MNWR. The total net return, or economic benefit of surface water for flood-irrigated pasture in Harney Basin, is estimated to range between $5 million to $17 million depending on water availability in a given year (Table 2).

Table 2. Net economic benefit of surface water for flood-irrigated pasture in Harney Basin, OR

[Return per acre-foot is estimated by dividing the return per acre by the estimated consumptive use of water per acre (Oregon Water Resources Department, 2020). The estimated return per acre-foot is based on water availability at the 50-percent exceedance level]

Subbasin	Net return per acre		Net return per acre-foot of water		Total economic return	
	Low	High	Low	High	Low	High
Silvies	$40	$162	$25.64	$103.85	$2,283,795	$9,249,369
Donner Und Blitzen	$40	$162	$25.97	$105.19	$451,792	$1,829,758
Silver	$40	$162	$25.97	$105.19	$582,052	$2,357,310
Malheur Lakes	$40	$162	$25.97	$105.19	$343,558	$1,391,412
Malheur National Wildlife Refuge	$90	$157	$58.44	$101.95	$1,350,000	$2,355,000
Harney Basin Total					**$5,011,197**	**$17,182,850**

Economic Benefit of Outdoor Recreation

The economic benefits of birdwatching and recreational fishing discussed here are estimated using the contingent valuation method (CVM) and the benefit transfer method (BTM). This economic benefit, or consumer surplus, of outdoor recreation is measured as the maximum amount of money an individual would be willing to pay above and beyond any out-of-pocket costs paid to still make the trip (Loomis and Walsh, 1997). Consumer surplus represents people's level of enjoyment or satisfaction from the outdoor recreation activity and is the appropriate measure for monetizing the value of nonmarket goods, which can lead to the direct comparison of the full range of costs and benefits of both market and nonmarket goods and services (Brown, Bergstrom, and Loomis, 2007).

An important step is to estimate the total annual fishing and birdwatching days in Harney Basin. Birdwatching and fishing are the primary focus of this assessment because they represent outdoor recreation activities most directly affected by surface water management in Harney Basin. Available data are drawn from the U.S. Fish and Wildlife Service's Refuge Annual Performance Plan (RAPP) (R. Roberts, U.S. Fish and Wildlife Service, written communication, Nov. 6, 2019) and from fishing data compiled by the Oregon Department of Fish and Wildlife (Oregon Department of Fish and Wildlife, 1980). MNWR averaged 25,813 visitors per year between 2012 and 2019 (after omitting 2016 estimates due to the MNWR closure), with an increase from 22,600 to 29,719 visitors over this period. However, not all visitors fish or birdwatch. Therefore, additional information is needed to segment total visitation by main purpose for visiting the refuge. Data for understanding primary purpose outdoor recreation activity at MNWR are drawn from an onsite visitor intercept survey conducted during the fall of 2010 and again during the spring of 2011 (Sexton et al., 2012a; 2012b). A total of 315 visitors agreed to participate in the survey, and 276 returned questionnaires. Among survey respondents, 64.1% reported birdwatching to be their primary activity on their most recent trip, and 4.3% reported fishing to be their primary activity. Applying the percentage of primary activity types for birdwatching and fishing to the reported RAPP visitor counts for 2019 (29,719 visitors) yields total visitors by primary activity type. After converting the number of visitors to visitor days by accounting for length of stay per visitor (drawn from Sexton and others [2012a; b]), the annual number of recreation days at MNWR is 1,642 days for fishing and 54,889 days for birdwatching (Table 3). We assume that the 54,889 days birdwatching is a conservative but approximate estimate of total days birdwatching in the Harney Basin since it does not include birdwatching opportunities on private and other public lands (for example, on U.S. Forest Service or Bureau of Land Management [BLM] managed lands).

Table 3. Number of visitors, length of stay, and number of days fishing and birdwatching in the Malheur National Wildlife Refuge, OR

Activity	Number of visitors[1]	Length of stay (days)[2]	Visitor days
Fishing	1,293	1.27	1,642
Birdwatching	19,059	2.88	54,889

[1]Data from the U.S. Fish and Wildlife Service Refuge Annual Performance Plan (R. Roberts, U.S. Fish and Wildlife Service, written communication, Nov. 6, 2019)

[2]Data from Sexton and others (2012a; b)

Other federally managed public lands in Harney Basin also offer fishing opportunities not captured in MNWR visitation statistics shown in Table 3. To arrive at a more complete calculation for Harney Basin, we rely on an Oregon Department of Fish and Wildlife (ODFW) fish management plan from 1980 for the Donner Und Blitzen River System (Oregon Department of Fish and Wildlife, 1980). In it, ODFW estimated around 8,000 angler days per year near Page Springs, OR, which includes the MNWR. Subtracting the number of angler days at the MNWR (1,642 days from Table 3) yields an estimated 6,358 angler days in the BLM managed portion of the Donner Und Blitzen River System not located on the MNWR (Table 4).

Table 4. Total days fishing and birdwatching at the Malheur National Wildlife Refuge and Bureau of Land Management Donner Und Blitzen River System near Page Springs, OR

Land unit	Annual number of days	
	Fishing	Birdwatching
Malheur National Wildlife Refuge	1,642	54,889
Donner Und Blitzen River System[1]	6,358	N/A
Total	**8,000**	**54,889**

[1]Data from Oregon Department of Fish and Wildlife (1980)

The CVM is used to estimate the economic benefits, or consumer surplus, associated with birdwatching (Champ, Boyle, and Brown, 2017). Data to measure consumer surplus were collected in the onsite visitor use survey at MNWR administered by Sexton and others (2012a; b) who asked survey respondents the following CVM question: "*As you know, some of the costs of travel such as gasoline, hotels, and airline tickets often increase. If your total trip costs were to increase, what is the maximum extra amount you would pay and still visit this refuge?*"

Survey respondents were asked to select a dollar amount from a list of eleven options ranging from $0 to $250. This CVM question yields value responses that are based on groups or intervals and can be statistically modeled using an interval regression (Cameron and Huppert, 1989; Welsh and Poe, 1998). An appealing alternative to relying on a statistical model is to use a more conservative nonparametric approach to calculate the value of birdwatching. This approach uses a Turnbull estimator that relies on the payment card responses for survey respondents who indicated that birdwatching was their primary activity (n=167) (Haab and McConnell, 2002). This approach finds a value of $128.26 per person per trip for birdwatching. Dividing this value by the average length of stay per visit for birdwatching (2.88 days) yields $44.53 per person per day. After adjusting for inflation using the Consumer Price Index provided by the U.S. Bureau of Labor Statistics (2022), this lower bound estimate is $150.24 per person per trip and $52.16 per person per day for birdwatching (in 2020 dollars). Aggregating the $52.16 per person per day estimate to all bird viewers (54,889 days at the MNWR) yields a total value of $2.8 million per year.

Total annual number of days fishing at MNWR and on BLM managed lands in the Donner Und Blitzen River system (8,000 days) are used to estimate the economic benefits to anglers. Using the Sexton and others (2012a; b) payment card contingent valuation survey data, a lower bound Turnbull estimate for fishing is calculated to be $90 per person per trip ($70.87 per person per day after adjusting for length of stay at 1.27 days; after adjusting for inflation, the per person per day value for fishing is $83.02 in 2020 dollars). However, owing the low number of observations for fishing (n=11), this estimate may be unreliable. We instead rely on the BTM to estimate consumer surplus associated with fishing in Harney Basin.

The BTM uses existing nonmarket valuation data from previously conducted studies and applies those benefit estimates to a new context (Johnston et al., 2015; Rosenberger and Loomis, 2017). For this assessment, consumer surplus estimates for fishing are drawn from the Recreation Use Values Database (Oregon State University, 2016). Following best practices, the database was restricted to trout fishing in Oregon, which recovered two observations appropriate for an average unit value transfer. The first study, Aiken and La Rouche (2003), estimated a value of $40 per person per day fishing (which is $57.97 per person per day in 2020 dollars). The second observation is drawn from Aiken (2009) who estimated a value of $58 per person per day fishing (or $73.74 per person per day in 2020 dollars). Averaging these two estimates yields a value of $65.85 per person per day fishing, which is slightly lower than the Turnbull estimate using the onsite survey data from Sexton and others (2012a; b). Transferring the average value estimate of $65.85 per person per day, the total consumer surplus for fishing in Harney Basin is $526,800 per year (Table 5). With 1,642 fishing days, the total annual value at the MNWR is $108,000 per year, and with 6,358 days, fishing in the Donner Und Blitzen River System near Page Springs, OR on BLM land is $418,674 per year.

Table 5. Economic benefits of recreational fishing at the Malheur National Wildlife Refuge and Bureau of Land Management Donner und Blitzen River system near Page Springs, OR

Land unit	Annual days	Benefit per day	Annual benefit
Malheur National Wildlife Refuge	1,642	$65.85	$108,126
Donner und Blitzen River System	6,358	$65.85	$418,674
Total	**8,000**	**$65.85**	**$526,800**

Other Indirect and Passive Use Economic Benefits

There are economic benefits supported by surface water in Harney Basin beyond those that support agricultural producers and outdoor recreation activities. For example, surface water may support ecosystem services that are indirectly used by and benefit people, such as carbon sequestration, nutrient cycling, and pollination services (Brown, Bergstrom, and Loomis, 2007). In addition to indirect values, there may be passive use values supported by surface water, including existence values and bequest values (Freeman, 2003). Based on the TEV framework, people may place a value on maintaining migratory bird habitat and populations supported by surface water in Harney Basin regardless of whether they live or recreate in Harney County. While the yellow-billed cuckoo (western population) (*Coccyzus americanus*) is the only bird species federally listed as threatened, several other bird species considered federal species of concern are known to exist on or near the MNWR (U.S. Fish and Wildlife Service, 2013). Past studies have shown that total economic value for preservation of threatened, endangered, and rare wildlife species can be large but varies across species type (Richardson and Loomis, 2009). In a similar study, Bowker and Stoll (1988) estimated that U.S. households would be willing to pay $55.13 per year to avoid the extinction of the migratory whooping crane (*Grus americana*). Other research has examined the total economic value of unique bird species, including peregrine falcon (*Falco peregrinus*) (Kotchen and Reiling, 2000), Mexican spotted owl (*Strix occidentalis lucida*) (Loomis and Ekstrand, 1997), northern spotted owl (*Strix occidentalis caurina*) (Rubin, Helfand, and Loomis, 1991), red-cockaded woodpecker (*Dryobates borealis*) (Reaves, Kramer, and Holmes 1999), and wild turkeys in New England (*Meleagris gallopavo*) (Stevens et al., 1991).

Similar logic applies to the protection of native fish in Harney Basin. For example, while redband trout are not federally listed as endangered or threatened, they are considered a species of concern by the FWS (MNWR and FWS, 2013). Past studies on the total economic value for preserving fish species have found a value ranging from $10 per Wisconsin household to protect the striped shiner (*Luxilus chrysocephalus*) (Boyle and Bishop, 1987) to $398 per Washington household to protect saltwater fish species in Western Washington and Puget Sound (Layton et al., 1999) (in 2020 dollars). Representing a reasonably similar context is the study conducted by Berrens, Ganderton, and Silva (1996) who estimated households in New Mexico would be willing to pay $48.43 per year to maintain minimum instream flow requirements for the protection of silvery minnow (*Hybognathus amarus*) habitat in the middle Rio Grande River. They argue that most of this economic value for silvery minnow is primarily composed of passive use values because the 3.5-inch-long fish is an undesirable species for anglers. These previously published values for bird and fish populations demonstrate the potential magnitude for preserving species in the Harney Basin, suggesting that the economic value for their protection could be quite high when aggregating across households.

Incentives for Conservation

Maintaining the joint benefits from irrigated pastureland and wildlife habitat in the Harney Basin while facing changing or low periods of surface water availability may prove challenging. Incentives for conservation on private land are an opportunity to promote working landscapes and wildlife habitat (Steven, Castley, and Buckley, 2013). One arrangement is “payment for ecosystem services (PES),” which is a policy instrument to maintain or increase the production of ecosystem services on private land that provide societal benefit. In the Harney Basin, habitat for migratory birds is an example of a good provided by the ecosystem that may be affected by flood-irrigated pasture used in cow-calf operations. However, agricultural producers are unable to realize or capture the full economic benefit of provided habitat, and thus they may not fully consider the joint agricultural and habitat production benefits in management decisions (Kroeger and Casey, 2007).

There are several examples throughout the United States where state or federal agencies make payments to maintain or improve ecosystem goods and services such as wildlife habitat on agricultural lands (Casey et al., 2006). In Harney Basin, state and federal funding has been used to support irrigation infrastructure improvement projects. The USDA EQIP, Ducks Unlimited, Intermountain West Joint Venture, Oregon Watershed Enhancement Board, and other organizations have partnered to provide financial and technical assistance to landowners in the basin to maintain and improve ecosystem services, such as wildlife habitat (C. Colson, Ducks Unlimited, written communication, July 7, 2020). From 2014 through 2020, Ducks Unlimited partnered with NRCS and the Oregon Watershed Enhancement Board to support more than $300,000 in conservation projects on approximately 1,800 acres in Harney County, OR. This financial and technical assistance improves irrigation infrastructure and is intended to improve the spreading of surface water across wet meadow habitats, reduce labor costs, and ultimately retain flood-irrigated pasture by discouraging land use conversion. The infrastructure improvements also include the construction of fish diversion and passage which improves native fish conditions (C. Colson, Ducks Unlimited, written communication, July 7, 2020). Understanding future surface water availability across the landscape, and its economic value for agriculture and recreation, improves opportunities for PES in the Harney Basin to be successfully and cost-effectively implemented.

Conclusion

Surface water is used for a variety of complimentary and competing purposes in the Harney Basin. Wet meadow pasture and migratory bird habitat are examples of complimentary uses of surface water. In contrast, there is concern that production of wet meadow pasture and habitat for native fish could be a future competing use for surface water. Having a clearer understanding of the magnitude of the various benefits supported by surface water in the Harney Basin can inform future management alternatives and the design of strategies, such as payments for ecosystem services arrangements, aimed at supporting conservation goals. While we estimate the economic benefit of surface water for flood irrigation to be upwards of $17 million per year, periods of low water are valued at $5 million per year, which translates to a loss in producer surplus of $8 million. With more severe and prolonged periods of drought, it is plausible that losses in producer surplus could be larger and leave longer-term impacts such as the discontinuation of ranching operations, and by extension, may impact the supply of migratory bird habitat provided by private ranch lands. We also estimate that the annual economic benefits of birdwatching and fishing are $2.8 million and $526,000, respectively. In order to conduct a tradeoff analysis that effectively integrates these recreation values, future research could link alternative water levels to birdwatching and angling. For example, how does birdwatching change in low water years? Does angling use vary in low water years in response to changes in fish abundance and catch rates? These questions could be explored by integrating hydrologic models with fish and wildlife population dynamic models in parallel with an improved understanding of recreators' behaviors in response to these changes.

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Are These Big White Dogs Worth the Expense? The Challenge of Determining the Costs and Benefits of Livestock Guardian Dogs

By Dan Macon[1] and Carolyn Whitesell[2]

Abstract

Livestock guardian dogs are used by sheep and goat producers throughout the West to protect livestock from predators. Recent analysis of data from the UC Hopland Research and Extension Center suggests that the costs of keeping dogs may outweigh the benefits of death loss prevention. However, this analysis omits several key economic benefits associated with using livestock guardian dogs. We offer an alternative framework for evaluating benefits, as well as for identifying potential cost savings. We also suggest a framework for incorporating simple economic analyses into an objective case study approach. We identify key drivers (economic and management) that may increase the economic efficiency of using livestock guardian dogs. Finally, we suggest future needs for research into the economics of nonlethal livestock protection tools, including livestock guardian dogs.

Keywords: Livestock guardian dogs, livestock protection tools, predator protection, livestock-wildlife coexistence

Introduction

Livestock guardian dogs (LGDs) have been used to protect livestock from predators for thousands of years. In North America, these dogs are used most frequently by sheep and goat producers (Coppinger et al. 1988; Gehring et al. 2011; VanBommel and Johnson 2012; USDA-APHIS 2015), although some beef cattle producers in the Northern Rocky Mountains and the Upper Midwest have used LGDs successfully to protect cattle (USDA-APHIS 2010; Gehring et al. 2010), and chicken producers in California have also successfully used LGDs (Macon and Whitesell 2021).

Despite the widespread and increasing adoption of LGDs as a livestock protection tool, the costs and benefits of using LGDs in production settings are not well understood. This lack of analysis is partly due to the complexity of evaluating these tools objectively and independently; developing case-control studies that account for all environmental, operational, and management variables is virtually impossible (Ecklund et al. 2017). Furthermore, ethical and economic considerations make designating an unprotected "control" group of livestock to test the effectiveness of a specific livestock protection tool untenable. Consequently, we have suggested a case study approach to documenting the effectiveness of specific tools (including LGDs) (Macon and Whitesell 2021).

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A recent evaluation of data from the University of California's Hopland Research and Extension Center (HREC) concluded that the costs of using LGDs (including acquisition and maintenance costs) exceeded the benefits (in terms of cost of sheep not lost to predators) over the 7-year useful life of the dogs (Saitone and Bruno 2020). At HREC, Saitone and Bruno (2020) show that net expected return over seven years (2013-2017) was -$14,671. In other words, the cost of buying and keeping the dogs exceeded the value of livestock saved by more than $14,000 over seven years. In light of this contrary empirical evidence suggesting that costs outweigh benefits, then, why do livestock producers continue to use LGDs?

Understated Benefits versus Overstated Costs

While the costs of LGDs outstrip the benefits they provide in Saitone and Bruno (2020), the authors concede that "the benefits associated with LGDs in this study are likely understated" (p. 107). We agree. Specifically, LGDs reduce indirect losses associated with depredation (including reduced weight gains, lower conception rates, and increased labor – see Ramler et al. 2014). Further, in real-world production settings, ranch-raised ewe lambs may have greater future value due to their local adaptation to management and forage conditions. Finally, LGDs may provide additional benefits through an impact on sheep behavior. Webber et al. (2015) suggest that sheep grazing with LGDs will travel greater distances than those grazing without LGD accompaniment, potentially indicating protected ewes may be exposed to more and more varied grazing opportunities.

On the cost side of the equation, Saitone and Bruno may overstate the costs of the dogs, primarily because they assume a linear relationship between livestock numbers and the number of dogs required for protection, as well as the labor required to care and feed each dog. In production settings however, the dog: livestock ratio varies, as do labor costs. Finally, producers who have greater success in bonding LGDs with livestock can lower their LGD acquisition and development costs.

Indirect Benefits from LGDs

While direct predator losses are relatively easy to quantify (the market value of a dead ewe and the future value of the lambs she would have produced are reasonably straightforward), the indirect impacts associated with predator-induced stress are less understood. These indirect impacts are likely related to the types of predators in the environment (coursing predators, like coyotes and wolves, may create a different level of stress than ambush predators, like mountain lions). Research in the Northern Rocky Mountains suggests that these indirect losses may be more economically significant than direct losses (Ramler et al. 2014). While that work was conducted with beef cattle, sheep producers likely suffer similar indirect losses in environments where canine predators are of concern. Additional work is needed to quantify the economic impacts of lower weight gains, lower conception rates, and increased labor; that research will provide a clearer picture of the benefits provided by LGDs when these indirect impacts are reduced or eliminated.

The loss of an individual animal also represents the loss of that animal's future genetic potential, as well as the loss of years of investment by the producer (Naughton-Treves et al. 2003). Lambs, calves, and kids generally learn grazing preferences from their mothers (Howery et al. 2010). These learned behaviors help producers adapt their flocks (or herds) to their specific environments. In addition, the spatial/temporal memories of livestock to specific geographic locations improve the grazing and reproductive efficiency of ranch-raised replacement females compared to outside genetics (Launchbaugh and Howery 2005). While the economic benefits per individual animal may be marginal, the cumulative effects suggest that the future value of a ewe killed by a predator may be greater than simply the market value of the offspring she will never have. In other words, a ewe's future contribution to flock genetics (and thus, her value) depend on weaning rate and longevity. For example, a ewe that weans an average of 1.5 lambs per year and that remains in the flock until eight years of age contributes more value than a ewe with a lower weaning rate or shorter lifespan. These factors go well beyond a simple calculation of the ewe's net present value.

During the study period analyzed by Saitone and Bruno (2020), breeding ewes could graze on less than 50% of available rangeland at HREC due to historic losses due to coyotes in specific pastures, suggesting that predator pressure directly affected stocking rate and grazing efficiency. On the other hand, Webber et al. (2015) found that ewes and lambs that graze on extensive rangelands in Idaho with LGDs traveled greater daily distances than unprotected sheep. The authors hypothesize that ewes and lambs that travel greater distances are more likely exposed to more and varied foraging opportunities, resulting in more efficient pasture use. In other words, LGDs may allow producers to increase stocking rate; even a 25% increase in forage access can have a significant impact on enterprise profitability, provided additional LGDs are not required. Table 1 demonstrates the potential increase in stocking rate (and grazing efficiency) resulting from using LGDs where sheep grazed unprotected previously.

Table 1: Potential Increase in Grazing Efficiency Associated With LGDs on a Theoretical 1000-acre Annual Rangeland Sheep Operation in California.

	Total Rangeland Acres	Grazable Acres	Typical Carrying Capacity (annual rangeland)	Total Ewes Grazed
Ranch A (No LGDs)	1000 ac	500 ac	1 ewe / 3 ac	167 ewes
Ranch B (2 LGDs)	1000 ac	625 ac	1 ewe / 3 ac	208 ewes

Cost Factors

While maintenance and feeding costs (including veterinary costs, labor for feeding dogs, and dog food costs) are significant in Saitone and Bruno (2020), perhaps the most important factor driving the cost side of this analysis is the optimal ratio of dogs to livestock. While evidence at HREC suggested that one LGD is required for every 100 breeding ewes, our case studies suggest much greater variation in real-world settings (Macon and Whitesell 2021) – see Table 2 (dog: sheep ratios range from 1:50 to 1:1,200). Producer decisions regarding the ratio of dogs to livestock are driven by time of year (e.g., sheep may be more vulnerable in late winter due to a lack of native prey), stage of production (e.g., lambing ewes may require more dogs than dry ewes because they are likely more vulnerable), grazing environment (e.g., extensive rangeland versus alfalfa stubble or irrigated pasture), and predators present on the landscape. See Table 2 below. Of course, the number of dogs required for an individual operation drives both the capital and operating costs associated with using LGDs.

Table 2: Sample Ratios of LGDs to Livestock From California Case Studies (Macon and Whitesell 2021).

	Livestock Type (Number)	Stage of Production	Pasture/Rangeland Type	Number of LGDs
Ranch 1	Laying hens (4,500) Beef cattle (120)	Egg production All stages (gestation, lactation, dry)	Coastal grassland	4
Ranch 2	Ewes (100)	Lambing	Oak woodland	2
Ranch 3	Ewes (1200)	Dry ewes (non-lactating, mature ewes)	Sagebrush steppe and mountain meadow	1

Labor costs associated with LGDs also vary greatly by operation type and management system. In a permanently fenced operation (like HREC), distance from headquarters and access to grazed pastures will drive the labor costs up associated with feeding and caring for dogs. In more intensively managed systems, where electric fencing and frequent livestock movement require daily attention, the marginal additional labor associated with dogs is part of the overall labor requirements of the operation. Similarly, in open range herded operations, where a herder camps with the sheep 24/7, feeding and caring for LGDs requires little if any extra labor.

As Saitone and Bruno (2020) note, bonding success and longevity are key components to calculating the capital costs associated with LGDs. Capital costs include the cost of acquiring a dog, as well as the development costs associated with raising a puppy to working maturity (typically 18-24 months of age). A long-term study of LGDs suggests a 45% loss rate caused by re-homing due to behavior problems or mortality (Lorenz et al. 1986), suggesting that improving bonding success and reducing mortality are critical economic considerations. Producers cull LGDs for a variety of reasons, including unwillingness to stay with livestock, harassing or killing livestock, or public liability concerns. LGD mortality rates are driven by a variety of factors, including direct conflict with predators, proximity to public roads, and trespassing on neighboring properties (Lorenz et al. 1986). Below, we compare the total capital costs associated with LGD acquisition and development in an operation with a 45% dog loss rate versus an operation with a 15% dog loss rate. Of course, a lower total capital cost results in a lower annual depreciation expense. See Table 3 below.

Table 3: Total LGD Capital Cost = (Acquisition Cost + Development Cost[3]) ÷ Success Rate[4]

[3] Development costs are the normal operational costs (dog food, veterinary care, etc.) incurred until the dog is mature enough to formally protect livestock – typically this period is 18-24 months.

[4] For our purposes, success rate is the percentage of dogs that are raised to adulthood (18-24 months) and are placed in a working situation (guarding livestock).

	Acquisition Cost	Development Cost (18 months)	Success Rate	Average Capital Cost of a Working Dog	Annual Depreciation (Assume 5-year working life and $0 salvage value)
Ranch A	$400	$900	55%	$2,364	$473
Ranch B	$400	$900	85%	$1,529	$305

A Case Study Approach

The case study approach we have outlined in previous work (Macon and Whitesell 2021) offers a framework for collecting real-world data on costs and effectiveness of LGDs. Based on producer interviews and researcher observations, these case studies collect objective information on a variety of factors, including:

- *Environment:* terrain, vegetation type, surrounding land uses, and livestock protection tools (or lack thereof) on surrounding landscapes.
- *Predators present on the landscape:* certain predators often target particular livestock species or classes (e.g., ewes vs. lambs) more frequently than other predators. Additionally, seasonal prey variations and preferences may influence predator pressure in specific situations.
- *Operational characteristics:* Species and class of livestock are directly related to predator susceptibility, as can a particular operation's production calendar. Parturition (lambing or calving) can be an especially vulnerable time for many operations. Conversely, running dry (non-lactating) females without their young in extensive settings may be less risky.
- *Time of year and duration:* Seasonal availability of natural prey, vulnerability of livestock based on stage of production, and the length of time that livestock and LGDs are present on a specific landscape create variability in the predator pressure experienced by operators.
- *Costs associated with LGDs:* these costs include the full cost of acquisition (purchase price and transportation), development costs during the bonding process (including veterinary care, dog food, and labor), operating costs (for an adult working dog; veterinary care, dog food, and labor), success rate (as defined above), depreciation, and equipment costs (feeders, etc.).

While case-control studies regarding LGD effectiveness (including costs versus benefits) are difficult to conduct, we believe our case study framework will help researchers and practitioners collect objective, site-specific data (including cost data) regarding these tools. Since this framework explicitly describes factors that may influence LGD effectiveness, it will allow practitioners to better evaluate their own operation in comparison to each case study.

Future Research Questions
Based on the complicated relationships identified by Saitone and Bruno (2020) and expanded on above, we believe there are a number of questions that warrant further study:

1. Can management systems and/or equipment increase the efficiency of labor associated with LGDs? For example, can creep feeding systems eliminate the need to travel to remote pastures to feed LGDs on a daily basis? Research at Texas A&M suggests that creep feeding systems can replace the need for daily hand feeding (Costanzo, personal. communication). Are there other management benefits associated with more frequent checks of LGDs and livestock (like lower disease incidence or livestock/dog mortality rates)?
2. Are specific bonding techniques likely to lead to greater bonding success? For example, does a high degree of interaction with humans during early puppyhood impair or enhance bonding with livestock? Similarly, are puppies successfully bonded by a producer to his/her livestock more cost effective than purchasing a working-age dog bonded by someone other than the producer?
3. Can we quantify increases in carrying capacity associated with LGDs? Similarly, can we quantify the production impacts of predator-induced stress on livestock?

Table 4 provides a cost versus benefit framework for considering the economic and production impacts of our answers to these research questions.

Table 4: Drivers of Possible Cost Savings and Benefit Enhancements in LGDs on Commercial Ranching Operations.

Potential Cost Savings	Potential Benefit Enhancements
• Improve LGD success rate (e.g., successful bonding and increased longevity) to reduce capital costs. • Optimize dog: livestock ratio (keep "just enough" dogs). • Increase efficiency of feeding LGDs (to reduce feeding labor).	• Reduced livestock stress may improve reproductive performance and weight gain. • Increased travel distances during foraging may allow producers to increase stocking rate on a given unit of land. • Maintenance of locally adapted livestock genetics may increase grazing efficiency.

Conclusion
As with many producer-level management decisions, the decision regarding whether to use LGDs (or any other nonlethal livestock protection tool, for that matter) is extremely complex. Producer attitudes towards a particular tool are directly related to that producer's confidence in the tool. If a rancher thinks a LGD will work on his/her operation, he/she is more likely to stick with the dog even when problems arise. In addition, Producer A may have a greater degree of success in raising and bonding LGDs with livestock than Producer B. Environment, management system, and other factors all impact the cost: benefit ratio of using LGDs. Perhaps the most difficult consideration to measure, however, is peace of mind. While most commercial producers factor an acceptable level of predator

loss into their economic decision making process, the value of peace of mind (or the absence of human stress) is difficult to quantify.

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Western Economics Forum | A Journal of the Western Agricultural Economics Association | WEF

Integration of Wildlife Economics with Land Use and Management Policies

By Bengt 'Skip' Hyberg[1] & Don English[2]

Abstract
We examine the effects of incomplete economic wildlife assessments in analyses of land use management strategies. We demonstrate that the use of a single important charismatic species or a single wildlife-based activity to capture the wildlife effects can result in a substantial understatement of the economic contributions and economic benefits resulting from land use management. We further examine the potential errors that may be introduced by using benefits transfer techniques to estimate wildlife benefits, even in areas considered to have similar characteristics.

Keywords: upland birds, waterfowl, deer, hunting, cost-benefit analysis, benefits transfer, Conservation Reserve Program, National Forest visitor use monitoring.

Introduction

It has long been recognized that a full accounting of the costs and benefits of a course of action is required for an unbiased analysis. In particular, analyses of alternative land management options, which can change wildlife populations, soil erosion, water runoff, nutrient cycling, water quality, carbon sequestration, and economic activity, require careful scrutiny to assure all important effects are included. In situations where the change proposed has multiple benefits, focusing on only a single effect will underestimate the benefits.

The same is true for estimates of the market and nonmarket effects of wildlife resources, which are generally garnered through land management. Changes in land use and land management result in multiple environmental changes, including changes in wildlife composition and population. All too often, analyses assessing a proposed set of actions estimate wildlife effects using a single charismatic species. This approach results in a similar underestimation of wildlife benefits as one observes when an environmental factor is ignored in an analysis. The more appropriate means to estimate the costs and benefits of wildlife management is to include the effects on multiple wildlife populations. Although these wildlife benefits would ideally be examined as part of a portfolio of environmental benefits within the landscape, we will limit our presentation to analyses of wildlife benefits to demonstrate the bias that can be introduced by focusing on a single species or variable. Our presentation will discuss results on private and public lands using both estimates of economic contribution, a measure of market effects, and economic benefits, which largely measure non-market effects.

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Further complicating wildlife costs and benefits estimation is the paucity of location-specific information on the value of wildlife benefits. This has led to the use of national or regional data that roughly approximates the population being examined, and employing the benefits transfer method (BTM) to apply values from related studies from other regions. We will briefly examine the use of BTM to demonstrate that, while it can offer an indication of relative value, its application can greatly alter the inferences drawn from an analysis, even when regions appear to be similar.

Private Lands

In 2015, Loomis et al. (2015) in coordination with the Farm Service Agency conducted a survey to estimate the economic contribution and economic benefits from hunting in North Dakota (ND) and South Dakota (SD), and the role of the Conservation Reserve Program (CRP) lands in generating this economic activity. Six versions of the survey gathered information regarding hunters' deer, upland bird, and waterfowl hunting activity in the two states. Data collected included expenditures; number, distance, and duration of trips; state of residence; and hunting on land enrolled in or adjacent to the CRP. These surveys provide primary data that enable the use of IMPLAN to estimate the Total Value Added (TVA) a measure of gross economic activity generated by hunters' expenditures, the net economic activity generated (TVA generated by non-resident hunters), and of the portion hunting activity on CRP lands in each state. Additionally, these data support the development of travel cost models that can be used to estimate hunter consumer surplus.

Gascoigne et al. (2021) revisited the Loomis et al. (2015) study, providing an improved methodology to estimate the economic contribution and benefit from hunting on and adjacent to CRP lands. Their study revises Loomis et al. (2015) estimates for SD upland bird hunting to better account for the portion of the hunting on CRP land. Gascoigne, et al.'s methodology was applied to the Loomis et al. estimates (Table 1b) to revise estimates for ND deer, upland birds, and waterfowl and SD deer and waterfowl hunting adjacent to and on CRP lands. Then, these estimates are used to demonstrate how an analysis using a single indicator species underestimates wildlife benefits, resulting in a bias against wildlife management. The analysis also demonstrates the potential for BTM to distort wildlife benefits.

Results

Table 1a presents the statewide Total Value Added (TVA) estimates for SD upland birds (Gascoigne et al., 2021) and Table 1b provides TVA statewide estimates for hunting in ND and SD from Loomis et al. (2015) and revised TVA estimates for CRP lands for each hunting activity in ND and SD. The revised estimates for the lands enrolled in the CRP were estimated by multiplying each estimate from Loomis et al. (2015) by the product of the percentage of hunters using CRP land and land adjacent to CRP and percent time spent on these lands (Table 2).

An analysis that focused on a single important hunting activity such as upland bird hunting in SD would estimate a large TVA ($87 million) but would underestimate the total economic contribution provided by hunting by one third ($41.6 million). Including waterfowl hunting would increase the estimated TVA to $108.6 million, but will still omit the $20 million (16%) economic contribution from deer hunting. This analysis still represents a conservative estimate of the bias because it omits any contribution from wildlife viewing, enhanced pollinator populations, or other wildlife effects.

A similar analysis of upland bird hunting in ND reveals a larger underestimate. The $41.2 million TVA from upland bird hunting understates hunting's economic contribution by nearly 50 percent. Including waterfowl hunting ($27.1 million) only captures 81 precent of the TVA from hunting.

Table 1a: Summary of Total Value Added from Hunting Upland Birds in South Dakota

	South Dakota All Lands	South Dakota CRP Land
(Million dollars)		
Upland Game Birds		
Contribution - All Hunters	$ 87.0	$ 24.3
Impacts of Non-Residents	$ 63.3	$ 17.7
Hunter Consumer Surplus	$ 488.7	$ 143.7

Source: Gascoigne et al. (2021)

Table 1b: Summary of Total Value Added from Hunting in North Dakota and South Dakota

	North Dakota All Lands	North Dakota CRP Lands	South Dakota All Lands	South Dakota CRP Land
	(Million dollars)			
Upland Game Birds[1]				
Contribution - All Hunters	$ 41.2	$ 15.2		
Impacts of Non-Residents	$ 23.0	$ 8.5		
Hunter Consumer Surplus	$ 133.0	$ 48.9		
Waterfowl				
Contribution - All Hunters	$ 27.1	$ 3.8	$ 21.6	$ 2.4
Impacts of Non-Residents	$ 15.5	$ 2.2	$ 6.7	$ 0.7
Hunter Consumer Surplus	$ 85.0	$ 12.0	$ 72.0	$ 7.9

Deer								
Contribution - All Hunters	$	15.7	$	4.0	$	20.0	$	2.9
Impacts of Non-Residents	$	0.3	$	0.1	$	2.9	$	0.4
Hunter Consumer Surplus	$	65.0	$	16.8	$	88.0	$	12.8
GRAND TOTAL								
Contribution - All Hunters	$	84.0	$	22.0	$	128.6	$	29.6
Impacts of Non-Residents	$	38.8	$	11.2	$	72.8	$	18.8
Hunter Consumer Surplus	$	283.0	$	74.0	$	648.7	$	164.4

Source: Loomis et al. (2015). (2014 dollars) The All Lands values are from Loomis et al. (2015). The values for CRP Lands are the All Land values modified using Gascoigne et al. (2021) methodology.

Using only upland bird hunting to estimate the wildlife economic contribution due to CRP lands in SD captures 82 percent ($24.3 million) of the TVA from hunting activity. Including waterfowl captures 90 percent ($26.7 million). Similarly in ND, upland bird hunting accounts for 69 percent ($15.2 million) of TVA from hunting due to CRP. Including waterfowl hunting ($3.8 million) captures 87 percent. In both states, using a single charismatic species understates the economic contribution from hunting by 18 to 31 percent, negatively biasing the analysis.

Table 2: Percentage of Hunting on CRP and Adjacent Land

	North Dakota			**South Dakota**		
	Percent using CRP	**Percent time on CRP**	**Percent of hunting on CRP**	**Percent using CRP**	**Percent time on CRP**	**Percent of hunting on CRP**
Upland Birds	56%	65%	37%	49%	55%	28%[1]
Waterfowl	17%	85%	14%	16%	71%	11%
Deer	35%	71%	26%	19%	78%	15%

*Percent of hunting on CRP lands = Percent using CRP lands) * Percent time on CRP lands)*

[1] From Gascoigne et al. (2021) Discrepancy due to rounding.

Hunter Consumer Surplus

Loomis et al. (2015) constructed travel cost models to estimate hunter consumer surplus for ND and SD (Table 3). The travel cost method uses variations in travel costs to the hunting area along with associated variation in trips to trace out a demand curve, from which the consumer surplus or benefit to the hunter is calculated. They estimated the consumer surplus for SD upland bird hunters to be $317 per day (Table 3). This is at the upper end of the range of the value of small game hunting trips for the Intermountain States and Pacific Coast States (Loomis and Richardson, 2007) and greatly exceeds the national consumer surplus Feather, Hellerstein, and Hansen (1999) estimated for pheasant hunters ($33 per day, adjusted for inflation to 2015 dollars). The SD estimate likely reflects higher quality pheasant hunting. The ND per day consumer surplus ($138) estimated is consistent with valuation studies in Pacific Coast States (CA, OR, WA) and the Southeastern U.S. (Loomis and Richardson, 2007).

Table 3: Hunters' Consumer Surplus[1]

	North Dakota		South Dakota	
	Per Day	Total ($ million)	per day	Total ($ million)
Upland Birds	$138	$133.0	$317	$477.5
Upland Birds on CRP		$ 49.2		$143.7
Waterfowl	$159	$ 84.8	$124	$ 71.9
Waterfowl on CRP		$ 11.9		$ 7.9
Deer	$129	$ 65.0	$164	$ 88.0
Deer on CRP		$ 16.7		$ 12.8
Total		$282.7		$637.4
Total CRP		$ 77.8		$164.4

Source: Loomis, 2015. Total CRP consumer surplus was calculated by multiplying the state total consumer surplus by the corresponding coefficient in Table 2.

[1] *The 90 percent confidence interval for ND and SD per day upland birds did not include the other state's point estimate. However, the each of the confidence intervals for waterfowl and deer hunting in each state included the point estimates for the other state.*

The per day consumer surplus values estimated for ND ($159) and SD for waterfowl ($124) are significantly higher than the averages for the other waterfowl studies across the U.S. (Loomis and Richardson, 2007). These values are within the upper values of studies found in the literature, likely reflecting the high quality of waterfowl hunting within the Prairie Pothole Region which, in wet years, accounts for 70% or more of North American duck production (Ducks Unlimited, 2021). The per day estimates for deer hunting in ND ($129) and SD ($164), while higher than for those found in the literature for the nearby Intermountain States, are within the upper range of such values (Loomis and Richardson, 2007).

The total hunter consumer surplus was estimated to be $637.4 million for SD and $282.7 million for ND. Using only the consumer surplus from upland bird hunting underestimates the economic benefit from hunting by 53 percent in ND and 25 percent in SD. The estimated consumer surplus from hunting on CRP lands, totaling $164.4 million for SD and $77.8 million for ND (Table 3), was calculated from the state totals for each form of hunting using the coefficients in Table 2.

Benefits Transfer Method (BTM)

The examination of hunter consumer surplus reinforces cautions raised about using BTM. Gathering the data needed to estimate consumer surplus for activities involving wildlife is costly. BTM offers analysts the opportunity to examine economic benefits across different regions at a reduced cost, by using estimates from studies conducted elsewhere. BTM can provide estimates of the economic benefits when local data is lacking. However, differences between the locations can be difficult to detect and can lead to poor estimates. North Dakota and South Dakota are two states that have many similar attributes. Both states are popular hunting destinations with high-quality upland bird, waterfowl, and deer hunting opportunities. However, their per day consumer surplus estimates for upland bird and waterfowl hunting show substantial variation. Using the estimates from SD for ND hunters would overstate the ND consumer surplus for upland birds by 129 percent and understate the consumer surplus for waterfowl by 22 percent. This demonstrates that use of BTM can distort analyses even when the regions are similar. Estimates from dissimilar locations would be expected to generate larger differences. Use of the Feather, Hellerstein and Hanson (1999) pheasant national estimate would underestimate benefits of upland bird hunting in SD by an order of magnitude.

The above results suggest BTM can be used for similar regions but with caution. Analysts and researchers considering the use of BTM are advised to carefully examine the sample size, data collection methodology, and activities being examined before conducting their analysis. BTM can provide general indicators of an activity's value, but is no substitute for direct estimates obtained from conducting valuation studies in the geographic area and species of interest.

Public Lands

Wildlife-related recreation on USDA-Forest Service lands is an important component of the recreation benefits provided by the agency. Results from the agency's National Visitor Use Monitoring (NVUM) program show that the National Forest System annually has about 7.3 million visits wherein hunting was the primary recreation activity (Table 4). Another 9.4 million visits have fishing as the primary activity, and 2.7 million visits that are primarily for viewing wildlife (2020 National Report: https:\\www.fs.usda.gov/about-agency/nvum).

Wildlife-related recreation plays a supporting role in many more visits to National Forest Service (NFS) lands. Hunting, fishing, or viewing wildlife is a secondary activity on almost 45 million other visits, or about 30% of all visits to NFS lands. It is quite common for visits that have main activities of hiking, camping, or pleasure driving to also include wildlife viewing as a part of the overall recreation experience.

In connection with the visits that have a wildlife-related main activity, visitors spent approximately $1.1 billion in 2019. Nearly all that spending was made in communities within 50 miles of the national forest. Overall, the spending by visitors contributes about $1.3 billion to GDP, and sustained approximately 15,000 full and part time jobs.

Table 4. Millions of Visits to NFS Lands for Wildlife Related Activities FY2020

	Primary Recreation Activity			Secondary Activity
FS Region	Hunting	Fishing	Viewing Wildlife	Wildlife Recreation
Northern	1.2	0.7	0.2	3.2
Rocky Mountain	0.8	1.8	0.4	8.5
Southwestern	0.4	0.9	0.5	4.8
Intermountain	0.9	1.1	0.2	4.6
Pacific Southwest	0.4	1.1	0.4	8.4
Pacific Northwest	0.6	0.7	0.3	5.9
Southern	2.2	1.6	0.4	4.6
Eastern	0.8	1.3	0.2	3.4
Alaskan	0.1	0.2	0.1	1.3
Total	7.3	9.4	2.7	44.8

Source: USDA- Forest Service, National Visitor Use Monitoring, FY2020. https://apps.fs.usda.gov/nvum/results

Measures of net economic value for these primary activity visits have been estimated via the travel cost method. This method values recreational access as a function of the time, travel, and out-of-pocket expenses made while producing the trip. At a national level, the values estimated in 2019 are $890 million for hunting visits, $1.1 billion for fishing, and $223 million for wildlife viewing visits (Rosenberger, et al, 2017). The average per trip surplus is about $121 for hunting, $113 for fishing, and $82 for wildlife viewing.

Managing forest landscapes for wildlife habitat has other spillover benefits for recreation. Managing landscapes for habitat and for scenic quality is interrelated. Viewing landscapes is even more common as a secondary activity than viewing wildlife. Almost 45% of recreation visits to NFS lands include viewing scenery as part of the visit (USDA 2021).

It is not possible to accurately estimate how wildlife viewing contributes to the economic values for the visits where it is a secondary activity. Standard techniques for estimating both spending and net values of recreation visits assume the primary activity generates the economic measures.

Table 5. Comparing Economic Outcomes of Wildlife-related Primary Purpose Visits, Forest Service Northern and Pacific Northwest Regions, FY2019

	Northern Region	Pacific Northwest Region
Hunting		
Primary activity visits (thousands)	1,087	663
Local visitor spending (millions)	$ 66.9	$ 72.1
Value added (millions)	$ 34.1	$ 36.0
Net economic value (million)	$ 106.7	$ 65.9
Value per visit ($)	$ 91.00	$ 84.00
Fishing		
Primary activity visits (thousands)	723	708
Local visitor spending (million)	$ 48.1	$ 50.4
Value added (million)	$ 25.3	$ 25.9
Net economic value (million)	$ 63.6	$ 55.2
Value per visit ($)	$ 84.60	$ 77.61
Wildlife Viewing		
Primary activity visits (thousand)	208	248
Local visitor spending (million)	$ 11.2	$ 12.0
Value added (million)	$ 5.8	$ 6.4
Net economic value (million)	$ 13.7	$ 15.4
Value per visit ($)	$ 72.24	$ 65.25
Total		
Primary activity visits (thousand)	2,018	1,619
Local visitor spending (million)	$126.2	$134.5
Value added (million)	$ 65.2	$ 68.3
Net economic value (million)	$184.0	$136.5

Source: [spending and value added] Marcille, K., H. Eichman. (2021); [net economic values] Rosenberger, et al. (2017).

Because wildlife viewing contributes far more frequently as a supporting activity, the totals obtained from only accounting for primary activity visits undercount the actual value of managing habitat for wildlife.

Table 5 compares the volume and the associated economic outcomes for visits that have a primary recreation activity of hunting, fishing, and viewing wildlife for two Forest Service regions, FY2019. The northern region contains national forests in Northern Idaho, Montana, and portions of North Dakota. The Pacific Northwest (PNW) region is made up of agency land in Washington and Oregon.

Visitor spending tracks the amount visitors spend within 50 miles of the areas where they recreated. This measure would exclude air travel costs that were paid prior to arrival in the local area. Similarly, fees paid to outfitters not based in the local area may be excluded. Such costs could be sizeable for outfitted trips for boutique activities such as elk hunting or fly fishing.

Over 1 million hunting visits to the northern region generate about $67 million of visitor spending in communities near national forests, 53 percent of visitor spending for the 3 activities. This direct spending creates about $34 million increase in value added to the regional economy. Somewhat fewer visits in the Pacific Northwest region generate larger local spending, and slightly larger regional contributions. This holds because per visit spending in the northern region is lower; a much higher percent of visits there are from nearby residents on day trips from home compared to the PNW region.

Habitat and resource improvements targeted to hunting and fishing recreation also create opportunities for wildlife viewing. In these regions, failing to account for primary purpose wildlife viewing visits in evaluating the benefits of such improvements would understate visitor spending by over $11 million in each region and the regional economic contribution by about $6 million. Another way to look at these figures is that the regional economic contribution of wildlife using only hunting would be understated by between 46 and 59 percent. Including both hunting and fishing would understate the regional economic contribution by approximately 10 percent and visitor benefits (consumer surplus) would be underestimated by about 8 percent in the northern region, and nearly 13 percent in the Pacific Northwest region. It is important to stress that wildlife viewing is a secondary activity for a substantial portion of visits to national forests; the number of these trips far exceeds trips with hunting, fishing and wildlife viewing as the primary purpose (Table 4). However, the contribution of wildlife viewing to the value of these trips is excluded from this analysis.
It is worth noting that the economic value of a visit for broad wildlife activities such as hunting, fishing, and wildlife viewing is approximately 10 percent greater for the northern region than for the Pacific Northwest region. Hence using BTM to estimate the economic value of one region using per visit estimates from the other leads to a commensurate over or underestimate.

Summary

We have illustrated how omitting wildlife activities, or a form of hunting can underestimate the benefits from land management. In examining hunting on private lands in the Dakotas, the analysis demonstrated that using only upland bird hunting understates the economic benefits by 18 to 53 percent, depending on the variable examined. On national forests, the analysis demonstrated focusing on hunting and fishing, omitting wildlife viewing activities understates the economic activity from wildlife-based activities by approximately 10 percent. Even these estimates are quite conservative because both examples omit important wildlife benefits.

These analyses provide insights for employing BTM to estimate the economic value of wildlife-based activities. The data presented here highlights the importance of carefully examining and understanding the data when using and interpreting BTM. The examination of hunting on private lands in ND and SD demonstrates that even using values from similar locations can result in substantial miscalculation. However, TMC estimated per visit values for the national forests were very similar. To a large extent this can be attributed to sample size. The number of observations for the National Forest survey ranged from 5,000 - 12,000 per region. In the analysis of hunting in the Dakotas, the number of observations for the state – hunting type combinations ranged between 267 and 378. The smaller sample size increases the confidence interval around the estimates and creates more opportunity for the use of point estimates to misrepresent the economic value of wildlife activities.

BTM can supply useful information concerning wildlife-based activity, providing either order of magnitude or a point estimate of the economic value. Analysts considering the use of BTM to estimate the economic value from wildlife activities need to examine not only the similarity between the locations, but also the sample size and confidence intervals around the estimates used.

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Economic Consequences of the Wolf Comeback in the Western United States

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Abstract
Gray wolves were eradicated from most of the United States in the 1940's but have made a comeback in parts of their historic range over the last two decades. First reintroduced into the Greater Yellowstone Ecosystem and central Idaho in the mid-1990's, wolves have subsequently dispersed into at least 7 western states. Coloradoans became the latest state to take interest in bolstering wolf populations, as residents passed a ballot initiative in November 2020 to reintroduce a self-sustaining population of gray wolves by the end of 2023. Conflicts between people in rural areas that might incur costs (such as livestock loss) and people in urban areas geographically removed from direct contact with wolves suggest that the distribution of benefits may not align uniformly with the distribution of costs. Given that Colorado will imminently make many policy decisions that have an impact on costs and benefits, we review available literature to better understand the magnitude of gainers and losers from wolf reintroduction in western states. Although no single study has included all possible economic values, the magnitude of impacts can be inferred by assembling a broad range of estimates for different types of values into a single space. Our review of existing valuation literature from western states indicates that the magnitude of economic benefits of wolves is many times higher than what it costs to manage wolves and to reduce or compensate for losses to livestock producers and others.

Introduction
A thriving population of wolves that once freely roamed throughout most of the continental United States was effectively eradicated by the mid-twentieth century, except for small remnant populations in northeast Minnesota and Isle Royale National Park in Michigan (Mech 2017). Both federal and state governments provided financial incentives - in the form of bounties- to those who killed wolves to facilitate eradication. The primary justification was to reduce wolf impacts to the livestock industry, reduce impacts to native game populations, and a general disdain for native predators. However, societal attitudes have changed, and wolves are recovering and spreading in parts of the continental US (primarily the upper Midwest and Western US). Most recently, Colorado voters passed a referendum to add their state to a growing list of Rocky Mountain States with a sustainable wolf population.

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Wolf recovery is not without conflict. Many livestock producers, hunters, and rural residents view wolves as a threat, while others view them as an integral part of natural ecosystems. The political reality that wolves generate conflict has stimulated research about how people with disparate interests envision and/or tolerate coexistence between wolves and people. Ways to reduce conflicts, such as management systems that reduce livestock predation and/or financial compensation for livestock losses, are also needed. Can economic research help address the ultimate question: is coexistence worth the conflict?

One way to address this question is to assess the economic costs and benefits of landscapes where people and wolves coexist. To our knowledge, no prior studies have fully calculated these values for any single example. Given renewed interests associated with wolf reintroduction in Colorado, our purpose is to explore what we already know about the monetary net value people place on wolves. We evaluate the economic attributes of wolves by assimilating data from published, but disparate, studies. This represents a preliminary step toward full understanding, given that data from different studies cannot be directly compared. Nonetheless, our compilation of existing economic information is complete enough to help decision makers improve their understanding of total economic tradeoffs regarding coexisting with wolves. We begin with a review of how gray wolves have recovered in parts of their historic range in the United States in recent decades, followed by a discussion about the economic benefits and costs of such recovery.

The Recovery of Wolves

Public attitudes towards wolves started changing in the mid-20th century, with increased interest in the preservation of wilderness more broadly (George et al., 2016; Kellert et al., 1996). Wolves became a federally protected species in the United States in 1970's through the passage of the Endangered Species Act (ESA). Surveys in the last two decades found generally positive public attitudes towards wolves and wolf reintroduction. For example, a 2014 survey of U.S. residents found 61% of respondents had positive attitudes towards wolves (George et al., 2016). Across 38 quantitative public opinion surveys conducted between 1972 and 2000 in the U.S., Canada, and Europe, an average of 51% of all respondents had positive attitudes towards wolves and 60% had positive attitudes towards wolf reintroduction (Williams et al., 2002).

The U.S. Fish and Wildlife Service (USFWS) is responsible for the management and eventual recovery of threatened and endangered species, including wolves. To help recover the gray wolf, the USFWS and the National Park Service reintroduced them into the Greater Yellowstone Ecosystem (GYE) in Yellowstone National Park and in central Idaho in the mid-1990s. The reintroduction was considered successful by most standards and the wolf population grew and expanded. Due to this recovery, over the past decade, gray wolves were removed ("delisted") from the ESA in Montana, Idaho, Wyoming, eastern Oregon and Washington, and parts of Utah. Wolf management authority was returned from the federal government to those states. Due to their relative abundance, wolves in Alaska were never added to the endangered species list. But in many other states - including Colorado and the Great Lakes states – gray wolves were still federally listed as endangered species under the ESA. The USFWS has concluded that the gray wolf is not in danger of extinction and thus has removed them from endangered status. As a result, in March 2019, USFWS proposed to remove all gray wolves in the continental United States from protection under the ESA. This policy decision was finalized in January 2021, which then turned management of gray wolves back to individual state wildlife agencies. As has been the case in the past, the delisting of wolves was challenged in court, and in February 2022, gray wolves in the lower 48 (except those in the northern Rocky Mountain states) were relisted on the ESA, returning management authority to the USFWS.

In November 2020, Coloradoans passed Ballot Proposition 114, a citizen-initiated ballot measure, to start reintroducing wolves to western Colorado by the end of 2023. Due to the controversial nature of the issue, Colorado Parks and Wildlife initiated a planning process that includes the formation of a Technical Working Group of experts as well as a public outreach process and a Stakeholder Advisory Group (SAG) led by a third-party facilitator. The SAG is tasked with developing recommendations for wolf management, which then will be considered by the Colorado Parks and Wildlife Commission, the citizen board, appointed by the Governor, which sets state regulations and policies for Colorado's state parks and wildlife programs.

Prior surveys conducted before the Colorado ballot initiative suggested high levels of public support. For example, a 1994 mail survey found that 71% of Coloradans would support wolf restoration (Pate et al., 1994), a 2001 phone survey found that 66% would support wolf restoration (Meadow et al., 2005), and a 2019 survey of an online sample recruited through an online survey recruitment platform found 84% support (Niemiec et al., 2020). However, the proposition passed with only 50.91% of votes in favor of wolf reintroduction to the state. Counties that voted yes were generally densely populated urban areas, primarily in the urban Front Range in Colorado, while counties that voted no generally had low population densities in rural areas in the Eastern Plains and Western Slope of the state.

Economic Benefits[5]

Some of the benefits a society receives from reintroducing wolves have markets and some do not. There are markets for fur and for hunting trips, but people do not have to pay anything just to know that wolves exist in the wild. Values for environmental goods can be divided into four basic groups: 1) direct values, including consumptive use (e.g., hunting) and non-consumptive (e.g., wolf viewing and research), 2) non-use values, including existence value (i.e., knowing wolves exist) and bequest value (i.e., retaining wolves for future generations), 3) option value (e.g., retaining the ability to hunt or view wolves for future generations), and 4) indirect values (i.e., values that transfer through some indirect means, such as habitat recovery if wolves help reduce overabundant big game populations). We know of no single study that reveals such a comprehensive understanding about the value of wolves. However, we can build a mosaic of what total value might look like by compiling examples from different published studies in the literature, as shown in Figures 1 and 2. The studies in these figures are not directly comparable since they cover different time periods, regions, and assumptions. So, we cannot just sum the values in either figure. However, these figures do provide an overall picture of the magnitude and totality of benefits related to having wild wolf populations and can be helpful when making decisions about how to manage wolves.

Consumptive and non-consumptive values that can be found through expenditures in markets are shown in Figure 1. Expenditures include what a person paid to travel to hunt or see a wolf, while

[5] Some of the information about benefits and costs comes directly from an unpublished extension information sheet written by Dana Hoag (2020) https://extension.colostate.edu/topic-areas/people-predators/wolf-economics-8-012/.

WTP indicates extra value that people receive from hunting or seeing a wolf. For example, non-resident hunters spent about $6,773[6] on gear and travel (ECONorthwest, 2014) to hunt wolves in Alaska (Figure 1), but would be willing to pay another $613 (Loomis, 2016) above their trip costs for the ability to hunt a wolf (Figure 2). Since they never had to pay that $613, that is considered a gain to society. That is, having wolves available to hunt produced an extra $613 for every non-resident hunter in Alaska. Expenditures, $6,773 in this case, represent the amount of money people are willing to transfer from some other use; they benefit the region where the transfer occurs at the expense of those regions losing the funds. Both consumptive and non-consumptive examples of expenditures are shown in Figure 1. For example, Duffield (2019) estimated that visitor spending related to wolves would generate $45.5 million per year in the GYE. Currently, the Yellowstone Wolf Tracker charges $700/day for a wolf viewing trip. Wolf hunting or trapping is also allowed in parts of Wyoming, Idaho, and Montana, and is under review in other states. Hunters and trappers spent over $400,000 just for licenses in Montana (Inman et al., 2019). Guided hunts in Idaho go for $3,800 (Richieoutfitters, 2020). Trapping generated over $200,000 to the regional economy in Alaska (ECONorthwest, 2014).

Figure 1: Expenditures related to wolves, based on disparate studies[a]

Consumptive	
<u>Wolf Hunting</u>	<u>Examples:</u>
• License Fees	• Hunt/trap license fees in Montana $432,2738 in 2018[I]
• Hunting Fees	• Guided hunting in Idaho $3,800/person per trip[R]
• Trapping	• $217,723/year in regional expenditures related to wolf trapping in Alaska[E]
• Travel/Retail	• Hunters spent over $6,773 on trip and gear to hunt in Alaska[E]
Non-Consumptive	
<u>Wolf Viewing</u>	<u>Examples:</u>
• Touring Fees	• Yellowstone wolf viewing tours $700/day[Y]
• Travel/Retail	• GYE state's annual visitation $45.5 million/year in regional expenditures related to wolf viewing[D]

a-Values adjusted to January 2022 CPI. GYE is Greater Yellowstone Ecosystem. Information provided is for illustration only and comes from disparate literature using different methods, different wolf or human populations, and different time periods. These values should not be added together.

Sources: I=Inman et al., 2019; E= ECONorthwest, 2014; CHCC, 2020; L=Loomis, 2016; Y=Yellowstone Wolf Tracker, 2021; D=Duffield et al., 2006 and Duffield, 2019; R= Richieoutfitters, 2020.

We also searched the literature for willingness to pay (WTP) studies about non-market values that we present in Figure 2. Figure 2 adds WTP studies to the consumptive and non-consumptive use categories found in Figure 1, and adds WTP for existence, bequest and option values, where markets have not been established. Economists have developed a variety of innovative methods to estimate non-market values, which are beyond our scope here;[7] most rely on surveys to illicit non-market values. We found only two such studies for the Rocky Mountain West. One older study calculated that the use and non-use value in the GYE would be $208 per household; 75% of that value, $156, is existence and bequest value (Duffield, 1991 as summarized in Loomis, 2016). The most recent study in Washington State (van Eeden et al., 2021) found that a typical household's

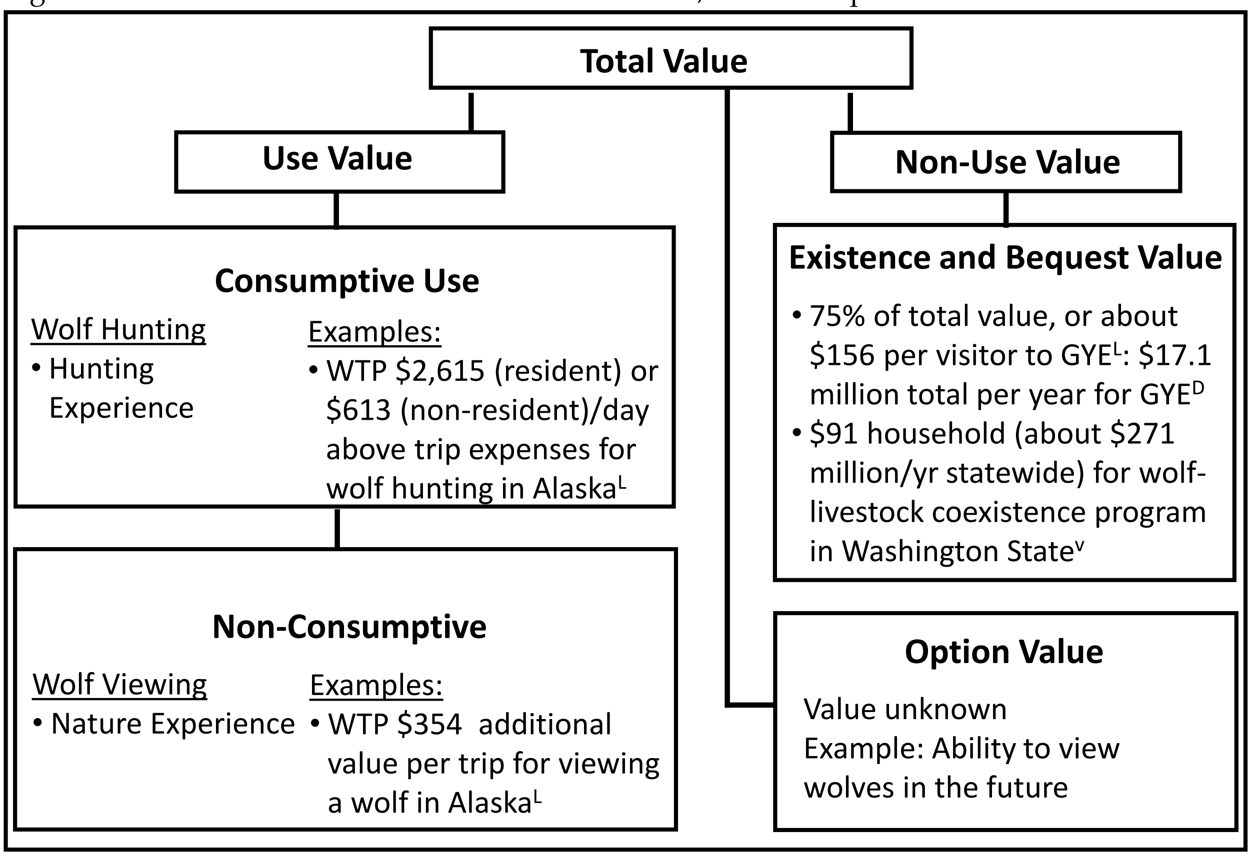
[6] All dollar values are adjusted by the Consumer Price Index to January 2022.

[7] See Champ, Boyle and Brown (2003) for a detailed description of non-market estimation methods, or the "Conservation Strategy Fund: Valuation of Ecosystem Services" for a simple description of non-market valuation methods (https://www.youtube.com/watch?v=0CHIs9dLvxA). Also consider Contingent Valuation, Choice Experiments, Hedonic Pricing and Travel Cost Method videos in the series.

WTP for a publicly funded wolf management program would be about $91/year, which amounts to about $271 million/year for the state. These authors estimate that the economic benefits are over 150 times the costs of the government program to manage wolves in Washington.

There is probably more opportunity to economically gain from non-consumptive uses of wolves than found in Figures 1 and 2, such as private viewing, commercial viewing, research, documentaries, photos, and artwork featuring wolves. While viewing opportunities in Yellowstone would likely be difficult to replicate in other regions, there may be opportunities in other states for more modest returns, especially when coupled with multiple forms of wildlife viewing.

Figure 2: Illustration of non-market values for wolves, with examples from diverse studies[a]



a- Values adjusted by CPI to January 2022. WTP is willingness to pay; GYE is Greater Yellowstone Ecosystem. Information provided is for illustration only and comes from disparate literature using different methods, different wolf or human populations, and different time periods. These values should not be added together.

Sources: D=Duffield et al., 2006 and Duffield, 2019; L=Loomis, 2016; v= van Eeden et. al., 2021.

Economic Costs

Costs generally fall into three categories: personal impacts, commercial production, and public management. Personal impacts occur when people have direct contact with wolves. There are no known studies about the costs of personal impacts, but there are indicators that costs occur. For example, some natural areas post warnings about the risk of wolf attacks when hiking, especially with dogs, which may raise alarm with some people. Although rare, people have been bitten, have experienced standoffs with wolves on the trail, and have even been chased away from campsites (MacKinnon, 2017). These potential negative encounters almost certainly lead some people to shift their recreational activities to other less preferred sites, e.g., further away or less scenic, but studies would be required to confirm their true impacts.

Commercial costs are incurred by livestock producers and commercial hunting outfitters through their influence on big game populations. Livestock producers incur direct and indirect costs. Direct cost is typically the fair market value (FMV) of any livestock killed by wolves. Indirect costs to livestock include: 1) non-lethal injuries, 2) lowered conception rates, 3) reduced weight, particularly of calves and lambs, at sale; 4) repairing fences; 5) repairing buildings; 6) silage and grain losses; and. 7) landowner's time (Harris, 2020). According to Harris' (2020) review of the literature, indirect economic losses are greater than the replacement cost of dead livestock (FMV). For example, one study found that calves in herds that experienced at least one animal lost to predation were 22 lbs. lighter and, when added across all calves in those herds, accounted for a greater loss than confirmed depredations (Ramler, 2014). Some studies found unverified and indirect losses to be up to 6 times that of verified losses (Steele et al., 2013; Sommers et al., 2010), while other researchers found these estimates to be overstated (Hebblewhite, 2011).

Although direct losses from wolf depredation on cattle and sheep accounts for less than 1% of the annual gross income from livestock operations in the Northern Rocky Mountains (Muhly and Musiani, 2009), these costs are unevenly distributed. Therefore, low average industry-wide costs mask high costs for some individual producers. Furthermore, low reported cost estimates do not include indirect costs. An accurate assessment of total costs to livestock is made more difficult by lack of depredation data. For example, the USFWS confirmed a total of 136 cattle (both adults and calves) and 14 sheep (adults and lambs) killed by wolves in 2014 in the Northern Rocky Mountain Region (U.S. Fish and Wildlife Service, 2015). In contrast, the National Agricultural Statistics Service reported 2,835 cattle and 453 sheep killed by wolves in the same region and year (USDA 2015a and b). The USFWS data likely understate losses because they do not include unfound or unreported depredation. The USDA estimates are likely high because they are self-reported by livestock producers. What is known is that mortality caused by wolves is a small economic cost to the livestock industry as a whole, but problematic to some individuals with large losses and high exposure to wolf populations. Finally, little is known about the cost tradeoff between losses and approaches to reduce or prevent livestock depredation.

The government also incurs costs to manage wolves. State government monitors wolves, prepares reports, and manages hunting licenses. The federal government also monitors and manages wolves where they are endangered. The government provides compensation payments through federal, state, and county programs, as do some non-governmental agencies. The USFWS estimated that, in 2015, almost $6.5 million was spent on managing wolves by state, federal, and tribal agencies in a region composed of northern Wyoming, Montana, North Dakota, the Idaho panhandle, Washington and Oregon (U.S. Fish and Wildlife Service et al., 2015).

In Colorado, fiscal analysis of Ballot Proposition 114 forecasts annual costs to the state of $350,000-450,000 for the first 2 years of the planning phase of wolf reintroduction. (Colorado Legislative Council Staff, 2019). Costs are expected to increase as the plan is implemented and wolves are reintroduced. Future costs will depend on the details of the plan developed by Colorado Parks and Wildlife. In summer 2021, state law HB21-1243 was signed into law, appropriating General Fund dollars to support gray wolf reintroduction from sources other than hunting and fishing license fees. $1.1 million was appropriated for FY 21-22.

Finally, some are worried that wolves will negatively impact big game hunting for deer, elk, pronghorn, and moose. At a statewide level, data from the northern Rocky Mountain states of Montana, Idaho, and Wyoming indicate that population sizes of elk (the primary prey of wolves) and hunter harvest have not declined since wolves were reintroduced starting in the mid-1990s. However, at a local level, the effects of wolves on big game can vary. For example, in the Greater Yellowstone Ecosystem, elk numbers are stable or increasing in some areas where wolves and elk interact, but they have declined in some regions. Wolves are more likely to effect big game populations when acting in conjunction with other factors that limit prey populations, such as harsh weather, other predators, and human hunters (Mech 2012). Wolves also can make big game more wary, move more, and use habitat differently by seeking greater cover, which would make hunting more challenging in some areas. An economic analysis in Montana concluded that, overall, wolves have not had a significant economic effect on elk harvest in the state (Hazen, 2012). Rather, demand for hunting shifted from the southwest region near Yellowstone to areas farther away from where wolves were first introduced. Based on the few studies that are available, hunting-related benefits in Colorado may not decline substantially overall statewide when wolves are restored. However, at a local level, if wolves contribute to declines in big game herds and hence hunting opportunities, this will result in costs to those reliant on hunting to support their livelihoods.

Conclusions

Once loathed and eradicated throughout much of their former range, wolves are making a comeback in the Rocky Mountain West. Although wolves have recovered in some areas, controversy remains due to deeply held feelings on both sides. Our goal is to provide an overview of the economic costs compared to benefits of wolves in the Rocky Mountain West. By assembling information from the few published studies available, we create a mosaic of what total economic benefits of wolves might be worth. We could not provide a definitive value because these disparate sources cannot be directly compared. Willingness to pay (WTP) for existence and bequest value alone exceeds $17 million per year just for the Greater Yellowstone Ecosystem. WTP for coexistence in Washington state adds up to nearly $270 million/year. And visitors spend over $45 million per year just to visit the GYE where they might catch a glimpse of a wolf. The cost of co-exiting with wolves includes personal impacts, commercial production, and public management. Sound estimates of the total costs are not known because conflicts are difficult to document. However, spending on state management programs, which includes compensation and cost sharing programs to offset commercial production costs, center between $1-1.5 million per year.

We posed the question at in the beginning of this manuscript: *is coexistence worth the conflict*? Of course, there are many things to consider besides dollars and cents, but from an economic standpoint, a review of available studies suggests that benefits cover costs multiple times over. Therefore, the answer depends on if and how benefits and costs are distributed. Will the majority of people who receive benefits, but incur no costs, be willing to transfer some of those benefits to a minority of ranchers and hunters that bear most of the costs? What is already known is that states with wolves offer cost sharing to help livestock producers adopt non-lethal ways to manage wolves and/or compensation for livestock losses, but budgets can be tight and stakeholders have diverse opinions about how much should be paid (Harris, 2020). For example, the Washington state study reported that the state spent $1.64 million on the costs of their wolf management programs in contrast to the 270 million projected benefit (adjusted by 2022 CPI). The information presented in this study can help all sides develop and implement more effective and equitable policies through a better understanding about the benefits and costs of a sustainable wolf population.

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Economic Approaches for Managing Migratory Bird Habitat Across Multi-Owner Landscapes

By Sonja H. Kolstoe[1], Jeffrey D. Kline[2], Luanne Lohr[3]

Abstract

Migratory bird populations rely on a continuum of habitat along their migratory path. Along the Pacific Flyway in the United States, this habitat consists of land under a mix of different management entities and landownerships including federal, state, and local land management agencies, Tribes, and private landowners. Effective management of migratory bird habitat relies on coordination among these different entities to ensure both sustained flyway continuity and habitat quality sufficient to maintain healthy migratory bird populations. We consider the challenges involved in the conservation planning problem in managing migratory bird habitat and suggest how economics can inform developing and facilitating coordinated strategies.

Short description (250-character limit): Migratory birds rely on a continuum of habitat on land owned and managed by different entities, from various government agencies to private landowners. We discuss how economics can inform efforts to improve the coordination of conservation planning and management.

JEL classification: Q24, Q26, Q28

Keywords: Migratory birds, Pacific Flyway, habitat management, habitat enhancement, conservation, spatial and temporal coordination

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Conflicts of interest: All three authors are employed by the USDA Forest Service.

I. Challenge of Multi-Ownership Landscapes

Migratory birds rely on continuums of habitats along their species' range, some of which may be thousands of miles in length. The individual habitats along these migratory flyways provide the landscape characteristics (e.g., food, cover, etc.) necessary to support summer breeding, winter non-breeding periods, and spring and fall migration. These factors add spatial and temporal complexity to conservation planning by expanding the areas of consideration from one to four landscapes. For optimal habitat management, conservation efforts must be coordinated across multiple types of landowners on a single landscape, a planning problem that is significantly more complex across

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multiple landscapes. International agreements address coordination across international borders, shifting the problem focus from facilitating international cooperation across borders to coordinating domestic conservation efforts. In the United States (U.S.) the Migratory Bird Treaty and the Western Hemisphere Convention are examples of international agreements that guide the international coordination effort, and the Federal U.S. Government assumes oversight responsibilities (through federal laws and agencies) for the coordination of the country's overall bird conservation objectives across different landowner types (Anderson et al., 2018; U.S. FWS, n.d.). There are four major flyways in the U.S. (Pacific, Central, Mississippi and Atlantic shown in the reference map in Figure 1) and we focus on the Pacific Flyway as our example.

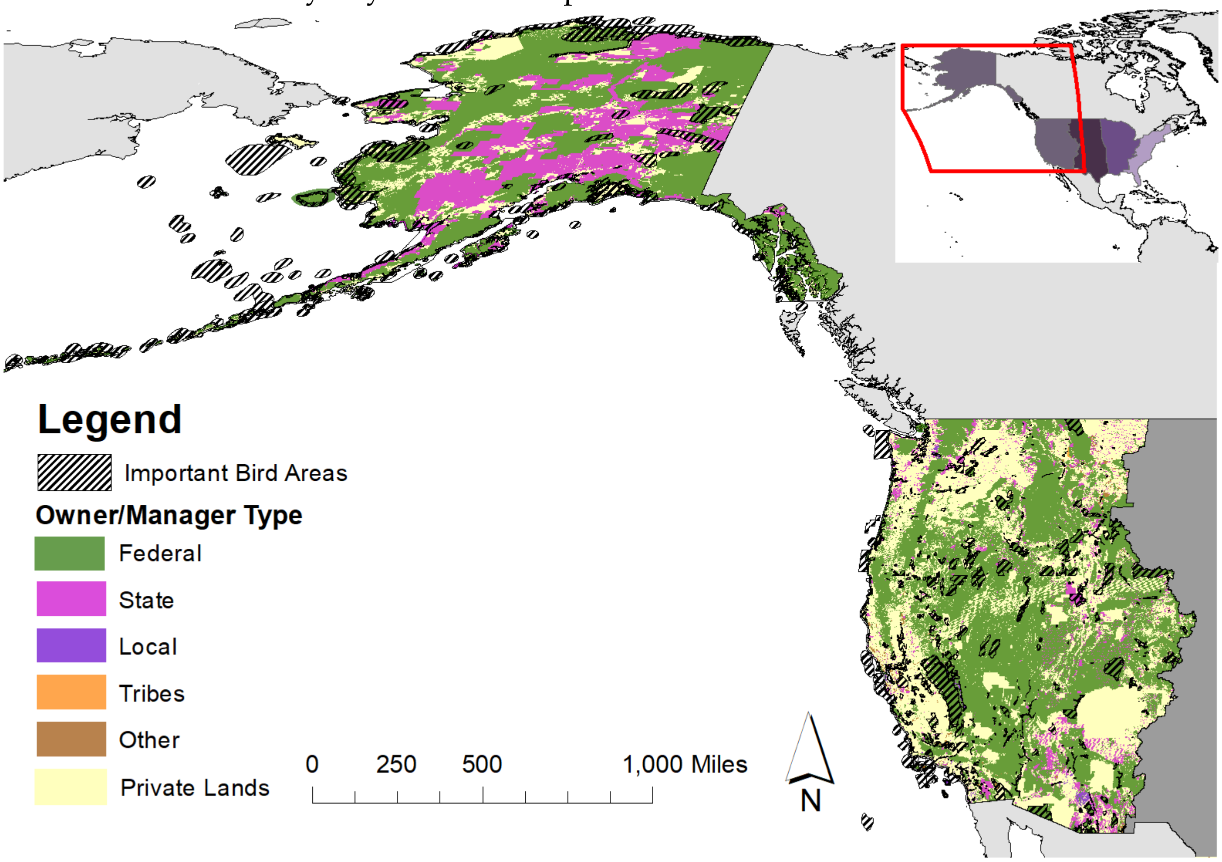

Figure 1. The main map above shows the manager types of protected land in the Pacific Flyway, grouped by Federal, State, Local, Tribal and Other. The reference map in the upper right-hand corner is of North America and shows the portions of the Pacific Flyway in the U.S. along the west coast as well as the three other flyways in the U.S. (Central, Mississippi, and Atlantic). The two largest federal land managers in the Pacific Flyway are the Bureau of Land Management and the Forest Service. Other federal land managers are: Agricultural Research Service, Army Corps of Engineers, Bonneville Power Administration, Bureau of Ocean Energy Management, Bureau of Reclamation, Department of Defense, Department of Energy, National Ocean and Atmospheric Administration, National Park Service, Fish and Wildlife Service, Natural Resources Conservation Service, and other Federal (TVA, ARS, BPA, DOE, etc.). BirdLife International developed the IBA criteria and works with partners across the globe. More information about Important Bird Areas (IBAs) and the criteria can be found on their website: http://datazone.birdlife.org/site/ibacriteria. In the U.S., the National Audubon Society is their partner organization and more information about IBAs within the U.S. can be found on their website: https://www.audubon.org/important-bird-areas. The main map's projection is Equal Earth (Sphere Equal Earth Americas), and the geographic coordinate system is GCS Sphere GRS 1980 Mean Radius. The map uses data from the Protected Area Database (PAD) 2.1 (U.S. Geological Survey (USGS 2020)), Important Bird Areas in the U.S. (Audubon Society 2021), and the administrative flyways from the U.S. FWS (2021). The reference map projection is Compact Miller (Sphere Compact Miller).

The Pacific Flyway (Figure 1) extends north-south through the western states of the U.S. from the U.S.-Mexico border into Alaska. Migratory birds in the Pacific Flyway have journeys spanning the gamut of a few hundred miles within a state to the extreme of the range extending several thousand miles. The longer migratory paths in the Pacific Flyway connecting summer breeding grounds in Alaska and Northern Canada with wintering non-breeding grounds in the Southwestern U.S. or Central or South America, or in the extreme case of the Artic tern: Antarctica. Competing land and water uses, natural disturbances (e.g., wildfire) and severe drought in the American West have led to habitat degradation and population declines for migratory species (Anderson et al., 2018; Rosenberg et al., 2019). The U.S. domestic coordination problem is evident by comparing the current essential habitat identified as Important Bird Areas (IBAs), using the international criteria for migratory birds, to landownership type (Figure 1). Lands within the Pacific Flyway identified as IBAs are held under a mosaic of different ownerships and management entities. In addition, there are risks affecting habitat, including human-caused disturbance involving land-use conversion and the spread of invasive species, and natural disturbances such as fire, drought, and climate change (Kirby et al., 2008; Reynolds et al., 2017). All these effects may cause degradation of habitat suitability if the spatial and temporal effects of the conservation planning problem are ignored. Without coordination, individual land managers, whether they are public land managers or private landowners, will independently choose to pursue strategies based on their own objectives. Even with similar intentions, independent actions may fail to realize networking benefits, and may result in a suboptimal conservation effort.

We identified two main types of ownership:(1) governmental entities, including local, state, federal, tribal, and other; and (2) private landowners, including industrial and nonindustrial owners. Although there are differences in the specific goals among different entities and ownerships, the two groups may be distinguished by their objectives in providing ecosystem services. Government entities (e.g., federal, states, and tribes) are entrusted with representative, legislative, and other authorities related to bird and habitat protection to preserve populations for both the present and future. Private landowners are generally utility maximizers and focus on ecosystem service benefits that generate financial return, and/or provide individual benefit to the landowner. Sometimes this can lead to the underprovision of habitat. Private, nonindustrial landowners tend to exhibit more heterogeneous goals and pursue a mix of financial and ecosystem services objectives which often is correlated with the size of land holding among individual landowners. Landowners of smaller parcels are more likely to consider financial objectives as predominant (Butler et al., 2020). Nonindustrial landowners may incorporate habitat objectives that are compatible with their financial objectives in which they would not otherwise invest. While such "voluntary" provision of public habitat benefits is noteworthy, it does not fully address the underprovision of habitat because such investments are not deliberately and systematically applied in critical locations. A cohesive and effective strategy for protecting and enhancing migratory bird habitat all along the Pacific Flyway would address the diversity of management entities and landownerships and their heterogeneous land management goals and objectives.

Public agencies and managers in the U.S. tasked with implementing conservation strategies generally can affect conservation via three avenues.[4] The first is biophysical and involves investing in

[4] The mission of government entities relates to their responsibility in the management of land for the conservation of species and their habitat. Below are examples of the missions from the four main U.S. federal agencies who manage federal lands. The Bureau of Land Management (BLM) mission is "To sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations." (U.S. DOI BLM, n.d.) The Forest Service (FS) mission states "The mission of the Forest Service is to sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations" (USDA FS, n.d.). The National Park Service (NPS)

landscape manipulations which conserve and/or enhance migratory bird habitat. The second avenue is socioeconomic and involves incentivizing private landowners to conserve and/or enhance habitat on private lands through regulation, financial incentives (e.g., taxes, subsidies), or education and technical assistance. The final avenue is institutional and involves negotiating, planning, and monitoring conservation and protection strategies across a mosaic of landowners and managers. Selecting what combination of effort might be most effective requires an understanding of the objectives of different landowners, as well as the biological requirements of the species of conservation interest. In some cases, individual actions might collectively complement each other. While in other cases, they might be competitive or antagonistic to one another. The challenge is to improve complementarity of actions among different types of landowners, to cost-effectively protect and enhance migratory bird habitat across the mosaic of management entities and landownerships.

We consider the conservation planning problem involved in managing habitat for migratory birds across multiple types of landownerships along the Pacific Flyway and suggest ways in which economists can contribute to habitat protection and enhancement efforts. To provide context, we present a brief history of migratory bird conservation policy in the U.S., then offer a general conceptual approach to the conservation planner problem at the flyway scale. Then, we outline future potential areas of research to improve economists' understanding of the conservation planner problem at the flyway scale.

II. Migratory Bird Conservation in the US

Migratory bird conservation has long been a national policy goal in the U.S., and the focus of several acts of Congress (Anderson et al., 2018). Initially, efforts focused on conserving habitat predominately on public lands (e.g., National Wildlife Refuge system, National Environmental Policy Act), regulating critical habitat (e.g., Endangered Species Act), and pollution sources (e.g., Clean Air Act and Clean Water Act whose objectives include reducing pollution to improve human and environmental health) (Kerkvliet et al., 2021; Liang et al., 2020). Over time, policy and conservation efforts evolved to also include collaborative efforts targeting conservation on private lands (e.g., Conservation Reserve Program, Sage Grouse Initiative, etc.). Apparently, conservation efforts on public lands alone were insufficient to sustain migratory bird populations (Anderson et al., 2018; Kerkvliet et al., 2021). The goal of these efforts are extended in new initiatives in the U.S. aimed at addressing declining biodiversity such as the America the Beautiful Initiative (U.S. Department of Interior (DOI), n.d.), which specifically focuses on the goal outlined in Executive Order 14008 of "conserving 30 percent of the nation's land and water by 2030.[5]" Although ambitious in its intention, this latest planned conservation effort will face the same challenges of affecting conservation across a mosaic of different ownerships and management entities.

Migratory birds throughout North America are under public trust, with oversight and management responsibilities falling to the federal government (Anderson et al., 2018). Birds provide many different ecosystems service benefits of ecological and economic importance to include

mission states "The mission of the National Park Service is to preserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations" (U.S. NPS, n.d.). The U.S. Fish & Wildlife Service (FWS) mission is "Working with others to conserve, protect and enhance fish, wildlife and plants and their habitats for the continuing benefit of the American people" (U.S. FWS, n.d.).

[5]Exec. Order No. 14008 3 C.F.R. 86 (7619-7633) (2021). The E.O. can be found at: https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad.

recreation, seed dispersal, pest control, nutrient cycling, ecosystem engineering, and pollination, among others (Whelan et al., 2008). Birds were once viewed as an infinite resource in the U.S., though the 19th and 20th century revealed the finite nature of these populations, prompting legislative conservation action. Early on, this primarily took the form of command-and-control methods such as (1) defining hunting rules and regulations; (2) land use restrictions to protect endangered species habitat; and (3) banning of dichloro-diphenyl-trichloroethane (DDT) (Anderson et al., 2018; Ando and Langpap, 2018). More recently, conservation efforts include market-based instruments such as: (1) payment for ecosystem services; (2) auctions to keep habitat flooded during critical migration periods; (3) conservation easements; and (4) Conservation Reserve Program (Anderson et al., 2018; Ando and Langpap, 2018). With the broadening species scope of migratory bird conservation by the end of the 20th century came a gradual evolution toward partnerships and coordination of efforts, reflecting the spatial extent of migratory species' ranges. An early example of such a cooperative effort—the North American Waterfowl Management Plan—spanning North America and cross international borders marked the beginning of implementing partnerships across multiple landownership and management entities (U.S. FWS, 2017). These efforts focus on leveraging existing conservation programs (e.g., conservation easements, Conservation Reserve Program, Land and Water Conservation Fund, etc.) to provide information and financial incentives for undertaking conservation on private lands paired with efforts on public lands to address population declines. These measures are largely voluntary and require participants to opt-in, thus incentives and partnerships alone may not be enough, as evident by the findings of Rosenberg et al. (2019) who noted an overall decline in bird populations. A bright spot in the Rosenberg et al. (2019) study were the increases observed in bird populations of waterfowl and raptors where past conservation efforts have been focused.

III. Conceptual Approach to the Conservation Planner Problem

Management and recovery efforts of migratory bird species in the U.S. occur primarily through conservation and enhancement of habitat necessary to support these populations. Ideally, cost-effective conservation investments (e.g., to acquire, protect and/or enhance necessary habitat) would consider the comparative advantages that different sites offer in terms of ensuring overall population success. The spatial and temporal dimensions of migratory birds and their habitat needs also must be considered. Conceptually, the conservation and management of migratory bird habitat can be viewed as occurring within a human and natural systems context (e.g., Kline et al. 2017) that features public land management agencies and diverse private landowners making decisions across landscape characterized by a mosaic of landownerships and land uses all along the flyway (Figure 2). Public land management agencies can influence habitat directly through the management of public lands, as well as indirectly through the implementation of policies and programs that incentivize complementary management activities on private lands. Public and private management activities affect changes in biophysical conditions of the landscape, resulting in either positive or negative outcomes for migratory bird habitat. Biophysical conditions also are influenced by disturbance factors, such as fire, insects, and disease, which influence biophysical outcomes of management. The biophysical outcomes, and potentially related economic outcomes related to agriculture, forestry, and other natural resource outputs, in turn act as feedbacks further influencing human-natural system dynamics. The whole process takes place within a broader context characterized by largely exogenous external factors, such as markets, politics, and climate, which exert further influence on public land managers, private landowners, and biophysical (e.g., habitat) conditions.

The conservation planning problem can be conceptualized as a prioritization process to identify habitat protection and enhancement locations and activities across the multi-agency and multi-ownership landscape. The conservation planning problem necessarily calls for information concerning: (1) the spatial and temporal biophysical requirements of migratory bird species of interest under present and future conditions; (2) the objectives of public land management agencies and private landowners who control land along the flyway; (3) how disturbances and other key external factors might influence future biophysical changes and thus future habitat needs; and (4) how best to coordinate needed collaborative efforts in ways that enable complementarity among public and private land management (Figure 2). Information on these four aspects provides insights on the conservation comparative advantages of different sites on a landscape.

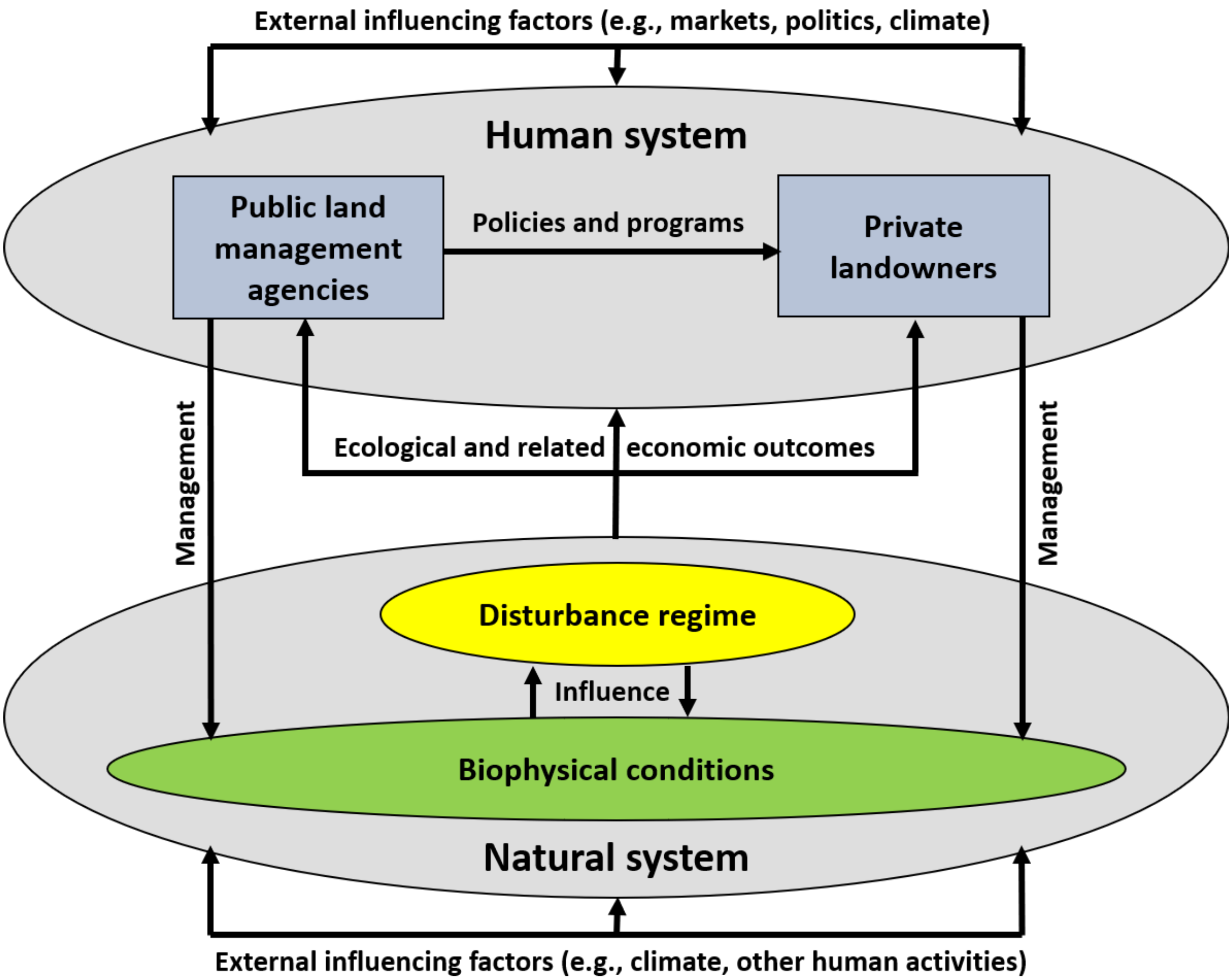

Figure 2. Migratory bird conservation occurs within a policy and management context characterized by the interactions occurring between public land managers and private landowners interacting with temporally-dynamic, biophysical conditions and disturbance regimes, all in a broader context of external factors including climate change and socioeconomic conditions. Habitat protection and enhancement and devising effective conservation strategies, depends on gaining an understanding of the factors affecting biophysical characteristics of migratory bird habitat, and how they can be influenced through land management activities of public land management agencies and private landowners. It also depends on gaining an understanding on the biophysical and socioeconomic factors of private agency and private landowner management, and how those activities could be influenced to affect improvements in habitat protection and enhancement. Figure adapted from Kline et al. (2017).

From a pragmatic perspective, devising cost-effective conservation strategies for landscapes accounts for the varying objectives of different public land management agencies, and different objectives and types of private landowners, as well as account for the range of potential future biophysical conditions give environmental risk factors (e.g., climate change, drought, wildfires, insects, and diseases). From a modelling perspective, we can think of the conservation planning problem for migratory birds being one where the model accounts for the landowners and landscapes spanning a migratory path. Within this path there are $i=1,\ldots,I$ different ownership types (e.g., the main two described above: (1) governmental entities, including local, state, federal, tribal, and other; and (2) private landowners, including industrial and nonindustrial owners) index by $j=1,\ldots, J$ owners within each i across $t=1,\ldots,T$ time periods spent on a landscape along the path migratory birds travel (e.g., t may be indexed by season, month, week, or day depending on the desired level of flexibility of the model). This model can be further indexed by migratory bird species, $n = 1, \ldots, N$ if the conservation objective is for multiple migratory bird species. Whether the model is seeking to model conservation investment for a single or multiple migratory bird species, the objective is to balance the returns where returns are to be measured in terms of ecosystem service benefits per unit of cost rather than benefits or cost alone and future risk as given by forecasted scenarios (e.g., climate change, drought, wildfires, insects, and diseases, etc.) (Alvarez et al., 2017; Ando and Mallory, 2012; Ando et al., 2018; Ando and Langpap, 2018).

Modern Portfolio Theory (MPT) model from the conservation finance literature is increasingly being used to guide decisions about where to make conservation investments on a landscape for various species' conservation efforts (e.g., fish, salamanders, birds, etc.) (Alvarez et al., 2017; Ando and Mallory, 2012; Ando et al., 2018; Ando and Langpap, 2018). Given limited conservation funding, the idea behind using MPT over a simple strategy of diversification is to increase the cost-effectiveness of conservation efforts and investments by selecting conservation investments which optimize the expected return of the portfolio and minimize the risk (Ando and Mallory, 2012). The expected return in this case is typically defined as a measure of benefit per unit of cost (Ando et al., 2018; Ando and Langpap, 2018). The weights of the portfolio are based on the investments on the landscape. Thus, a portfolio's expected return value is the weighted average of the return of all assets held in each scenario (Ando and Mallory, 2012).

The focus of the MPT model's optimization problem is the asset's future expected performance across a range of future scenarios given the conservation planning objective(s). The MPT results give the expected return and variance (which may be reported in standard deviations) for each portfolio across future forecasted scenarios. Plotting them on a graph identifies the set of efficient portfolios located on the frontier (Alvarez et al., 2017; Ando and Mallory, 2012; Ando, Howlader, and Mallory, 2018; Ando, Fraterrigo, et al., 2018; Ando and Langpap, 2018). This frontier identifies the menu of options and can be thought of as the "protection possibility" frontier, by identifying the land parcels on a landscape to protect or enhance. MPT may help in improving the cost-effectiveness of conservation investments relative to a simple diversification strategy when (1) investments have negatively correlated outcomes across scenarios; (2) the second-best expected return is almost as good of a return as identified under the first-best expected return; and (3) there is little uncertainty in the outcomes of the assets across future scenarios (Ando, Fraterrigo, et al., 2018). Also, if the conservation planning is for multiple species and/or objectives, then scenario correlations between objectives need to be considered, as different issues may arise if the objectives respond similarly or differently to forecasted scenarios (Ando, Howlader, and Mallory, 2018). Other hierarchical models such as Multi-Decision Criteria Analysis may also prove useful to understand the tradeoffs and constraints in the conservation planner problem and may be used in conjunction with MPT (Eaton et al., 2019).

IV. Existing Partnership Efforts

Partnership efforts across governmental agencies and private landowners are increasingly common in practice as stakeholders have shown the ability to unite behind a common goal (e.g., North American Waterfowl Management Plan, Sage Grouse Initiative, etc.). However, to date it is not well understood why partnerships are successful (or not) about achieving their objective(s), indicating this is an area that merits further study. For an example of an analysis of a recent partnership effort, we can look at the study by Wollstein and Davis (2017) who conducted a qualitative analysis of the Sage-Grouse Initiative (SGI) to understand private landowners' voluntary conservation actions and efforts in Lake County, Oregon, as sage grouse were being considered for listing under the ESA. Their results reveal private landowner participation was largely motivated by a complex combination of incentives, both positive and negative, to include landowners' desire to reduce future uncertainty and avoid being subject to ESA restrictions. In this instance, the threat of regulatory action under the ESA provided an upper bound to the cost private landowners may incur in the future if ESA restrictions were to be implemented and the status quo with conservation actions provided a set of lower bound alternatives. Governmental agencies provided financial and technical assistance to support these voluntary conservation measures being undertaken by these private landowners in their Candidate Conservation Agreements with Assurances (CCAAs) (Wollstein and Davis, 2020). In Oregon alone, over 150 private landowners signed CCAAs whose commitment represented protection and enhancement on over 2.3 million acres of sage grouse habitat on private land (Wollstein and Davis, 2020). Partnerships such as those developed under the SGI represent what is feasible when there are focused efforts on a particular objective. Such efforts provide a template of how to promote a continuum of habitat across land parcels and ownerships needed to sustain a biodiverse ecosystem for migratory birds and other species.

V. Moving Forward

Given the complex nature of the conservation planning problem, we suggest that economists can most effectively address identified issues around migratory bird habitat by: (1) describing the preferences of landowners toward conservation of migratory birds; (2) characterizing costs and benefits of ecosystem services associated with migratory birds and their habitats; (3) evaluating comparative advantages for habitat protection and enhancement; and (4) evaluating partnership cooperation opportunities to increase habitat continuity and quality (i.e., decrease habitat fragmentation and increase restoration) along the spatial and temporal extent of the flyway. Economists, working collaboratively with wildlife and other biophysical scientists, may devise decision frameworks recognizing net flows of benefits resulting from habitat protection and enhancement. In addition, economists can determine optimal applications of protection and enhancement efforts (e.g., spatial subsidies, education, and technical assistance, etc.). Understanding tradeoffs across land ownerships requires being able to characterize the benefits and costs for individual and joint action when seeking to determine what conservation efforts to prioritize such as protect and/or enhance.

Due to the nonmarket nature of many ecosystem service benefits, Mallory and Ando (2014) and Alvarez et al. (2017) point to complications in estimating benefits of assets for models such as MPT when they are measured in different units (e.g., monetary and non-monetary). Provisioning, regulating, and supporting ecosystem services as well as other cultural ecosystem services could be quantified to describe the net benefits from actions taken on both public and non-public lands. To date, valuation estimates exist primarily for benefits from birdwatching and hunting and typically in specific locations. Data collection on bird populations over time has provided information needed for scientists to calculate nonmarket benefits of migratory birds and associated ecosystem services. Crowd-sourced data (e.g., citizen science projects, social media, wildlife webcam viewing, etc.) complement existing data collected by governmental agencies and provide additional resolution on a larger spatial and temporal extent than previously available (Keeler et al., 2015; Fisher et al., 2018; Kolstoe and Cameron, 2017; Kolstoe et al., 2018; Loomis et al., 2018). Designing appropriate methods for testing the validity and reliability of crowdsourced data will unlock a large source of value information pertaining to migratory birds, a current void in the literature (Bagstad et al., 2019). Statistically testing the data, as well as addressing the sample selection bias present in such samples of convenience, is critical to confident modeling with the data (e.g., Cameron and Kolstoe, 2022; Kolstoe, Vander Naald, Cohan, 2022). Ideally, future valuation work will consider the interdependence of species within ecosystems and the importance of diverse ecosystems as biodiverse landscapes have been found to be more ecologically resilient (Baumgärtner and Strunz, 2014; Ando and Langpap, 2018). This could enable providing information regarding the value of migratory birds to the U.S. public, and more general biodiversity values, and how the ecosystem services are affected by natural and human-caused disturbance. These valuations could also factor into models of cooperation to better understand the set of possible bargaining solutions to obtain a given objective.

VI. Conclusion

Economists can likely make their greatest contribution to migratory bird habitat protection and enhancement by focusing research efforts on select aspects of the conservation planner problem. Addressing the spatial and temporal coordination challenge of the conservation planner problem for migratory birds involves both biophysical and socioeconomic considerations. Biophysical considerations include knowledge about the specific habitat needs of different migratory bird species and identifying those locations along the Flyway that will provide the greatest chance for continued success of different species of management interest. Socioeconomic considerations include identifying the mix of investments and incentives necessary to attain the desired biophysical characteristics, given the heterogeneity in the goals and objectives of the various public land management entities and private landownerships involved. The key tasks for economists seeking to help resolve this challenge include: (1) assisting in evaluating the comparative advantages of habitat protection and enhancement in different locations; (2) providing decision support to public land managers to effect protection and enhancement activities where desired; and (3) developing approaches to incentivizing desired activities among private landowners while recognizing the mix of landownership objectives. These tasks become more critical as climate change and other disturbance factors increasingly shift and impact bird ranges and habitats (Anderson et al., 2018; Rosenberg et al., 2019).

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Incorporating Landowner Preferences into Successful Migratory Species Conservation Policy

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1. Introduction

Migratory species conservation has become a growing policy concern worldwide (Harris et al., 2009; Berger, 2004). The unique characteristics of migratory species challenge the effectiveness of existing conservation programs that have protected other wildlife (see Conte et al., 2021). Effective conservation programs targeting migratory birds differ from programs designed to protect migratory fish or ungulates (i.e., hoofed mammals) given differences in species behavior and habitat continuity requirements. Therefore, conservation programs must be context-specific, and dependent on species, place, and time (Conte et al., 2021).

Migratory species, especially land migrators such as ungulates, need spatially explicit conservation actions along pre-defined migration routes. Unlike sedentary species whose habitat is limited in scope, migratory species often traverse the landscape and require habitat across expansive, seasonal areas. As a result, effective conservation programs require significant coordination among landowners and managers to ensure habitat connectivity (Albers et al., 2021). Without coordination, existing conservation programs are likely to result in habitat fragmentation (Panchalingam et al., 2019), which can be especially detrimental to migratory species.

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For migratory species that require contiguous habitat along their migratory route, gaps in one conservation action may limit the effectiveness of others. In such situations, conservation programs that rely on voluntary actions by landowners must elicit high landowner participation and coordination. Failure to account for landowner preferences for conservation program features (e.g., eligibility requirements and payment schemes) can severely limit conservation effectiveness (Mason et al., 2020).

Although there is growing literature on policy to incentivize conservation coordination (e.g., Panchalingam et al., 2019; Banerjee et al., 2014; Parkhurst and Shogren, 2007; Parkhurst et al., 2002) and on landowner preferences for conservation program features (e.g., Brown et al., 2019; Mozzato et al., 2018; Zimmermann and Britz, 2016; Lastra-Bravo et al., 2015; Raggi et al., 2015; Uthes and Matzdorf, 2013; Defrancesco et al., 2008), landowner preferences in situations with a need for spatially targeted conservation actions with high levels of coordination is not yet well understood (Goldman, Thompson, and Daily, 2007). Further, since successful conservation programs for migratory species is highly context-dependent, landowner preferences need to be understood not only for the specific conservation action needed, but also the location and timing of conservation actions.

We discuss the existing literature on landowner preferences for conservation and the case of ungulate migration in Wyoming to highlight the challenges and some research needs for creating effective conservation programs. One unique challenge for ungulate protection in Wyoming is the need for conservation coordination among both private landowners and public land managers. Although landowner preferences for conservation programs is just one component needed for successful protection of migratory species, it is vital to creating successful policy (Mason et al., 2020). Further, since landowners may interact with, and have some influence on, public land management decisions, a fuller understanding of landowner preferences for migratory species' conservation programs may also aid in understanding public land manager support for such programs.

2. Landowner Preferences for Migratory Species Conservation

Many conservation programs depend on voluntary participation from willing landowners, making it critical to understand the incentives and motivations of potential landowner participants (see Borges, Emvalomatis, and Lansink, 2019; Dessart et al., 2019). Recent literature has focused on determining the factors that influence landowner participation in conservation actions. All else equal, shorter contract duration, lower paperwork burden, and increased flexibility in contract terms are preferred (see for example, Hansen et al., 2018; Christensen et al., 2011; Espinosa-Goded, Barreiro-Hurl, and Ruto, 2010). Although none of these studies focused on the specific needs of migratory species, these basic landowner preferences would presumably persist for their conservation as well. Yet the specific need for spatially coordinated conservation may lead to additional needs for successful conservation policies for migratory species.

Through laboratory experiments, Panchalingam et al. (2019) found that current conservation programs may incentivize landowners to only conserve fragmented habitat, suggesting the need for policy that incentivizes coordination among landowners. Coordination incentives may be most critical for conservation policies for migratory species where actions taken along a migratory route may be of little to no value if the route is compromised elsewhere. One such coordination incentive is the agglomeration bonus, which introduces an additional payment to the base payment when conserved land parcels border one another to create contiguous habitat. The additional payment provides a coordination incentive to private landowners to reunite fragmented habitat across property boundaries (see Parkhurst et al., 2002; Smith and Shogren, 2000). Although, the agglomeration bonuses have been shown to provide desired spatial patterns of habitat cost-effectively in laboratory experiments (e.g., Banerjee et al., 2014; Parkhurst et al., 2002), landowner preferences for this coordination incentive are less known.

Through a choice experiment, farmers were found to be willing to participate in a tree-planting program in Germany, Spain, and Switzerland, but were resistant to coordinating their actions with neighbors without additional coordination incentives (Villamayor-Tomas et al., 2019). This result supports the idea that additional incentives, such as an agglomeration bonus, may be necessary in instances where coordination is desired for environmental reasons.

Ferré et al. (2018) found landowner support for coordination incentives. The authors conduct an experiment where farmers in Switzerland are asked to undertake collective action to raise the water table. This action would harm some farmers' profits but will improve environmental outcomes and also potentially improve private agricultural profits in the long term. No environmental benefits are generated unless all farmers decide to take collective action, so agglomeration payments are made only if all players in the group choose the environmentally desired activity. Ferré et al. (2018) find that a constant agglomeration payment, rather than one that varies with farmer opportunity costs, generates greater participation at lower program cost, perhaps due to social concerns regarding equity.

Studies focused specifically on landowner preferences for spatial coordination provide additional insights. In a choice experiment survey of wine growers in France, Kuhfuss et al. (2015) find that a conservation program to encourage less herbicide-intensive practices had higher participation rates, enrolled more land, and was more cost-effective when additional payments for spatial coordination were included. Both studies demonstrate that a conditional collective bonus improves participation and increases environmental benefit at an overall lower program cost: Ferré et al. (2018) finds collective action was required to realize the benefits, whereas in Kuhfuss et al. (2015), the threshold was put in place to encourage participation rather than due to any underlying physical trigger.

In Sheremet et al. (2018), private forest owners in Finland were asked to choose between disease and pest-control programs with different attributes, including a spatial coordination bonus, in a choice experiment. In the authors' preferred econometric specification, the bonus has exactly the same coefficient as the payment level, perhaps suggesting less landowner interest in spatial coordination in this particular context. These studies suggest landowner preferences for spatial coordination may depend on landowner perceptions and the specific context of a given policy. Therefore, the success of conservation policy that includes a coordination incentive feature therefore must be context-specific, and dependent on species, place, and time.

3. Migratory Ungulates and Conservation in Wyoming

The case of ungulates in Wyoming highlights the complexity of the migratory species conservation challenge and the need for land managers and policy makers to understand landowner preferences for conservation. Ungulate migratory routes require spatial and seasonal coordination across multiple public and private landowners for successful conservation, which creates a complex challenge for policy makers. Mule deer, elk, pronghorn antelope, moose, and bison in Wyoming often migrate long distances between summer and winter ranges (Kauffman et al., 2020). Migration allows these ungulates to take advantage of seasonally available forage throughout the year and avoid harsh winter conditions in order to increase individual and collective survival (Aikens et al., 2017; Merkle et al., 2016). While strategically using the landscape to improve survival, the various ungulates that migrate through Wyoming can have migration routes ranging from a few miles long, to well over 100 miles, and migration periods taking a few days to several months. The Red Desert to Hoback mule deer migration route, for example, spans 150 miles (second longest known migration in North America) and deer spend 4 months per year traversing the route (Kauffman et al., 2020).

These iconic ungulate migrations of big game species help contribute to local communities through tourism and recreation activities. In Wyoming, big game hunting, fishing, and wildlife watching contributed $802 million in direct spending, generating over $1 billion in total economic activity in 2017 (Taylor, 2018). Agricultural producers reported $29 million in agricultural tourism and recreational services as farm-related income in 2017 (NASS, 2021). Spending on outdoor recreation added $1.7 billion to the state economy, accounting for 4.2% of the state's gross domestic product in 2019 (US BEA, 2020). These economic values and the migratory species themselves, however, are being threatened. Through habitat fragmentation from energy development, roads, and other disturbances from anthropogenic sources, some ungulate species in Wyoming are in decline and historic migration routes have been lost (Berger, Cain, and Berger, 2006). For instance, mule deer abundance decreased 36% in Wyoming during intensive energy development (Sawyer et al., 2017).

Given the wealth of migratory species in Wyoming and the importance of wildlife to the economy, effective conservation efforts are critical to the continued fitness and survival of these migratory species. Effective conservation programs need to encompass a range of characteristics about both migratory behavior and the migration route itself (Wyckoff et al., 2018). Scientists have documented, for example, that many migration routes link key stopover sites—locations along a route where animals spend proportionately more time during their migration (Sawyer and Kauffman, 2011). These sites appear critical for route conservation; however, their importance must still be assessed within the broader context of route continuity.

Both federal and state migration corridor conservation policies use these scientifically defined routes and route characteristics to focus conservation funding on the landscape. In 2018, the US Department of Interior issued Secretarial Order 3362, "Improving Habitat Quality in Western Big-Game Winter Range and Migration Corridors," which directs state agencies in 11 western states to focus on state priority migration corridors (US DOI, 2018). Scientists and policy makers in Wyoming were working to map and protect migration corridors even before this Secretarial Order was issued (WGFD, 2019). Specifically, the Wyoming Game and Fish Department (WGFD), directed by the Wyoming Game and Fish Commission, outlined three migration corridors (WGFD, 2019). In 2020, Governor Gordon of Wyoming issued an executive order designating these three migration corridors for mule deer and establishing a process for establishing new migration corridors for mule deer and antelope (WY GO, 2020). This executive order directs state agencies to protect the movement of mule deer and antelope between seasonal ranges in designated migration corridors, including through conditions on state-issued permits for surface activity.

Under the executive order, local working groups with representation from county and tribal governments, as well as recreation, conservation, agriculture, and industrial interests, work to evaluate the effectiveness of each corridor designation on the migratory herd as well as opportunities for improved conservation and impacts of restrictions on development. The executive order does not apply to privately owned land, so all migration corridor conservation on private lands is voluntary. However, the order does state that private landowners should be "encouraged and incentivized to manage for the functionality of migration corridors" (WY GO, 2020). This language suggests a clear role and path forward for the development of voluntary conservation of habitat for migratory species on private lands.

Funding for projects aimed at improving state-designated migration corridors on private lands in Wyoming originates from a variety of federal, state, and county agencies, trusts, and project offices working in partnerships with national, regional, state, and local non-profit organizations. Two of the most commonly implemented measures are wildlife-friendly fencing and conservation easements.[6] Wildlife-friendly fencing is designed to allow antelope, mule deer, and other ungulates to pass through fencing that would otherwise impede their passage. Under a conservation easement, landowners work with a land trust to permanently protect their land from future development, thereby reducing *new* pressures on migration corridors from residential and other human development.

In addition to fencing and conservation easements, habitat leasing is an emerging market-based conservation tool that may take hold in the future. It has been supported by at least one of Wyoming's designated migration corridor working groups (Nagler, Bannon, and Rashford, 2021; PVMCWG, 2021). Under a habitat lease, a landowner would receive an annual payment for providing wildlife habitat for the length of a multi-year contract.

Land ownership characteristics along a migration route can also significantly influence conservation features and complexity. Much of the western US is characterized by a complex mix of public and private land ownership. Migration routes cross through lands managed by multiple federal and state agencies as well as private landowners. All of these entities have different incentive structures, legal authority, and management goals. Adding to this complexity is the potential for additional owners/managers with subsurface mineral rights – the development of which can influence surface disturbance and the integrity of migration routes. Along the Red Desert to Hoback mule deer migration route in Wyoming, for example, land is actively managed by multiple federal and state agencies, including the Bureau of Land Management (with multiple field offices having management responsibility), US Forest Service, National Parks Service, WY Game and Fish, and WY Office of State Lands and Investment; over 1,200 different private or corporate landowners, including agricultural owners, and energy companies (WY, 2021; WGFD, 2021); and numerous private companies with subsurface ownership rights (USGS, 2021). In these complex situations, failure to account for landowner preferences and coordination will severely limit any conservation program's effectiveness (Mason et al., 2020).

Although there is a need for coordinated conservation efforts by private landowners, current conservation actions in Wyoming are decided by individual landowners without a structure to

[6] Other conservation measures often undertaken in the semi-arid landscapes of Wyoming include habitat and forage enhancement, such as grass management, weed control, fire mitigation or rehabilitation, landscape-scale fertilizer and herbicide application, implementing grazing management plans, and brush removal. These measures aim at to improving livestock grazing, habitat for other species such as the greater sage-grouse, as well as habitat and forage for migrating ungulates.

incentivize coordination. Conservation easements and wildlife-friendly fencing actions are based on the preferences for conservation of each individual landowner. Yet, successful conservation policy will have to include actions at a landscape level that protect routes for migratory species across ownership boundaries (Conte et al., 2021). For example, wildlife-friendly fencing has limited benefit for wildlife movement if none of the surrounding neighbors also have it. Understanding how landowners will respond to such policy is critical to designing effective policy. Interviews and surveys asking private landowners about their experiences and concerns surrounding migration conservation policies on their land provide a glimpse into how their preferences interact with programs and management practices.

Interviews with a limited number of landowners participating in Red Desert to Hoback migration corridor conservation projects highlighted how motivations driving participation in migration-focused programs overlap with ranch business as well as personal conservation values and goals (Nagler, Bannon, and Rashford, 2021). Participating landowners viewed wildlife-friendly fencing as beneficial for both livestock and migrating wildlife on their lands. For example, fences modified to accommodate migrating ungulates were viewed as less likely to be damaged by wildlife, reducing fence maintenance costs to the ranch. Likewise, conservation easements were viewed by participating landowners as beneficial to preserving wildlife habitat alongside protecting working agricultural lands and facilitating estate transfers to the next generation of ranchers.

How particular conservation targets and management practices are perceived by landowners can influence landowner participation. Ranchers surveyed in southwestern Wyoming, for example, were more willing to undertake management practices associated with the target of mule deer migration corridors (rather than sage grouse habitat or water) (Hansen et al., 2018). This could be due to the fact that producers may perceive mule deer habitat enhancements as less disruptive to the underlying ranch operation than practices undertaken to enhance sage grouse habitat or improve water resources.

Based on a series of interviews and a meeting of landowners, including those participating and not currently participating in conservation programs, landowners expressed several concerns about corridor designations, including the potential for increased land-use regulations on private lands, challenges in developing mineral rights, and threats to public land grazing allotments (Bennett and Gautier, 2019). Although the corridor strategy implemented by the WGFD (see WGFD, 2019) and Governor Gordon's executive order does not address agricultural or recreational uses of private property, there was a general concern that the designations would be the beginning of a "slippery slope" to increasing regulation of private property to conserve migrations. Other landowners had more specific concerns about how designations could impact the development of mineral rights since the corridor strategy directs WGFD to comment on federal surface projects, such as oil and gas leases, on a "case-by-case basis." WGFD may recommend, for example, no surface occupancy or the deferment of leases if they would significantly impact corridors. Landowners expressed concern that WGFD comments could delay or limit the development of their mineral rights as oil and gas development typically requires the aggregation, or pooling, of mineral rights across a large area to make infrastructure investments economically viable.

Many landowners also expressed concern about the potential for migration corridor designations to be used by environmental groups to challenge the renewal of leases on public land grazing allotments (Bennett and Gautier, 2019). Public grazing allotments are critical to many livestock operators in Wyoming and the West as the primary source of summer forage. Some ranchers in the West have experienced legal challenges to grazing on allotments due to wildlife-livestock conflicts, mainly from predation from large carnivores or from disease transmission risk from domestic to bighorn sheep. The ranching community is sensitive to new dynamics from corridor designations that could be used to disrupt access to grazing on allotments.

Based on the same 2019 study (Bennett and Gautier, 2019), several landowners also expressed support for corridor designations and identified potential opportunities emerging from state designations. Several landowners felt that the designations could increase the availability of financial incentives to improve range conditions or upgrade ranch infrastructure through cost-share programs. Several landowners also mentioned that the emphasis on migration corridors has created funding opportunities for the voluntary sale of conservation easements on properties in designated corridors, which was of interest to several interviewed landowners. The National Fish and Wildlife Foundation, for example, invested $9.2 million, combined with $50.5 million in matching contributions from partners, throughout the West between 2019 and 2021 (NFWF, n.d.). These investments funded a range of projects including placing over 105,000 acres under conservation easement, removing or installing 372 miles of fencing to improve landscape connectivity, and improving range conditions on hundreds of thousands of acres by treating invasive weeds, removing conifers, and implementing grazing plans.

Many landowners also felt that the attention to migration corridors could attract new investments in highway infrastructure to increase motorist safety and reduce wildlife-vehicle collisions. These landowners, and their friends and family, are frequent drivers on highways in migration corridors and aware of the danger of large numbers of ungulates moving across roads. A 2016 study of a series of 6 wildlife overpasses and underpasses near Pinedale, Wyoming documented an 81% reduction in wildlife-vehicle collisions (Sawyer, Rodgers, and Hart, 2016) and constructing more highway overpasses and underpasses was the most popular of 8 policy options for conserving migrations in a 2019 poll of registered Wyoming voters (Gautier, Bennett, and Bonnie, 2019).

Finally, several landowners expressed interest in innovative ideas connected to migration corridor conservation. These ideas ranged from landowner to landowner but included concepts such as developing models for short- or medium-term habitat leases (e.g., 10- to 30-year leases) as an alternative to perpetual easements and providing transferable hunting tags as incentives for landowners adopting conservation practices. While it is uncertain whether these ideas will have traction, these landowners felt that the attention to migration corridors created a unique policy window to advance concepts that met their own land management goals.

4. Discussion and Recommendations

Conservation of migratory ungulates poses unique challenges for effective conservation policy. The need to create contiguous habitat along expansive predefined routes, that can have different spatial and temporal habitat needs and span numerous privately and publicly managed land parcels, presents a complex conservation challenge. In particular, the need for complex spatio-temporal coordination will require a more nuanced understanding of landowner preferences in this unique context.

Using the case study of ungulate migration in Wyoming, we highlight the diverse preferences and interests of landowners for conservation of migration routes. Since current conservation policy depends on voluntary actions by individual landowners, their preferences will dictate the success of such policies. Policy makers and conservation groups need to understand landowner preferences to create effective policy. Understanding landowner preferences could also improve how programs are promoted. For example, in areas where landowners express a strong preference for term leases rather than permanent conservation easements, highlighting the temporary nature of the program could improve uptake. Additionally, promoting the benefits to livestock production of fence improvements for migratory species, could create win-win perceptions that improve participation. The local working group structure established in Wyoming for the protection of each migratory route will help to elicit local landowner preferences and facilitate landowner coordination. Incorporation of explicit landowner coordination incentives into conservation policy will further protect habitat of migratory species.

Further, since many migrating species require spatially explicit conservation action, successful policy must be at a landscape level, which may require additional incentives for coordination among landowner conservation efforts. As such, future research should focus on 1) soliciting information on both individual landowner preferences, and landowner opinions and preferences for coordination mechanism, such as agglomeration bonuses; and 2) explicit accounting for the specific context of actual migration routes with their unique species-specific conservation requirements and mixes of land ownership.

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Figure 1 Land Use and Ownership in the Red Desert to Hoback Mule Deer Migration Route in Wyoming