An Analysis of Wolf-Livestock Conflict Hotspots and Conflict Reduction Strategies in Northern California

A group project submitted in partial satisfaction of the degree of Master of Environmental Science and Management for the Bren School of Environmental Science & Management

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As authors of this Group Project report, we archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a year-long activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

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Explanation of Client Relationship

Defenders of Wildlife, a nonprofit organization based in Washington, D.C., has worked for over 30 years to support coexistence between wolves and humans. It seeks to continue this work in California, and has thus commissioned this report, which identifies locations of favorable wolf habitat in present-day California and conducts an analysis of wolf-livestock conflict reduction strategies. Understanding where these apex predators may live in California, and which conflict reduction methods are feasible to implement for local communities, can help stakeholders create targeted strategies for reducing wolf-livestock conflict. We have produced a report that supports informed decision-making, and bridges information gaps regarding conflict deterrence options, for any and all stakeholders to this issue, which may include Defenders of Wildlife, the California Department of Fish & Wildlife, other partner and regulatory agencies, environmental groups, and the state's ranching communities and their associations, such as the California Cattlemen's Association.

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List of Abbreviations

AIC	Akaike Information Criterion
AKWA	Areas of Known Wolf Activity
ATV	All-Terrain Vehicle
AUC	Area Under the Curve
BIOS	Biogeographic Information & Observation System
BLM	Bureau of Land Management
CDFW	California Department of Fish and Wildlife
Defenders	Defenders of Wildlife
ESA	Endangered Species Act
FOIA	Freedom of Information Act
GMU	Game Management Unit
Maxent	Maximum entropy
MRLC	Multi-Resolution Land Characteristics
NASS	National Agricultural Statistics Service
NLCD	National Land Cover Database
ODA	Oregon Department of Agriculture
ODFW	Oregon Department of Fish and Wildlife
ROI	Region of Interest
RSF	Resource Selection Function
SDM	Species Distribution Model
TIGER	Topologically Integrated Geographic Encoding and Referencing
UBI	Ungulate Biomass Index
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USPAD	United States Protected Areas Database
WDFW	Washington Department of Fish and Wildlife

Abstract

The recovery of gray wolf (*Canis lupus*) populations in the Western United States has led to the species' dispersal into regions of former inhabitation. California now hosts a small population that is protected under federal and state law. If the state's population continues to grow, local livestock producers may face an increasing risk of conflicts between wolves and their livestock with no lethal means to prevent such conflicts. Thankfully, a variety of non-lethal conflict reduction strategies exist and are successfully used elsewhere in the West. This report finds that California (especially the northern half of the state) contains great amounts of favorable wolf habitat and that large portions of this habitat exist near active livestock grazing land, which are thus at risk of experiencing wolf-livestock conflicts. It further finds that Northern California-based livestock producers consider (a) the removal of wolf-attractants from the landscape, and (b) the use of range riders to deter wolves from active grazing lands to be the most locally-feasible conflict reduction strategies. Our results can support the region-specific implementation of wolf-livestock conflict reduction programs by the state's interested stakeholders, including conservation groups, resource managers, and members of the livestock industry.

Executive Summary

Gray wolves thrive in packs and tend to hunt ungulate prey on the flat, wide open spaces that border the safety of the forest. In the Western US, this is the same type of landscape that many early settlers deemed too arid and rocky for farming, but perfect for grazing livestock. Wolves in this region thus often came into contact and conflict with humans and their property. Settlers understandably responded to this threat by eliminating (e.g., by shooting, poisoning, trapping. etc.) wolves that threatened their livestock. As the frontier closed, United States government agencies took an active role in eradicating the species and making the West safer for ranching. Shortly after the turn of the 20th Century, few wolves were left anywhere in the continental US. They were soon extinct throughout the West, including California.

Though several generations of ranchers and livestock producers still struggled to prevent coyotes, mountain lions, and other predators from attacking their livestock, wolves no longer posed any threat, and thus commercial ranching operations adapted to a landscape devoid of wolves. But this dynamic changed when the gray wolf was listed under the Endangered Species Act of 1973 -- the government then had a mandate to support the survival and recovery of wolves. In 1995 and 1996, US Fish & Wildlife Service facilitated the relocation of 66 wolves into Idaho and Wyoming, and since then the wolf population of the West has grown in the Northern Rockies and towards the Pacific. Their return has been accompanied by a return of wolf-livestock conflicts. Over the last seven years, the estimated wolf population in Oregon has grown from 14 to over 100, while the annual number of livestock losses to wolf depredation (i.e., predation events that result in losses of property) has hovered between 10 and 30 (with a decline of about 50% from 2014 to 2015). In the summer of 2015, California observed its first recorded wolf pack in over 90 years. The state's first confirmed depredation occurred a few months later.

The study described here is an effort to facilitate the development of a response to this impending potential source of conflict in California. We assume that a viable strategy for "coexistence" (as the species' current protected status implicitly requires) must begin with the minimization of conflicts between wolves and livestock. Since most reported conflicts involve wolf attacks on livestock, we conducted spatial analyses to forecast potential conflict hotspots in California, and a feasibility analysis to determine what specific conflict reduction strategies may be most applicable to the broad region that seems likely (at least at first) to experience the most conflicts -- the ranching communities of Northern California.

Therefore, this report analyzes publicly available landscape and land use data, as well as information from prior research about wolves' habitat selection and wolf-livestock conflict risk mapping, to determine (a) what locations in California offer the best "potential" habitat for wolves; and (b) what regions of California's livestock production may be most at risk of wolf-caused conflicts. Additionally, this report analyzes survey responses from 124 Northern California-based livestock producers. The survey captured concerns about wolves and other predators in the region of interest, as well as the familiarity and feasibility of seven conflict

reduction strategies and potential barriers to implementation. Finally, this report synthesizes the results of these analyses in order to make region-specific recommendations regarding the goal of minimizing wolf-livestock conflict through conflict reduction programs, and working towards a coexistence regime that allows wolves and livestock to share the landscape with minimal conflict.

Our spatial analysis indicates that the best potential wolf habitat, based on forest cover and prey availability, generally includes: the National Forest lands of Northwestern California (e.g. Klamath, Six Rivers, and Shasta-Trinity National Forests) and their environs, the National Forest lands of the southern Cascades and north and north-central parts of the Sierra Nevada's western foothills, and the forested coastal or mountainous parts of Mendocino County. Following on this, the regions that may be most prone to wolf-livestock conflicts include the livestock-producing portions of western Siskiyou and Shasta Counties, eastern Humboldt County, most of Trinity County, the southern Cascades and the northern Sierra foothills.

The results of our feasibility analysis show strong and fairly ubiquitous negative attitudes toward wolves and significant concern about the impact of wolves on livestock. Of the seven conflict reduction strategies addressed, attractant removal and range riders were considered the most feasible. Attractant removal, which is the practice of moving animal carcasses and other predator attractants away from rangelands, was significantly preferred over the other six conflict reduction strategies, and 56% of respondents claimed they would be "somewhat likely" or "very likely" to implement this strategy. Another relatively popular option was the use of range riders (on horseback or ATVs) to maintain a frequent presence on the range. Forty percent of survey respondents said it is feasible, and 12% already implement some form of range riding. The most-cited challenge of implementation for this strategy was the cost of hired labor. In general, the range of responses and concerns led to conclusions that there must be a diversity of predator-deterrence options for livestock producers, specific to the context of each community and ranch.

These combined results lead us to recommend that, if and when California's wolf population grows, Defenders of Wildlife, the California Department of Fish & Wildlife, ranchers, and other interested stakeholders should plan to initiate conflict reduction programs within the geographical areas highlighted in the conflict risk map. Additionally, these groups should work closely with local ranchers and communities to find the most relevant solutions for each locale. The results of our survey suggest that attractant removal and range riders may be the most culturally and logistically feasible strategies for inclusion in conflict reduction programs in Northern California.

1. Objectives and Background

Project Objectives

As wolves return to their formerly inhabited locations in the Western US, they occasionally come in conflict with some human activities, especially livestock grazing. The purpose of this project is to understand where wolf-livestock conflicts may occur as wolves return to California, and how such conflicts could best be reduced. We thus have two primary objectives:

1. Identify potential conflict hotspots between wolves and humans, particularly in regards to livestock depredation. Potential hotspots will be identified through the use of spatial analyses of human land use and predicted wolf habitat.

2. Develop region-specific recommendations for the implementation of proactive strategies to reduce wolf-livestock conflict in Northern California. This analysis will be based on the perceived feasibility of these strategies among livestock producers in the region, as well as literature and case studies of successful reduction strategies in other regions.

This report outlines important background information related to these objectives, the methodology we undertook to meet the objectives, and our subsequent findings.

Background

History and Controversy

Throughout human history, humans have encountered the challenge of coexistence with large terrestrial carnivores. Predators that lived near settlements presented either competition for local resources or a direct personal threat. It is not surprising, then, that once humans became able to take wholesale control of this situation, by physically destroying and removing aggressive predators from the landscape, they did. This happened many centuries ago in Europe -- the continent's inhabitants were successful in eliminating the land's native lions, bears, wolves, and other large carnivores.

Similar phenomena played out on the American continent, but in different ways and at different stages. Some research suggests that human inhabitants of North America during the late Pleistocene and early Holocene eras (ca. 12,000-9,000 years ago) played a role in the mass extinction of many of the continent's megafauna and large carnivores (Fiedel and Haynes 2004). But some large predators, like grizzly bears, mountain lions, and wolves, survived that event, and maintained healthy populations and a wide distribution across the wild landscapes of the West (including California) until much more recently.

European-American colonization in California, beginning with the arrival of the Spanish in the 16th century, and accelerating with the California Gold Rush and subsequent American settlement in the mid-19th century, led to a period of active or accidental extermination of many animals (Kellert et al. 1996). These settlers responded to the wild dangers of the frontier by incrementally, and then systematically, exterminating the large predators or forcing them into the most remote and inhospitable corners of the state. The California grizzly bear (*Ursus arctos californicus*) was exterminated by 1908 (Snyder 2003). In 1924, the state's last recorded gray wolf (*Canis lupus*) was killed and collected near Litchfield in Lassen County (Grinnell et al. 1937). The same scenario played out throughout the American West. Wolves were almost entirely removed from the lower 48 states by the 1930s, and though populations remained in Canada and Alaska, their ability to repopulate the lower 48 was prevented by unrestricted wolf hunting in the US and by the federal government's ongoing predator management policies, which were implemented by the US Department of Agriculture's Wildlife Services program (Robinson 2005).

But the growth of modern environmentalism in the second half of the 20th century (alongside the related phenomenon of the increasing urbanization of the American populace) caused a change to the nation's approach to wolf management. Legislators listed gray wolves on the Endangered Species Act (ESA) of 1973, which made it unlawful for any group or individual to "take" (i.e., to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect or attempt to engage in any such conduct) a wolf. The ESA also compelled the US Fish and Wildlife Service (USFWS) to support wolf recovery in the species' former range. In the twenty years following the passage of the ESA, wolves recolonized some parts of the Upper Midwest and northern Montana. In 1995 and 1996, USFWS translocated wolves from British Columbia and Alberta, Canada, to both Yellowstone National Park and Idaho's Frank Church River of No Return Wilderness. In all, the agency introduced 31 wolves to Yellowstone and 35 wolves to Frank Church (USFWS et al. 2000). These translocations accelerated the species' recovery in the Rocky Mountains and eventually the Pacific Northwest. The two populations, along with small populations that naturally travelled from Canada into Montana and Washington, initiated the growth of this region's wolf population to its current estimated size of about 1,800 individuals (USFWS 2015).

As wolf packs grow from the birth of successive new generations, some individuals, especially young adults, tend to disperse into nearby unpopulated habitat (Pletscher et al. 1997). A study of 30 dispersing, radio-collared wolves in the Northern Rockies showed an average dispersal age of about three years, a dispersal distance of 96.3 km, and both male and female wolves dispersing similar distances (Boyd and Pletscher 1999). Similar studies have shown that wolf dispersal paths and subsequent habitat selection is influenced by environmental variables, including relative forest cover, prey density, and human impacts like development and road density (Mladenoff et al. 1999; Larsen and Ripple 2006). Much of the West, including California, contains large patches of landscapes that provide the mix of environmental attributes that can support individual dispersers and whole wolf packs.

This movement and habitat selection behavior led to the recent arrival of wolves in northeastern Oregon from Idaho. The Oregon Department of Fish & Wildlife (ODFW) first documented successful wolf reproduction in the state in 2008, and have since conducted annual winter counts. The state's wolf population increased from 14 wolves in 2009 to 110 in 2015, with packs primarily residing in available habitat in northeastern Oregon. In 2011, a young radio-collared wolf, known to ODFW as "OR-7," left that region's Imnaha pack, travelled southwest to the Cascades, and south into California, becoming the state's first recorded wild wolf in almost a century. OR-7 roamed the state for over a year before returning to Oregon's southern Cascades, finding a mate, and beginning a pack. Camera traps have documented photos of the pair and their young pups, living less than 50 miles from the California border in the Rogue River region. In January 2015, scientists confirmed two additional wolves (known as the Keno pair) in that region, even closer to the California border (ODFW 2015b).

In August 2015, the California Department of Fish & Wildlife (CDFW) released a series of photographs from a camera trap that showed evidence of a wolf pack (two adults and five pups) living near Mt. Shasta in Siskiyou County, California (CDFW 2015). In October, CDFW reported that it had collected scat samples from four of the pack's individuals, and subsequent DNA analysis confirmed that the animals are gray wolves. Another radio-collared wolf, known to ODFW as OR-25, crossed the California border in January 2016, and has since returned to Oregon (Center for Biological Diversity 2016).

These developments clearly illustrate that wolves have begun their return to Northern California. OR-7's arrival inspired the submission of a petition to the California Fish and Game Commission, imploring the Commission to consider listing the gray wolf as endangered under the California Endangered Species Act (CDFW 2015). Over the course of several years, the Commission solicited input from scientific experts and the public, and on June 4, 2014, found that the listing was warranted. Explaining the Commission's decision, Commission President Michael Sutton said that "there is no species more iconic in the American West than…the gray wolf [and] we owe it to them to do everything we can to help them recolonize their historic range in this state" (Weiser 2014). Because wolves are thus protected under the federal and state ESAs, California state management agencies and local communities are now in the position of having to learn to coexist with wild wolves for the first time in recent history.

As Sutton's comments indicate, wolves represent a unique aspect of American culture. This makes them a flashpoint for identity politics and complicates their management. The protection of wolves in the ESA was cheered not just by many environmentalists -- it was also welcomed by many Americans who may not have identified as environmentalists, but who have a sense that wolves hold an iconic, almost mythical place in our national heritage, and that they thus have some special "right" to exist within it (and thus also an "existence value" that can be economically quantified).

While Sutton and others have pointed to "moral" arguments to support wolf conservation, others point to more ecological benefits of wolf recovery. Some scientists have linked their presence to improved ecosystem structure and function (Mech and Peterson 2003; Ripple and Beschta 2004). As apex predators, wolves have great impacts on the landscapes they inhabit, and their presence and predation has led to trophic cascades throughout their ecosystems (Ripple and Beschta 2004; Fortin et al. 2005; Hebblewhite et al. 2005). A study of trophic cascades in Yellowstone National Park showed a shift in elk behavior -- before the reintroduction of wolves, Yellowstone elk regularly browsed the valley riparian zones and damaged streamside habitats; after reintroduction, the elk spent less time in these and other landscapes where wolves may more easily stalk and hunt them (Ripple and Beschta 2011). This avoidance behavior prevented elk from over-browsing young aspen, willow, and cottonwood in the riparian areas, and allowed for the growth of new groves, the stabilization of stream banks, the decrease in stream water temperatures, and the creation of new habitat for countless species. Many scientists have thus welcomed the recovery of wolves.

Rarely, though, have those who celebrated the recovery also made their living by ranching the West. The region's livestock producers were most likely to bear the "new" costs of sharing the landscape with this species that threatened their property. These producers were already accustomed to dealing with (and trying to prevent, often lethally) attacks from all manner of predators -- coyotes especially, but also mountain lions, bobcats, bears, large raptors, and more. But many perceived the presence of wolves to be a bigger threat than them all, and bristled at their sudden legal inability to shoot, or even harass, an animal that could pose such a threat.

Wolf attacks can indeed cause injury, death, or stress to livestock, and as the population of wolves has increased, conflicts between humans and wolves have become more frequent (Mech 1995; Breck and Meier 2004). California's new Shasta Pack seems to have already caused at least one such problem -- in December 2015, CDFW confirmed a "probable" wolf-predation event on a calf in Siskiyou County (Ortiz 2015). Depredation results in a direct loss of income for impacted livestock producers, and affected producers often point out that most people who support the continued dispersal of wolves do not live near wolf habitat, and thus do not have to deal with the "burden" of living in close proximity to these predators.

Multiple surveys support the argument that people with the least experience with wolves (often wealthy, urban residents) tend to be the ones who favor wolf conservation (Williams et al. 2002; Kaltenborn et al. 1999). This disconnect implies that, without some type of compensation program, livestock producers who lose animals to depredation events bear the costs of wolf conservation without receiving the benefits (Muhly and Musiani 2009). To complicate this situation further, differing social constructions for wolves often strengthen this disconnect and push disparate parties further apart (Scarce 1998).

So the issues of wolf protection, reintroduction, and recolonization of former habitat are issues that strike at the heart of American identity and ethics, and thus often put people who interpret the issue differently on two "sides" against one another. The heated debate resulting from these different worldviews shows no sign of ending, and yet some agreement about the desired level (and means) of coexistence is becoming more urgent as wolf populations spread across the West. The arrival of wolves into California has forced the state's interested parties to consider how the protection of wolves can occur simultaneously with the minimization of their negative effects on livestock producers. The experiences of the Upper Midwest, the

Northern Rockies and the Pacific Northwest show that coexistence requires substantial investment of resources into conflict reduction strategies and the creation of culturally diverse coalitions to implement these programs across a large and heterogeneous landscape (Clark et al. 2013). Efforts to model potential wolf distribution in California and to map the most at-risk sites of wolf-livestock conflicts, as well as to analyze current conflict trends in the West and the regional use of conflict reduction strategies, can help bring clarity and focus to this complicated state issue.

Species Distribution Modeling

The scale of the landscapes involved in wolf-livestock conflicts can pose a daunting challenge to managers working to optimize their conflict reduction efforts. In recent years, conflict and coexistence researchers have developed methods to identify the hotspot locations within the landscape that may be most at risk for depredation events (Miller 2015). However, only rarely has risk mapping research been used by wildlife managers and livestock producers to prioritize implementation of wolf deterrence programs (Miller 2015).

Most recent attempts to spatially model wolf-livestock depredation risk have focused on regions that already support significant wolf populations and existing spatial data describing locations of known depredation events (Hebblewhite et al. 2005; Treves et al. 2011; Behdarvand et al. 2014). Because there is only one known wolf pack in California, and only one recorded conflict, our analysis cannot use similar methods to map conflict risk. Nevertheless, we can use other proven methods to analyze the landscape characteristics of California and determine (a) the relative wolf habitat favorability that these landscapes offer, and (b) the relative risk of exposure to favorable wolf habitat that faces the known grazing lands in the state. In this study, we developed a model to effectively produce part (a), and then compared the result to maps of livestock grazing locations in California to produce part (b). The resulting maps show the state's predicted wolf habitat and its potential wolf-livestock conflict hotspots, and meet this study's first objective.

Scientists and agencies in the United States have created gray wolf distribution models ever since the original reintroduction of wolves into Yellowstone and central Idaho (Mladenoff et al. 1995, 1999; Larsen and Ripple 2006; Oakleaf et al. 2006). However, given wolves' long absence in the state, and the subsequent massive changes humans have imposed upon landscape use and structure, no data or information exist about where wolves will likely settle in California. As such, any species distribution model (SDM) will need to be informed by data and results from studies done in other regions. Several of these studies come from Western states (including Oregon), where environmental variables are similar to those in California. These studies identified land cover, landscape ownership characteristics (public or private), human population density, road density, and prey (elk and deer) population density as the best predictors of wolf distribution (Mladenoff et al. 1995; Larsen and Ripple 2006; Oakleaf et al. 2006).

A wide variety of modeling techniques can be employed to map gray wolf distribution, including the use of resource selection function (RSF) models (e.g., logistic regression), general additive models, and the use of software like Maxent (based on a maximum entropy approach). This report evaluates three different SDMs to model potential wolf habitat in California: (1) a simple "predicted range map" model, using methods applied by ODFW to map wolf range in Oregon; (2) a logistic regression model; and (3) a multivariate maximum-entropy (Maxent) model. These models are described and compared below.

Conflict Risk Mapping

Conflicts are influenced by many factors, such as the amount of livestock and size of the wolf population in a region. In California (as in Oregon) many ranches are located within river valleys or in lower-elevation foothill landscapes. This landscape is also important habitat for wolves' primary prey -- elk and deer. When wolves follow these ungulates, they venture into close proximity to cattle and sheep that also graze these lands (ODFW 2010a). Once in close proximity to this potential prey, wolves may choose to attack, and will preferentially target low-weight calves that are (a) less guarded by people, (b) near an active wolf den, and/or (c) in the heaviest forest cover. These conclusions suggest that wolves hunt cattle in a similar fashion as their wild prey, and will attack the most vulnerable animals.

This demonstrates the importance of how different regional landscape attributes can directly lead to a greater frequency of wolf-livestock conflicts. Understanding what characteristics of a region result in more livestock depredation by wolves can be crucial to reducing the frequency of these conflicts (Treves et al. 2004). Important factors include human and road density, as well as the amount of forest cover and pasture land. Wolves tend to prefer hunting in areas with low forest-density (but still near the safety and cover of forests) where they can chase prey over longer distances. Because of this tendency, many attacks occur in flat pasture or shrublands -- landscape types that are often used for cattle grazing, and thus potentially most at-risk for conflicts (Miller 2015).

Another important wolf-livestock conflict factor is the timing of attacks. Although livestock grazing periods in the open range vary by state due to differing climatic regimes, most of the documented occurrences of wolf depredation occur from May to October. This is likely because a wolf pack's nutritional demand increases in the late summer, when young pups have grown larger and exhibit an increased appetite (Musiani 2005). This coincides with ranchers' tendency to put livestock out on summer grazing lands, which are often more remote and less monitored (Sulak and Huntsinger 2002).

Present Day Conflict

Before the reintroduction of wolves in the mid 1990's, USFWS estimated the potential depredation impact of a small wolf population in the Northern Rockies through its development of an Environmental Impact Statement. The agency estimated that 100 wolves would take 10-20 cattle and 50-70 sheep per year in each reintroduction area, representing a total annual loss between $2,000 and $30,000 (Bangs and Shivik 2001). These estimates were proven high in the years following reintroduction as confirmed depredations sometimes accounted for just one-half or one-third of predicted values. Nonetheless, wolf population counts and livestock depredations have increased steadily since reintroduction (as shown in Table 1.1), and these conflicts are an important problem for the region.

Table 1.1. Wolf-livestock depredation counts in Montana, Idaho and Wyoming between 1996 - 2010 (USFWS 2016).

	Year			
	1996	**2000**	**2005**	**2010**
Minimum Wolf Count	150	400	1000	1700
Wolf Depredations of Cattle	11	32	97	188
Wolf Depredations of Sheep	37	80	244	245

Wolves arrived to Oregon more recently than the Rockies, and though the population in the state is fairly small, it has caused the loss of relatively more livestock per wolf than wolves did in the early years after reintroduction in the Rockies. Wolves caused a total of 56 cattle deaths and 72 sheep deaths in the first five years of their presence in Oregon (from 2009 to 2014), with a total known wolf population of just 9 individuals in 2009 and 77 in 2014 (ODFW 2016). Conversely, in Washington State a similarly small wolf population (10 individuals in 2008 and 68 in 2014) caused only 11 cattle and 29 sheep losses between 2007-2014 (Wiles et al. 2011). Compared to wolves, coyotes pose a greater absolute threat to livestock - in Oregon between 1996 and 2002, coyotes were responsible for losses of 222 cattle and 1,408 sheep (ODFW 2010a). Although losses due to coyotes demonstrate that depredation on livestock has been a continuous problem for livestock producers, they also suggest that wolves are just the newest potential threat that producers face in their operations. As wolf populations continue to grow, these producers will face an increased risk of wolf-livestock conflicts.

In an effort to more equitably share the costs associated with coexistence, Defenders of Wildlife (Defenders) pioneered the use of compensation programs to reimburse ranchers for lost potential revenue due to confirmed wolf depredation events. Defenders' program ran from 1987 to 2009, and paid a total of $1,368,043 to livestock producers for confirmed depredations (Defenders 2010a). The program was deemed a successful way to more equitably distribute the costs of coexistence, and federal and state governments and tribes have in recent years taken on more responsibility for compensating producers who have lost livestock to wolves.

While compensation for depredation events helps livestock producers absorb the loss of an animal, it is a reactive mechanism to deal with conflicts that might have been avoided through more proactive measures. Additionally, direct losses due to deaths are not the only impacts of predators -- the presence of wolves near livestock can cause these animals stress and lead to reduced reproduction and diminished weight gain, which indirectly lead to financial losses to producers (Laporte et al. 2010). Cattle may also become more aggressive in the presence of wolves, making them more difficult for ranchers to manage and increasing the hazards to guard dogs (ODFW 2010a). But there are few ways for Oregon (or any other state) to adequately measure and compensate for these indirect losses. Thus various preemptive conflict reduction strategies, some of which strive to prevent (or otherwise deter) wolves from coming near livestock grazing areas, seem to offer the best non-lethal methods for the minimization of losses to producers.

Conflict Reduction Programs and Strategies

Defenders and other conservation groups, resource managers and livestock producers have begun to transition their activities towards the implementation of conflict reduction programs. Defenders has helped ranchers finance and initiate conflict reduction strategies across the Northern Rockies, the Pacific Northwest, and the Southwest (Defenders 2010b). Its Northern Rockies program, in operation since 1998, has involved collaboration with local communities, producers, resource managers, state and tribal biologists, academic researchers, other conservation groups, and federal authorities to develop, test, and recommend a variety of conflict reduction tools (Defenders 2016). The program has helped fund implementation of some strategies -- by 2009, Defenders had contributed $331,800 to fund almost 100 "proactive projects" in areas where wolves came into conflict with livestock producers (Defenders 2016).

Defenders also leads the Wood River Wolf Project, a cooperative coexistence program operating in Idaho's Wood River Valley since 2007. The program has focused specifically on minimizing conflicts between wolves and sheep. Since the program's inception, it has kept sheep losses to wolves at 90% lower than losses reported in the rest of the state (Defenders 2016). Additionally, Idaho Department of Fish and Game (which has the authority to lethally remove problem wolves) has not been asked to kill any wolves in the region due to conflicts with livestock.

ODFW and the Washington Department of Fish and Wildlife (WDFW) have also set up cost-sharing programs to assist livestock producers interested in participating in conflict reduction. As of 2013, WDFW had contracts with 41 landowners to support the implementation of such strategies, including the movement of cattle from highly impacted areas or the sharing of information about the location of radio-collared wolves (WDFW 2015). The agency also employs 11 wildlife-conflict specialists to work with and advise landowners who are impacted by wolves and other predators (WDFW 2015).

The USFWS also provides funding for conflict reduction through its Wolf Livestock Demonstration Project Grant Program. This program provides $900,000 annually to 10 states to support livestock producers who are willing to use non-lethal deterrence tools. Up to 50% of implementation costs may be covered through the program (Defenders 2014). The 2015 Oregon Wolf Conservation and Management Annual Report highlights ten counties that received a total of about $123,000 for prevention and implementation costs (ODFW 2016). (See Appendix A and B for detailed timelines of Washington's and Oregon's implementation of conflict reduction strategies)

Described below are seven widely used conflict reduction strategies.

Fladry

Fladry involves the installation of long string lines with brightly-colored flags spaced about every 18 inches. The movement of these flags appears to interfere with wolf hunting patterns and stops them from crossing fences (ODFW 2010a). Fladry is most effective when used to protect smaller pastures or grazing areas rather than large-scale rangelands.

Turbo fladry includes these aspects of fladry and adds the electrification of fencing. This version is more expensive but also more effective at deterring wolves. Both WDFW and ODFW have agreed to some cost-sharing measures to support ranchers in the implementation of these strategies.

There are several major drawbacks of fladry and turbo fladry. First, these strategies pose financial and logistical challenges; installation can be costly and cumbersome, and their use is sometimes recommended for areas of only one square mile. A study from the University of Nebraska claimed the first kilometer of fully functional turbo fladry would cost $2,308, and $2,032 for every additional kilometer installed (Lance et al. 2010). Second, they require regular maintenance to replace missing, torn or aged flags, and to ensure flags are at the proper height above the ground or not wrapped around the line. Cost of maintenance is higher for turbo fladry. Third, fladry is effective for only about 90 days for a given wolfpack (slightly longer for turbo fladry), at which point the pack tends to become acclimated to the flags (Gehring et al. 2006). Given these constraints, the best use of fladry may be as temporary protection of small areas that have a high potential to attract wolves, such as birthing areas for calves and lambs, or bedding grounds for sheep. Fladry and turbo fladry can give these vulnerable livestock time to grow before the effectiveness of the deterrence fades.

Attractant Removal

Wolves will sometimes scavenge for food, and thus may seek out livestock carcasses and bone piles. This can be avoided by physically removing wolf-attractants like dead (or dying) livestock, carcass pits, and bone piles from exposed landscapes (ODFW 2010a).

One drawback to this conflict reduction strategy is that, in remote and difficult to access regions of grazing lands, it can be a challenge for ranchers to find and remove or bury carcasses before they attract wolves. Traits about the landscape (e.g., rocky and hard ground surfaces) may preclude livestock producers from being able to bury carcasses, or state law may prevent them from doing so (as is the case in California). In some locations, WDFW and ODFW offer free disposal sites for producers to dispose of carcasses, or may even offer agency assistance with carcass removal (ODFW 2010a). Defenders has also partnered with the Blackfoot Challenge, a Montana program focused on rural conservation, to support a carcass and bone pile removal program, and has implemented attractant removal as part of the Wood River Wolf Project.

Guard Dogs

Guard dogs have been used to protect sheep and cattle globally for thousands of years. Commonly used dog breeds include Anatolian Shepherds, Great Pyrenees, Akbash and Maremma. These breeds tend to have a strong instinct to protect their herds and will respond aggressively to the presence of wolves or other threats, including by alerting their human owner of wolf presence (ODFW 2013). Livestock guarding donkeys and llamas have proven successful alternatives to dogs in some situations when dogs may not be appropriate. Guard dogs are especially effective at protecting sheep -- Colorado sheep producers without dogs saw losses due to predators two to six times greater than producers with guard dogs near their herds (Andelt and Hopper 2000).

Livestock guarding dogs can be costly, ODFW estimates about $800-$1,500 for a single dog (not including annual fees such as food and veterinary care), and additional resources are needed for training. Guard dogs may also be attacked by wolves that view them as competitors (Bangs and Shivik 2001). The number of cases of guard dog deaths due to wolf attacks has prompted WDFW and ODFW to agree to compensate livestock producers for killed guard dogs (ODA 2013).

Range Riders

The use of range riders or wildlife field technicians is an effective way to increase human presence on the landscape and deters wolves and other predators. The practice was traditionally important on large grazing lands but has become less necessary with the extirpation of many large predators. It can be accomplished on horseback, off-road vehicle, or ATV. Range riders can also track, observe, and report on wolf movements, and, when range conditions allow, may also work to keep livestock closely grouped through stockmanship practices.

Range riders are best utilized when they know the locations of wolves via GPS from radio-collars. This information allows them to focus on their efforts on impacted or soon-to-be impacted areas. WDFW and ODFW have been sending text messages regarding the locations of radio-collared wolves to livestock producers and range riders since 2012 (WDFW 2013; ODFW 2012). Even without this information, range riders may be able to independently track wolf activity and alert neighboring livestock producers of nearby wolf packs.

Like some other conflict reduction strategies, range riders come at a high cost. WDFW partnered with Conservation Northwest to implement a range rider pilot program in 2012, and the state's initial cost estimate for hiring one range rider for one grazing season of five months was $20,000 (Kramer 2013). WDFW and Conservation Northwest each agreed to pay approximately half this cost. This pilot program has been successful and 2015 marked its fourth year of implementation. In nine project seasons over the course of three years, no ranchers in this program have lost livestock due to wolf depredation, and no livestock producers have contacted officials to lethally manage wolves on their property (Conservation Northwest 2015). ODFW also considers range riders an effective deterrence strategy and has split the costs of hiring range riders with livestock producers using funds from a $15,000 grant provided by the USFWS in 2010 (ODFW 2010b).

It may also be possible to combine the function of range riders and attractant removal. As mentioned in Conservation Northwest's program update, range riders can also identify sick or injured cattle and remove them from the main herd (Conservation Northwest 2015). This serves to diminish wolves' interest in the herd as a whole by eliminating this living attractant. Range riders may be able to find deceased livestock more quickly than the livestock producer because they are already out patrolling the property. Thus by finding and removing these sick, injured or deceased livestock, range riders can perform two non-lethal deterrence methods at once.

Alarm and Scare Tactics

Alarm and scare tactics are used to frighten wolves away from an area. These tactics can include a combination of bright lights and loud sounds, such as an air horn or high beam flashlight. These particular tools can be purchased at relatively low cost (Stone et al. 2016). More complicated automated lighting (e.g., infrared emitter or motion activated lights) may be effective for relatively small areas, though these can also disturb livestock or nearby residents. Similar to fladry, these tactics may lead to individual wolves or wolf packs becoming accustomed to such displays, reducing their effectiveness. In response to this, some groups are testing a new scare tactic called the "foxlight," which changes its light pattern to mimic human motion and to potentially lengthen effectiveness. But so far, this tool shows only a temporary period of success (30 days or less), and thus may be better utilized in urgent, temporary situations (Stone et al. 2016).

An additional scare tactic can involve the use of non-lethal munitions such as cracker shells, rubber bullets, bean bags, or paintballs. But these munitions can present an unintended hazard both to the target and user -- they can strike wolves in a sensitive region (such as the eye), and equipment malfunctions can harm the user. Rubber bullets can be lethal if fired from a short distance, and can pierce through a wolf's skin even at greater distances. Due to the risk involved, permits and training can be required, or in some places it may be illegal (Stone et al. 2016). ODFW has referred to these tactics as "non-lethal injurious harassment," which makes it a violation of the ESA.

Livestock Management

Several herd management techniques can protect livestock from depredation events:

Calving Season

Calving (the birthing of calves) is an activity that may attract wolves, due to the sounds and smells of the birthing process (Stone et al. 2016). Unfortunately, this activity generally occurs in the spring when adult wolves are often hunting for food for their new pups. But by intentionally adjusting the timing of calving to an earlier or later part of the year, a livestock producer can avoid this period of high wolf nutrient demand, and thus better protect his or her livestock from conflicts. Another tactic is to condense the calving period to shorter time spans (by encouraging cows to calve simultaneously) to limit the total amount of time wolves and other predators may be exposed to young calves.

A producer can also make adjustments to the calving process itself, such as "shed-lambing," in which lambs are birthed in an enclosed shelter (e.g., a barn) rather than out in a field, or by keeping calves in enclosures until they reach a critical body mass (Stoynov et al. 2014).

A drawback to this strategy is that it ignores the timing of demands of the market for beef or lamb. Some livestock producers must calve all year in order to meet market requirements. Others may be forced to calve at a certain time each year to have enough cattle ready for harvest at a designated time. Climate conditions may also force livestock producers to calve or lamb earlier or later. These constraints minimize a livestock growers' flexibility in deciding when and for how long to calve or lamb each year.

Moving Livestock

Moving livestock away from areas of high wolf activity can also minimize conflicts. This requires the livestock producer to own or lease a property large enough to allow for such livestock movement. The time required to gather potentially scattered cattle and drive them to another area may also be a challenge. As part of its Wolf Coexistence Partnership program, Defenders has used cost-sharing methods to help some ranchers deal with the financial and logistical challenges of moving livestock to alternate grazing pastures.

Cost and Cultural Considerations

Wolf-livestock conflict reduction strategies vary in cost, and though many producers implement them on their own, many rely on the aforementioned programs run by state agencies or regional nonprofits. Cost data are available for some programs as mentioned above, but are in many cases scarce or nonexistent, and can be inconsistent across states and programs.

Beyond cost, successful coexistence programs are heavily dependent upon the sociopolitical environment of the region of interest (Treves and Karanth 2003; Treves et al. 2009). That is, while prior research and scientific trials have analyzed the particular effectiveness of various strategies (Musiani and Visalberghi 2001; Davidson-Nelson and Gehring 2010), actual implementation of any strategy must consider the unique local conditions of culture, politics, and economics. This makes it essential that regulatory agencies and conservation groups engage and form partnerships with potentially impacted stakeholders like ranching communities. Additionally, conservation groups and natural resource managers must tailor information to these communities, as natural resource dependent communities often do not rely on the same pieces of evidence as scientists do (Weeks and Packard 1997). With appropriate stakeholder engagement, partnerships with livestock managers can utilize local knowledge and increase the likelihood of conflict reduction.

2. Spatial Analysis

Species Distribution Methods

Data Sources
Environmental predictor variables were selected based on significant factors in related studies, and included land cover classes, landscape ownership characteristics (public vs. private), human population density, road density, and prey population density. The following datasets were gathered from reputable sources and were used for all three SDMs described below (see Appendix A for maps of these data layers):

Land Cover Classes
Land cover raster data were acquired from the National Land Cover Database (NLCD) and created by the Multi-Resolution Land Characteristics (MRLC) Consortium at $30m^2$ resolution.

Land Ownership
Land ownership data were acquired from the National Gap Analysis Portal's United States Protected Areas Database (USPAD), a branch of the United States Geological Survey (USGS). These data provided an inventory of public and private land for both California and Oregon.

Human Population
Human population data were acquired from LandScan (designed and provided by Oak Ridge National Laboratory). This dataset offers the finest resolution ($800m^2$) of global population distribution available, and represents an ambient population average (a twenty-four-hour average estimate of the population present in a spatial unit).

Road Density
Road location data were acquired from the United States Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER) data collection.

Prey Distribution and Abundance
California Roosevelt elk (*Cervus canadensis roosevelti*), tule elk (*Cervus canadensis nannodes*) and mule deer (*Odocoileus hemionus*) range maps were acquired from CDFW's Biogeographic Information & Observation System (BIOS) database.

Population estimates for Roosevelt elk, Rocky Mountain elk (Cervus elaphus), and mule deer were acquired from Oregon and California Departments of Fish and Wildlife at the resolution of management units. The Departments of Fish and Wildlife use these management units in order to administer big game hunting and allocate hunting permits.

Wolf Presence
ODFW's Areas of Known Wolf Activity (AKWAs) data were provided in the form of fifteen individual polygons throughout Oregon (including the Keno, Desolation, Chesnimnus, Catherine, and Sled Springs pairs as well as the Imnaha, Wenaha, Walla Walla, Snake River, Umatilla River, Minam, Mt. Emily, Meacham, South Snake, and Rogue packs). These data were acquired in the fall of 2015.

Species Distribution Models

Model 1: Oregon Department of Fish and Wildlife
This model follows ODFW methods (ODFW 2015), which built on the methods of previous wolf habitat modeling efforts (Mladenoff et al. 1995; Carroll et al. 2003; Oakleaf et al. 2006). ODFW found that forest cover, prey range, human population density, and road density best predicted wolf distribution in the state, based on 16 AKWAs. The agency's approach required first mapping the state's forested land (based on NLCD data), elk range (according to ODFW), human density (based on US Census block data), and road density (based on Bureau of Land Management data). It then retained all locations that are forested, within elk range, and considered outside the "contracted range" (i.e., "those areas no longer available to wolves because they are dominated by human habitation or roads," ODFW 2015). This contracted range included those locations that have a human population density greater than 4 people per km^2 and/or a road density greater than 3.5 km of road per km^2. This analysis was resampled to a resolution of 1.0 km^2 and projected into NAD 1983 CA Teale Albers in ArcGIS.

Forested Areas: We extracted from the NLCD land cover raster data only those land cover types classified as forest (deciduous, evergreen, and mixed). We added a 2000-meter buffer to these areas, in order to include forest edge habitats that may be used by wolves.

Elk and Deer Ranges: We combined California elk range maps into one range layer. We used a California mule deer range map layer to represent deer range in the state. ODFW did not account for deer range in its analysis because it argued that deer are present in all elk ranges and assumed wolves depend more on elk. But this ignores the fact that deer may be present where there are no elk, and that these deer-only areas may offer enough prey to support wolf populations. For this reason, and because California has many fewer elk than Oregon but more abundant deer populations throughout the state, we decided to produce two SDMs -- one that used elk range to produce a version of the ODFW analysis, and a separate SDM that predicts habitat based on the California mule deer range.

Contracted Range: Locations that offer forest cover and are contained within the prey ranges described above can be unsuitable for wolves if they have been sufficiently impacted by human development. ODFW refers to such areas as "contracted range," and defines them as a combination of locations with a) a human population density greater than four people per km^2, and b) a road density greater than 3.5 kilometers of roads per km^2. These locations are thus considered unsuitable for wolf habitat. ODFW determined these thresholds through analysis of the human impact characteristics of those observed Oregon locations where wolves choose to live. Given that the rest of our analysis assumes that conditions are similar for Oregon and California, we continue this assumption in this case.

> *Human Density:* We extracted cells with human population densities greater than four people per square kilometer, and added a 1600-meter buffer to these high-density cells in order to acknowledge the impact that density has on edge zones.
>
> *Road Density:* A small selection of roads (those classified as bike paths, recreational off-road paths, pedestrian walkways, etc.) were removed from the analysis, to acknowledge that these paths may not deter wolves from landscape use. A linear magnitude per unit area was calculated (in this case, kilometers of road per 1.0 km^2), and the resulting data layer was reclassified into two categories - cells with less than 3.5 km of road/km^2, and cells with 3.5 km of road (or more)/km^2.

The contracted range was removed from a combined forested and elk range map. We also eliminated contiguous patches with an area less than 500 km^2, which Carroll et al. (2003) determined to be a minimum size to support a wolf pack. This removed a total of 152 patches (totaling 2,979 km^2) from the elk model, and 913 patches (totaling 12,674 km^2) from the deer model.

Model 2: Logistic Regression

This method was used to understand the relationships between independent environmental variables (i.e., land cover classes, prey population estimates, human density, road density, and land ownership status) and a dichotomous dependent variable (i.e., wolf presence). The resulting model was tested in Oregon and applied to California to reveal gray wolf habitat probability.

Because wolves only recently began arriving to California, the state currently lacks a sufficient number of confirmed wolf presence locations to use as input data for the analysis described here. As such, we built our model using data from Oregon, which has a substantial number of wolf presence data points. This approach provides two advantages: (1) Oregon has the most similar landscape features to California when compared to other Western States with established gray wolf populations, and (2) the wolf packs established in Oregon will likely be the source of continued wolf dispersal south into California (as shown by OR-7, OR-25, and the adults in the Shasta Pack).

The various prior research efforts to predict wolf distribution in the Western US have, despite their use of differing methodologies, generally agreed on the independent environmental variables that determine wolf distribution. These variables include human and road densities, prey density, forest cover, and public lands. Data addressing each of these factors were collected and manipulated according to the following methods.

Model Resolution

Data were acquired in a variety of spatial resolutions and formats. In order to most easily perform the necessary calculations, each dataset was resampled to a universal resolution of 100 km^2. Oregon and California together equal 678,996 km^2, making a 100 km^2 resolution a desired nexus of both limited computing processing ability and a relatively fine-scale analysis.

A fishnet grid (a feature class in ArcGIS that contains a net of rectangular cells) was generated for Oregon and California that captured this desired resolution in square grid format. This grid was used to produce spatially consistent calculations of the datasets defined below.

Environmental Variables

i) Land Cover Classes

Two different versions of this dataset were developed: (1) seventeen individual land cover types (open water; perennial ice/snow; developed low, medium, and high intensity; developed open space; barren land; deciduous, evergreen, and mixed forest; dwarf scrub; shrub/scrub; grassland/herbaceous; cultivated crops; pasture/hay; wood wetlands; and emergent herbaceous wetlands); and (2) six broad classes of land cover types (water, developed, bare, forest, shrub, herbaceous, agriculture, and wetland), where similar land classes were grouped together in a similar fashion to the NLCD groupings (Table 2.1). Both the individual and broad land cover classes were calculated as a percent within each 100 km^2.

Table 2.1. Individual NLCD land cover classification groupings for "Broad" land cover data. Individual land cover classes organized into broad cover classes according to the National Land Cover Database groupings; number in parenthesis is the NLCD land cover classification identification.

	National Land Cover Database "Broad" Category Groupings							
	Water	Developed	Bare	Forest	Shrub	Herbaceous	Agriculture	Wetland
Individual Classification / Description (NLCD Value)	Open Water (11)	Developed, Low Intensity (22)	Barren Land (31)	Deciduous Forest (41)	Dwarf Scrub (51)	Grassland / Herbaceous (71)	Cultivated Crops (82)	Woody Wetlands (90)
	Perennial Ice/Snow (12)	Developed, Medium Intensity (23)		Evergreen Forest (42)	Shrub / Scrub (52)		Pasture / Hay (81)	Emergent Herbaceous Wetlands (95)
		Developed, High Intensity (24)		Mixed Forest (43)				
		Developed, Open Space (21)						

ii) Land Ownership

Each raster cell of land ownership data for California and Oregon was acquired at an original scale of 1:100,000. This raster was converted to either "private" or "public" designations based upon classifications set forth by the USPAD. We then calculated the percentage of each 100 km^2 cell that was classified as public lands.

iii) Human Density
Human population density data were acquired for Oregon and California at 30 arc seconds (approximately 1km^2) resolution and then resampled to match this analysis' spatial resolution.

iv) Road Density
Road density data for Oregon and California were calculated per 100 km^2. The US Census TIGER road dataset is detailed and includes roads ranging from major highways to desolate logging roads, but these roads do not have an equal impact on gray wolf distribution. As such, we opted to include only "primary" and "secondary" roads in our calculations. Primary roads, as defined by the US Census TIGER database, are divided, limited-access highways within the interstate highway system or under state management. TIGER identifies secondary roads as main arteries, usually in the U.S. Highway, State Highway, and/or County Highway system.

v) Prey Density
Prey density for California and Oregon included mule deer, Roosevelt elk, and Rocky Mountain elk. Population estimates for mule deer and elk were provided at the Wildlife/Game Management Unit (GMU) level for both California and Oregon, respectively. These population estimates are provided in a very coarse resolution when compared to the other data sets; deer and elk are in essence "evenly distributed" across each GMU, which range in size from a minimum of 750 km^2 in Oregon to a maximum of 68,700 km^2.

While mule deer populations are spread across the entire state of Oregon, ODFW does not have deer population data for 22 GMUs in western Oregon. It was important to compensate for this data gap by predicting mule deer population size in these 22 GMUs. We did this by generating a multivariate linear regression using the available GMU's deer population estimates and land cover class data. Our results suggested that deer population was significantly correlated with five land cover classes: bare rock, forest, shrubland, herbaceous, and agricultural land (Table 2.2). While we used this model to predict the deer population sizes for the GMUs lacking data, the original ODFW population estimates were used for the state's remaining 47 GMUs.

Table 2.2. Results of the multivariate linear regression to predict deer population. Results of the multivariate linear regression to predict deer population size in the 22 western OR GMUs (R^2 = 0.96; $F(5, 86) = 452.3$). The y-intercept was forced through 0, as there can be no deer in an area that does not have some amount of land cover.

Variables	Coefficient	Standard Error	t-Value	p-Values
Bare Rock	-2.138 e -06	9.422 e -07	-2.455	0.01611
Forest	3.474 e -06	2.071 e -07	16.774	<0.001
Shrubland	3.685 e -07	1.321 e -07	2.79	0.00649
Herbaceous	1.692 e -06	6.280 e -07	2.694	0.0085
Agricultural	1.801 e -06	5.524 e -07	3.261	0.00159

In order to improve the resolution of the deer and elk population estimates from the coarse GMU structure *and* to maintain the total CDFW and ODFW counts within each GMU, prey population estimates were redistributed only to habitat types generally associated with these species. These habitat types include developed open space, forest, shrubland, herbaceous grassland, agricultural land, and wetlands (Heffelfinger et al. 2006; Unsworth et al. 1998). Deer and elk were effectively removed from more heavily developed lands, open water, bare rock, snow, and ice land cover classes. We then used the original fishnet grid to calculate the average elk and deer density per $100km^2$.

To better compare the relative biomass of elk and deer, an Ungulate Biomass Index (UBI) was used to normalize the data (Larsen and Ripple 2006). This UBI considers the relative biomass of one elk to be equivalent to the relative biomass of three deer (Keith 1983; Fuller 1989; Mladenoff et al. 1995; Fuller et al. 2003). Therefore each cell's deer density values were divided by three and simply added to elk density values to generate a generic UBI value for each cell.

vi) Wolf Presence

To apply these data to the fishnet grid, we used a binary code - any grid cell that overlapped with an AKWA polygon received a 1 (representing wolf presence). Employing this binary code allowed us to forego making assumptions about wolf pack size and to simply use an overlay of our fishnet grid and the AKWA polygons. This accounts for the roughly 80 wolves in Oregon but 187 presence points generated for Oregon; these presence points do not indicate number of individuals, but the $100km^2$ cells associated with wolf colonization.

vii) Pseudo-Absences

In order to create the most accurate models, logistic regression SDMs require the use of "absences" that indicate locations unsuitable to colonization by the species of interest. But because gray wolves are still in the process of colonizing vast landscapes throughout the West, it is impossible to know if locations in which they are not present indicate true absence points or merely areas that wolves are capable of colonizing but have not yet reached. Since, for this reason, there were no true "absence" data points available for our analysis, we needed to generate what are called "pseudo-absences." According to Barbet-Massin et al. (2012), randomly selected absence data that are of equal magnitude to presence data yield reasonably reliable and accurate SDMs.

We therefore applied a random point generator to our fishnet of Oregon to classify 187 random pseudo-absences. These were confined to all parts of Oregon outside the AKWAs, and each AKWA included a 10km external buffer to minimize spatial autocorrelation (i.e., the extent to which spatial characteristics and their associated environmental variables tend to be clustered together) (Mladenoff et al. 1995).

Model Selection

Logistic regression models analyze landscape and habitat features associated with wolf pack home ranges; however, wolf-habitat relationships vary slightly depending on the landscape in which the wolf pack exists. The variety of the published wolf SDM works cited in this document provided our analysis with a clear understanding of the variety of significant predictor variables for wolf presence data.

In order to determine the best model, we tested and ran many combinations of variables. To select the best model, we considered:

1. Akaike Information Criterion (AIC) model scoring. This metric indicates the relative strength of a statistical model for a given set of data;
2. Each variable's ability to significantly predict favorable wolf habitat, or the p-value; and
3. Collinearity and interactions between individual variables. High correlation between variables can skew a model's fit (Dormann 2013).

Model 3: Maxent

Our third model approach was a SDM based on multivariate maximum-entropy modeling. Maxent is a machine-learning method that creates a logistic output (similar to logistic regression), with habitat suitability values ranging from 0 (unfavorable) to 1 (optimal) (Phillips and Dudík 2008). Maxent is a popular SDM tool that compares well to other SDM approaches. It also requires only presence data, which makes it especially helpful for this exercise, given our data limitations (Elith and Graham 2009). By iterating the model 500 times, we were able to analyze variable interaction (such as collinearity) and variable importance in determining favorable wolf habitat.

Model Resolution

All environmental variables were resampled to a 1 km^2 resolution.

Variables

The Maxent model used the same independent environmental variables as the logistic regression model:

1. land ownership data, which were used as binary categorical data (1 for public or 0 for private ownership);
2. human density (humans/km^2);
3. road density (m of roads/km^2);
4. prey density, in the form of ungulate biomass index, based on deer and elk densities;
5. land cover classes, also used as categorical data, with each cell classified as the land cover class that covered the majority of the cell.

See *Environmental Variables* under *Model 2: Logistic Regression* for more information on data sources and management.

Presence and Absence

Presence points were created by randomly distributing 300 points within the Oregon AKWAs. Though there are not 300 wolves in OR, this model is not estimating the number of wolves, but rather the probability of favorable habitat. These presence points were able to adequately cover the AKWAs within the state. As a substitute for pseudo-absences, Maxent randomly distributed 10,000 background points throughout Oregon. The model was built using Oregon data only, and then projected into California to (1) maintain similarities between methodologies, and (2) limit a potential source of error as Maxent is shown to perform less accurately when the presence points cover only a small part of the region (VanDerWal et al. 2009). To test the success of the model, 15% of points were removed from the model training data to later use as points to test the model's specificity (i.e., its ability to predict presence) and sensitivity (i.e., its ability to predict absences).

Model Selection

In order to determine the best model, we tested and ran many combinations of variables. To select the strongest model, we considered:

1. AUC (area under the curve) Model Score. A random model's AUC=0.5, and a perfect model's AUC=1 (Phillips et al. 2006). Models with AUC values between 0.5 and 0.7 are considered poor performers; between 0.7 and 0.9 are moderate; and above 0.9 are high performers (Manel et al. 2001);
2. Each variable's "percent contribution," as calculated by Maxent as it iterates the model multiple times. This value represents the increase in predictive capacity of the model provided by each variable (Phillips and Dudík 2008); and
3. Collinearity and interactions between individual variables. High correlation between variables can skew a model's fit, as well as the estimations of AUC and percent contributions.

We also created a Maxent model that used the same combination of variables utilized by the selected logistic regression model in order to compare the two methodologies and their outputs.

Species Distribution Results

Model 1: ODFW

As noted above, this model produced two results: (1) an SDM of wolf habitat in California informed by elk range (Figure 2.1), and (2) another SDM informed by deer range (Figure 2.2). The elk-based map identified a total wolf habitat area of about 32,301 km^2 between 7 patches. These are mostly located in the far northwestern part of the state, with small patches in other parts of the coastal mountain ranges from Mendocino National Forest to Los Padres National Forest. The deer-based map identified a total wolf habitat area of about 124,160 km^2 between 14 patches. These are primarily in the forested and mountainous regions of the northern half of the state, but also stretch down the Sierra Nevada and coastal ranges to parts of Santa Barbara and Los Angeles Counties.

To test how closely our methodology hewed to ODFW's, we applied our methods to Oregon and compared our results to its results. If the methodologies were exactly the same, we would expect the area identified as wolf habitat by our model to overlap perfectly with the area identified by ODFW. However, we found them to be slightly different, with an overlap of 96%. This is likely because ODFW used its own state-based sources for some of its data inputs, while our analysis used datasets provided by national sources (since we looked at both Oregon and California). Importantly, almost all AKWAs fall entirely within the ranges identified by both ODFW and our analysis; only one AKWA (the large home range of the Imnaha pack) falls partially (~30% for each) outside of both models.

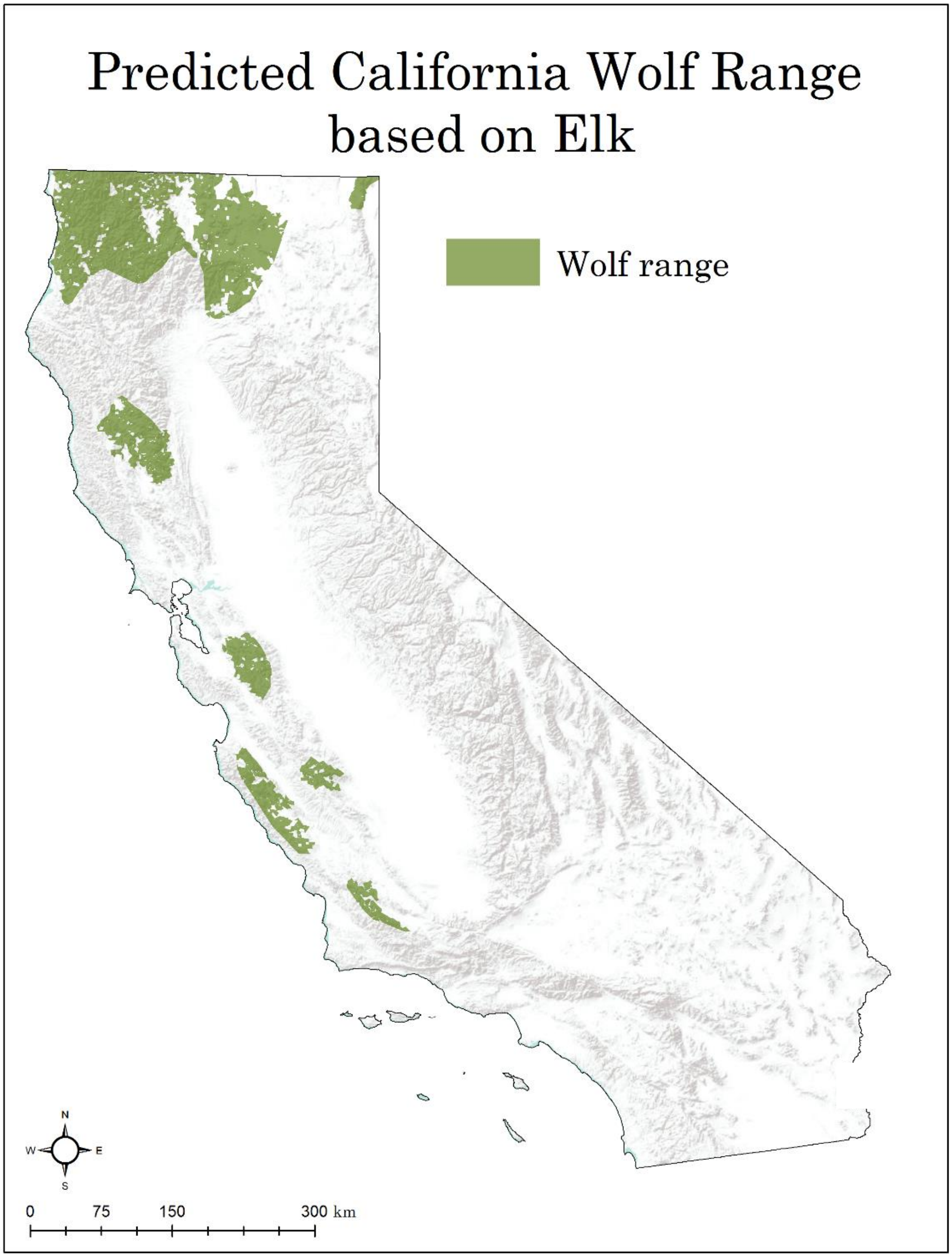


Figure 2.1. Results of ODFW-inspired, elk-based analysis of potential gray wolf habitat in California. Wolf distribution model assuming elk as the primary prey source. This map depicts 1km^2 locations that a) are forested (or within 2000 meters of forest); b) are contained within elk range; c) have human densities of 4 or fewer people and are not within 2000 meters of such dense areas; and d) have fewer than 3.5 kilometers of roads.

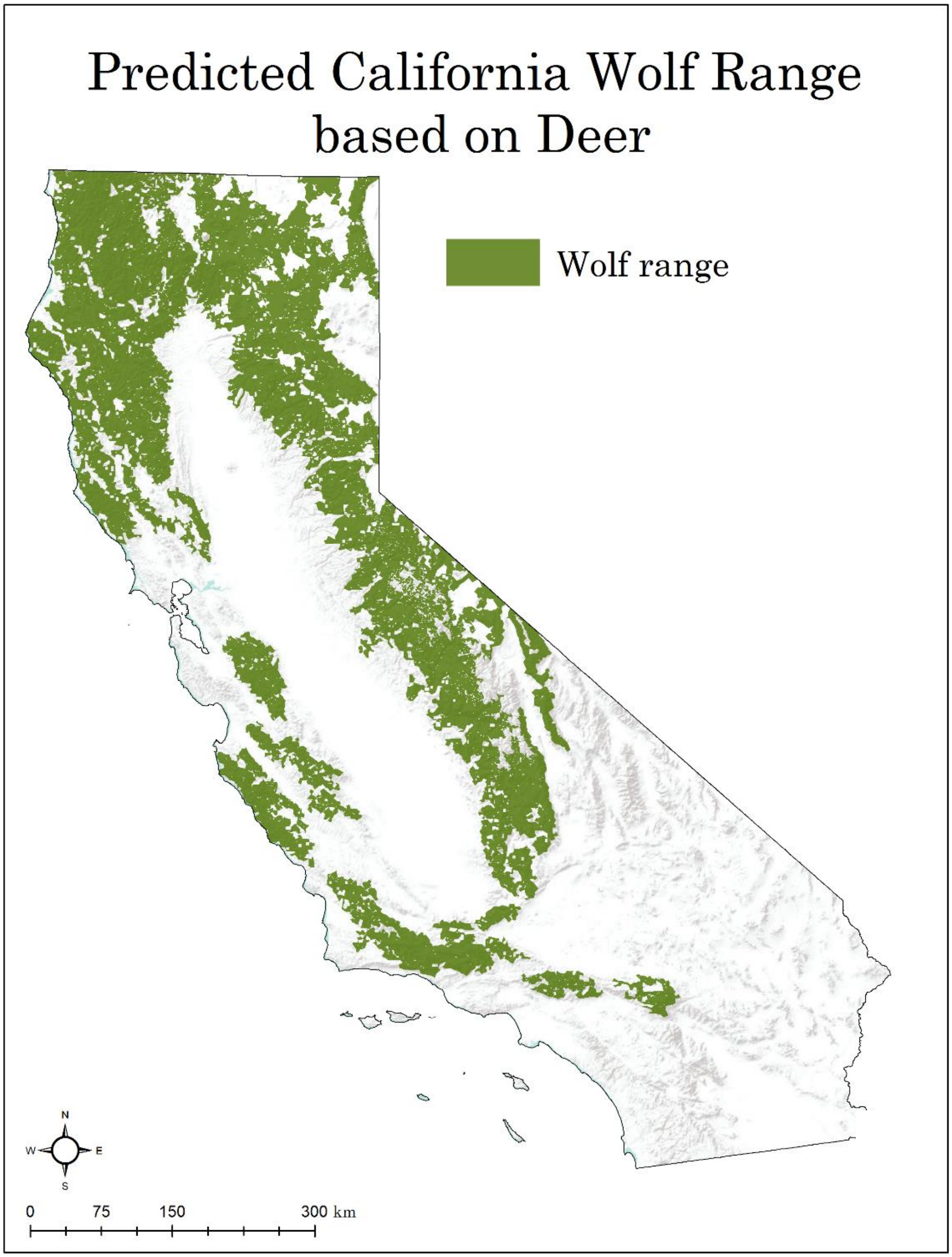


Figure 2.2. Results of ODFW-inspired, deer-based analysis of potential gray wolf habitat in California. Wolf distribution model assuming deer as the primary prey source. This map depicts $1km^2$ locations that a) are forested (or within 2000 meters of forest); b) are contained within mule deer range; c) have human densities of 4 or fewer people and are not within 2000 meters of such dense areas; and d) have fewer than 3.5 kilometers of roads.

Model 2: Logistic Regression
Employing the selected model as outlined above, we have identified a gradient showing probability of favorable wolf habitat across all landscapes in California with a resolution of 100 km^2 cells. The predicted probability of favorable habitat values exist on a scale of 0.0-1.0 (0.0 indicates 0% favorability and 1.0 indicates 100% favorability). For this report, we make the additional assumption that higher probabilities will result in proportionally greater likelihoods of wolf colonization in each respective region cell. The mapped results are displayed below (Figure 2.3).

Model Selection
Several models were created based on many combinations of variables. Table 2.3 shows the results of two models -- one that includes all five environmental variables and a second that includes only percent forest cover and the ungulate biomass index. We decided to limit our logistic regression model analysis to just the selected model with these two independent variables. This decision was statistically validated through the application of model fit criteria analysis -- the Akaike Information Criterion (AIC). The selected model received an AIC score 3.37 less than the raw model; this indicates a better model fit.

Table 2.3. Results of logistic regressions for predicting suitable gray wolf habitat in California. Results of two logistic regressions for predicting suitable gray wolf habitat in Northern California using different combinations of predictor variables. The "raw model" includes all variables cited in gray wolf distribution model literature and "selected model" includes only variables selected by the statistical variable selection method (associated coefficients, standard errors, z-values, p-values, and AIC scores). Asterisks indicate statistical significance.

Model	Variables Included	Coefficient	Standard Error	z-Value	p-Value	AIC Score
Raw Model	Intercept	-2.67	0.513	-5.22	<0.001**	353.15
	Forest	1.65	0.539	3.06	0.002**	
	Prey	1.35	0.198	6.84	<0.001**	
	Human	-1.15E-04	0.000	-0.91	0.364	
	Road	1.90E-04	0.000	-1.14	0.254	
	Land Ownership	-6.00E-02	0.429	-0.07	0.944	
Step-function	Intercept	-3.17	0.368	-8.62	<0.001**	349.76
	Forest	1.61	0.459	3.51	<0.001**	
	Prey	1.49	0.168	8.91	<0.001**	

Previous SDMs performed for western states display variable model parameter selection (Table 2.4). Many of these models (e.g., Larsen and Ripple 2006 and Oakleaf et al. 2006) selected forest cover and prey population densities (e.g., Oakleaf et al. 2006) as significant variables for predicting wolf presence.

Table 2.4. Gray wolf species distribution model selected variable comparison. Comparison of three western state gray wolf species distribution models selected variables. These SDM's include Mladenoff et al. 1995, Oakleaf et al. 1996, and Larsen and Ripple 2006.

Selected Model	Mladenoff (1995)	Oakleaf (1996)	Larsen & Ripple (2006)
Percent Forest Cover	Road Density	Forest Cover	Percent Forest Cover
Ungulate Biomass Index	Fractal Dimension	Human Density	Percent Public Ownership
		Elk Density	
		Sheep Density	

For this type of probability output, it is typical to determine a threshold of favorability (or a "cutpoint") in order to say with greater confidence that wolves may be most likely to colonize specific locations. Deciding on a cutpoint for wolves is challenging due to their habitat generalist nature; nonetheless, we observed that only six of the 187 presence points had a predicted probability of less than 0.3. This means that, according to this model, 96.79% of the confirmed wolf presence locations in Oregon were selected at over a 0.3 probability. Given this, we selected a cutpoint of 30% to indicate those locations that may offer the "most favorable" wolf habitat relative to all others.

Model Test Results

We performed two methods of model testing to statistically validate the logistic regression model. The first method removed 10% of the pseudo-absence data (randomly selected) from the original model and tested to determine if those selected pseudo-absence removals were then predicted by the model as true absences (< 0.3 probability). The test identified the removed pseudo-absence locations as true absences at a 100% success rate. It should be noted that more traditional testing methods use presence location instead of absence, but our test used absences because there are limited presence data points and removing 10% of the presence data would significantly weaken the model.

The second model-testing method was based on a test that Larsen and Ripple (2006) applied to their gray wolf distribution model. Here, the probabilities of known presence data points are averaged together, as are the probabilities of pseudo-absence points. Larsen and Ripple (2006) had a success indicator threshold of presence data averaging to greater than 50% and absence data averaging less than 50%. Our model's averaged favorable habitat probability was 70%, and its averaged absence probability was 30%. This indicates that, according to the 50% threshold, our model is sufficiently accurate.

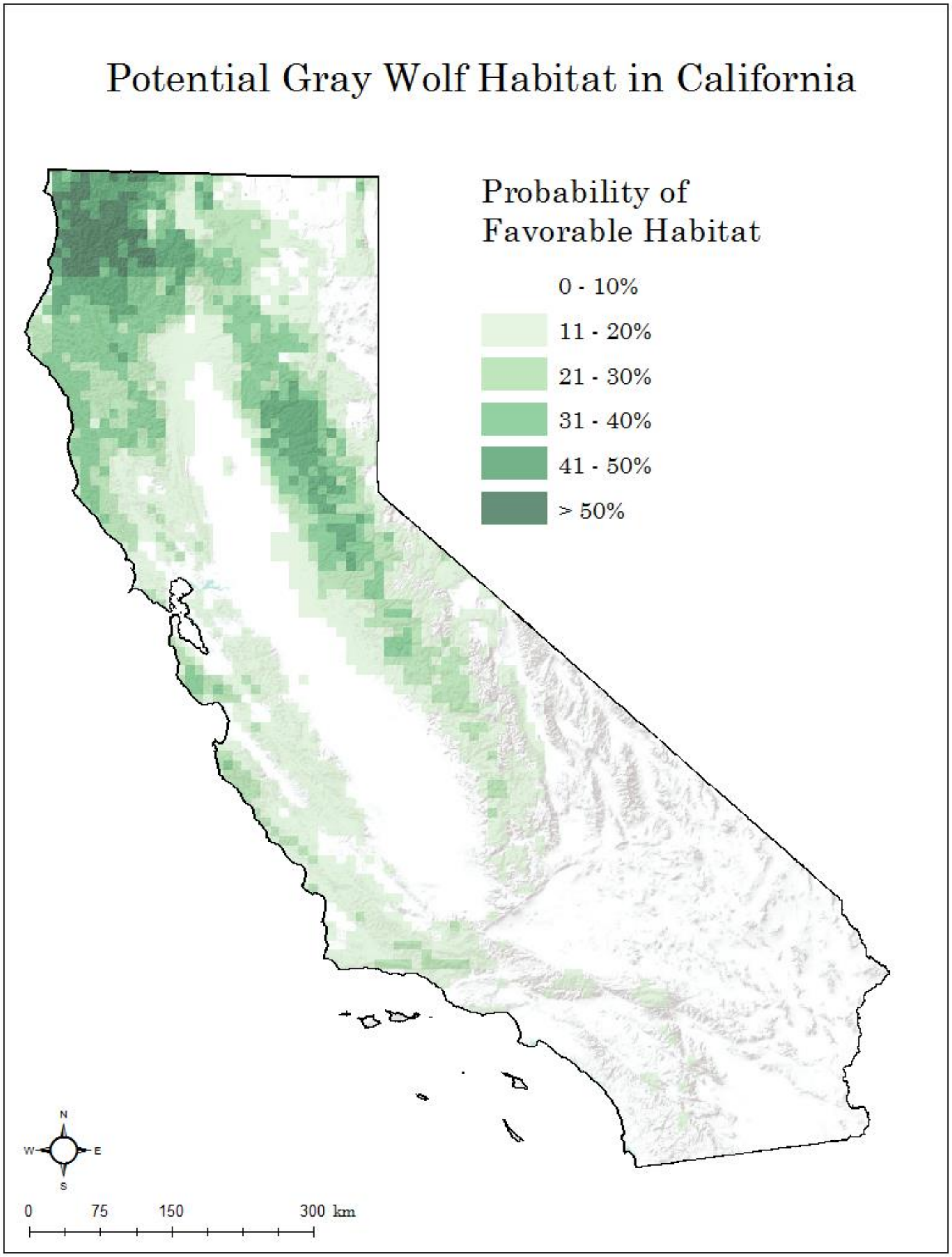


Figure 2.3. Logistic regression results of potential gray wolf habitat in California. Probability of favorable habitat (0 - 59%) of gray wolf habitat in California.

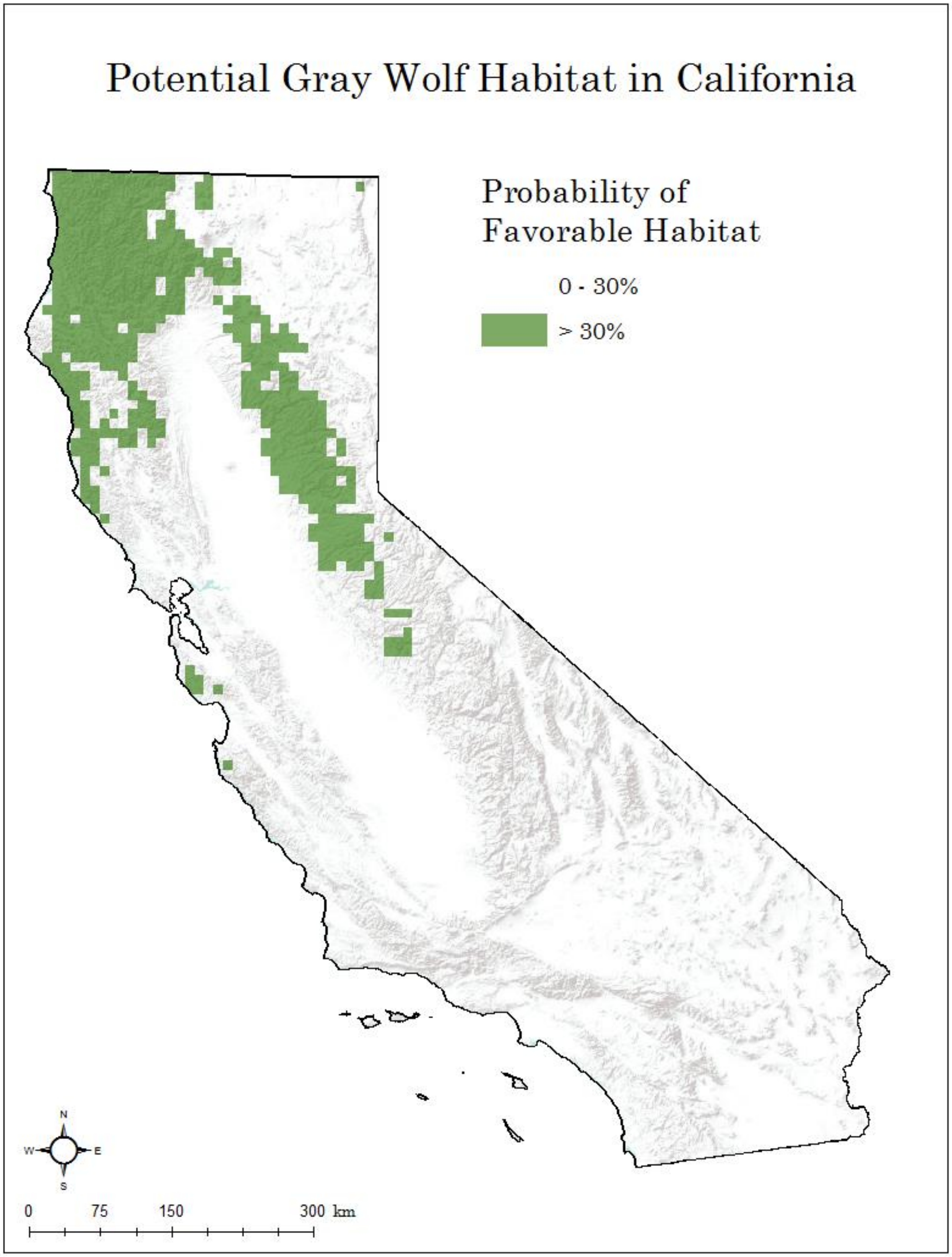


Figure 2.4. Logistic regression results of potential gray wolf habitat with cutpoint of 30%. Showing potential habitat in California based on a determined 30% probability as determined by our cutpoint analysis.

Model 3: Maxent

Of the three model results shown in Table 2.5 the model selection criteria led us to select Model 2 as the final Maxent model. The model has a high AUC score (AUC=0.922), as well low collinearity between variables. Model 3 used the same variables as those in the selected logistic regression model, and so was also “high-performing.”

Table 2.5. Maxent Model comparison. Three models are shown, including Area Under the Curve (AUC) score (models scored above 0.9 are considered high performers) and percent contributions of included variables.

		Percent Contribution of Variables						
Model	**Model AUC Score**	**Land Ownership**	**Human Density**	**Road Density**	**Prey Density (UBI)**	**Land Cover Classes**	**Forest Cover**	**Notes**
1	0.918	0.1	9.5	1.9	82.4	6.1	--	All variables included
2	0.922	--	10.4	--	83.2	6.3	--	Selected model due to AUC score, lack of variable collinearity, literature
3	0.914	--	--	--	98.5	--	1.5	Same variable combination used in selected logistic regression model

Maxent iterated each model 500 times, and was able to determine variable importance, or “percent contribution,” by making small changes to the model and recording model improvement. The UBI was clearly the most important variable, contributing 83.2% of the total model predictive power (Table 2.5).

Maxent also analyzed the specificity and sensitivity of the model to suggest logistic cutpoint values to represent binary habitat and “non-habitat.” A threshold calculated by Maxent minimized over- and under-predictions, thus balancing specificity and sensitivity (Freedman 2009). See Figure 2.6 for the binary output derived from this cutpoint. This binary model predicted 59,914 km^2 of favorable habitat in California.

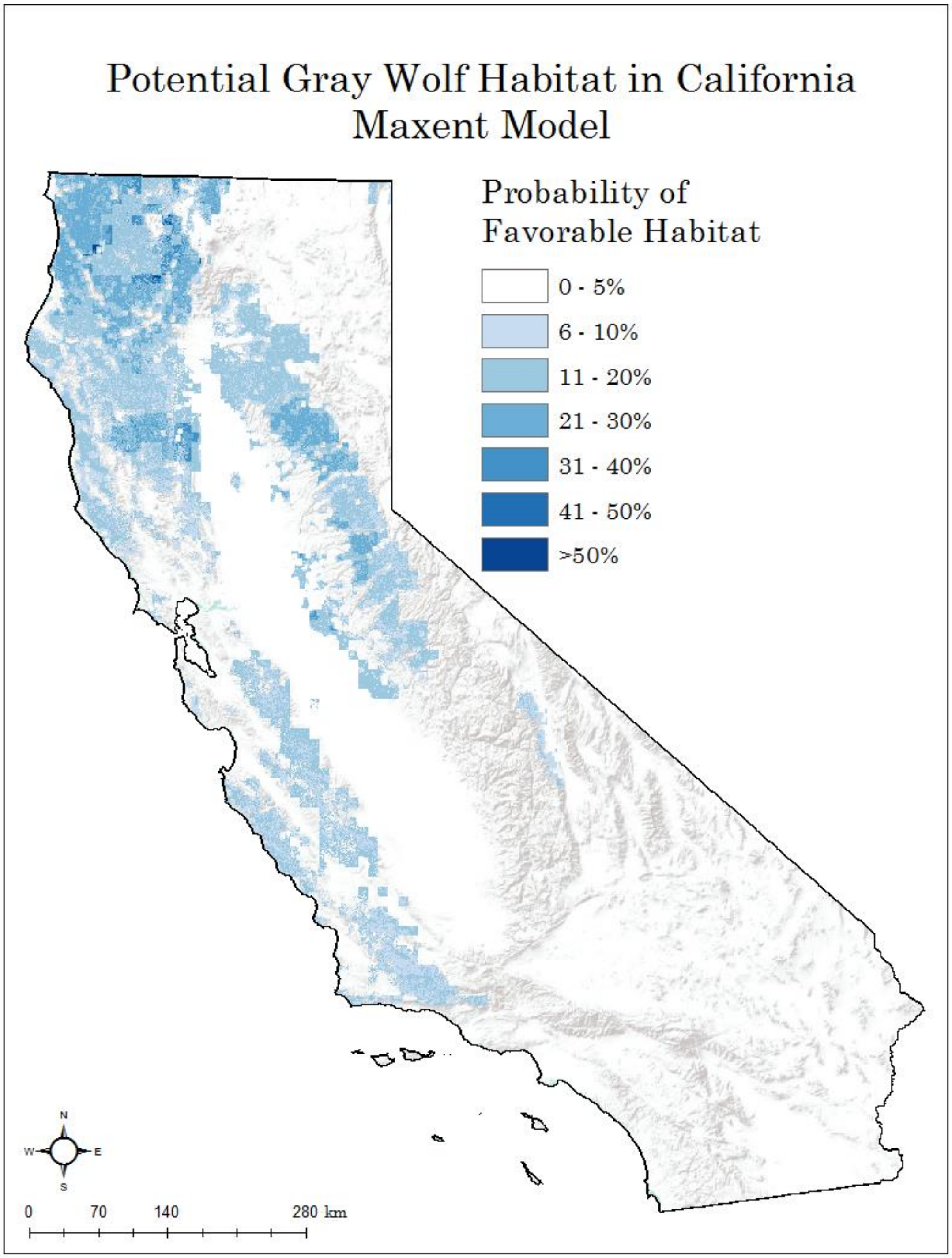


Figure 2.5. Results of Maxent model of potential gray wolf habitat in California. The legend shows the predicted probability of favorable habitat (maximum probability in CA was 58%). This analysis was trained on presence points within AWKA areas in Oregon, as well as "background" points in Oregon, and then projected into California. The selected model incorporated human density, land cover classes, and prey density (as the Ungulate Biomass Index) as predictor variables.

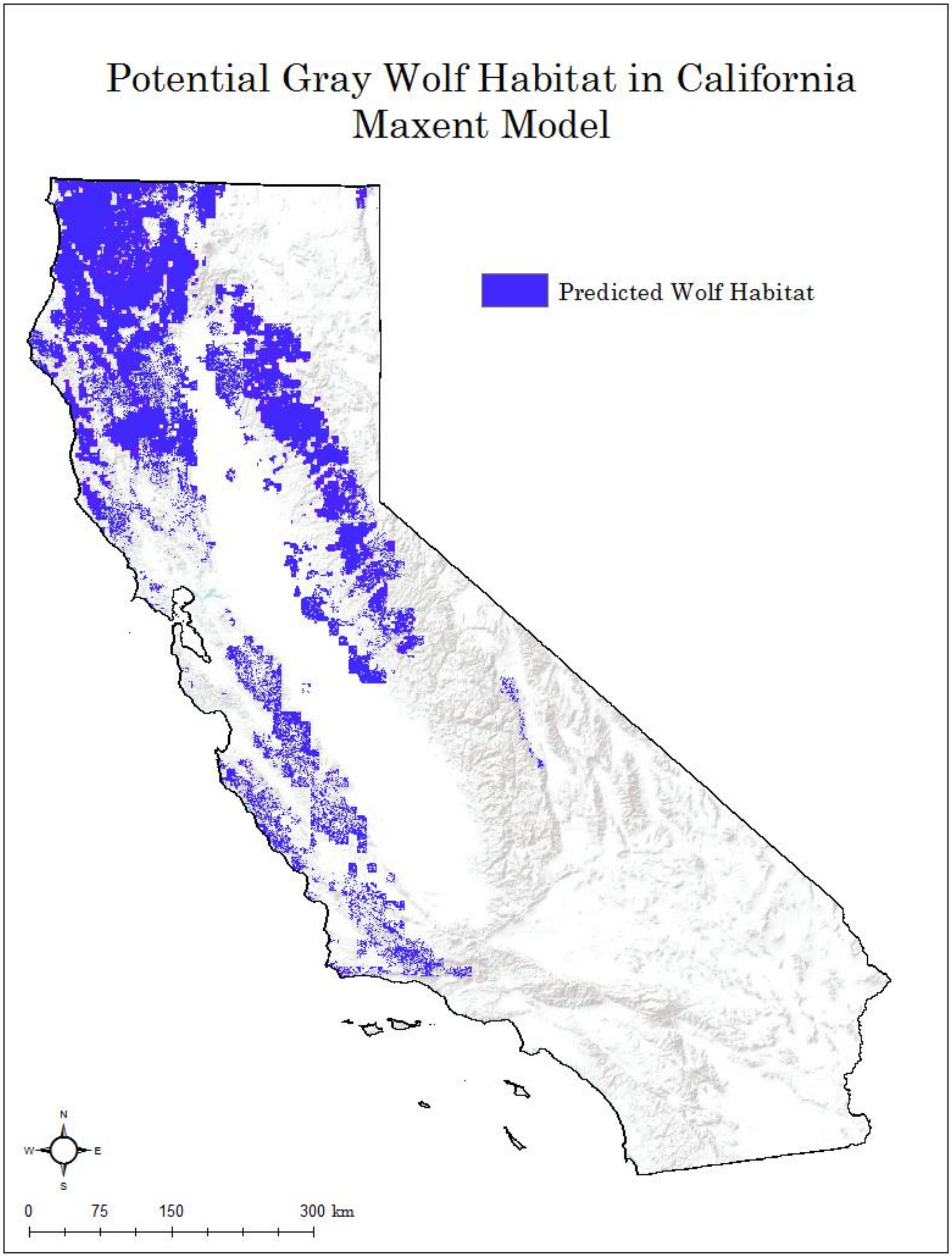


Figure 2.6. Binary results of Maxent model of potential gray wolf habitat in California. Following Figure 2.5, this figure shows a binary of all possible habitat as calculated by Maxent (determined by a threshold of 0.091), and which balances sensitivity and specificity.

Model Comparison & Discussion

An important distinction between the ODFW approach, logistic regression, and Maxent approaches was that the ODFW method did not provide a gradient to see *relative* quality of habitat. The logistic regression and Maxent models calculated the probability of relative wolf presence for each 100 km^2 and 1km^2, respectively. Most published wolf SDM research utilizes prey density data (as opposed to prey range) that identifies a geospatial spectrum of combined elk and deer density. Areas of greater density are considered more favorable wolf habitat. This accounts for the variability of prey's use of the heterogeneous landscapes within its range, and thus adds a level of complexity and nuance to such models. ODFW's methods, on the other hand, may over-estimate potential wolf habitat, since portions of the modeled prey range may actually be rarely used by prey. The incorporation of prey density data may thus provide for finer-scale analysis, and the resulting habitat favorability gradient could allow for more detailed quantitative and qualitative comparisons.

On the other hand, there may be a compelling reason to over-predict habitat if interested stakeholders prefer to "cast a wide net" and capture all locations that may have some reasonable ability to support wolf populations. But the objective of our spatial analysis is to hone in on locations most likely to support wolves, in order to determine potential conflict hotspots. A model that over-predicts potential habitat may be an inappropriate tool to inform the targeted implementation of conflict reduction strategies.

The models suggest that a significant portion of potential wolf habitat lies within National Forest or Park boundaries (Appendix B). The large swaths of potential habitat shown in the north and northwestern parts of the state are mostly contained within Six Rivers, Klamath, Shasta-Trinity, and Lassen National Forests, and Redwood National Park. Most of the potential habitat depicted in the vicinity of the Sierra Nevada foothills are within or near Plumas, Tahoe, Eldorado, Stanislaus, Sierra, and Sequoia National Forests. Additional (though fewer) potential habitat patches are found in Mendocino and Los Padres National Forest, as well as various state parks. If wolves continue dispersing into the parts of California depicted in our analysis, and if they remain protected, then the CDFW, USFWS, and the US Forest Service (and possibly the National Park Service and California Department of Parks & Recreation) may be compelled to work closely together in the requisite monitoring and management of this endangered species.

Both the logistic regression and the Maxent model predict high probability of favorable habitat in Northwestern Oregon. Though this may be reasonable based on environmental variables, it should be noted that ungulate densities were projected using our ungulate linear model. This adds another level of uncertainty to this region, and the model may over-predict habitat favorability. However, ungulate densities for all California management units and all AKWAs were provided by CDFW and ODFW, respectively. As such, this uncertainty does not pertain to the majority of our prediction.

Maxent modeling has been shown to be mathematically equivalent to generalized linear modeling, specifically Poisson regression modeling, which closely resembles logistic modeling (Renner and Warton 2013). Therefore, any differences between the results of our logistic regression and our Maxent model are based only on how the methods were applied (i.e., selection of variables, generation of pseudo absences, number of iterations, etc.) rather than any differences in the core analysis.

Both the Maxent and logistic regression models produce probability outputs. The total range of probabilities is very similar between both models; logistic regression calculating from 0.0 to 0.59 and Maxent calculating from 0.0 to 0.58. The distribution of these probabilities differs quite greatly, however. This is clearly illustrated from the average probability for all of California -- the logistic regression and Maxent models determined an average of 0.13 and 0.03, respectively.

In an effort to compare all three model results, we calculated the area of overlap between all results (Table 2.6). The area predicted by both the logistic regression model and the Maxent model was greatest at 43%, the percentage of overlap between the Maxent model and the ODFW model was second at 36%, and the overlap between the logistic regression and the ODFW was the least at 33%. Moreover, when we compared the results of all three models, 25% of the landscape predicted as favorable wolf habitat overlapped (see Appendix C for a map of this result).

Table 2.6. Three model comparison. A comparison of habitat selected by each of the three models (logistic regression, Maxent, and the Oregon Department of Fish and Wildlife methodology).

	Logistic Regression	Maxent	Oregon Department of Fish and Wildlife
Logistic Regression	1.0	0.43	0.33
Maxent	-	1.0	0.36
Oregon Department of Fish and Wildlife	-	-	1.0

We chose to use the output predictions modeled by the logistic regression as inputs for our analysis of potential wolf-livestock conflict zones in California. Progressing with a single output is beneficial in regard to transparent interpretation of future process results (though the similarity of each model's predicted favorable habitat strengthens our confidence in the results of each approach). Logistic regression is well regarded in the field of species distribution modeling and resource selection functions. Additionally, the logistic regression method allowed for a more customized and region-specific analysis when compared to the Maxent model due to the data limitations with the latter.

Model Limitations

Attempts to precisely pinpoint potential gray wolf habitat may be quixotic. Despite our efforts, uncertainty remains whether wolves in California will seek and use similar habitat and landscapes as they use in the Rockies and Oregon. Our methods used environmental predictor variables that research from these regions identified as significantly correlated with potential wolf habitat. But California has a great diversity of landscapes, habitat types, and climate zones, and this variability may be inadequately accounted for by our chosen SDMs. An additional limitation of using only two variables in the final model is that the impact of road density on gray wolf distribution may be under represented. For example, our selected model shows at least one cell of "highly-favorable habitat" with a major interstate (e.g., I-5) running directly through it. This cell may still represent favorable wolf habitat given its size (100 km^2) in comparison to the size of the highway. In addition, Zimmermann (2014) found that wolves displayed ambivalent responses to roads depending on the spatial scale, road type, time of day, behavioral state, and reproductive status.

While the less forested (and warmer and drier) parts of California are, in our results, not shown to contain much favorable wolf habitat, wolves may be able to move into and subsist in these areas. Mule deer (and other potential prey) range throughout much of Southern California, and if wolves make it into the southern stretches of the Sierra Nevada foothills (as our ODFW and logistic regression models suggest they could), there may be little stopping them from continuing into the parts of Los Padres, Angeles and San Bernardino National Forests that have few human-caused disturbances. After all, the Mexican wolf (*Canis lupus baileyi*) is a subspecies of the gray wolf that, historically, ranged throughout much of the Southwestern US, including what is now Southern California. There are not currently any Mexican wolves in this part of the state, so the local scattered mountain lion populations offer the only major competition in these deer-abundant areas (CDFW 2007). The gray wolf may thus have more adaptive capacity than recent SDMs have implicitly attributed to them, and we cannot discount the fact that our cutpoint results may describe fewer "probable" wolf habitat zones in California than actually exist.

Additionally, the next logical consideration after identifying potential favorable habitat patches is to evaluate connectivity and movement between patches. We used the software program Circuitscape to model this issue of connectivity between the two most favorable habitat patches in California (see Appendix D for results of this analysis).

Lastly, none of the SDMs described here include any temporal analysis. We will be unable to confirm our SDM results until wolves colonize more area in Northern California. Because this colonization could take many years, efforts to ground proof our results may be infeasible for some time.

Conflict Map Methods

Large tracts of favorable wolf habitat identified by our selected model are located close to or contain known grazing lands used by California livestock producers. We can expect that conflicts could occur if the state's wolf population grows according to its potential. The experiences of other states offer clear support for this argument -- all states have experienced at least some level of wolf-livestock conflict, despite the fact that wolves in these states are *primarily* hunting wild prey like elk and deer.

Most conflict risk mapping research is informed by related spatial depredation data from the region of interest (Miller 2015). These data are not sufficient for our region of interest, so the methods of those research projects cannot be replicated for this study. Instead we opted to conduct a simple overlay of the results of the selected model with a combined layer of known grazing activity to forecast the locations of possible conflict hotspots. Though this is a coarse and simplified approach, given the lack of data for this region, it would be folly to attempt to produce a more precise conflict risk map.

Grazing Activity

Grazing-related data were acquired from NLCD, the Bureau of Land Management (BLM), and the US Forest Service (USFS). To spatially define the "active grazing" layer, we extracted NLCD cells classified as "grassland/herbaceous" or "pasture/hay" (originally at a resolution of 30 m^2) and applied a buffer of 250 meters to each cell. This buffer accounts for the fact that livestock may graze a short distance from prime grazing land. The resulting layer was generalized to 1.0 km^2. This layer was then combined with two other layers: (1) grazing allotments leased by the BLM and the USFS; and (2) lands classified by the California Department of Conservation as "grazing land" (defined as "land on which the existing vegetation is suited to the grazing of livestock," and based on both vegetation and soil characteristics). This resulting layer is the completed layer of active grazing land (Appendix V Figure 13).

Conflict Mapping Results

After construction of the active grazing layer, we extracted the selected model (showing relative favorability wolf habitat) through the mask of grazing activity to complete the overlay mentioned above. The resulting map (Figure 2.7) shows all predicted wolf habitat that overlaps with public and private areas that we assume may be used (at least occasionally) for grazing livestock. Because the gradient of the selected model indicates the relative likelihood that wolves may inhabit a given cell, we assume that those cells that offer more favorable wolf habitat are at an equivalently more likely level of conflict. We thus created a model of "conflict hotspots" (Figure 2.8), which we define as those active grazing locations that offer a favorable habitat probability greater than 30% (using the cutpoint of the selected model).

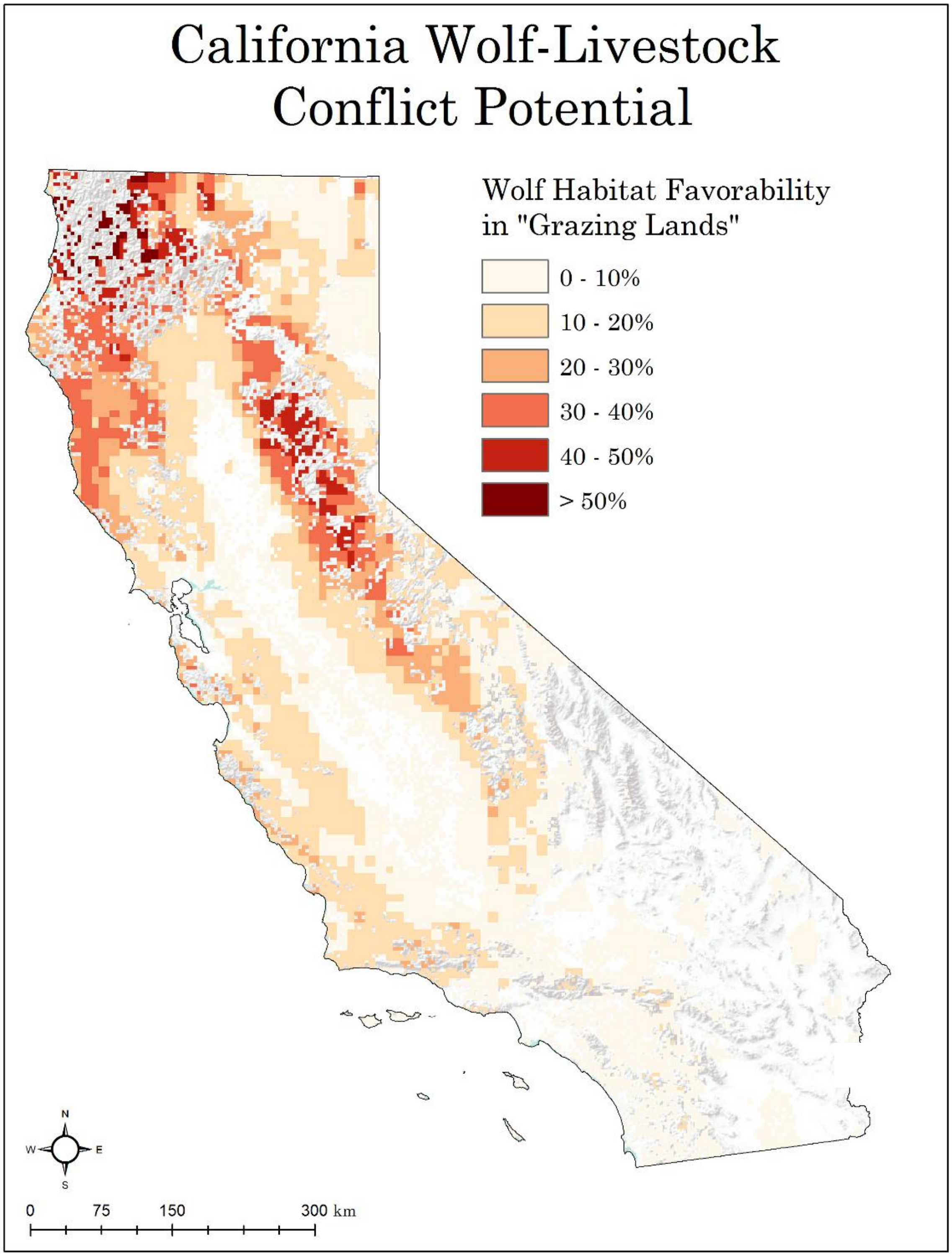


Figure 2.7. Potential wolf-livestock conflict zones in California. An overlap of the selected model results with known grazing activity in California.

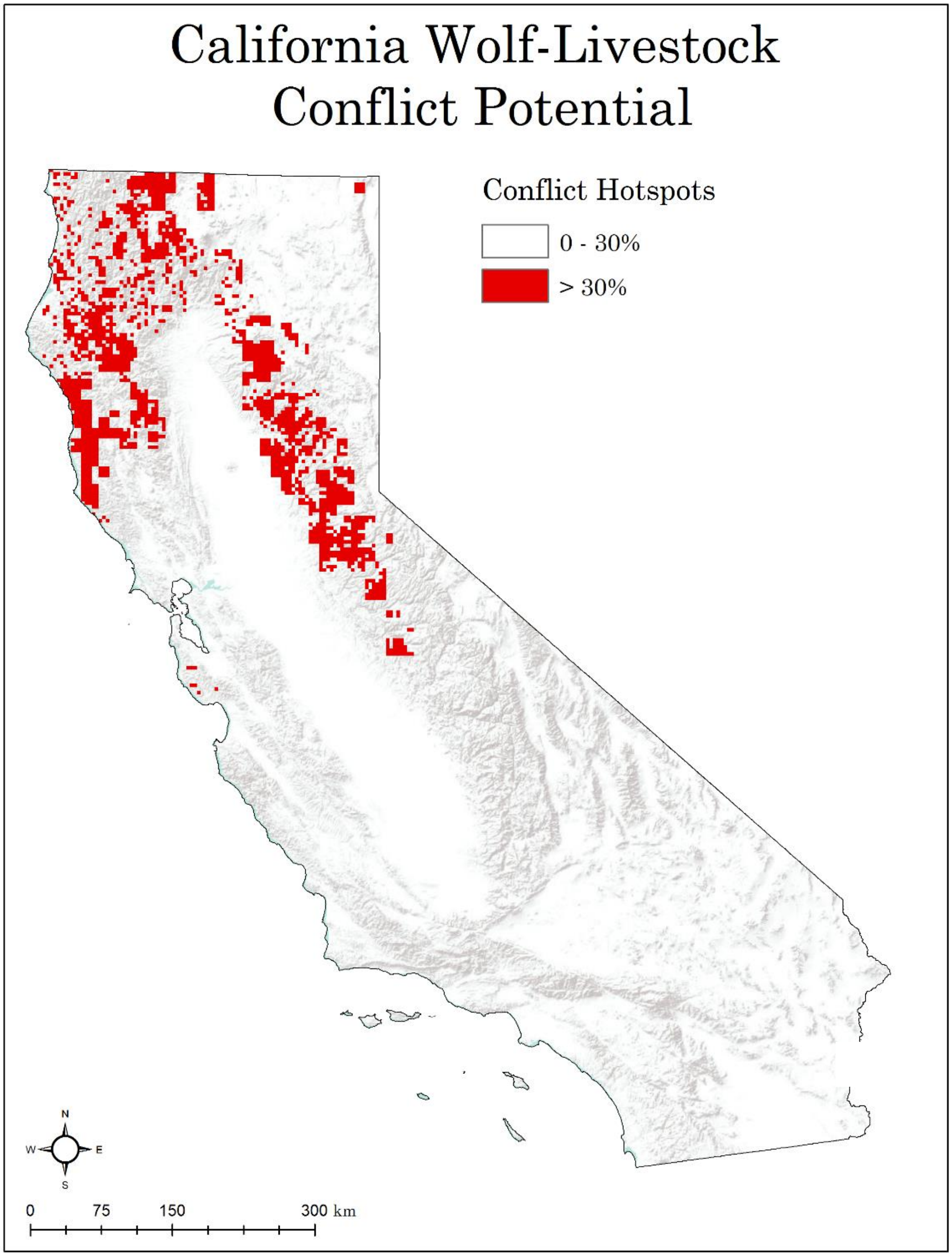


Figure 2.8. Potential wolf-livestock conflict hotspots in California. These results assume that conflict potential is perfectly correlated with wolf habitat favorability, and that "hotspots" are overlap between active grazing land and predicted habitat above the 30% cutpoint.

The model indicates that the California locations most at risk of conflict include parts of the Klamath Mountain range in western Siskiyou and Shasta Counties and northern and central Trinity County, as well as western Humboldt County and the grazed parts of the southern Cascades and the northwestern foothills of the Sierra Nevada. Mendocino County also has many medium risk zones.

Conflict Model Limitations and Considerations

The active grazing layer described above (and upon which the conflict risk map is based) captures a very coarse perspective of grazed lands. It includes large federal allotments that are often many hundreds of square kilometers in size and which contain a great variety of landscapes, from prime grazing areas to dense and mountainous forests. Some of these allotments may be only sparsely grazed, while others have cattle on them for the majority of the year. Additionally, the selected model identifies locations of favorable wolf habitat based on forest cover and ungulate density, which may be attributes that are negatively correlated with the density of active cattle grazing (i.e. forests that support dense populations of elk and deer may be unlikely to be actively grazed by substantial numbers of livestock). For these reasons, the active grazing layer may over-predict the presence of livestock and as a consequence, our conflict map may over-predict the overlap between livestock activity and favorable wolf habitat.

Some research suggests that open field rangeland located near forested and prey-dense wolf habitat are at greatest risk of conflict, while areas of lowest risk are where forest is dense and relatively unbroken (Treves et al. 2004; Treves et al. 2011). The grazed portions of northwestern California closely resemble those “high risk” locations. However, some older studies linked wolf-livestock conflicts to shortages of wild prey (Mech et al. 1988; Meriggi and Lovari 1996). These latter studies may suggest that locations that offer relatively *unfavorable* wolf habitat but that can still support wolves (e.g., northeastern California), and which are very actively grazed, could be especially susceptible to conflicts caused by the few wolves that live there.

Given that open fields bordering substantial forest cover are so susceptible to conflicts, it would have been possible to isolate NLCD grassland and pasture cells that border NLCD forest cells in order to pinpoint especially risky sites. But we did not attempt to do so because such an analysis would have led to the identification of high risk locations at the resolution of parcels and small holdings; this is too fine a scale for the purposes of this study. We intended only to suggest a regional-scale understanding of those locations most at-risk to conflicts. These general locations may be considered “top priority” for regional piloting and implementation of conflict reduction strategies. Additionally, timing could be an uncertain role in conflict risk. For example, it is possible that, as the early-colonizing wolves fill the most favorable habitat, late arrivals could be pushed to those areas that offer less-favorable habitat and less prey. Little research has been done concerning this matter; it will be interesting to see if such a situation plays out in Oregon as that state sees continued growth of its wolf populations.

3. Feasibility Analysis

In order to develop recommendations for conflict reduction strategies specific to Northern Californian livestock producers, it is essential to gauge this community's familiarity with the strategies and to understand how the community's members perceive the strategies' feasibility for implementation in their operations. To collect related regional data about demographics, attitudes toward wolves, familiarity with and likelihood of implementing certain conflict reduction strategies, we developed and distributed a three-part survey to livestock managers and producers in Northern California to (see Appendix E). The survey allows us to access local knowledge about the region's landscapes in order to guide the development of region-specific recommendations for conflict reduction.

Region of Interest

As spatial and economic data are often grouped by county, we defined our region of interest (ROI) based on county boundaries, and included Lassen, Shasta, Trinity, Humboldt, Del Norte, Siskiyou, and Modoc counties (Figure 3.1). We determined our ROI based on (1) input from Defenders of Wildlife, and (2) proximity to Oregon and current areas of known wolf activity, thereby increasing likelihood that wolves will recolonize this area first.

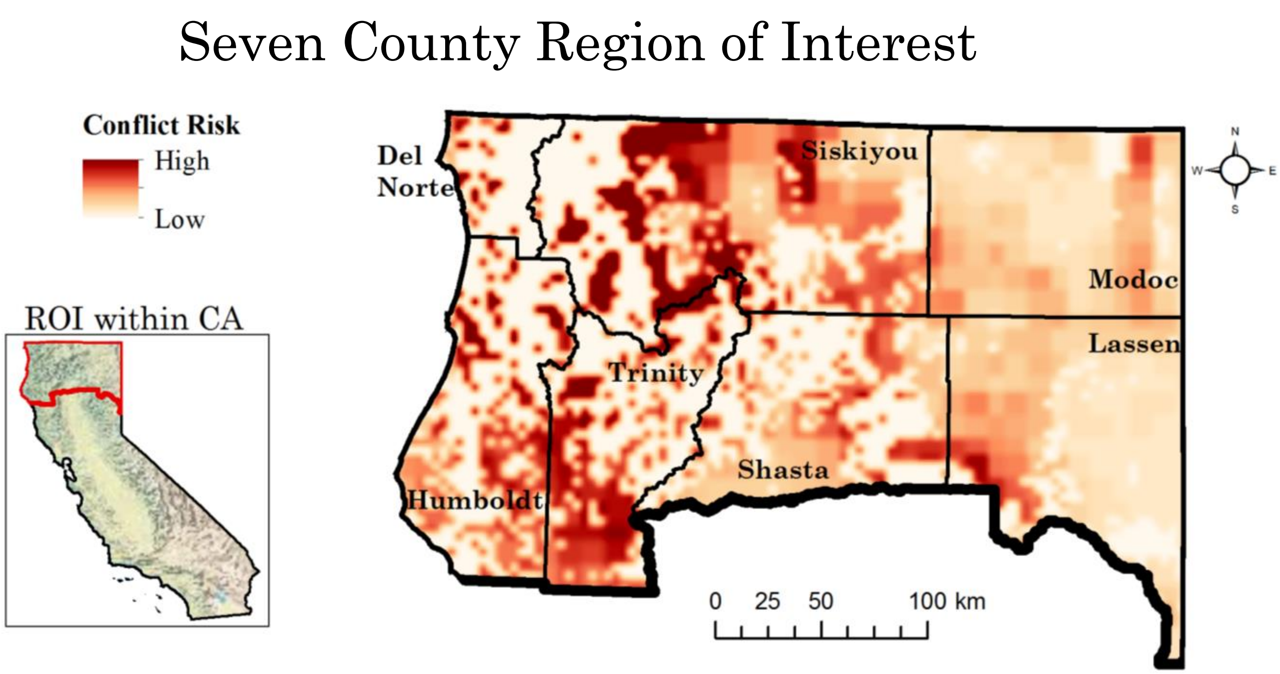


Figure 3.1 Feasibility analysis region of interest and conflict hotspots. The survey was distributed to these seven countries given their proximity to current wolf pack locations. The gradient shows the favorable habitat, as predicted by our logistic regression model (with dark red demonstrating higher favorability), that overlaps with grazing lands.

California Cattlemen's Association and California Rangeland Conservation Coalition often complete surveys and studies that include livestock producers across the state, but it is rare to focus on this specific region. The region is primarily rural, with low population densities and a high reliance on the agricultural industry, especially cow and calf operations (USDA NASS 2014). There are few cities, and Redding (in Shasta County) is the major urban area. Many residents, especially livestock producers, live many miles from services. The area is ecologically diverse, and includes many different livestock production types and methods. This feasibility analysis, though geographically focused, may thus be applicable outside of this region.

Methods

Survey Development

The survey design was modeled on a similar survey developed by Defenders and distributed to California ranchers (Cheatum et al. 2011). Due to the contentiousness of the subject, we reviewed several other rancher-specific surveys regarding wolves in order to align our survey questions with current research (e.g., Browne-Nuñez et al. 2015; Naughton-Treves et al. 2003; Pate et al. 1996; Tucker and Pletscher 1989).

We shared a draft of our survey with several ranchers (and other members of the ranching community) to obtain feedback about the relevance of the questions for the community. The survey was also reviewed by Defenders of Wildlife staff and Bren School faculty, including the project adviser. These experts read the survey with an eye for question design, bias, and survey best practices. Finally, the survey was reviewed and approved by the University of California, Santa Barbara Human Subjects Committee, which ensures the health and safety of survey respondents and verifies that the survey meets the ethical principles for the protection of human subjects in research.

The survey consisted of three sections:

1) General attitudes and experiences with wolves and other predators

This section included six multiple choice questions designed to gauge the respondent's attitudes toward large carnivores. The first three questions addressed the impact of large carnivores on an individual's livestock operation. The next two questions focused on attitudes toward wolf protection policies, asking the livestock producer about the acceptable size of a potential wolf population and under what circumstances should a producer be permitted to shoot and kill a wolf. The final multiple choice question asked whether the respondent has had interactions with a wolf on his or her property. This section ended with an open-ended question about whether the respondent currently uses any predator deterrence practices to deal with animals like coyotes or mountain lions.

2) Knowledge and perceived feasibility of conflict reduction strategies

This section presented seven conflict reduction strategies that literature and case studies consider to be the most common or potentially relevant wolf deterrence tools (see background on Conflict Reduction Strategies). The section was prefaced by a short description of the purpose of the questions, and an explanation that each management technique had been implemented elsewhere in the United States. Each strategy was described in brief detail, and respondents were asked four questions:

1. What is your degree of familiarity with the conflict reduction strategy? (five-point Likert scale)
2. Is it possible to use this strategy on your land? (Yes/No)
3. If not, why not? (open-ended question)
4. How likely would you be to implement this strategy to minimize wolf-livestock conflicts? (Five-point Likert scale, ranging from 1 (very unlikely) to 5 (I already implement this strategy)).

Likert scale questions are common in survey design, and allow for several types of data analysis. The questions do not limit the participant to simple responses of just "yes" or "no," and instead allow individuals to weigh each option differently and express their relative levels of disagreement or agreement with the survey's posed statements. Ideally, this flexible gradient makes the question easier for participants to answer, and allows for the survey to capture more of the complex affiliations and perceptions of the respondents. Additionally, Likert scale answers produce nonparametric, ordinal data that, after analysis, can produce more detailed and nuanced results.

3) General demographic information
The third and final section of the survey included 12 demographic questions regarding the respondent's age, gender, and education, as well as ranch-specific questions such as acres owned, acres leased, number of years spent ranching, and primary use of land. Because the survey's overall topic of interest is controversial, and because requests for personal information can be construed as invasions of privacy, this section offered answers in multiple-choice format, which we hoped would increase the respondent's trust and comfort level with providing accurate answers (see Appendix F for the demographic data of our survey respondents).

<u>Distribution</u>
In order to reach the greatest number of potential survey respondents, we chose to distribute hard copies of the survey along with prepaid return envelopes. We explored multiple options regarding the acquisition of contact information (names and addresses of our target group). In the end, the best option was to submit a Freedom of Information Act (FOIA) request for this contact information. This request, which was fulfilled by the United States Department of Agriculture (USDA), included names and addresses of all registered livestock producers in our seven-county ROI.

The original contact list received from the USDA included 986 names and addresses. We removed duplicates and invalid addresses, resulting in a list of 570 livestock producers. Contacts did not necessarily reside within the seven county region, but all owned or managed livestock in this region. The survey included a cover letter which explained the purpose of the survey, encouraged participation, and ensured confidentiality as well as non-obligation for future participation in any related endeavor.

During a field excursion to the ROI, surveys were also hand-delivered to a dozen ranchers in Lassen and Shasta counties. Additionally, California Cattlemen's Association, University of California Cooperative Extension offices, and local farm bureaus were informed about our survey before mailing in an attempt to build positive relationships with important stakeholders in the area.

Due to time and budget constraints, as well as a relatively high response rate of 21.8%, the survey was only distributed once with no follow-up mailings.

Data Entry

Surveys were received from mid-December to mid-February. After survey responses were entered, entries were verified for data quality control purposes and to minimize data entry errors using a random number generator to check one third of the surveys.

Based on observed trends in survey responses, we created categories of coded responses for the eight open-ended questions in the survey. While the exact language and framing of each of these open-ended responses varied, there were a few common sentiments that appeared most frequently. As an example, one respondent stated "3000 acres is way too much portable fences and flags" while another said "too large an area" in response to barriers for implementing fladry, and both responses were categorized as "too much land." This method allowed us to collapse a large number of responses into a more manageable number to perform meaningful analyses and make reasonable conclusions about the open-ended responses (Table 3.1).

If a respondent's response did not directly address the question being asked, the response was categorized as "Not Relevant" and was not included in the total response count for that question. For example, one response that was labeled not relevant stated, "what I don't understand is why Canadian wolves were reintroduced instead of our native wolves," in response to a question about current methods of protection from large carnivores. While the information conveyed in this response may be of value in analyzing the overall attitudes of the respondent, it did not provide insight into the question at hand and was therefore categorized as not relevant. We took a conservative approach to this categorization process to ensure that only a minimum of responses were omitted, and even slightly tangential responses were included in the analysis. For example, if a respondent provided a novel barrier to implementation that seemed to conflict with our previous knowledge, it was still included in the analysis for that question.

Table 3.1. Analysis of representative survey responses and coded categories. Respondents were asked open-ended questions about the barriers to implement each conflict-reduction strategy, and these responses were appropriately coded into categories during data entry. Examples of verbatim responses and entered code are shown here.

Strategy	Representative Response (verbatim)	Coded Barriers to Implementation
Fladry	We have 45 miles of fence around our range.	Too much land
Attractant Removal	We have a boneyard where carcasses are dumped. Our landfill does not accept carcasses and it costs over $100/ dead animal to have the tallow co[mpany] come pick up the carcass.	No depository; costs
Guard Dogs	Possible conflict with neighboring dogs and my cattle dogs. Cost of dogs and upkeep.	Neighbors; costs
Range Riders	Not economically feasible. There are many other things that need to be done on a ranch. If I have to spend a third of my time babysitting my cattle, I might as well quit the business. But maybe that is the endgame for some proponents.	Costs; time
Alarm & Scare Tactics	Predators get use[d] to these sounds + lights eventually; no electricity available; to[o] large an area	Habituation; lack of electricity; too much land
Moving Livestock	Lack of available space.	No other land
Calving Changes	Changing my calving period will not be advantageous to my need for increased grass for the age of the calves. I'd have to decrease my herd or lease more ground that is not available. This triggers a bidding war for leased ground.	Profits; natural resources

Extreme Responses

The issue of wolf conservation is contentious. The survey responses show a wide range of sentiments and concerns regarding wolf recolonization of Northern California. Due to the intense attitudes conveyed in several of the surveys, we made an effort to separate extreme, protest responses (i.e., those surveys that suggested the respondent was uninterested in engaging with the researchers or sharing accurate information related to their concerns) from the rest of the survey sample. To make this distinction, we categorized any respondent that reported "Very Unlikely" to implement every proposed conflict reduction strategy as "unengaged." Conversely, any respondent that selected any option besides "Very Unlikely" for at least one of the seven strategies was categorized as "engaged." We recognized that this seven-question criteria may not accurately capture the intent of the respondent, however it was the best method to separate the respondents into these two categories.

There were 17 surveys in which the respondent failed to provide a response for one or more of the questions that were used to establish these two categories. To resolve this, we applied the same method as described above, except only on those questions that were answered.

This resulted in the categorization of 11 additional respondents as engaged and six as unengaged. This methodology resulted in a total of 96 engaged respondents and 28 unengaged respondents.

Because it is impossible to glean the intentions of the respondents categorized as unengaged, this distinction was not used to exclude any respondents from the analysis. The split categories did allow for further analyses, however, to determine if there were significant differences between these two subsets of the survey respondents throughout other portions of the survey.

Statistics

Descriptive statistics were calculated on each part of the survey to summarize the distribution of responses. Chi-square tests of association were conducted to test for significant associations between variables. A Friedman test for ranks was used to determine whether the differences in the reported rank of the seven conflict reduction strategies were significant.

Results & Discussion

Survey Respondents

We received 124 survey responses, resulting in a response rate of 21.8%. Men accounted for 72.0% of total respondents and 50.0% of respondents were greater than 60 years old. Thirty-eight respondents own or lease land in Modoc County, making it the county with the greatest number of respondents. We only received one survey from Del Norte County and two surveys from Trinity County (Table 3.2). We received surveys from 102 cattle ranchers, three sheep ranchers, and 14 who manage both cattle and sheep.

Table 3.2. Distribution of respondents' land holdings by county. The majority of surveys came from Modoc and Siskiyou counties, though 29.9% of respondents managed land in more than one county.

County	Num. Respondents Who Own/Lease Land	County Response Rate
Siskiyou	35	28.2%
Shasta	18	14.5%
Lassen	24	19.4%
Modoc	38	30.6%
Humboldt	29	23.4%
Del Norte	1	0.8%
Trinity	2	1.6%

Our respondents were not evenly distributed across counties. Chi-squared testing showed significant difference between the proportions of surveys mailed to each county of interest, and the proportion received from each county ($\chi^2(6) = 22.52$, $p<0.0001$). We received more responses from Lassen County than our other county average response rates, possibly due to the time we spent in the county interviewing ranchers and residents. Our lowest county-specific response rate was from Humboldt County at 16%. It is important to note that though all survey respondents indicated they operated in at least one of our counties of interest, 69 of our surveys were mailed to addresses outside of this region. These producers likely operate in the ROI but have a home address in a different town. We have no method of knowing where these producers operate or if they returned the survey.

The majority of respondents own or lease more than 500 acres, which is unsurprising given the large ranches that are common in the region. Many landowners leased land, 29.0% from a federal agency (either BLM or USFS) and 63.7% from another private landowner. Many ranchers in this region and throughout the state utilize high elevation BLM and USFS grazing allotments during the summer months, when their lower elevation pastures lack appropriate feed (Sulak and Huntsinger 2002).

Part 1: Carnivore Conflicts

The majority of survey respondents demonstrated a moderate to strong aversion to wolves and other large predators. The majority reported having experienced negative impacts from predators, an insufficient current level of protection, and a desire to eliminate, shoot, and kill any recolonizing wolves (Figure 3.2). While the most frequent response for each question suggests an overwhelmingly negative perception of wolves, there is a notable number of responses that do not express such a view. Somewhat surprisingly (due to the very recent return of wolves to the state), 11.3% of respondents reported having had an interaction with a wolf on property they own, lease, or manage. If this reported number is accurate, an engagement program designed to improve rancher tolerance of wolves and implement effective conflict reduction strategies should be developed as soon as possible to avoid potential losses to the reestablishing wolf population.

In order to determine whether an association exists between willingness to engage with the research and attitudes toward wolves and large carnivores, a chi-square analysis was conducted for each multiple choice question in Part 1 of the survey. A chi-square test performed on a 5 x 2 contingency table revealed a significant association between willingness to engage and past experience with large carnivores ($\chi^2(4) = 15.93$, $p = 0.0055$). Similarly, there was a significant association between willingness to engage and reported satisfaction with current level of protection from large carnivores ($\chi^2(4) = 13.54$, $p = 0.0060$). Chi-square analyses for the remaining multiple choice questions in Part 1 found there was no significant association between willingness to engage and expected impact of wolves ($\chi^2(4) = 2.38$, $p = 0.73$), acceptable size of wolf population ($\chi^2(3) = 6.54$, $p = 0.072$), and opinion on the legality of killing a wolf in CA ($\chi^2(3) = 6.22$, $p = 0.10$). Because each of these chi-square analyses included at least one entry with less than five counts, a Monte Carlo simulation for probabilities was conducted in order to approximate the sampling distribution. This method provided essentially equivalent results, and so it was assumed that the original analyses were appropriate.

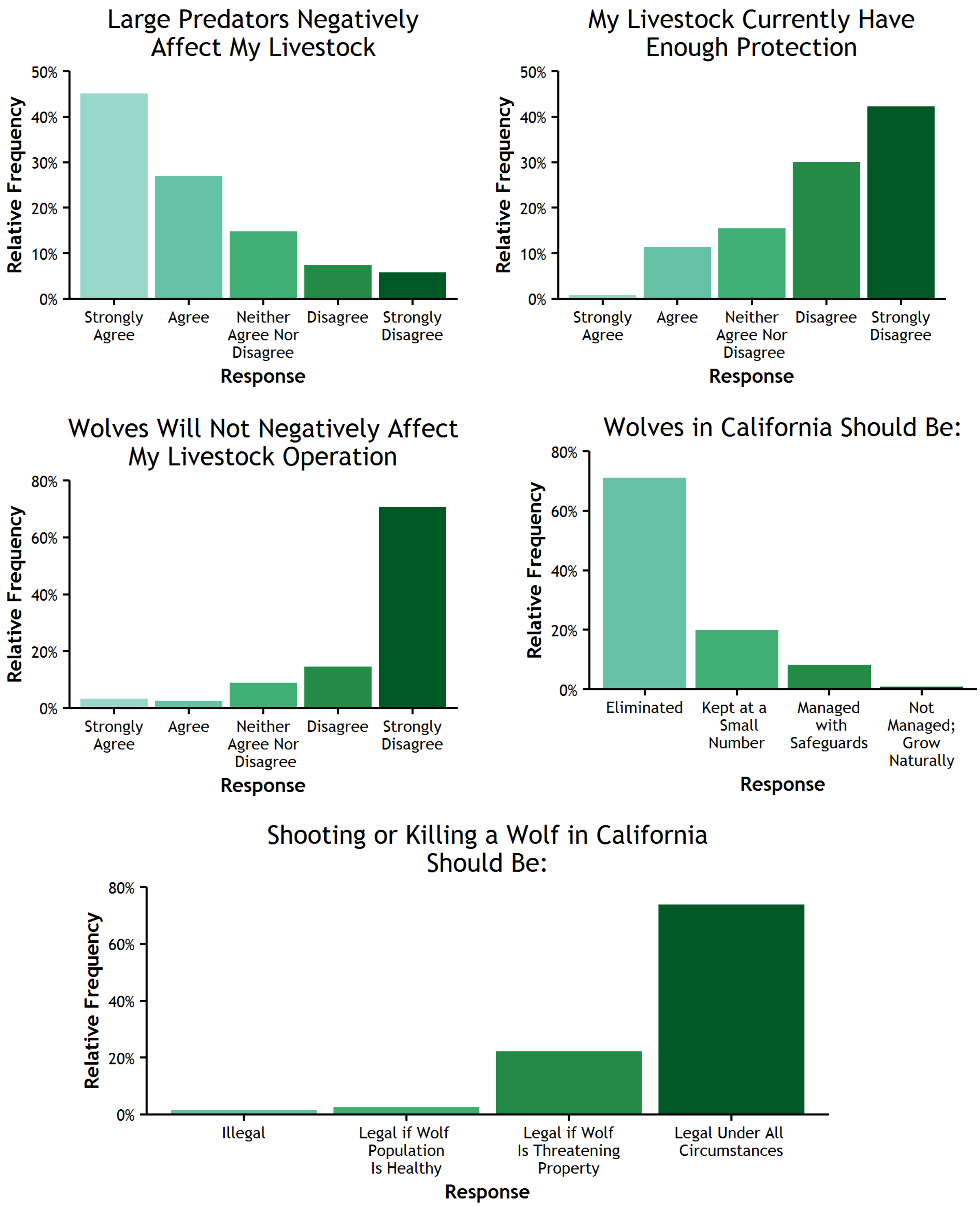


Figure 3.2. Distribution of responses for multiple choice questions on attitudes towards large carnivores and wolves. Each graph corresponds with a question from Part 1 of the survey.

Survey respondents provided a wide range of methods that are currently used to protect their livestock from large carnivores (Figure 3.3). Many of the 110 respondents who provided an answer for this question listed more than one method of protection, which means that there are more responses than ranchers (a total of 141 responses). For example, a single respondent highlighted the use of a county trapper, coyote calls, and game cameras as primary methods of protection, resulting in three responses for one livestock producer. Forty responses to this question matched exactly with, or were closely related to, one of the seven conflict strategies referenced in the survey. Some respondents reported already using guard animals, increased human presence, altered calving, fencing, alarm tactics, and attractant removal to protect their livestock from large carnivores. Lethal control is substantially more common than the other strategies listed. The preference for lethal control of current problem predators presents an interesting complication for future wolf deterrence, since the animals are protected under by the ESA. This makes the feasibility of non-lethal strategies (described in Part 2) all the more relevant.

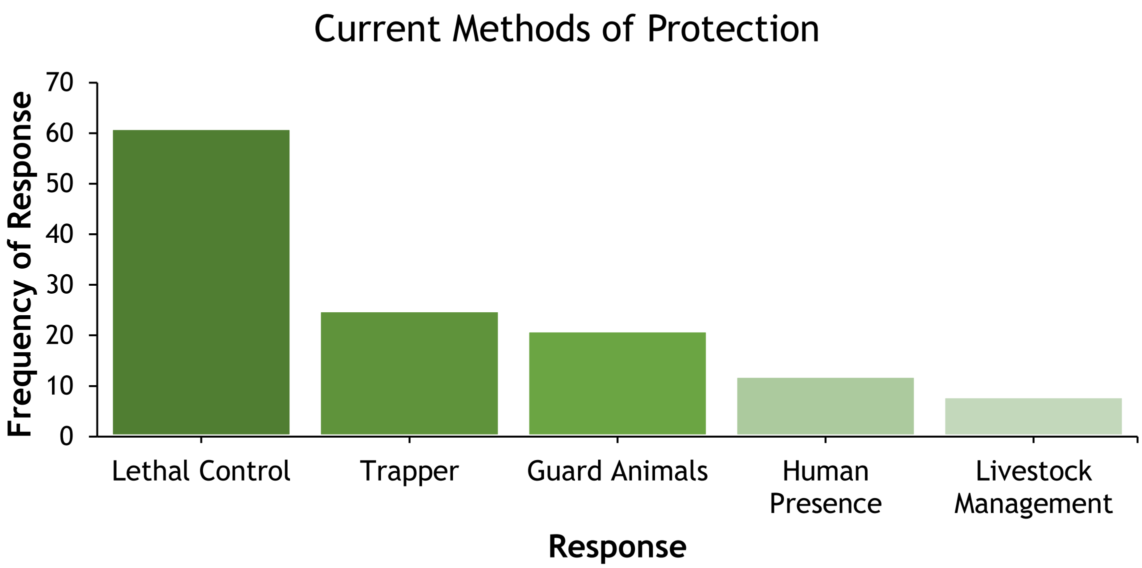


Figure 3.3. Current methods used to protect livestock from large carnivores. Of the 110 livestock producers that provided an answer for this question, 99 provided *at least one* relevant response (n=141). Fourteen other, unique methods were reported, including private hunters, fencing, coyote calls, game cameras, alarm tactics, attractant removal, and nonlethal deterrents.

<u>Part 2: Conflict Reduction Strategies</u>

Cross-Strategy Comparison

The survey was designed to compare the self-reported familiarity, feasibility, likelihood of implementation, potential barriers, and preference for each of the seven targeted conflict reduction strategies. Attractant removal was the only strategy that a majority of respondents believed was feasible on their land, and more than a quarter of respondents already remove carcasses and other attractants to some degree (Table 3.3). On the other end of the spectrum, 84% of producers noted that fladry was not feasible (due mostly to large acreage), and the median implementation rating was "very unlikely to implement."

Table 3.3. A summary of the primary results for each conflict reduction strategy. Familiarity and Implementation Likelihood are calculated as the median responses on the Likert scale for each question. Feasibility is calculated as the percentage of respondents stating it would be possible to implement that strategy. Primary Barrier is the most frequent coded response for the open-ended questions relating to why a strategy cannot be implemented. The Rank is calculated as the median rank response for each strategy.

	Familiarity	**Feasibility**	**Implementation Likelihood**	**Primary Barrier**	**Current Implementation**	**Rank**
Strategy	(median score)	(% yes)	(median score)		(% already implement)	(median score)
Fladry	Slightly	16	Very Unlikely	Too much land	1	7
Attractant Removal	Very	56	Somewhat Likely	Too much land	28	2
Guard Dogs	Very	28	Very Unlikely	Too much land	8	4
Range Riders	Very	40	Somewhat Unlikely	Costs	12	4
Alarm & Scare	Moderately	23	Very Unlikely	Too much land	2	5
Moving Livestock	Moderately	17	Very Unlikely	No other land	4	7
Calving Changes	Moderately	31	Very Unlikely	Schedule	10	5

For each of the seven strategies addressed in the survey, some proportion of respondents reported the strategy would be possible to implement on their land, and at least one producer already implements each strategy. In total, respondents indicated attractant removal and range riders may be the most feasible strategies for this region. These strategies have the highest percentage of people who already implement each practice (46.4% and 26.0%, respectively, as shown by purple bars in Figure 3.4). These strategies also have the largest percentages of people who are reportedly likely to implement (42.0% and 47.8%, respectively, as shown by orange bars in Figure 3.4). As a point of comparison, only 20 respondents (16.1%) reported that fladry would be possible on their land, and only 30.0% of those were likely to implement (Figure 3.4).

While some conflict reduction strategies are clearly perceived to be more feasible for Northern California, each strategy has some proportion of respondents who are likely to or already implement it on their land. This suggests that the suite of strategies provides a diverse and effective toolbox for livestock producers to choose from in order to protect their herds under their specific production conditions during different times of the year. For example, the one respondent who reported already using fladry to protect against predators implements this strategy in a textbook manner -- it is only used on small pastures for short amounts of time to protect livestock when they are particularly vulnerable to depredation events.

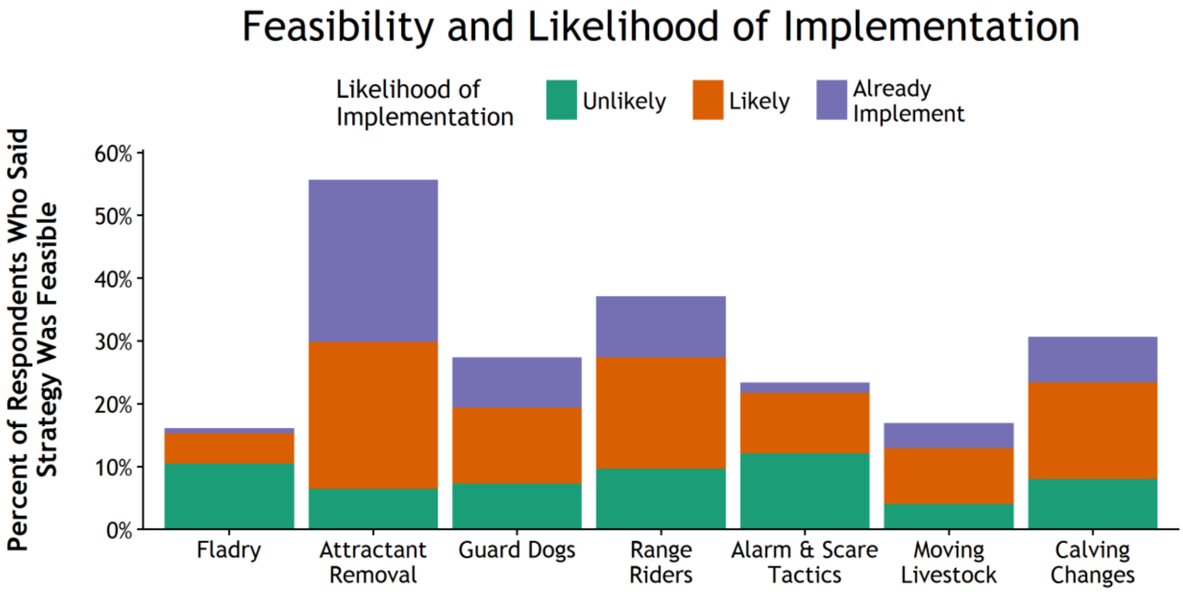


Figure 3.4. Percentage of respondents who believe conflict reductions strategies are feasible on their land. Responses were grouped by likelihood of implementation; unlikely to implement (green, answered 1 (very unlikely) or 2 (somewhat unlikely)), likely to implement (orange, answered 3 (somewhat likely) or 4 (very likely)), or already implement (purple, answered 5 (already implement)) on Likert scale question.

In addition to the higher percentage of reported feasibility for attractant removal and range riding, respondents also showed significant preference for these two strategies when asked to rank willingness to implement for each strategy (Friedman $\chi^2(6)=135.06$, $p<0.0001$) (Figure 3.5). Fladry, alarm & scare tactics, and moving cattle were ranked as the least willing to implement, with "7" being the median ranking of fladry and moving cattle (i.e., least willing) (Figure 3.5). Post-hoc testing demonstrated that attractant removal ranked significantly better than all other strategies, with a median rank of 2. Range riding, though not significantly different from the middle-of-the-pack strategies (Group B, Figure 3.5), was the only other strategy to have less than 25% of respondents rank it 7 (least willing to implement). Respondents were allowed to rank multiple strategies the same number; for this analysis we only removed respondents who had no variance in ranking (i.e., all strategies ranked the same, or no strategies ranked). Though respondents were generally not inclined to make any change to their production and land management strategies, with some arguing they have spent years and considerable cost developing their current methodology, this ranking demonstrates strong preference for specific strategies as compared to others.

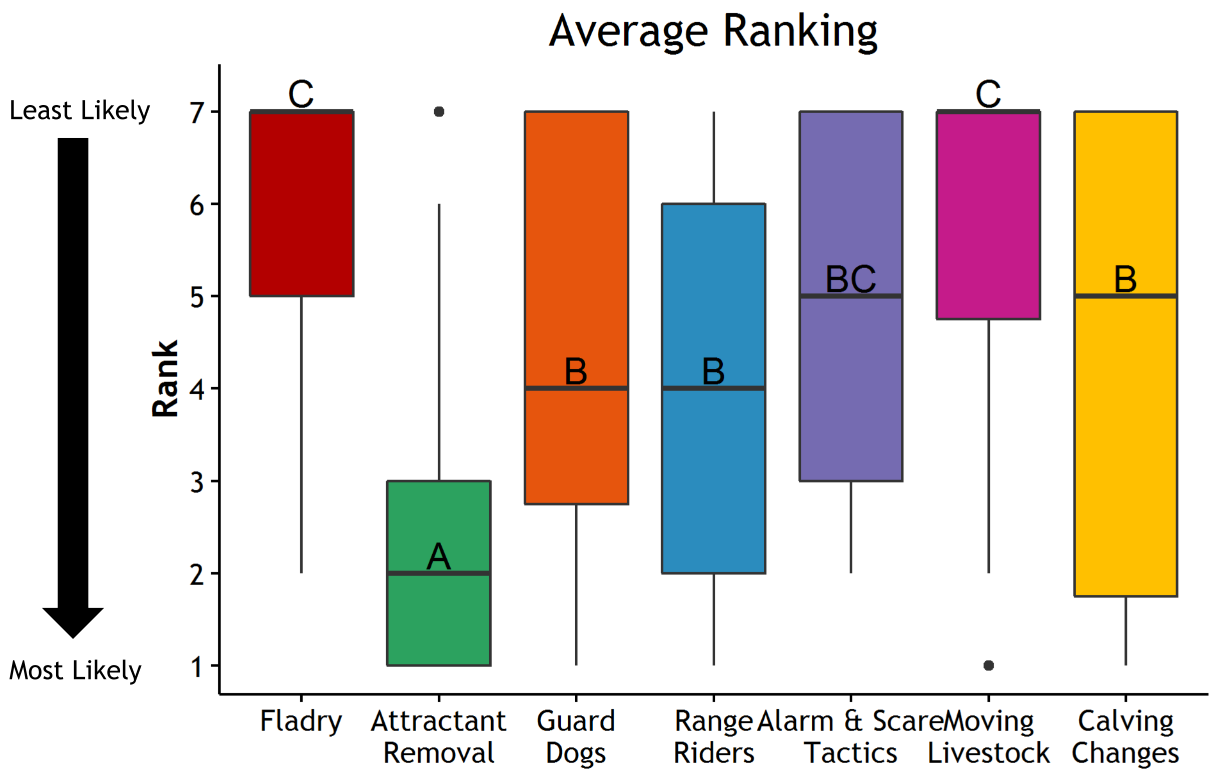


Figure 3.5. Conflict reduction strategies ranked by willingness to implement. Respondents were asked to rank the surveys from 1 (most willing to implement) to 7 (least willing to implement). A Friedman test demonstrated significant differences among median ranks ($\chi^2(6)=135.06$, $p<0.0001$). Post-hoc testing clarified differences among the seven strategies, as indicated by different letters (like letters indicate no significant difference). Box plots illustrate the minimum (whisker), first quartile (lower box limit), median (bold line), third quartile (upper box limit), and maximum ranking (whisker). Outliers are designated by black points. Attractant removal (green) was ranked significantly better than other strategies. Surveys were not included in the analysis if they indicated no preference between any strategies (n=88).

Though some of the strategies are preferred over others, barriers for implementation and the concerns that our survey respondents raised should be considered for all strategies. We analyze the responses regarding each of the strategies separately, focusing on familiarity, perceived feasibility, and potential barriers to implementation. This analysis provides a stronger understanding of which strategies are better suited to the needs of ranchers in Northern California and what problems would need to be addressed in order to encourage successful implementation. The following strategy discussion is ordered according to perceived and reported feasibility, beginning with the most feasible strategies.

Attractant Removal

Attractant removal is reportedly the most feasible and significantly preferred compared to the other conflict reduction strategies, and it has the largest percentage of respondents who already implement it on their land. Respondents were relatively familiar with attractant removal before completing this survey, with 62% of respondents being either "very" or "extremely" familiar with the practice and only 13% answering "not at all familiar" (Figure 3.6). Fifty-six percent of respondents answered that attractant removal would be possible on their land. A chi-square test determined a significant association between familiarity with attractant removal and perceived feasibility ($\chi^2(4) = 18.17$, $p = 0.00114$), which suggests that being more familiar with attractant removal may increase a producer's receptivity to the strategy. Of the respondents who said they were "extremely familiar" with attractant removal prior to the survey, 83.3% believe it would be feasible on their property, while of those who were "not at all familiar" with the strategy, only 21.4% believe it would be possible (Figure 3.6).

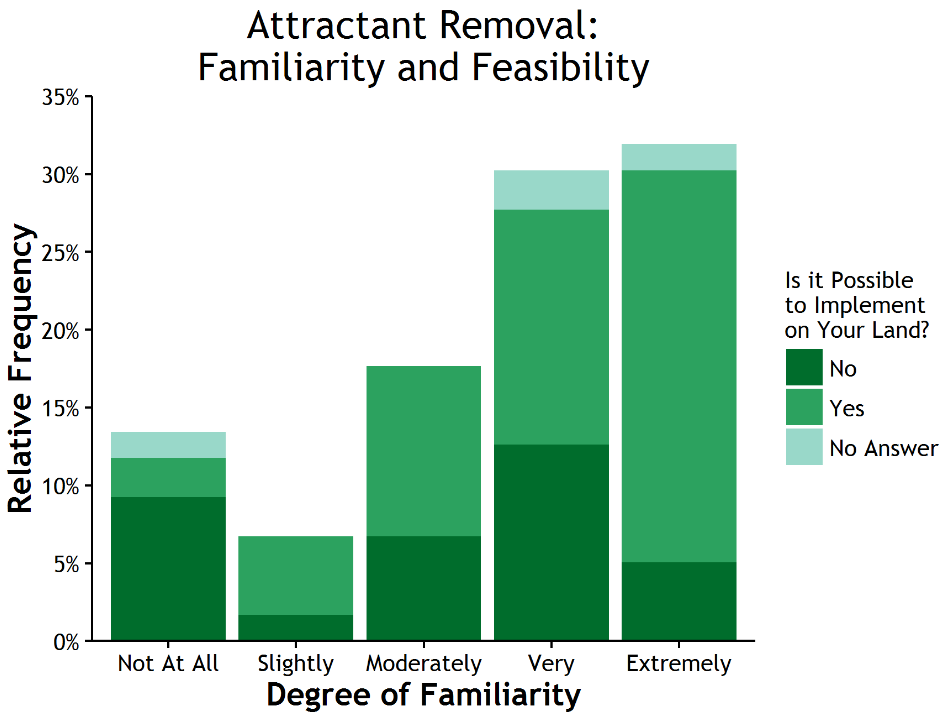


Figure 3.6. Familiarity and perceived feasibility of attractant removal. Respondents who did not provide an answer to the familiarity question were excluded from analysis (n=119).

Livestock producers who reported that it would be impossible to practice attractant removal on their land cite amount of land, rough terrain, and predator behavior as some of the top reasons why successful implementation would be difficult (Figure 3.7). The primary issue that these producers described is the issue of scale, but "rough terrain" and "hard to find" both point to the same concern over the perceived inability to cost-effectively find these attractants. In other words, these three main barriers could potentially be addressed if the onus to find and remove attractants was not placed entirely on individual ranchers; it is possible that the time and labor costs associated with finding the attractants decreases the perceived feasibility of attractant removal for many livestock producers.

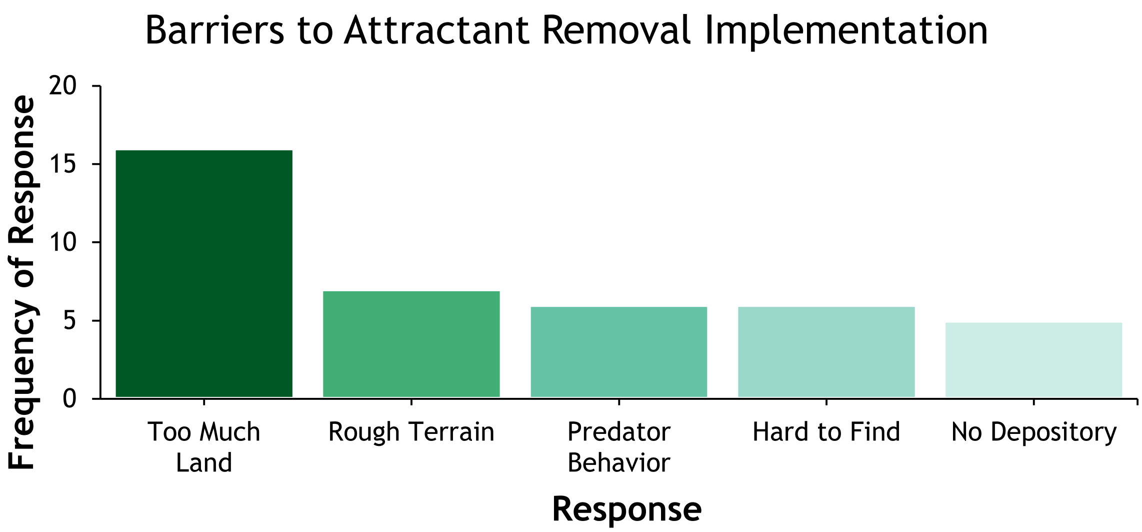


Figure 3.7. Barriers to the successful implementation of attractant removal. Of the 55 livestock producers that provided an answer for this question, 46 provided *at least one* relevant response (n=53). Fourteen other barriers were highlighted, including time, costs, deer kills on property, legal barriers to bury, weather, and leased land.

Several respondents were concerned about the absence of convenient and legal dumping locations for carcasses and other attractants. Multiple respondents explained that the nearest legal carcass disposal site was hundreds of miles away and that they could not justify making this trip every time an animal died on their land. This concern, though not a major barrier for implementation, may be easily addressed if more disposal sites were established across the counties with frequent need, or if there was a subsidized service that could collect carcasses from remote ranches.

The category represented as "predator behavior" encompasses concerns based on the claims that wolves prefer fresh kills rather than scavenged kills, predators are more likely to get to a carcass before livestock managers, and wolves may return to a herd even if there are no remaining carcasses. Regardless of the degree of truth behind each of these listed barriers, it is crucial for proponents of a potential attractant removal program to connect with livestock producers and discuss these concerns more completely.

As 28.3% of respondents already implement attractant removal on their land and an additional 26.6% of respondents reported that they are somewhat or very likely to implement attractant removal, this is a strategy that merits considerable attention. Conservation groups interested in promoting coexistence should look at successful programs, such as Blackfoot Challenge in Montana or programs run by ODFW and WDFW, for best practices in implementing wide scale attractant removal programs. While the issue of expansive tracts of land is significant and valid, a government or nonprofit-run program might be able to assist livestock producers to maximize effectiveness of this strategy, even on massive rangelands.

Range Riders

The use of hired range riders to patrol rangeland is reportedly the second most feasible conflict reduction strategy. Survey respondents were generally familiar with the strategy prior to completing this survey, with 54% of respondents either "very" or "extremely familiar" with the practice. Forty percent of respondents said it would be possible to use range riders as a method of reducing wolf-livestock conflicts on their land. As shown in Figure 3.8, the perceived feasibility of implementation tended to increase with increasing familiarity, though there was not a significant association ($\chi^2(4)=6.98$, $p=0.137$).

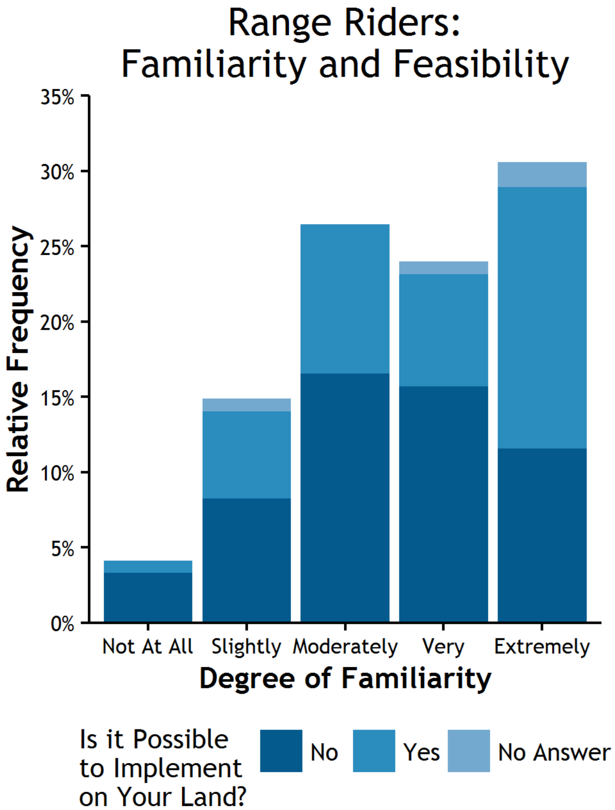


Figure 3.8. Familiarity and perceived feasibility of range riders. Respondents who did not provide an answer to the familiarity question were excluded from analysis (n=119).

Exorbitant costs and expansive rangelands are the most frequently reported barriers to implementation for range riding as a wolf-livestock conflict reduction strategy in Northern California (Figure 3.9). Although cost concerns likely underlie many of the reported barriers for each strategy, range riders is the only strategy for which livestock producers explicitly cited costs as the primary barrier. Multiple respondents stated that this strategy could be effective on their land but demonstrated a strong unwillingness to cover the costs, which suggests that a government or nonprofit-subsidized range riding program may be a welcomed approach among livestock producers in Northern California.

About 12.1% of survey respondents reported current use of range riders, while another 18.5% reported that they are somewhat or very likely to implement the strategy on their land. These relatively high likelihoods of implementation, even without a proposal for an outside party to bear some of the costs, suggests that this strategy could be especially successful if it were fleshed out into a formal program. As has been done in other states, a conservation organization could partner with producers or with the CDFW to cover the costs of a pilot program to test the effectiveness and determine whether to further invest in this program. If this program were to be developed, the CDFW should seriously consider providing range riders with spatial information on radio-collared wolves to maximize their efficiency.

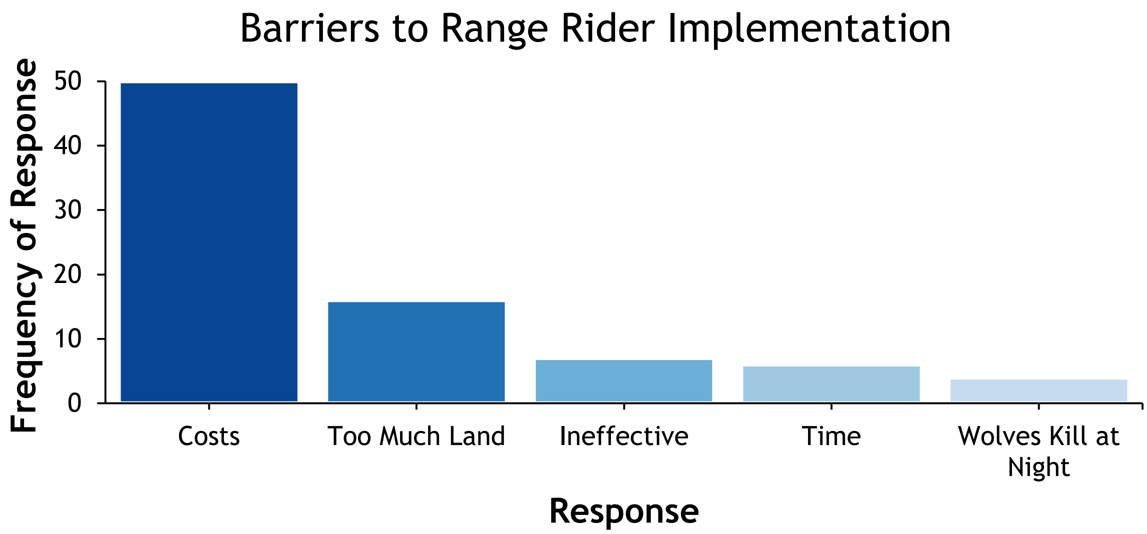
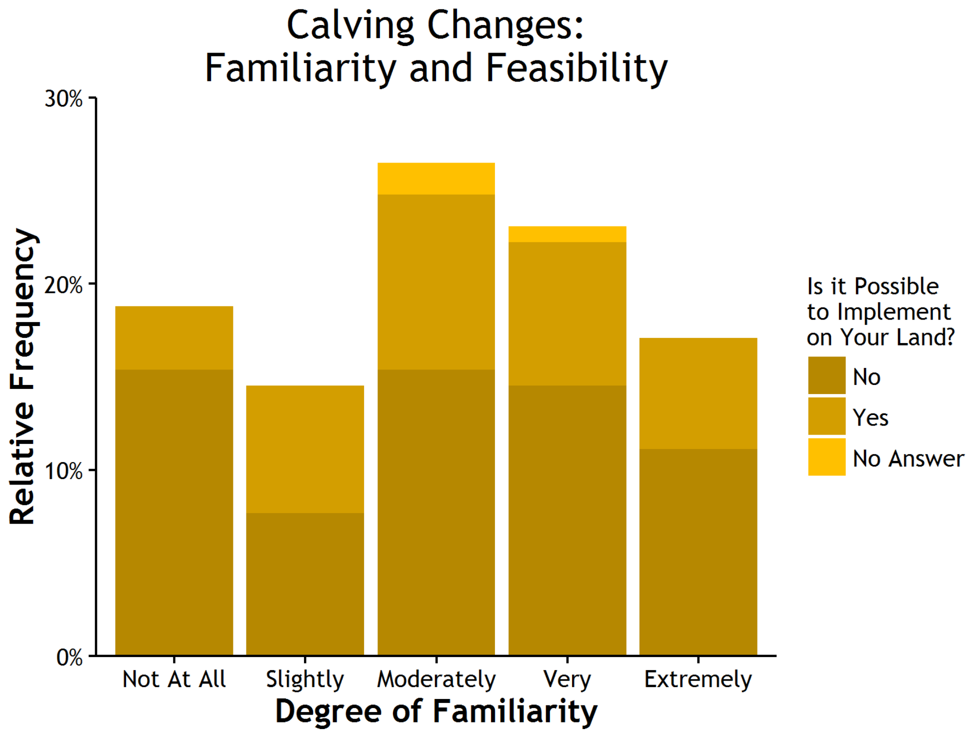


Figure 3.9. Barriers to the successful implementation of a range rider program. Of the 75 livestock producers that provided an answer for this question, 69 provided *at least one* relevant response (n=91). Eight other, unique barriers were provided, including rough terrain, labor, complexity, scattered herds, bad past experiences, and too much cross fencing.

About 12.1% of survey respondents reported current use of range riders, while another 18.5% reported that they are somewhat or very likely to implement the strategy on their land. These relatively high likelihoods of implementation, even without a proposal for an outside party to bear some of the costs, suggests that this strategy could be especially successful if it were fleshed out into a formal program. As has been done in other states, a conservation organization could partner with producers or with the CDFW to cover the costs of a pilot program to test the effectiveness and determine whether to further invest in this program. If this program were to be developed, the CDFW should seriously consider providing range riders with spatial information on radio-collared wolves to maximize their efficiency.

Calving Changes

The alteration of calving practices to minimize calf susceptibility to wolf depredation is reported as the third most feasible strategy, with 31% of respondents reporting that it would be possible to implement this type of livestock management strategy on their land. Familiarity with calving changes as a conflict reduction strategy varies greatly among survey respondents and it is not significantly associated with perceived feasibility of implementation; similar proportions of respondents in each category of familiarity reported that it would be possible to implement (Figure 3.10, $\chi^2(4)=3.94$, p=0.414).



Familiarity and perceived feasibility of changing calving season. Respondents who did not provide an answer to the familiarity question were excluded from analysis (n=117).

Barriers to successfully changing calving season were much more varied and difficult to categorize as compared to the other strategies (Figure 3.11). The main reported concern is that livestock producers have developed schedules for calving based on many factors, including herd structure, market demand, and land availability, and do not believe they could shift this schedule. In all of the barriers to implementation provided, livestock producers emphasized that they do not have the flexibility to alter their calving based on predator behavior. Fourteen respondents believed changing calving season would not be effective, in some cases explaining that wolves hunt year round and that adult cattle are also susceptible to depredation events.

Although there is a wide range of barriers to successful implementation reported for changing calving practices, this is still a comparatively popular strategy with 17.7% reportedly somewhat or very likely to implement it on their land. While 10.5% of respondents reported that they are already doing some form of altered calving, it is important to recognize that the majority of these respondents practice shortened or atypical calving seasons for reasons besides protection from depredation events. Because of this distinction, we do not recommend the expenditure of considerable resources on the implementation of calving changes; responses indicated that the majority of respondents were not willing to alter their practices to accommodate wolves. While the attitudes of ranchers in Northern California captured in this survey suggest that they are currently unwilling to alter their calving practices, they may be more likely to shift their practices to align with changes in the market structure of meat production or demand-side changes if more top-down policy changes were implemented.

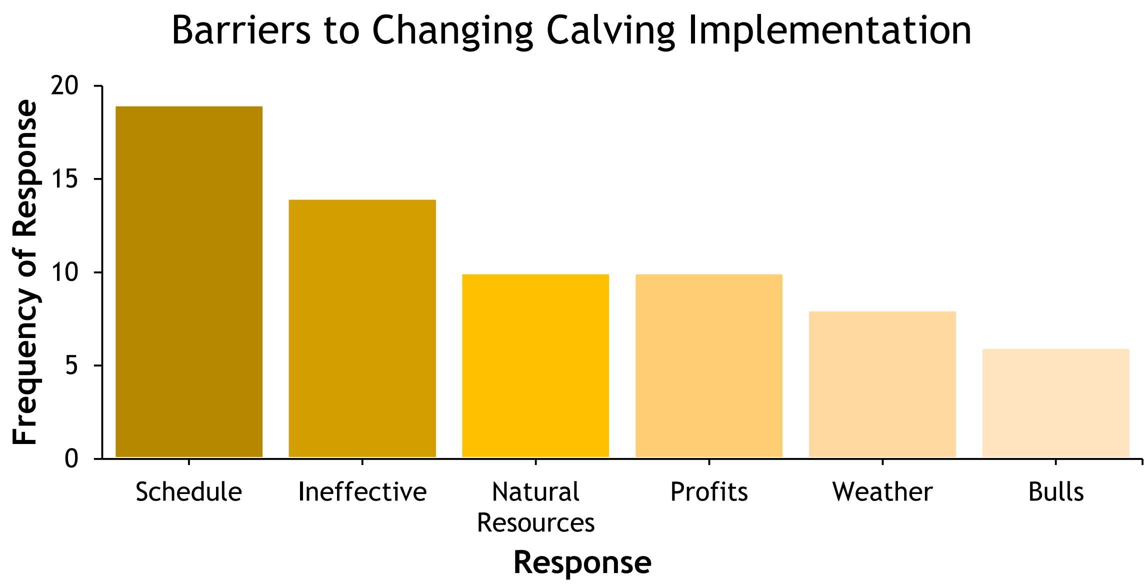


Figure 3.11. Barriers to altering calving practices. Of the 74 livestock producers that provided an answer for this question, 71 provided *at least one* relevant response (n=78). Eleven unique barriers were described by respondents, including costs, free range, different management priorities, carnivore adaptation, breeding on home range, no other land, year-round operation, and leased land.

Guard Dogs

Slightly less than one third of survey respondents reported that it would be possible to implement the use of trained guard dogs on their land, making it the fourth most feasible strategy. Respondents were generally familiar with the strategy prior to completing this survey and a chi-square test determined a significant association between familiarity with guard dogs and perceived feasibility ($\chi^2(4) = 13.44$, $p = 0.0093$). This suggests that an increased familiarity with the use of guard dogs for livestock protection may be associated with an increased perception of feasibility. Of the 35 respondents who said they were "extremely familiar" with the use of guard dogs, 50% believed it would be possible to utilize guard dogs as a method of wolf-livestock conflict reduction on their property (Figure 3.12).

Guard dogs are traditionally more favorable and effective for sheep producers as opposed to cattle producers. Indeed, 70.0% of respondents who already implement guard dogs as a conflict reduction strategy have sheep, and 58.8% of these woolgrowers believed that it would be possible to use guard dogs on their land (as compared to 29.9% of all respondents). Similar to range riding, the primary reported barriers to successful implementation of guard dogs are the size of the land and the costs, although in this case the amount of land is cited much more frequently than costs (Figure 3.13).

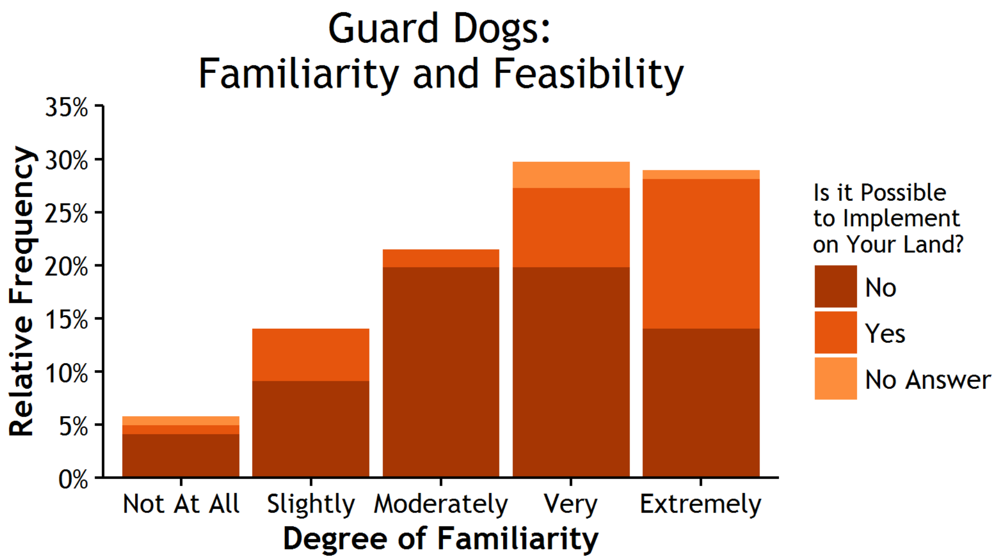


Figure 3.12. Familiarity and perceived feasibility of guard dogs. The majority of respondents were either "very" or "extremely" familiar with the strategy, though 70% of respondents did not think dogs would be feasible. Respondents who did not provide an answer to the familiarity question were excluded from analysis (n=119).

Although the use of guard dogs does not rank far behind calving changes based on likelihood of implementation, with 13.7% respondents reportedly somewhat or very likely to implement and 8.0% already using this strategy, this strategy should be targeted more specifically at sheep producers as opposed to all livestock producers. To address the producer concern that wolves can kill livestock guard dogs, conservation groups and the CDFW could consider adopting a policy similar to that of ODFW and WDFW to compensate livestock producers for guard dog losses.

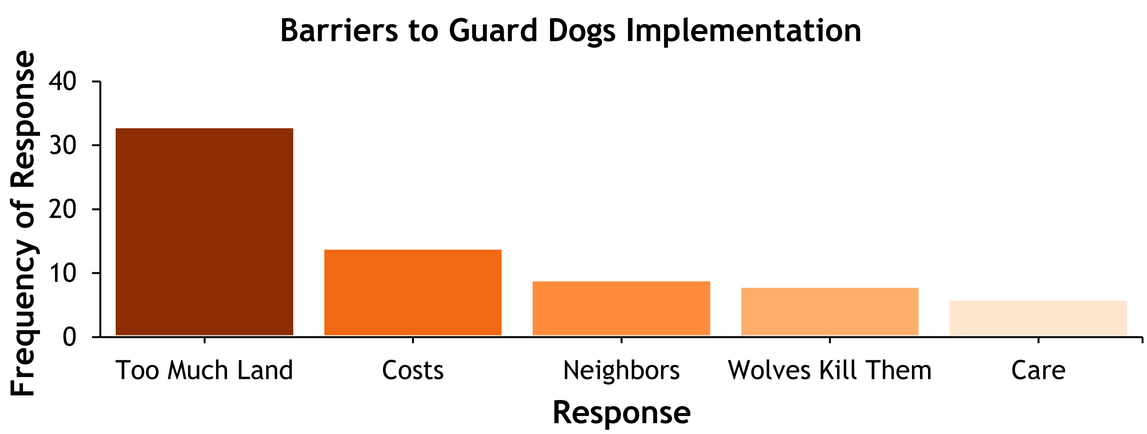


Figure 3.13. Barriers to the successful implementation of guard dogs. Of the 85 livestock producers that provided an answer for this question, 75 provided *at least one* relevant response (n=85). Fifteen other, uncommon barriers include: effectiveness, movement of livestock, rough terrain, predator adjustment, dog aggression, insurance issues, and a negative effect on cattle.

Alarm and Scare Tactics

The use of alarm tactics to scare wolves away from livestock is reportedly only slightly less possible to implement than guard dogs, but livestock producers are noticeably less likely to implement such tactics. Familiarity with the strategy varied greatly among survey respondents -- the greatest proportion of respondents said that they were "moderately familiar" with this strategy (29%, Figure 3.14). Twenty-three percent of respondents said it would be possible to use alarm and scare tactics on their land and perceived feasibility was not associated with the respondent's familiarity ($\chi^2(4)=1.87$, $p=0.760$, Figure 3.14).

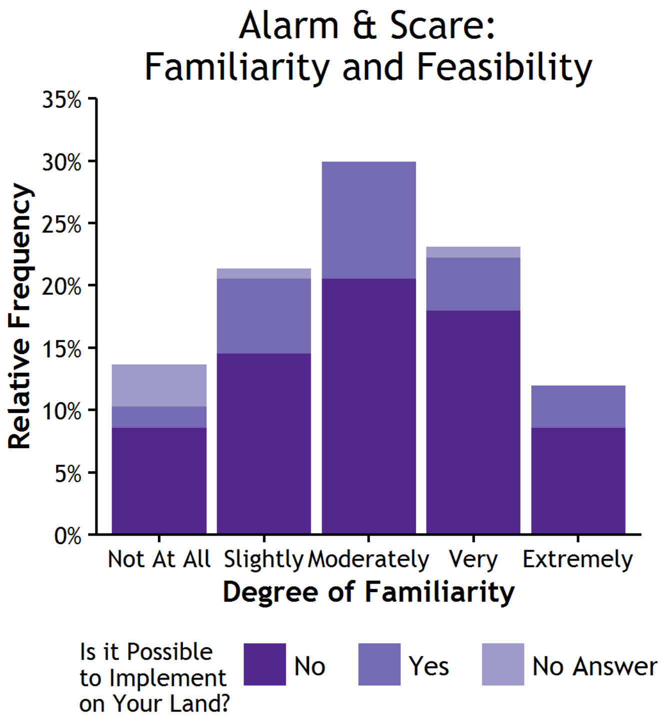


Figure 3.14. Familiarity and perceived feasibility of alarm and scare tactics. Respondents who did not provide an answer to the familiarity question were excluded from analysis (n=117).

Survey respondents who reported that it would not be feasible to use alarm tactics provided several explanations for barriers to successful implementation, including too much land and costs (Figure 3.15). Some of the respondents explained that these tactics are not effective at deterring wolves, and some raised the concern that, even *if* this practice were effective in small areas, their operations are too large for this to be a practical solution. The barrier of land size likely cannot be addressed with a state or nonprofit subsidized program, as the equipment required to sufficiently deter wolves would not be able to cover the large areas of land necessary to protect livestock from depredation events. This strategy, as with guard dogs and fladry, could potentially be used only in smaller pastures at times when livestock are particularly susceptible to depredation, especially since it is a relatively low-cost option. New alarm tactic technology is being developed, and a serious breakthrough with automated alarms could make this strategy more functional and feasible.

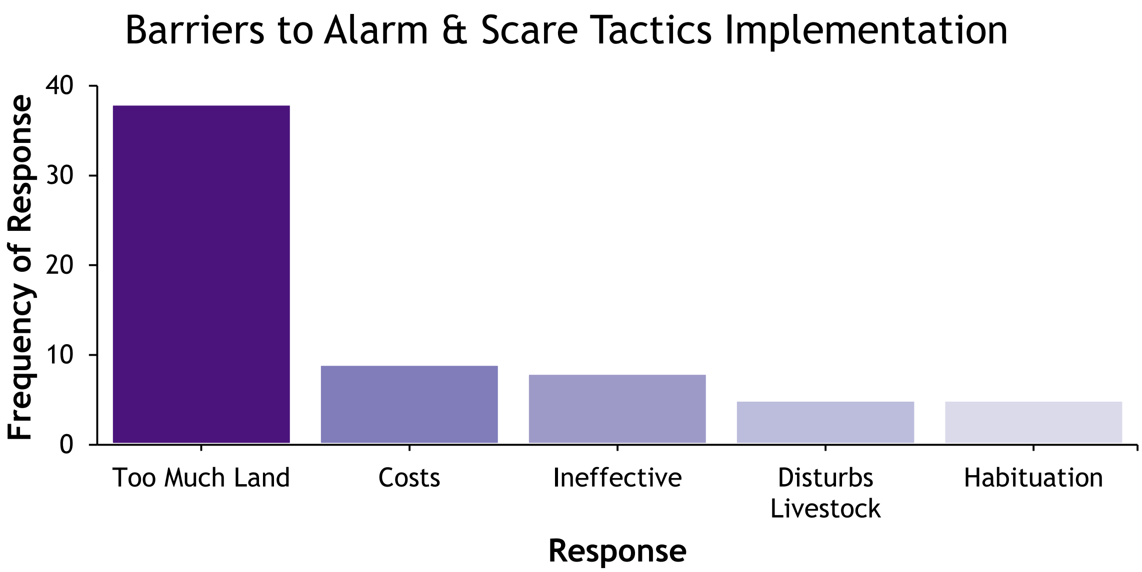


Figure 3.15. Barriers to the successful implementation of alarm and scare tactics. Of the 82 livestock producers that provided an answer for this question, 71 provided *at least one* relevant response (n=84). Nineteen other, less common barriers were given, including: neighbors, public lands, lack of electricity, time, labor, wildlife disturbance, putting the equipment in place, and wind.

Only 1.6% of respondents currently use this method of deterrence while 12.9% of producers stated they would be somewhat or very likely to implement it. This low likelihood of implementation suggests that conservation efforts should not emphasize the use of this strategy to livestock producers in Northern California; resources would likely be better used to advocate for strategies such as attractant removal or range riders that are perceived as being more feasible and effective.

Moving Livestock

The practice of moving livestock from area to area in order to avoid zones of wolf activity is reported as the second least feasible strategy. Similar to alarm and scare tactics, familiarity with the strategy varied greatly among survey respondents and only 17% of respondents said it would be feasible to use this type of livestock management approach to reduce wolf-livestock conflict on their property. Perceived feasibility of moving livestock is not significantly associated with familiarity of the tactic (Figure 3.16, $\chi^2(4)=7.57$, p=0.109).

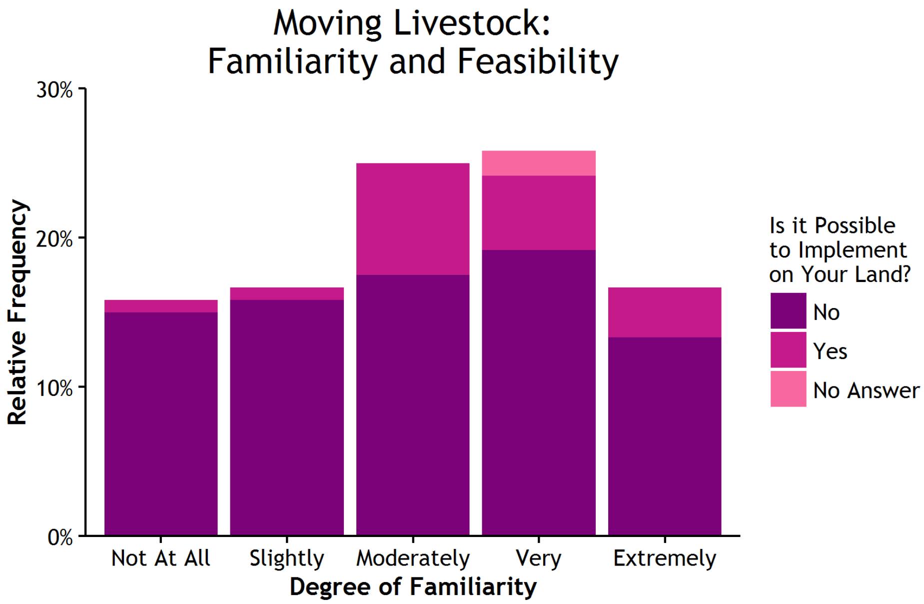
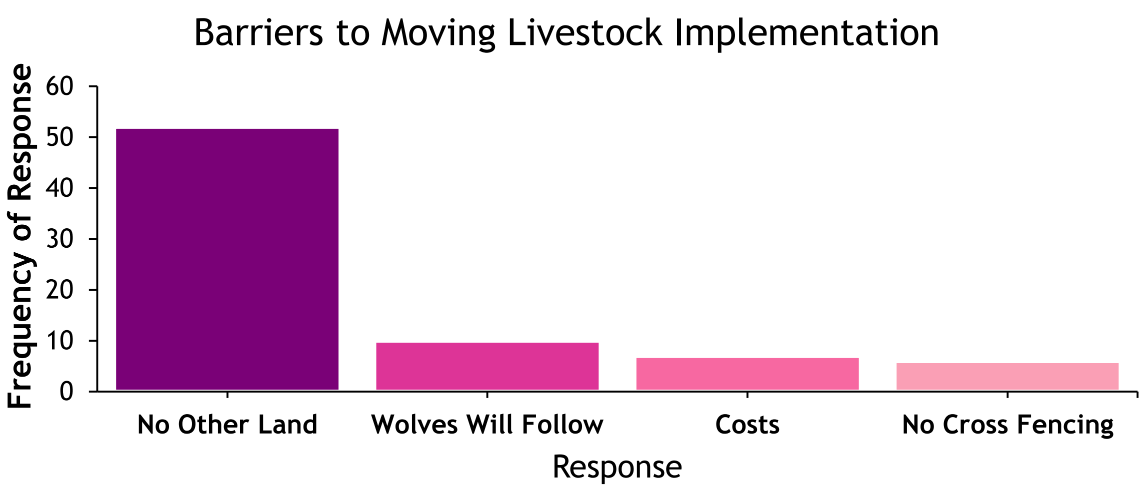


Figure 3.16. Familiarity and perceived feasibility of moving livestock. Respondents who did not provide an answer to the familiarity question were excluded from analysis (n=121).

The primary identified barrier to this conflict reduction method is a lack of other lands to move livestock to, which is unique to this strategy (Figure 3.17). Livestock producers in Northern California already own and lease the land that they can afford, and few other areas exist that they can feasibly move their livestock to. Producers may also lack adequate cross-fencing to create separate pastures. The availability of feed and previously-scheduled pasture rotations may further restrict the use of alternative pastures. Furthermore, multiple producers stated that the persisting drought makes it even more difficult to find rangeland with proper forage.



3.17. Barriers to the successful implementation of moving livestock. Of the 93 livestock producers that provided an answer for this question, 83 provided *at least one* relevant response (n=88). Thirteen other, unique barriers were mentioned, including: time, feed, labor, public land, different management priorities, inefficient cattle movement, effectiveness, and cattle behavior.

While the majority of respondents listed “too much land” as a barrier for most of the other proposed strategies, a lack of separate tracts of land far enough apart to avoid wolf activity greatly limited the perceived feasibility of this strategy. Only 4% of respondents currently use this strategy, reportedly for reasons aside from livestock protection, and only 12.9% of respondents reported they were somewhat or very likely to implement. The insufficient available land for livestock producers in Northern California is likely not a barrier that can be successfully addressed, and therefore this strategy should not be a priority for implementation.

Fladry

Fladry is the least preferred and least feasible conflict reduction strategy addressed in the survey. Respondents were relatively unfamiliar with the practice before completing the survey -- 47% of respondents were “not at all” familiar, and an additional 20% were only “slightly” familiar (Figure 3.18). Only 16% of respondents said it would be possible to implement fladry on their land and perceived feasibility of fladry tended to decrease with increasing familiarity, though there was no significant association (Figure 3.18, $\chi^2(4) = 5.22$, p=0.265).

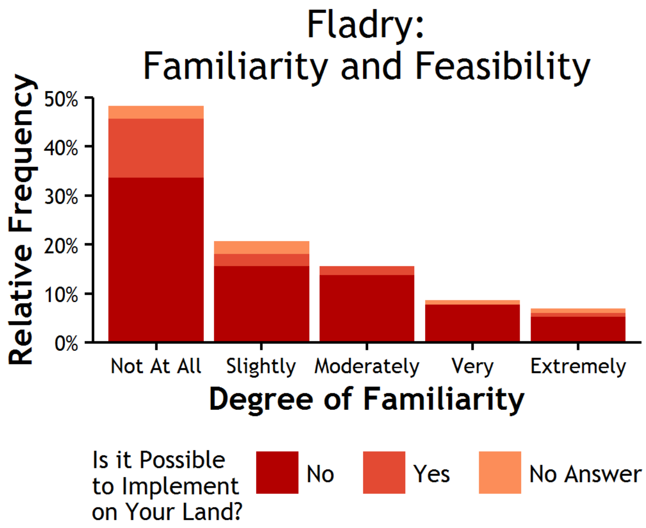


Figure 3.18. Familiarity and perceived feasibility of fladry. Respondents who did not provide an answer to the familiarity question were excluded from analysis (n=118).

Producers who reported that it would not be feasible to utilize fladry on their land cited too much land and rough terrain as the primary barriers to successful implementation (Figure 3.19). While amount of land is the primary barrier to implementation, even livestock producers operating on comparatively fewer acres did not tend to view fladry as a feasible strategy. Because fladry is often only effective in the short term, it would be inadvisable to advocate for fladry implementation on the large rangelands that make up a large portion of the livestock industry in Northern California. Instead, it may be more useful to promote the use of fladry in calving or lambing areas, which tend to be smaller tracts of land, when livestock are particularly susceptible to wolf depredation. As only 8.9% of respondents reported that they are somewhat or very likely to implement fladry on their land, this strategy should not be heavily promoted among the livestock producers in Northern California.

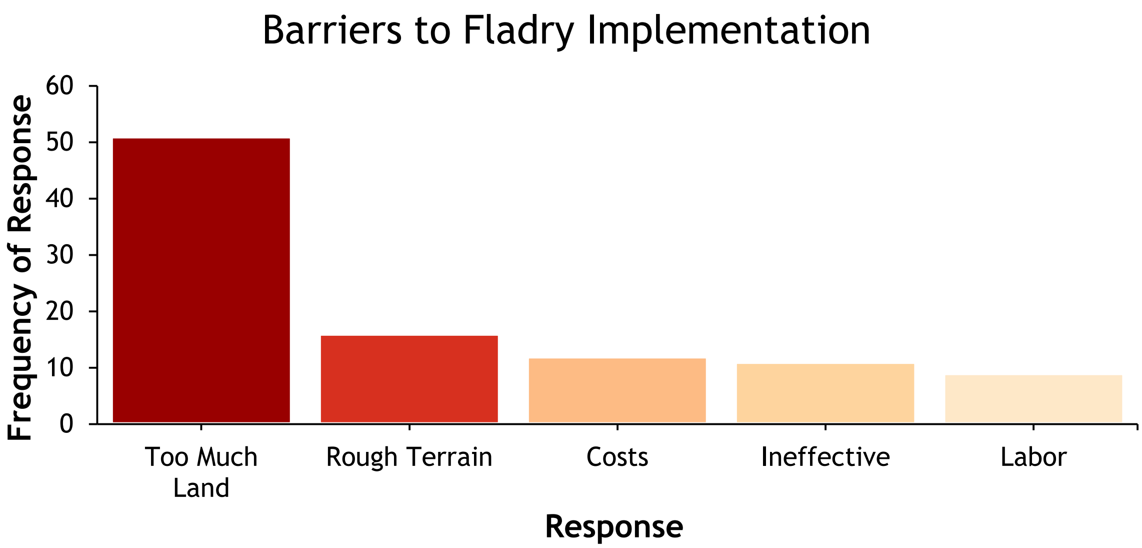


Figure 3.19. Barriers to the successful implementation of fladry. Of the 93 livestock producers that provided an answer for this question, 87 provided *at least one* relevant response (n=113). Fourteen other, unique barriers were mentioned, including: time, weather, lack of fencing, damage from wild animals, flags frightening livestock, vandalism, aesthetic issues, and leased land.

Historically, California rangeland has been owned and managed in large tracts with infrequent human interaction with herds. Many of the reported barriers to implementation for each strategy are artifacts of this system. This system is unlikely to change in the near-term, and thus strategies that do not consider acreage or topography will not be helpful or possible in our ROI. Other concerns, such as costs or labor, could be transferred away from the landowner, making the strategy more feasible and the producer more likely to implement. It is clear, due to the heterogeneity of responses, that the toolbox of practices to reduce wolf-livestock conflicts will have to be diverse and malleable; there is no single strategy that will work for all producers, nor one that will deter all wolves. These survey results are meant primarily to describe trends and concerns about the list of strategies, which is not exhaustive.

4. Recommendations and Conclusions

Our analyses provide three key results:

1. There is vast favorable wolf habitat in Northern California.
2. Large portions of this predicted habitat exist on landscapes that also support grazing activity, and as such are at risk of experiencing wolf-livestock conflicts.
3. According to livestock producers in the region of interest, attractant removal and range riders are the most locally-feasible conflict reduction strategies.

The conflict risk model results indicate that western Siskiyou and Shasta counties, northern and central Trinity County, western Humboldt County, and parts of the Sierra Nevada's northwestern foothills, may be the state's highest-risk locations, assuming continued wolf population growth. Survey responses of participants from (or near) those regions suggest that attractant removal and range rider programs are more feasible (and currently more widely used) than the other conflict reduction strategies included in the survey.

We thus conclude that Defenders, its partners, and other stakeholders that may consider how to plan for coexistence in Northern California should a) focus near-term implementation on the geographical regions highlighted in the risk maps, and b) consider attractant removal and range riders as the strategies that offer the greatest cultural and logistical feasibility.

The only part of California currently known to be inhabited by wolves is in the Mt. Shasta region of Siskiyou County. This is only a short distance east of identified conflict hotspots in Siskiyou and Trinity counties, and close to the Sierra foothill hotspots. Our results suggest that the Siskiyou County depredation event of December 2015 (which CDFW linked to the local Shasta Pack) may be a harbinger of things to come for the region. The region should thus be the site of conflict reduction pilot programs, supported by CDFW and other stakeholders and informed by lessons learned from the variety of successful conflict reduction programs implemented in Oregon, Washington, and the Northern Rockies.

CDFW should also consider monitoring packs in a similar manner as ODFW, through the use of a radio collar on at least one pack member of each pack in the state. Information gathered by radio collars could provide invaluable data for the scientific study of wolves in California (e.g., the study of pack habitat selection, movement corridors, in-state dispersal patterns, etc.). Radio collars could additionally support the success of some of the conflict reduction strategies mentioned above (e.g., range riders) if approximate real-time wolf location data can be shared with relevant official parties.

A common concern of the survey respondents was the cost of conflict minimization programs. Ranch operations already incur many costs associated with livestock protection; the use of new wolf-related deterrence strategies would impose additional costs. Because the "benefits" of some future level of coexistence with wolves would be dispersed (i.e., California in general would reap benefits from their presence, through improved ecosystem function and the public's perceived value of species protection), the costs should also be dispersed rather than concentrated. That is, California livestock producers should not be expected to cover all or even most of these costs. There are many examples of cost-sharing programs in other Western states (some are described above), and these can provide inspiration and lessons about how best to institute innovative cost-sharing partnerships for conflict reduction programs in California.

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Appendix A: Washington State Non-Lethal Deterrence Strategy Timeline

Year	Summary	Source
	Range Riders	
2012	Conservation NorthWest's Range Rider Pilot Program begins. This article updates the success of this program so far: Of the 9 project seasons finished, no ranchers participating in this program have lost any cattle to wolves	"Range Riding in Washington — Conservation Northwest."
2013	Range Riders mentioned as a possible option to extend human presence and deter wolf depredation on livestock	"Washington Gray Wolf Conservation and Management: 2013 Annual Report - WDFW Publications | Washington Department of Fish & Wildlife."
2013	One year into the range rider pilot program has yielded success, with one rancher in Eastern Stevens County, who had her entire herd return after grazing on private and US Forest Service allotments.	"Range Riders Help Ranchers Deter Wolves - Business - MailTribune.com - Medford, OR."
2015	Source discusses the Range Rider Pilot Program's success over its 3 year period of operation. Now the program is being expanded.	"Range riders head into the field" - Conservation Northwest

Year	Summary	Source
	Attractant Removal	
2011	First official mention of removing attractants as a way of deterring wolves is mentioned on page 91 of this nearly 300 page document. It outlines this method as being required to receive compensation for wolf depredation on livestock.	Wolf Conservation and Management Plan - Washington State
2014	A case where a rancher used to non-lethal deterrents such as removing attractants to prevent wolf depredation on livestock, but it failed and lethal action was required.	"FAQ - Lethal Action to Protect Sheep from Huckleberry Wolf Pack | Washington Department of Fish & Wildlife."
2015	An instance where the WDFW is recommending ranchers to use a state funded carcass pit	"Wildlife Managers Report on Efforts to Deter Wolf Attacks - Washington - Capital Press." http://www.capitalpress.com/Washington/20150714/wildlife-managers-report-on-efforts-to-deter-wolf-attacks.
2015	Another case where the state wants livestock producers to know of a new carcass dumping pit. The growth of the wolf population in this state speaks to the success of this method non-lethally deterring wolves	"State Wolf Population up 30 Percent, Four New Packs in Washington | Members | Dailyrecordnews.com."

Year	Summary	Source
	Guard Dogs	
2011	The WDFW states that livestock owners with dogs used to guard livestock are eligible for compensation if their dogs are killed by wolves	Wolf Conservation and Management Plan - Washington State
2012	LPD (livestock protection dogs) mentioned as a tool to defend livestock against wolf depredation in Washington. Donkeys, llamas and alpacas can be used as well.	"Cascadia Wildlands » Livestock Protection Dogs and Other Non-Lethal Tools to Deter Wolves."
2015	A rancher was using 4 guard dogs in Stevens county, Washington but still lost sheep to the huckleberry pack.	"Northeast Washington wolf pack injures guard dog" - Livestock Capital Press
2015	Update on the use of non-lethal deterrence in Washington and WDFW's pledge to livestock producers to share the cost in guard dogs among other strategies (estimated over $300,000).	"Wildlife Managers Report on Efforts to Deter Wolf Attacks - Washington - Capital Press."

Year	Summary	Source
	Alarm & Scare Tactics	
2002	A sound/light system that activates when radio-collar wolves are nearby is developed. (Known as a RAG box).	Breck et al. 2002
2011	Recommended non-lethal technique to deter wolf depredation by the WDFW. RAG boxes are also encouraged as well as propane cannons.	Wolf Conservation and Management Plan - Washington State
2013	WDFW releases a flow chart outlining how to receive compensation for wolf caused livestock kills. Hazing wolves using non-lethal munitions (scare tactic) is highlighted as a non-lethal deterrence method.	Washington Department of Fish and Wildlife 2013
2015	More information on the use of alarm/scare tactics to deter wolves from attacking livestock in Washington.	"Living with Livestock and Wolves: A Practical Guide to Avoiding Conflicts Through Non-lethal Means" - Washington Department of Fish and Wildlife

Year	Summary	Source
	Fladry	
2011	Recommends fladry and turbo fladry as an effective method of protecting livestock.	Wolf Conservation and Management Plan - Washington State
2011	Defenders of Wildlife report discussing Washington is testing the effectiveness of fladry and turbo fladry.	"Final Report: Turbo-fladry Experimental Project" - Defenders of Wildlife
2012	Source mentions fladry as a method to deter wolf depredations in Washington	"Cascadia Wildlands » Livestock Protection Dogs and Other Non-Lethal Tools to Deter Wolves."
2013	WDFW begins sharing costs of many non-lethal wolf deterrents such as fladry	"Gray Wolf Conservation and Management: Wolf-Livestock Conflict Deterrence Updates" - Washington Department of Fish and Wildlife
2014	Article describing the successful implementation of Fladry in Washington State	"Fladry protects wolves and livestock in Teanaway" - Conservation Northwest

Appendix B: Oregon State Non-Lethal Deterrence Strategy Timeline

Year	Summary	Source
	Range Riders	
2005	Mentions range riders as being an effective non-lethal deterrence method against wolf depredation. Estimates the cost of hiring a range rider to $1,800 to $2,500 a month.	Oregon Wolf Conservation and Management Plan
2010	Range Rider Program started in Wallowa county, Oregon. This program is the result of $15,000 US Fish and Wildlife grant to assist local livestock producer take a preemptive approach to managing human-wolf conflict. ODFW will compensate the livestock producer for the cost of this range rider and transmit locations of nearby radio-collared wolves.	"Range rider program implemented to help reduce livestock losses to wolves" - The Observer 2010
2011	Discusses that the Range Rider Program has been continued in an agreement between Defenders of Wildlife and a livestock producer.	Wolf Program Update - Oregon Department of Fish and Wildlife
2013	The Oregon Wolf Conservation and Management annual report lists there now being 4 range riders operating in the state. Also updates on the funds given to Wallowa and Umatilla counties for range riders and fladry: $15,532 and $15,500, respectively. This grant came from the Oregon Department of Agriculture.	Oregong Wolf Conservation and Management 2013 Annual Report - Oregon Department of Fish and Wildlife
2014	Range Riders mentioned as a "typical deterrence activity" that will be funded by the ODA to support the minimization of wolf depredation. $105,500 was divided amongst 8 counties to support these activities.	"Oregon gives money to counties for wolf conservation, livestock reimbursement" - Casey O'hara Oregonlive
2015	The ODFW and USFW continue to fund range riders in Oregon as a method to reduce wolf-human conflict in this update by the ODFW	Wolf Program Update - Oregon Department of Fish and Wildlife

Year	Summary	Source
	Attractant Removal	
2005	Confirms carcasses as a potential attractant and recommends removing dead animals as a way of reducing potential conflicts.	ODFW Wolf Conservation and Management Plan
2011	Mentions the ODFW looked at bone pile location data in 2010 and compared how often a radio-collared wolf visited these sites. The high frequency of its presence near these bone piles compelled the ODFW and landowners to participate in a bone pile removal project.	Oregon Wolf Program Update, 2011 - Oregon Department of Fish and Wildlife
2011	Oregon Department of Agriculture started its Wolf Depredation Compensation and Financial Assistance Program. This bill (HB 3560) grants money to counties with wolves to help start non-lethal deterrence activities and programs	"Wolf Depredation" - Oregon.gov
2012	Attractant removal listed as a non-lethal deterrence strategy to be used by livestock producers in Washington and Oregon as wolf populations' increase.	"Cascadia Wildlands » Livestock Protection Dogs and Other Non-Lethal Tools to Deter Wolves."
2013	Crook county awarded $3,000 to remove bone piles from the ODA.	"Crook gets wolf grant" - Dylan J. Darling, Bend Bulletin 2013
2014	Source discusses $53,000 grant given to the ODA from the USFW to help implement non-lethal deterrence methods. "Reducing attractants: bone pile removal, carcass disposal sites" is listed first and mentioned as what "preventative grant money has historically" gone to.	"ODA awarded grant to deter wolves from preying on livestock" - Farm Progress, November 2014
2015	The ODFW gives a detailed description of why attractants such as carcasses or bone piles should be removed to avoid wolf depredation, and claims "Carcass and bone pile removal may be the single best action to keep from attracting wolves to areas of livestock."	"Non-lethal measure to minimize wolf-livestock conflict" - Oregon Department of Fish and Wildlife

Year	Summary	Source
	Guard Dogs	
2005	Mentions guarding dogs as a way to prevent wolf depredations and estimates their cost at $800-$1,500. The plan also explains that guard dogs are less at risk from being killed by wolves when several are present.	Wolf Conservation and Management Plan- Oregon Department of Fish and Wildlife
2011	Source mentions a $100,000 grant program (from the ODA) that is "nearly ready" to compensate livestock producers that lose cattle and working dogs to wolves.	"Wolf Depredation compensation program nearly ready" - Wallowa Valley, 2011
2013	Detailed description by the ODFW on the use of guard dogs including the most desirable breeds (Anatolian, Akbash, Pyrenees). Also mentions other animals such as donkeys can be used for the same purpose.	"Area-specific Wolf Conflic Deterrence Plan Umatilla River Pack" - Oregon Department of Fish and Wildlife, 2013
2014	News report about guard dogs injured by wolves while protecting sheep flocks in Oregon. Other than three dogs that were injured, he believes a fourth was killed because it was the most aggressive and gone missing since the attack.	"Wolves kill Oregon sheep injure protection dogs" - Capital Press
2015	Wolf depredation on sheep occurs in Northeast Oregon despite the use guard dogs and increased human presence (range riders) in the region. At the publication of this article (Sept. 15th, 2015), 77 wolves were documented as residing in Oregon	"More sheep killed by Mount Emily wolves" - East Oregonian, 2015

Year	Summary	Source
	Alarm & Scare Tactics	
2005	Mentions using "non-lethal injurious harassment" such as rubber bullets, bean bag projectiles to scare away wolves. However those using this tactic must have a permit to do so. Radio activated guard (RAG) devices are also mentioned as possible wolf hazing method in which the ODFW will provide the resources to implement this method	Oregon Wolf Conservation and Management Plan
2009	RAG boxes are used as non-lethal deterrence method after a livestock	http://www.dfw.state.or.us/news/2009/september/090509.asp
2011	Lethal action to deter wolf depredation cause by the Inmaha pack. Source	http://www.outdoornews.com/June-2011/Oregon-officials-
2012	Source discusses the use of RAG boxes to frighten wolves. Mentions the	https://www.cascwild.org/livestock-protection-dogs-and-
2013	ODFW mentions they have issued 24 hazing/harassment permits as of 2013.	http://www.fws.gov/mountain-
2014	ODFW conducts a meeting in Summerville, OR to discuss new rules regarding	http://www.lagrandeobserver.com/2014022877668/News/Local-
2015	ODFW detailed description of the use hazing of wolves to deter depredation in a non-lethal manner. Describes hazing as the emission of loud noises such as air horns, shooting in the air, as well use of spot lights. It goes on to describe harassment as either "non-injurious" or "non-lethal injurious." Non-injurious harassment does not require a permit as long as the user owns the land.	http://www.dfw.state.or.us/Wolves/non-lethal_methods.asp#Hazing

Year	Summary	Source
	Fladry	
2005	Discusses fladry several times as a method to non-lethally deter wolves from an area of property. Like hazing materials, they also pledge to offer "necessary resources" to implement this strategy	Oregon Wolf Conservation and Management Plan
2009	ODFW news release about using fladry as a method to non-lethally stop wolves	http://www.dfw.state.or.us/news/2009/september/090509.asp
2011	Update from the Defender of Wildlife on the use of fladry in Oregon. 10 various	http://www.defendersblog.org/2011/10/op-ed-wolf-
2012	The Malheur county advisory wolf depredation and compensation committee was formed and used $3000 from the ODA to install a mile of fladry	http://malheurco.org/malheur-county-wolf-depredation-compensation-program
2013	Specific to the Inmaha pack and includes several references to fladry (as well as turbo-fladry) as an effective method to keep wolves away from an area.	ODFW Wolf Conflict Deterrence Plan Update
2014	Fladry is discussed as a non-lethal deterrent for ranchers to use against wolf-	https://californiawolves.wordpress.com/west-coast-
2015	Lists fladry as a "non-lethal preventative measure" but also admits it is not feasible over very large grazing lands. It also not an effective long term solution as wolves eventually acclimate to its presence	http://www.dfw.state.or.us/Wolves/non-lethal_methods.asp#Barriers

Appendix C: Maps of Spatial Data Sources

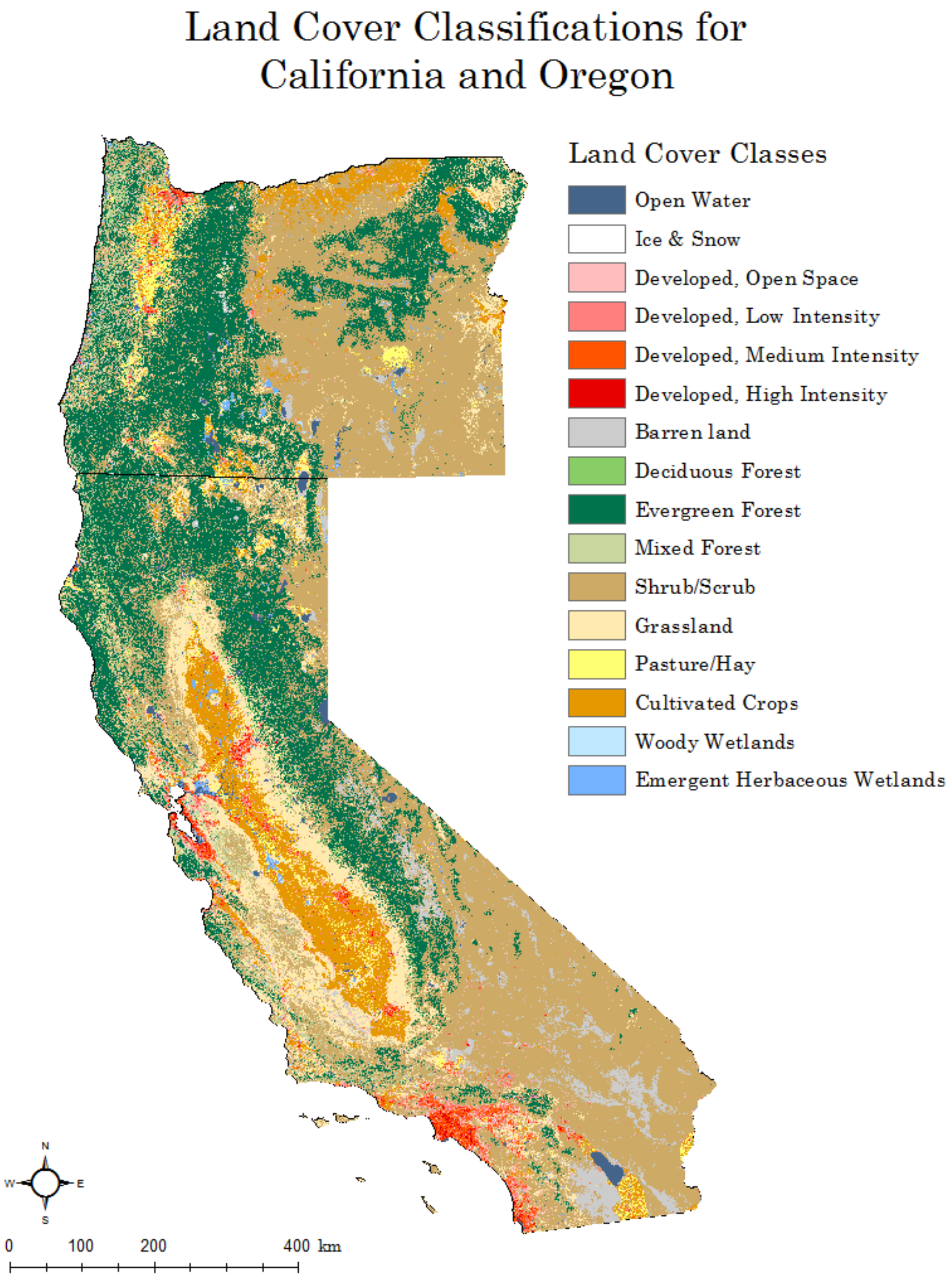

Figure C.1. Land Cover Classifications for Oregon and California. Land cover classifications, as provided via National Land Cover Database by the United States Geological Survey, displayed as at a 30m x 30m resolution.

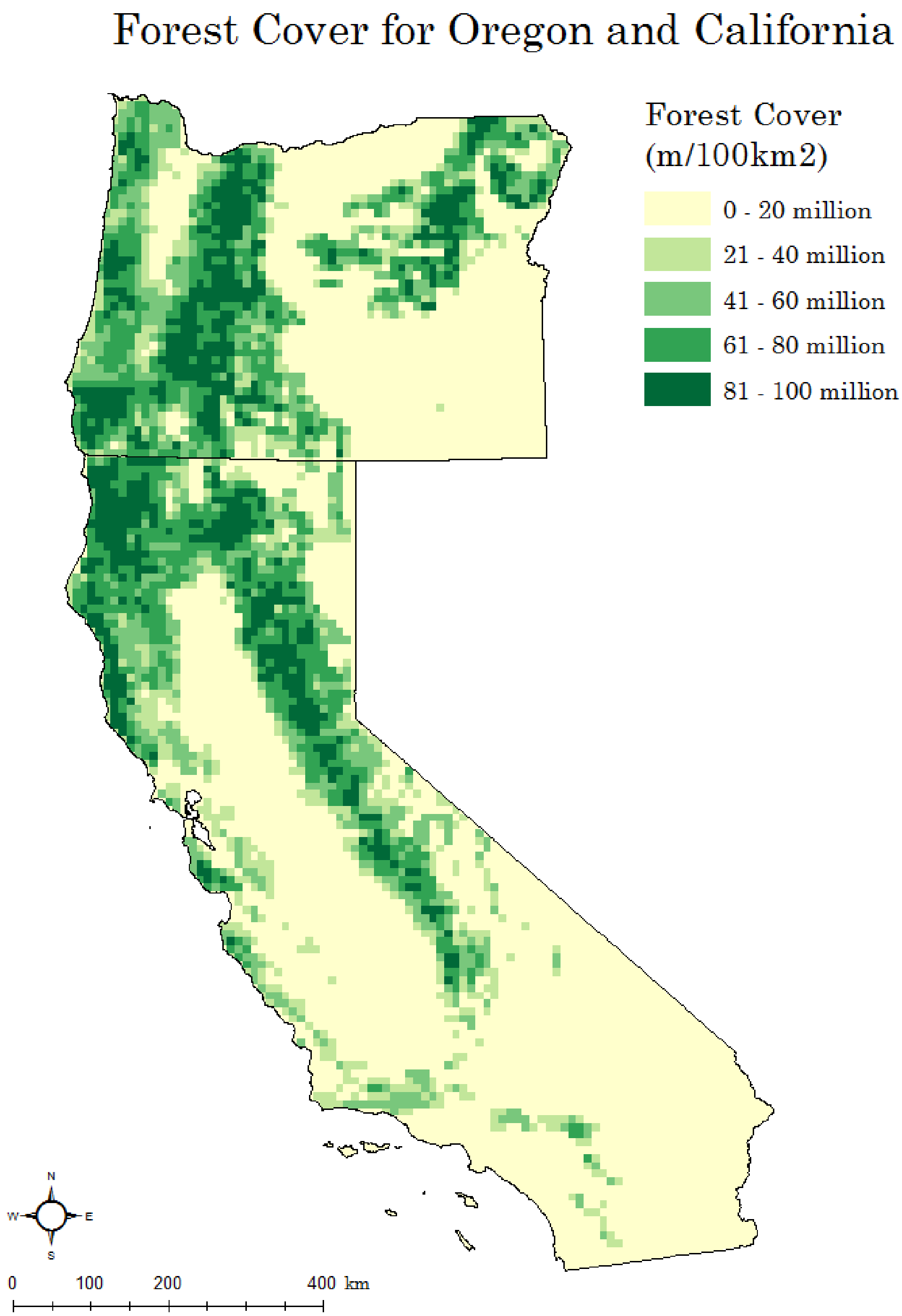

Figure C.2. Forest cover for Oregon and California. National Land Cover Database designation of deciduous forest, mixed forest, and evergreen forest combined and shown as density of meters per 100 square kilometers.

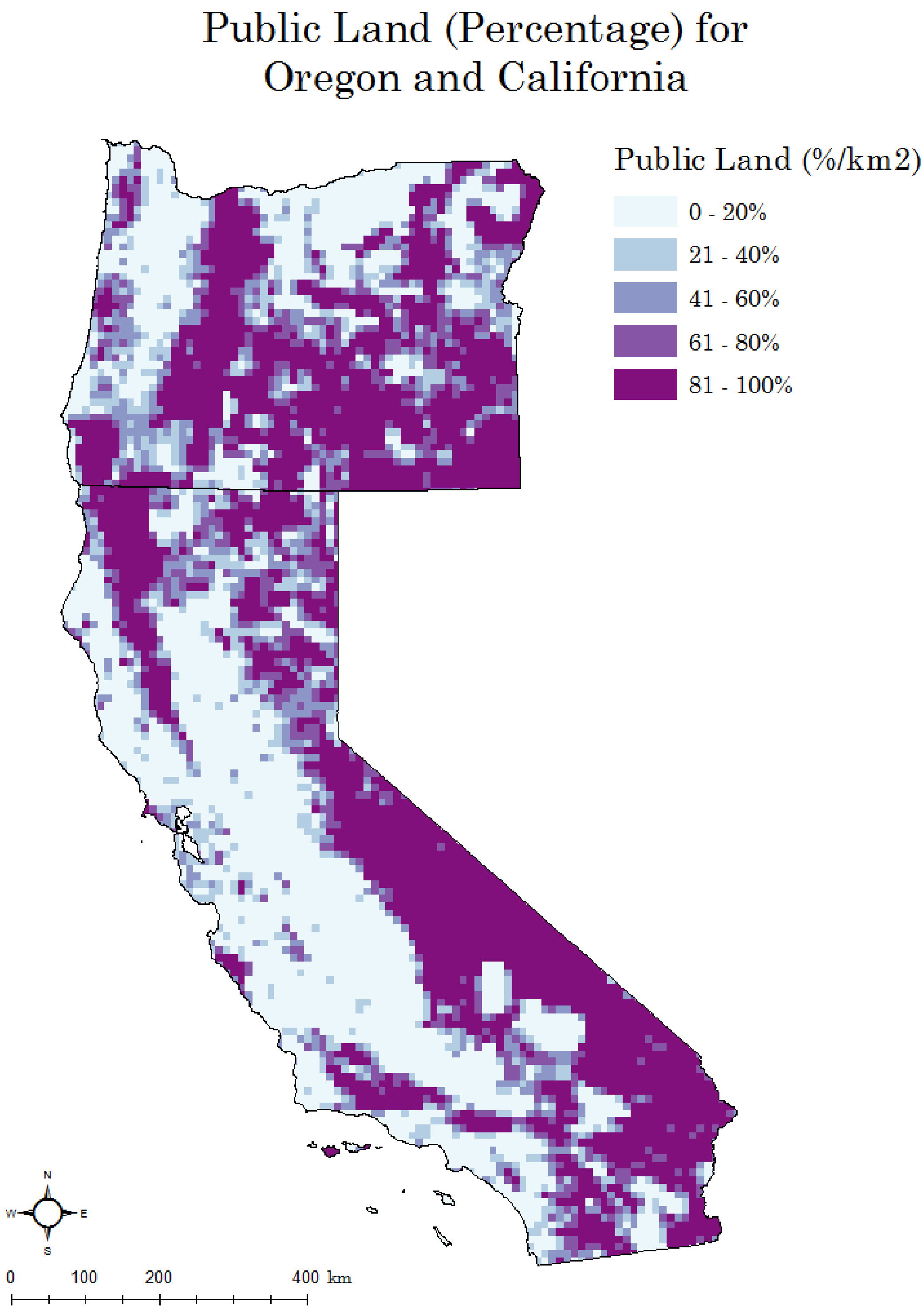

Figure C.3. Public land for Oregon and California. Public lands, as defined by the United States Protected Area Database, as a percent of square kilometer.

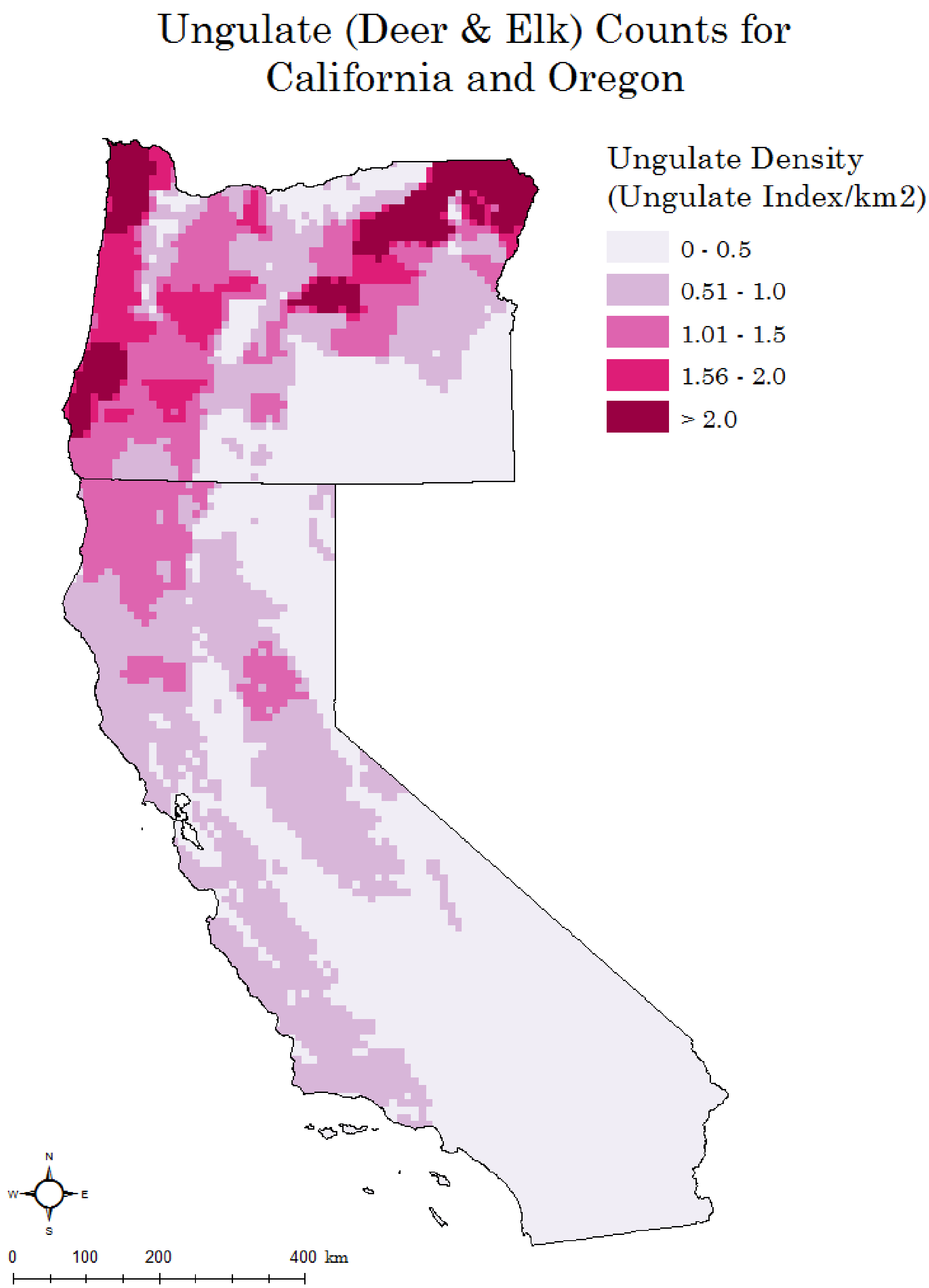

Figure C.4. Ungulate counts for Oregon and California. Ungulate index counts (mule deer, Roosevelt elk, and Rocky Mountain elk) as provided by Oregon and California Departments of Fish and Wildlife. The ungulate index was constructed using the ratio of 3 deer equaling 1 elk.

Elk Range: California and Oregon

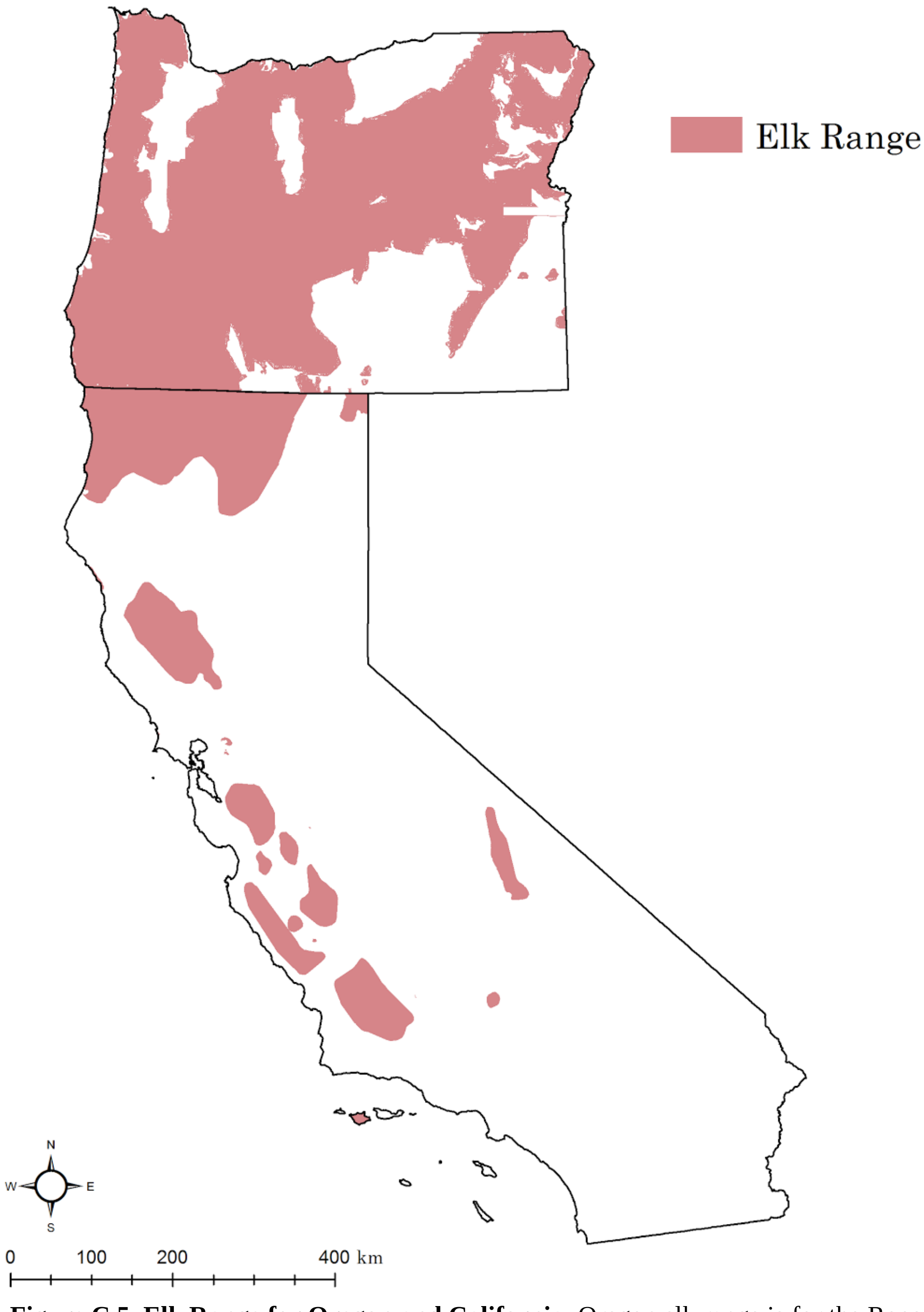

Figure C.5. Elk Range for Oregon and California. Oregon elk range is for the Roosevelt and Rocky Mountain elk, as provided by the Oregon Department of Fish & Wildlife. California elk range is for Roosevelt elk and tule elk, as provided by CDFW's Biogeographic Information & Observation System (BIOS) database.

Figure C.6. Deer Range for California. California mule deer range as provided by CDFW's Biogeographic Information & Observation System (BIOS) database.

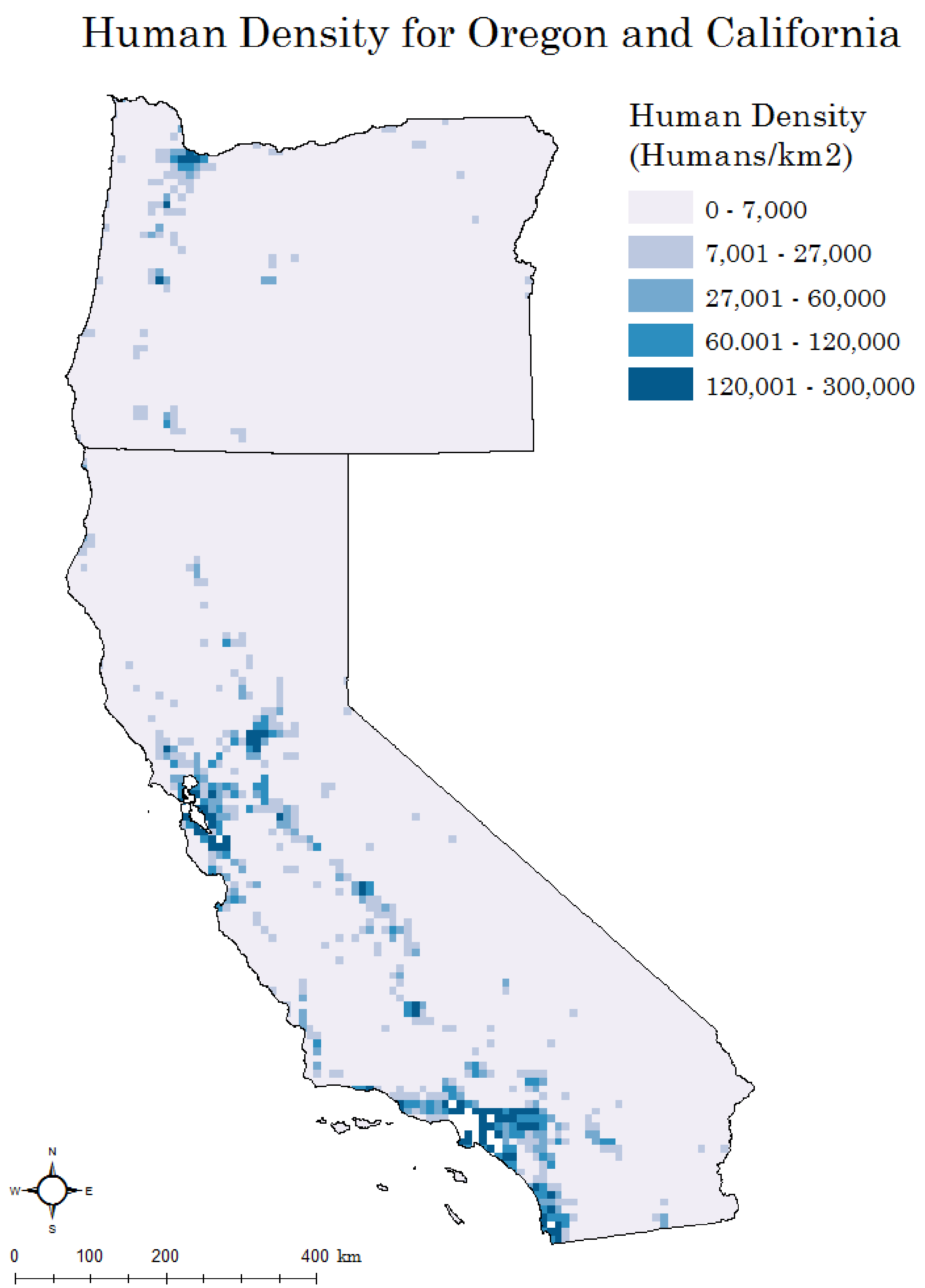

Figure C.7. Human density for Oregon and California. Human density, provided via LandScan by Oak Ridge National Laboratory, displayed as humans per square kilometer.

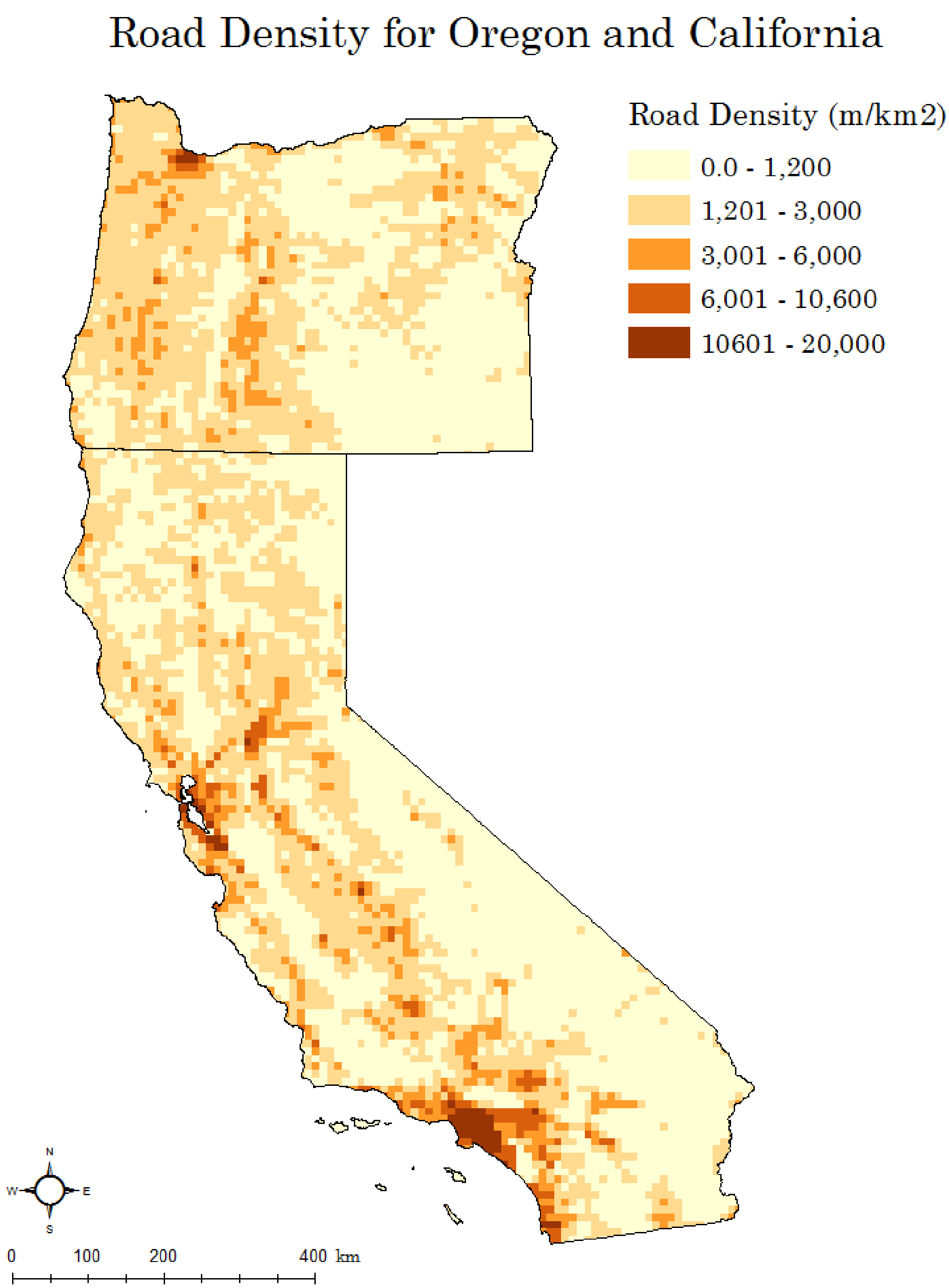

Figure C.8. Road density for Oregon and California. Road density, as provided via TIGER by the United States Census, displayed as linear meters of roads per kilometer squared.

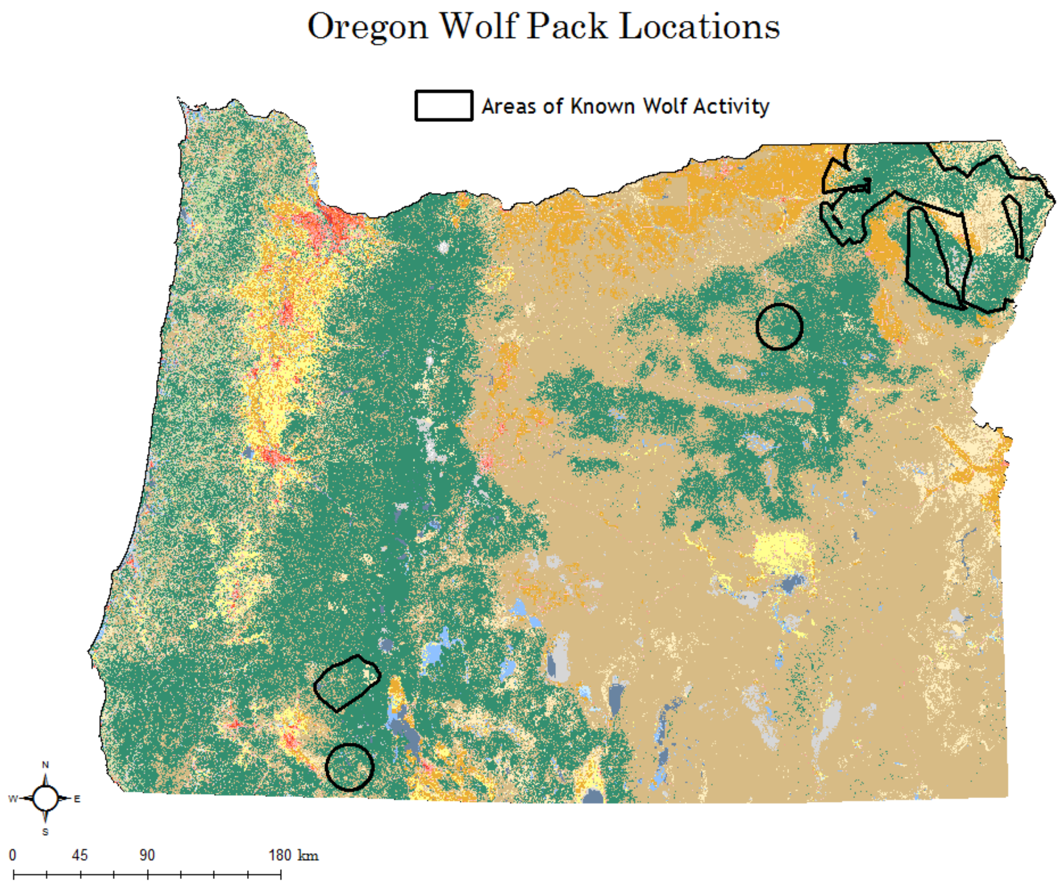

Figure C.9. Areas of known wolf activity (AKWA). Zones of confirmed wolf pack/pair locations for Oregon, as provided by the Oregon Department of Fish and Wildlife. Black polygons indicate an AKWA.

Figure C.10. Mule deer management units for California and Oregon. Management units used for mule deer in Oregon and California, as provided by Oregon and California Departments of Fish and Wildlife.

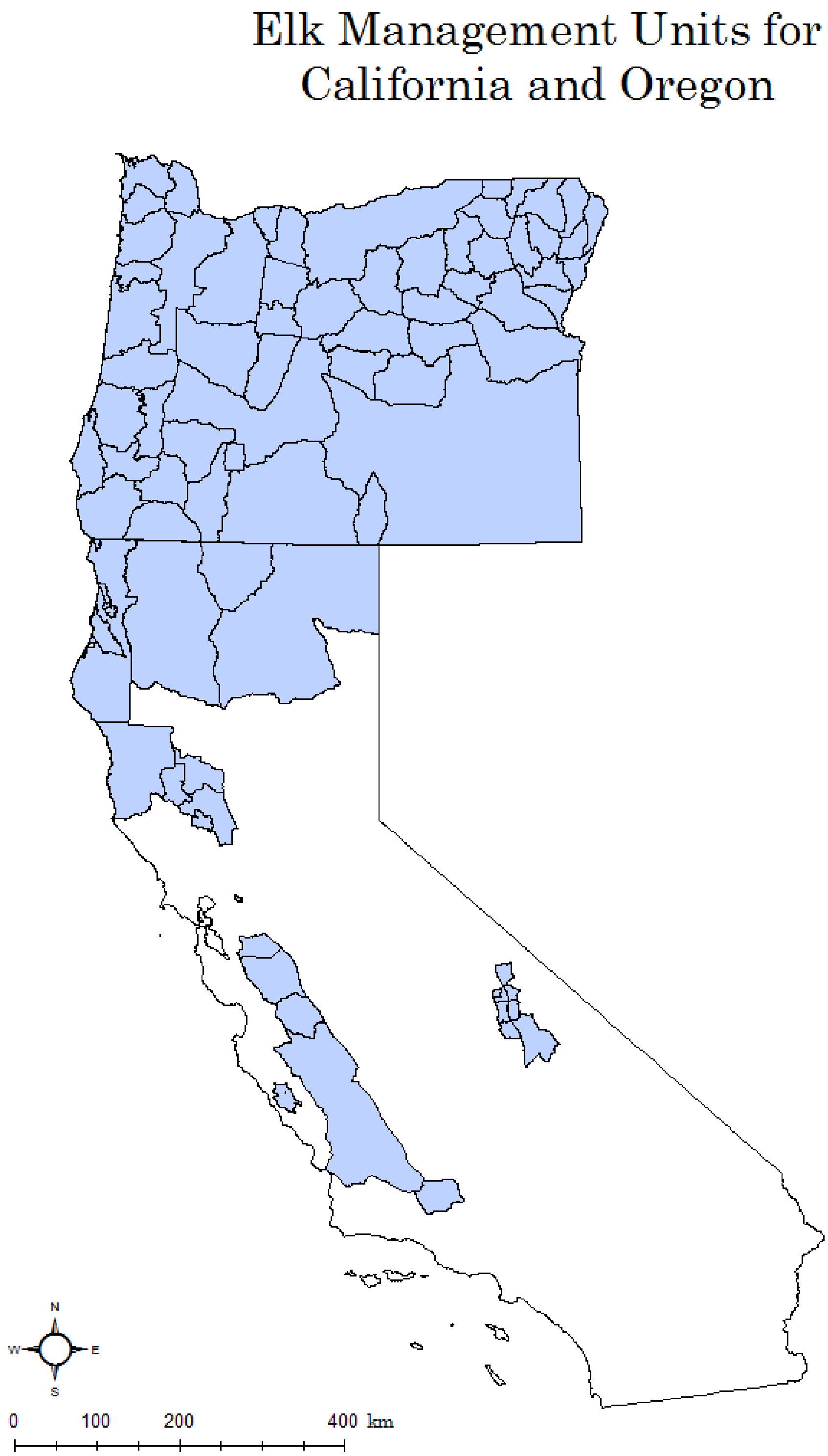

Figure C.11. Elk management units for California and Oregon. Management units used for Roosevelt elk, Rocky Mountain elk, and tule elk in Oregon and California, as provided by Oregon and California Departments of Fish and Wildlife.

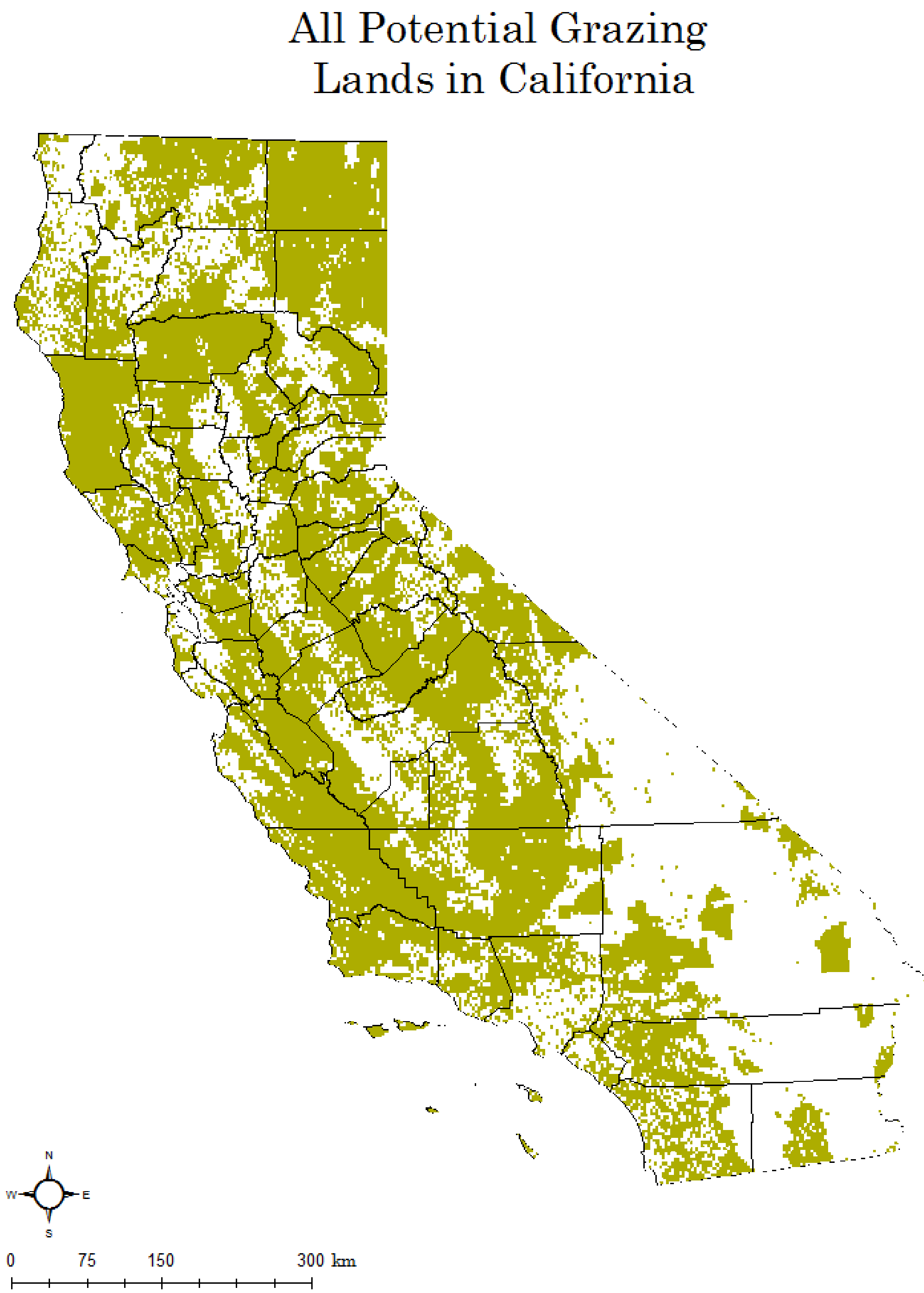

Figure C.12. All potential grazing lands in California. This data layer is composed of NLCD pasture and hay layers, United States Forest Service's forest allotment data, the Bureau of Land Management's grazing allotment data, and Department of Conservation's rangeland mapping data.

Appendix D: USDA National Forest Service Lands in California

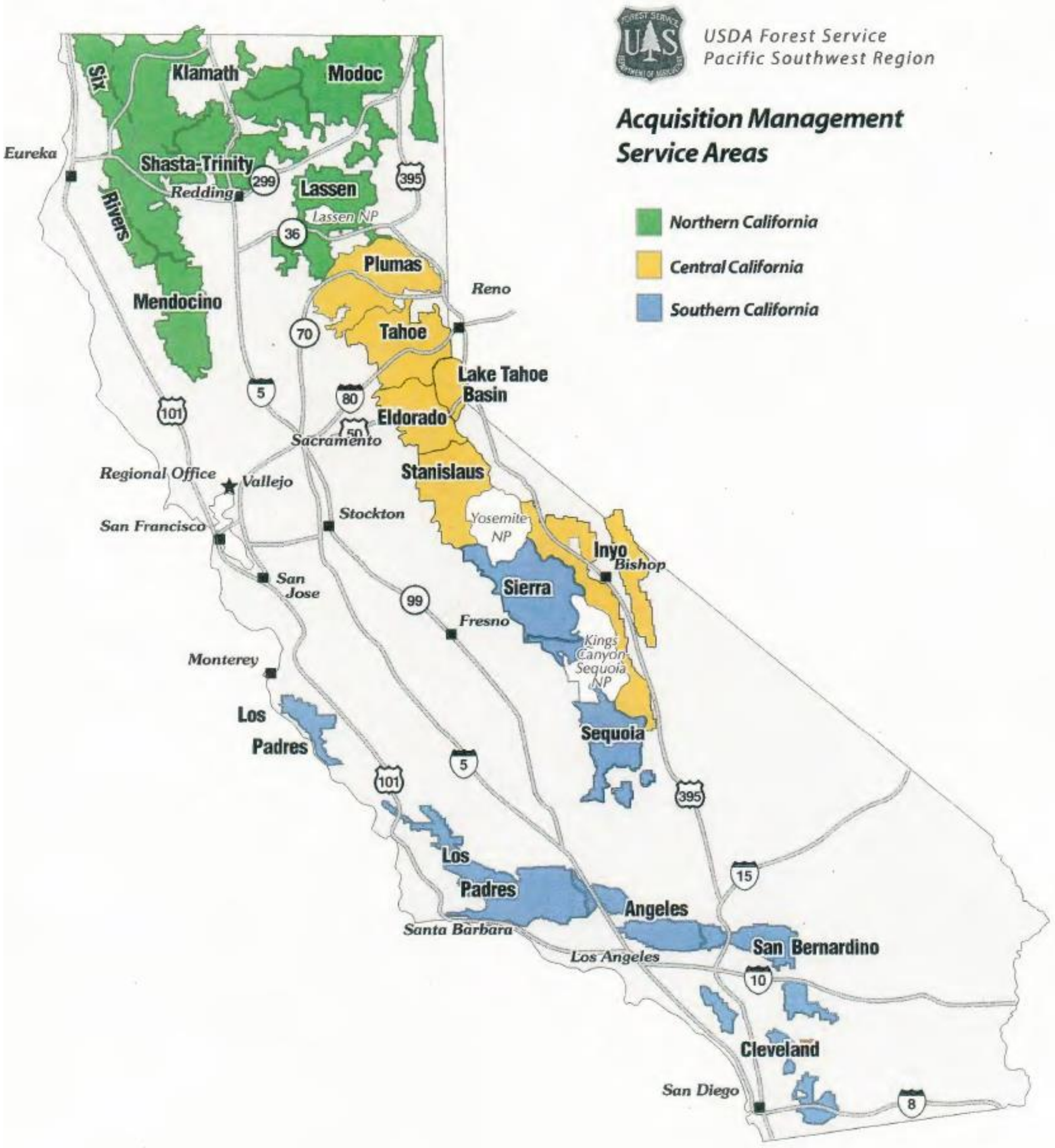

Figure D.1. USDA National Forest Service areas in California. This allows for comparison between the favorable wolf habitat produced by the selected model and the existing USDA National Forests (Source: USDA, fs.usda.gov).

Appendix E: Three Species Distribution Model Comparison

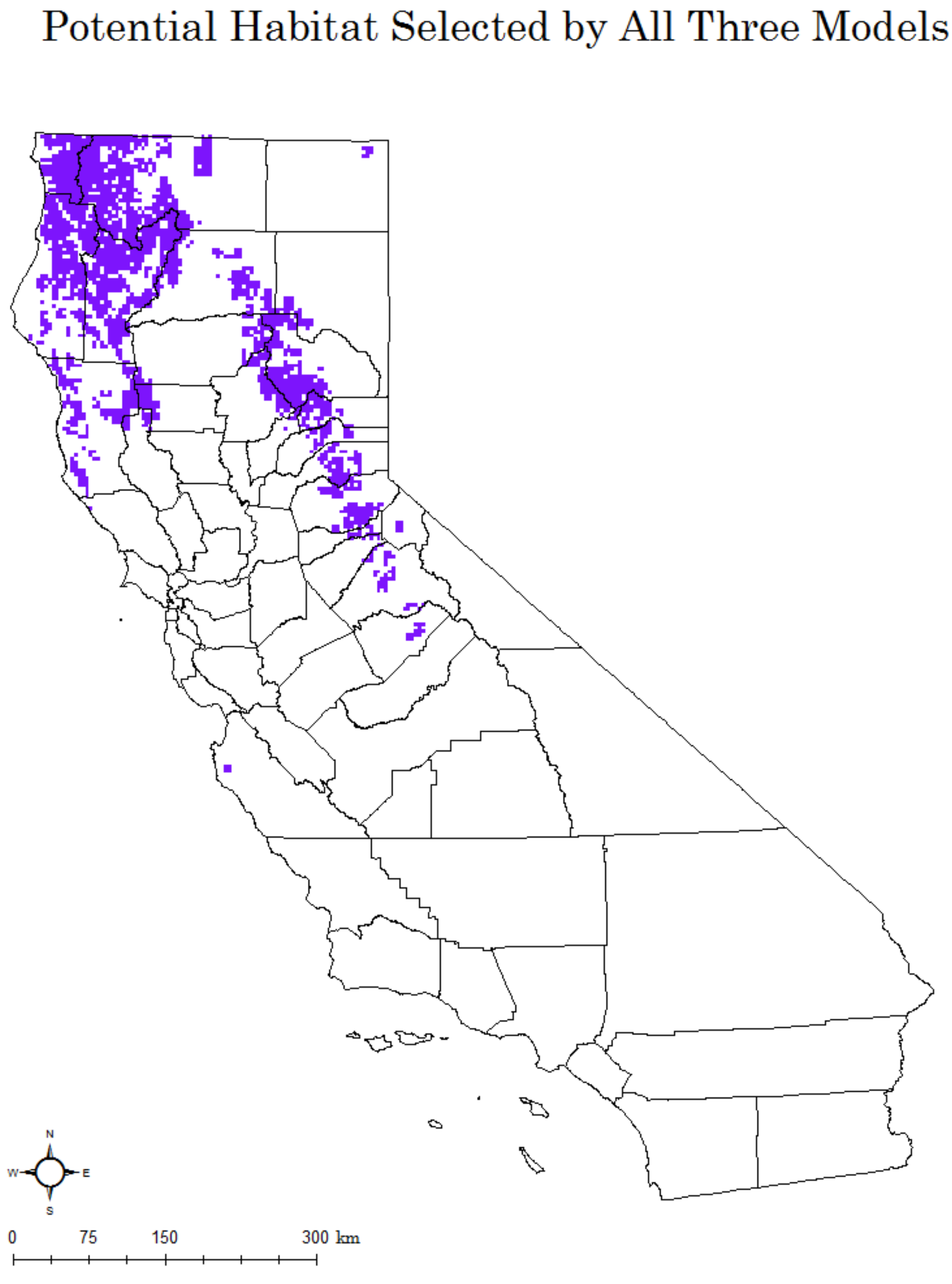

Figure E.1. Three model comparison. Purple area indicates areas selected by all three species distribution models (logistic regression, Maxent, and the Oregon Department of Fish and Wildlife methodology).

Appendix F: Connectivity Analysis (Circuitscape)

Background & Significance

It is important to understand where gray wolves will likely colonize in California to best gauge where conflicts may arise between the livestock production industry and these new predators. However, identifying these locations develops only part of the picture. Movement between suitable patches exposes gray wolves to different landscapes, and in turn, different stakeholders of that land. Traveling from one suitable patch to another may not be entirely intuitive due to different resistances an animal may experience along the way (i.e. roads, highways, cities, large rivers, etc.). Thus, having a deeper understanding of gray wolf habitat connectivity will allow for a more thorough comprehension of where these wolves may exist in Northern California, who they may encounter along the way, and the overall impact this species will have on the landscape.

Circuitscape is an open-source software program that borrows algorithms from electronic circuit theory and combines this with random walk theory to predict connectivity in heterogeneous landscapes. Circuitscape employs similar logic to how an electron will follow the path of least resistance through a circuit, so too will an animal traveling across a landscape from one habitat patch to another. Its most common applications include modeling plant and animal gene flow and identifying areas important for connectivity conservation. Employing the use of circuit theory complements traditional connectivity models due to its implementation of random walk theory as well as its ability to simultaneously analyze multiple dispersal pathways. Landscapes are seen as conductive surfaces, with resistances (ability to move through) assigned to different landscape features types. Low resistances are assigned to landscape features that are most permeable to movement (or sometimes gene flow) and high resistances are given to movement barriers. Circuitscape calculates effective resistances, current flow, and voltages across the landscapes that can then be related to ecological processes, such as individual movement (Brad McRae, Circuitscape.org).

Methods

We used Circuitscape (version 4.0), in tandem with ArcGIS, to model connectivity between likely wolf habitat across landscapes in Northern California. Due to wolves' generalist nature and their ability to travel great distances (Gese and Mech 1991), we limited our resistance files to land cover classes and roads. Focal node data, or wolf pack locations that Circuitscape models connectivity between, were used from the spatial analysis conducted above. Because gray wolves have not colonized California yet (except for a few temporary instances) we had to use areas from the model where probability of favorable habitat was highest (this included two California locations: the "Northwest" node and the "Northern Sierra" node).

<u>Land Cover</u>

Land cover raster data were acquired from the National Land Cover Database (NLCD) and created by the Multi-Resolution Land Characteristics (MRLC) Consortium at $30m^2$ resolution. Each land cover classification that existed within our region of interest (California), was assigned a resistance value (Table F.1) based upon methodologies and justifications set forth by Castilho et al. (2011) and Theobald et al. (2012). As mentioned earlier, the higher the value of resistance, the more impermeable that land cover type is to wolf movement. Thus, highly developed regions are better at precluding wolf movement than forested areas.

Table F.1. Resistance values for relevant land cover classes and roads in Northern California.

Landcover class	NLCD code	Resistance Level (0 - 100)
Developed, Open Space	21	52
Developed, Low Intensity	22	64
Developed, Medium Intensity	23	90
Developed, High Intensity	24	90
Barren Rock	31	90
Deciduous Forest	41	0
Evergreen Forest	42	0
Mixed Forest	43	0
Scrub	51	68
Shrub / Scrub	52	68
Grassland / Herbaceous	71	68
Pasture / Hay	81	65
Cultivated Crops	82	65
Woody Wetlands	90	11
Emergent Herbaceous Wetlands	95	11
State Highways	Primary roads	50
Interstate	Secondary roads	85

Roads

Road location data for California was transformed into a road density per $100km^2$ using a fishnet grid. This road data is rather detailed and includes roads ranging from major highways to desolate logging roads. It would be unwise to assume all of these roads had equal impact on gray wolf distribution. Wolves may actually use remote logging roads as a type of movement corridor. As such, we selected to include only “primary” and “secondary” roads. Primary roads, as defined by TIGER, are generally divided, limited-access highways within the interstate highway system or under State management, and are distinguished by the presence of interchanges (such as Interstate 5 and 84). TIGER identifies secondary roads as main arteries, usually in the U.S. Highway, State Highway, and/or County Highway system. These roads have one or more lanes of traffic in each direction, may or may not be divided, and usually have at-grade intersections with many other roads and driveways.

Focal Nodes (wolf presence)

In Circuitscape focal nodes indicate areas of colonization for the species being analyzed in the region of interest. In this analysis we have used three gray wolf focal nodes (one in Oregon and two in California). The Oregon node, called "Northeast Oregon," includes the majority of the Areas of Known Wolf Activity (AKWA) as published by the Oregon Department of Fish and Wildlife. Each of the polygons represents a different wolf pack know to be active in that region. The two nodes in California, named "Northwest California" and "Northern Sierra," were identified through the spatial analysis performed above. Each of these nodes were chosen for their relatively high probability of favorable wolf habitat (the two highest locations in California).

Results

The resulting map (Figure F.1) indicates connectivity between three gray wolf focal nodes (one in Northeast Oregon, two in Northern California). Areas of red/yellow color schemes indicate the path of least resistance as modeled by electric theory and random walk theory. The less resistance an animal faces while dispersing to a different habitat patch, the larger the correlating voltage. It is important to note that theses pathways are not direct (the least cost pathway) but meander according to resistances of land cover and roads.

These results vary depending on the number of focal nodes entered into the model as well as by the resistances assigned to each dataset.

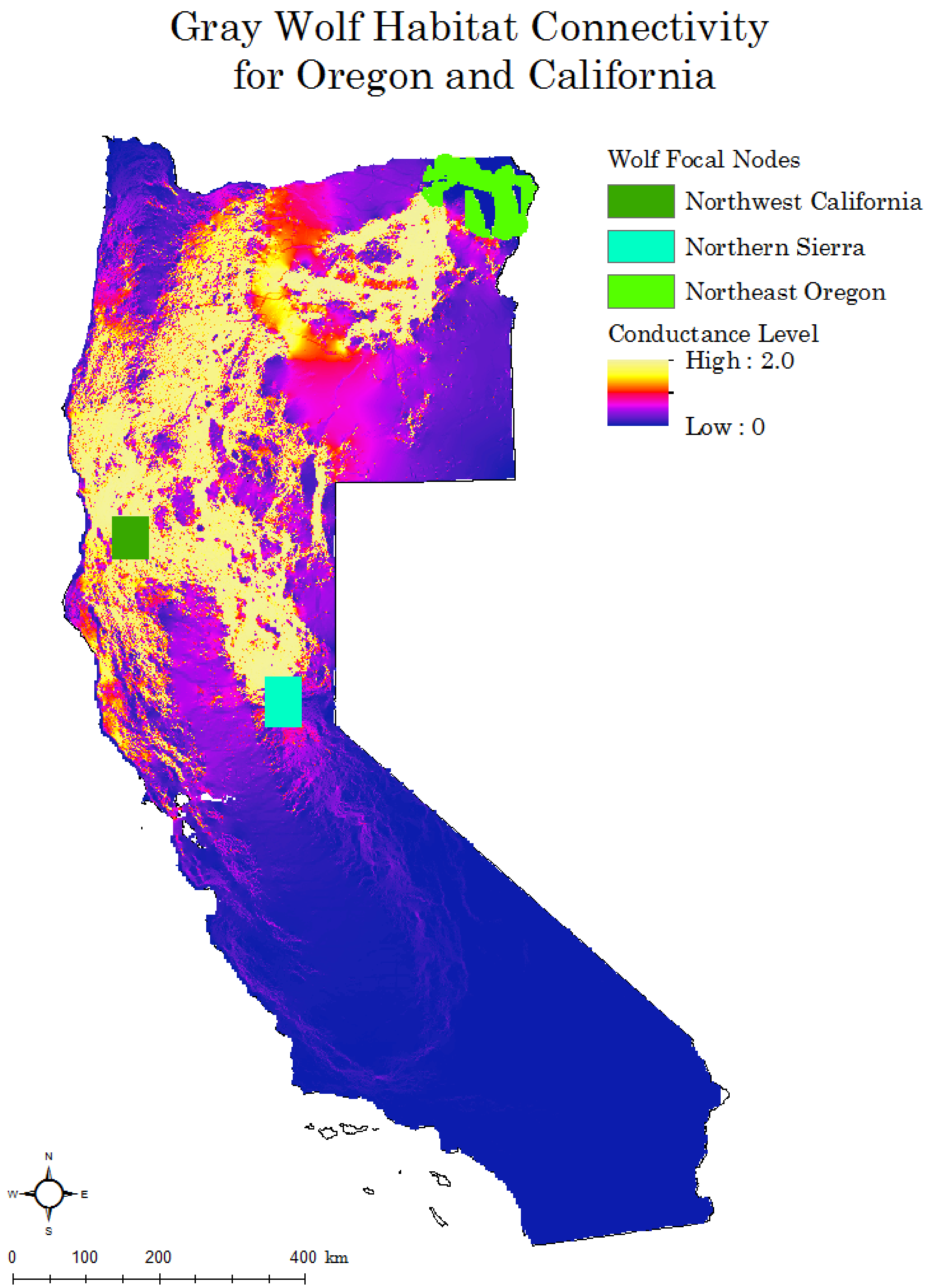

Figure F.1. Gray wolf habitat connectivity for Oregon and California as modeled by Circuitscape. Habitat connectivity was modeled using three wolf focal nodes (the green shades including Northwest California, Northern Sierra, and Northeast Oregon). Connectivity between these three nodes is ranked from high to low; yellow areas indicate low resistance (movement corridors) while blue areas indicate high resistance (barriers or areas harder to move through).

Discussion

These results provide a visual representation of the gray wolf displaying its generalist trait. Most of Northern California is dominated by red and yellow, meaning this region is relatively conducive to wolf movement. There are also clear pathways from Oregon where most wolves reside presently, thus based on this map, there are few areas limiting natural wolf migration into California. This is important to note because, as our other methodologies have displayed, there are multiple regions of high favorable habitat for the gray wolf in Northern California, and these areas are highly accessible. The generalist trait can be observed by the land cover resistance values as well, there are no land over types with a resistance value of 100. This means there is no land cover type able to completely preclude wolf movement.

Another important observation from this map is how high the conductance is between the Northwest California habitat node and the Northern Sierra habitat node. This is likely to become a region of frequent travel by wolves moving between each habitat. As previously mentioned, this figure not only displays which areas of Northern California wolves will move to, but how they will likely reach these destinations. This in turn has potential consequences for livestock producers operating within this pathway. Even though a rancher may be grazing livestock in an area relatively distant from the two habitat nodes (and in what our models predicted as less favorable habitat) they still may be at a relatively higher risk of conflict with dispersing wolves.

An additional method to interpreting these model results is to focus on the regions of higher resistance found in Northern California and Oregon. There are several of these areas in Northeastern California and Southeastern Oregon that are modeled as more challenging for wolves to move through. These zones are likely to concentrate dispersing wolves (in areas known as “pinch points”), and can create a situation where conflicts arise between these predators and livestock producers outside of areas designated in the spatial analyses mentioned in this report.

Appendix G: Survey Text

Livestock & Wolf Conflict Prevention Survey

Dear Livestock Producer,

This survey, sent to livestock managers and producers throughout Northern California, will help determine which, if any, livestock management techniques may help prevent wolf predation in the region.

Your voluntary completion of this survey will be kept anonymous and confidential – responses will not be associated with names or contact information, and no individual information will be released. If you do not want to answer a certain question, please omit it and continue with the rest of the survey. Your responses do not indicate any level of commitment to implement (or not) any of the practices discussed below.

Please use the enclosed envelope to return your completed survey. No additional postage is necessary. A timely reply is very much appreciated.

Thank you for your participation

Photo: Diana Hunter

UCSB

UNIVERSITY OF CALIFORNIA
SANTA BARBARA

RESEARCH CONSENT FORM

We would like to ask you to participate in a University of California research study. We are gathering opinions from livestock producers throughout Northern California to determine their perspectives on techniques to reduce conflicts between livestock and predators (particularly wolves). The survey is strictly voluntary. Your input is valuable to understand this important issue.

This survey has been sent to more than 400 livestock producers throughout Siskiyou, Modoc, Shasta, Lassen, Trinity, Humboldt, and Del Norte counties. An analysis of these responses may help inform efforts in each county to provide producers with tools and information to reduce losses of livestock to wolves.

There are no risks associated with this survey. Collected information is entirely confidential and will not be associated with your name or contact information in any way. Your responses do not indicate any level of commitment, on your part, to change or implement any of the strategies discussed below.

There is no monetary or other direct benefit to completing this survey. Your responses will contribute to the general understanding of how best to reduce wolf-livestock conflict in your region.

If you have any questions about this research project, please contact feel free to contact us:

[redacted] [redacted]

If you have any questions regarding your rights and participation as a research subject, please contact the Human Subjects Committee at (805) 893-3807 or hsc@research.ucsb.edu. Or write to the University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050

PARTICIPATION IN RESEARCH IS VOLUNTARY. YOUR SIGNATURE BELOW WILL INDICATE THAT YOU HAVE DECIDED TO PARTICIPATE AS A RESEARCH SUBJECT IN THE STUDY DESCRIBED ABOVE.

Signature of Participant: ____

Date: ______________

Livestock & Wolf Conflict Prevention Survey

Part 1: Carnivore Conflicts

Please respond to the following questions regarding large carnivores.

1. Large carnivores (e.g. bears, mountain lions, coyotes) have had a negative impact on my livestock operation.
   __ Strongly Agree
   __ Agree
   __ Neither Agree nor Disagree
   __ Disagree
   __ Strongly Disagree

2. My livestock currently have enough protection from large carnivores.
   __ Strongly Agree
   __ Agree
   __ Neither Agree nor Disagree
   __ Disagree
   __ Strongly Disagree

3. Wolves will not have a negative impact on my livestock operation.
   __ Strongly Agree
   __ Agree
   __ Neither Agree nor Disagree
   __ Disagree
   __ Strongly Disagree

4. In your opinion, wolves in California should be:
   __ Eliminated
   __ Kept at a very small number
   __ Managed and allowed to grow naturally, with safeguards to prevent conflicts
   __ Not managed, allowed to grow naturally

5. Shooting or killing a wolf in California should be:
   __ Illegal
   __ Legal only if a wolf appears to be threatening private property
   __ Legal only if the wolf population is healthy
   __ Legal under all circumstances

6. Have you ever had interactions with a wolf on your property or a property you lease/manage?
   __ Yes
   __ No

7. How do you currently protect your livestock from large carnivores?

____
____
____
____

Part 2: Conflict Reduction Strategies

In this section, we describe conflict reduction strategies that have been used throughout the US. We recognize that you may already use some of these strategies, and some may be impossible. You will be asked about your familiarity with each strategy and its feasibility of implementation in your operations.

1. **Fladry or Turbo-fladry**

"Fladry" is a string of evenly spaced, brightly-colored flags designed to interfere with wolf hunting patterns and scare them away from an attractant. These portable fences require regular maintenance to keep flags blowing freely and to replace aged, faded, or torn flags. They are most effective when used as a short-term deterrent on relatively small pasture/grazing areas. Turbo-fladry includes an electrified rope, which is more expensive but greatly increases the effectiveness.

a) What was your degree of familiarity with fladry before you received this survey? (circle the number option):

Not at all Familiar	Slightly Familiar	Moderately Familiar	Very Familiar	Extremely Familiar
1	2	3	4	5

b) Is it possible to implement fladry systems on your owned and/or leased land?

____Yes ___No

If No, why not? ____

____

____

c) How likely would you be to implement this strategy to minimize wolf-livestock conflicts?

Very Unlikely	Somewhat Unlikely	Somewhat Likely	Very Likely	I already implement this strategy
1	2	3	4	5

2. **Attractant Removal**

Wolves are attracted to dead animals - the presence of a single carcass can attract and keep wolves in livestock areas. Physically removing dead livestock can solve this problem. Removal can include burying, hauling carcasses to an appropriate location like a landfill, or, when removal is not possible, applying treatment such as lime, cover, or temporary fencing. This could include the removal or burial of bone piles.

a) What was your degree of familiarity with attractant removal before you received this survey? (circle the number option):

Not at all Familiar	Slightly Familiar	Moderately Familiar	Very Familiar	Extremely Familiar
1	2	3	4	5

b) Is it possible to implement this strategy on your owned and/or leased land?

____Yes ____No

If No, why not? ____

____

____

c) How likely would you be to implement this strategy to minimize wolf-livestock conflicts?

Very Unlikely	Somewhat Unlikely	Somewhat Likely	Very Likely	I already implement this strategy
1	2	3	4	5

3. Guard Dogs

Specific breeds of guardian dogs can be effective at protecting livestock from wolf depredation. Multiple dogs are usually recommended, but this may depend on the level of local wolf activity, size of grazing area, and behavior characteristics of the dogs.

a) What was your degree of familiarity with guard dogs before you received this survey? (circle the number option):

Not at all Familiar	Slightly Familiar	Moderately Familiar	Very Familiar	Extremely Familiar
1	2	3	4	5

b) Is it possible to use guard dogs on your owned and/or leased land?

__Yes ___No

If No, why not? ____

____

____

c) How likely would you be to implement this strategy to minimize wolf-livestock conflicts?

Very Unlikely	Somewhat Unlikely	Somewhat Likely	Very Likely	I already implement this strategy
1	2	3	4	5

4. Range Riders

Wolves tend to avoid humans, and increasing human presence on the range can reduce or deter wolf depredation. Range riding may be initiated primarily by a desire to deter wolves, but range riding that is already a part of existing ranching operations can also effectively deter wolves. It can also help communities track wolf activity, minimizing conflicts for multiple producers. Under specific conditions, range riders may also bolster a calf's instinct to remain within the herd and close to its mother.

a) What was your degree of familiarity with range riders before you received this survey? (circle the number option):

Not at all Familiar	Slightly Familiar	Moderately Familiar	Very Familiar	Extremely Familiar
1	2	3	4	5

b) Is it possible to use Range Riders on your owned and/or leased land?

__Yes __No

If No, why not? ____

____

____

c) How likely would you be to implement this strategy to minimize wolf-livestock conflicts?

Very Unlikely	Somewhat Unlikely	Somewhat Likely	Very Likely	I already implement this strategy
1	2	3	4	5

5. Alarm or Scare Tactics

Alarm or scare tactics include any combination of alarm system with lights and/or loud sounds, which scare wolves away from property. Such tactics may be primarily used for the protection of defined/enclosed areas or small pastures, but in certain situations can deter wolves from larger and more expansive areas (especially calving pastures) or to alert producers of wolves in the area.

a) What was your degree of familiarity with alarm and scare tactics before you received this survey? (circle the number option):

Not at all Familiar	Slightly Familiar	Moderately Familiar	Very Familiar	Extremely Familiar
1	2	3	4	5

b) Is it possible to implement this strategy on your owned and/or leased land?

__Yes __No

If No, why not? ____

____

____

c) How likely would you be to implement alarm or scare tactics to minimize wolf-livestock conflicts?

Very Unlikely	Somewhat Unlikely	Somewhat Likely	Very Likely	I already implement this strategy
1	2	3	4	5

6. Husbandry Changes: Moving Livestock

If wolves are frequently in an area, producer may move livestock from a grazing area of known wolf activity to other grazing lands with less wolf activity or no wolf activity.

a) What was your degree of familiarity with moving livestock to reduce predation before you received this survey? (circle the number option):

Not at all Familiar	Slightly Familiar	Moderately Familiar	Very Familiar	Extremely Familiar
1	2	3	4	5

b) Is it possible to implement this strategy on your owned and/or leased land?
___Yes ___No
If No, why not? ____

c) How likely would you be to implement this strategy to minimize wolf-livestock conflicts?

Very Unlikely	Somewhat Unlikely	Somewhat Likely	Very Likely	I already implement this strategy
1	2	3	4	5

7. Husbandry Changes: Calving

Condensing the length of the calving period minimizes the amount of time young calves are vulnerable to predation by wolves or other carnivores. Producers have also changed the scheduling of insemination to start earlier in the year in order to have more established calves when wolves and other carnivores begin to hunt.

a) What was your degree of familiarity with changing calving methods to reduce predation before you received this survey? (circle the number option):

Not at all Familiar	Slightly Familiar	Moderately Familiar	Very Familiar	Extremely Familiar
1	2	3	4	5

b) Is it possible to implement this strategy on your owned and/or leased land?
__Yes __No
If No, why not? ____

c) How likely would you be to implement this strategy to minimize wolf-livestock conflicts?

Very Unlikely	Somewhat Unlikely	Somewhat Likely	Very Likely	I already implement this strategy
1	2	3	4	5

8. Please rank the seven strategies listed above from 1 (most likely) to 7 (least likely), according to what you would be willing to implement on your property.

___Fladry/Turbo-fladry
___Attractant Removal
___Guard Dogs
___Range Riders
___Alarm or Scare Tactics
___Movement of herd away from wolf activity
___Changes of calving practices

Part 3: Demographic Information

1. Gender:
   - ☐ Female
   - ☐ Male
2. Age
   - ☐ <30 years
   - ☐ 30-45 years
   - ☐ 45-60 years
   - ☐ >60 years

3. Level of education
   - ☐ Some High School
   - ☐ High School Diploma/GED
   - ☐ Technical School/ Vocational
   - ☐ Some College
   - ☐ Four-year College Degree
   - ☐ Graduate/Professional Degree

4. How many years have you *personally* managed rangeland in CA? ______________
5. How many years has your family managed rangeland in CA? __________________
6. In what county/counties do you operate your ranch? _________________________

7. How many acres do you *own?*
   __ No acres
   __ <200
   __ 200 - 500
   __ 500 - 1,000
   __ 1,000 - 5,000
   __ 5,000 - 10,000
   __ >10,000

8. How many acres do you *lease?*
   __ No acres
   __ <200
   __ 200 - 500
   __ 500 - 1,000
   __ 1,000 - 5,000
   __ 5,000 - 10,000
   __ >10,000

9. If you lease land, from whom do you lease? (check all that apply)
   __ Bureau of Land Management (BLM)
   __ U.S. Forest Service (USFS)
   __ State of California
   __ Private landowners

10. What is the *primary* use of your land? (check all that apply)
    __ Cattle Grazing
    __ Sheep Grazing
    __ Horse Grazing
    __ Timber
    __ Other (please specify) ______________________________________

11. If you manage livestock, what is the approximate size of your herd? _____________________

Thank you very much for completing this survey. Your answers will remain confidential, and your input will help us understand possible ways to reduce wolf-livestock conflict. Please return this survey using the enclosed envelope or mailing it to:

[redacted]

Many thanks!

Appendix H: Survey Demographics

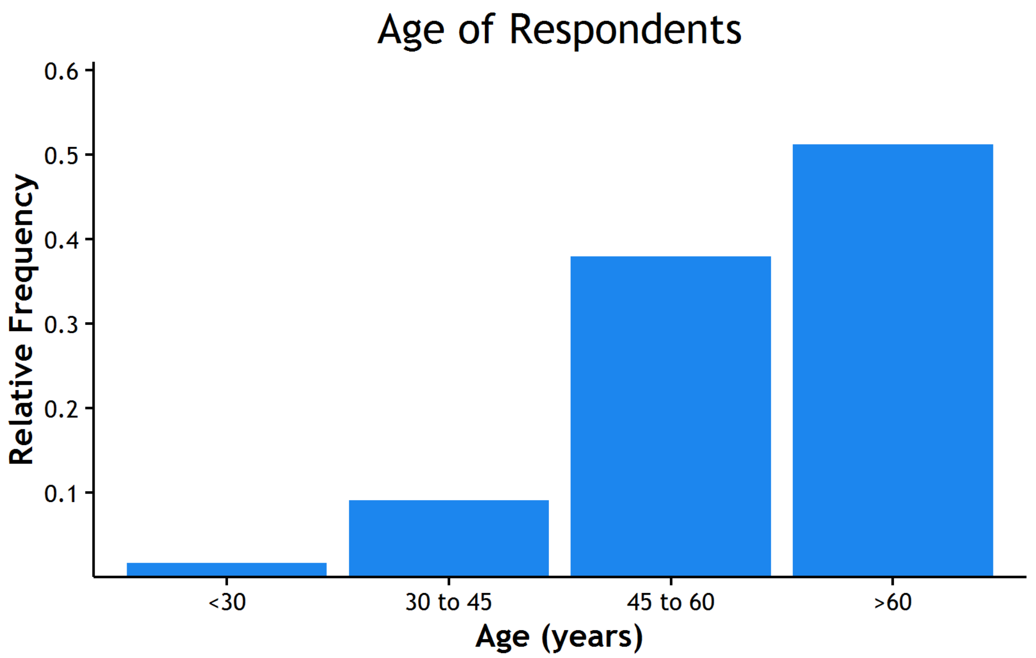

Figure H.1. The self-reported age of respondents, demonstrating that the vast majority of respondents are older than 45 (n=121).

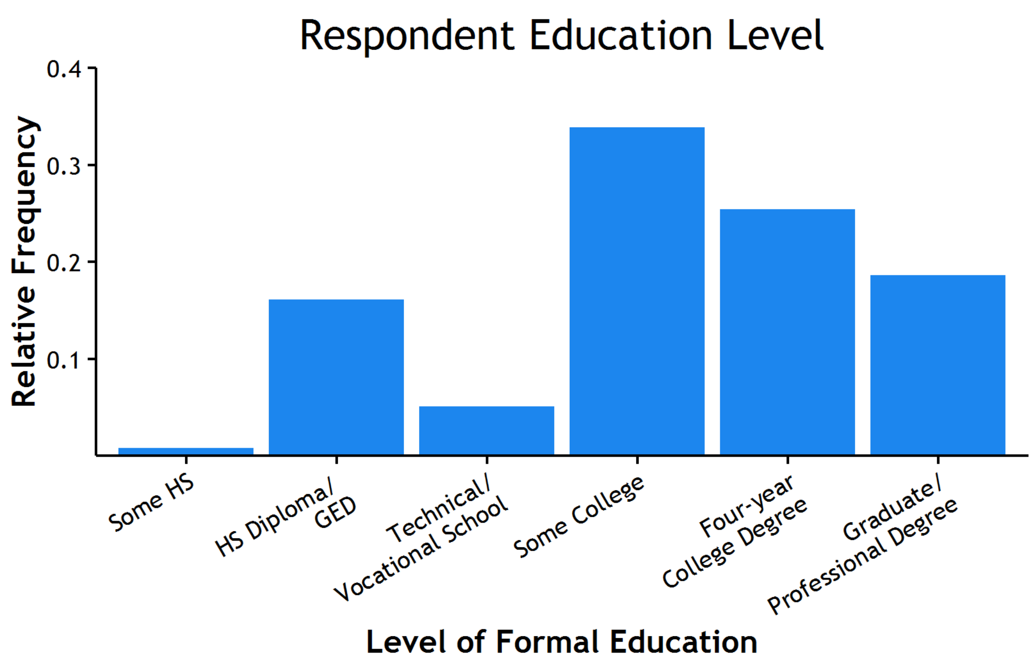

Figure H.2. The self-reported level of education of respondents (n=119).

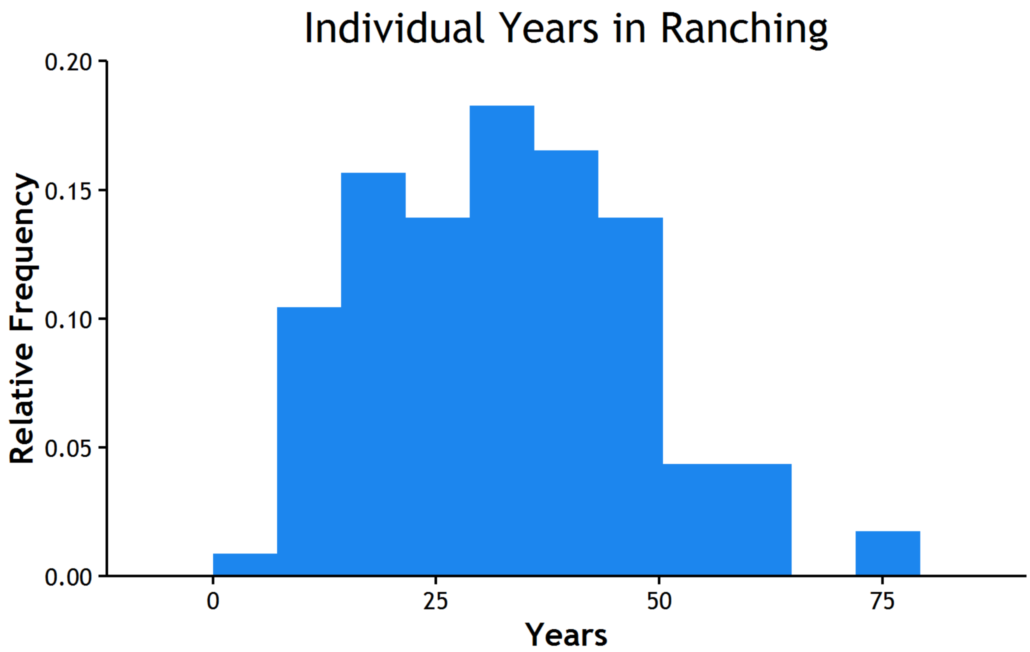

Figure H.3. The self-reported number of years that the individual respondent has been ranching (n=115).

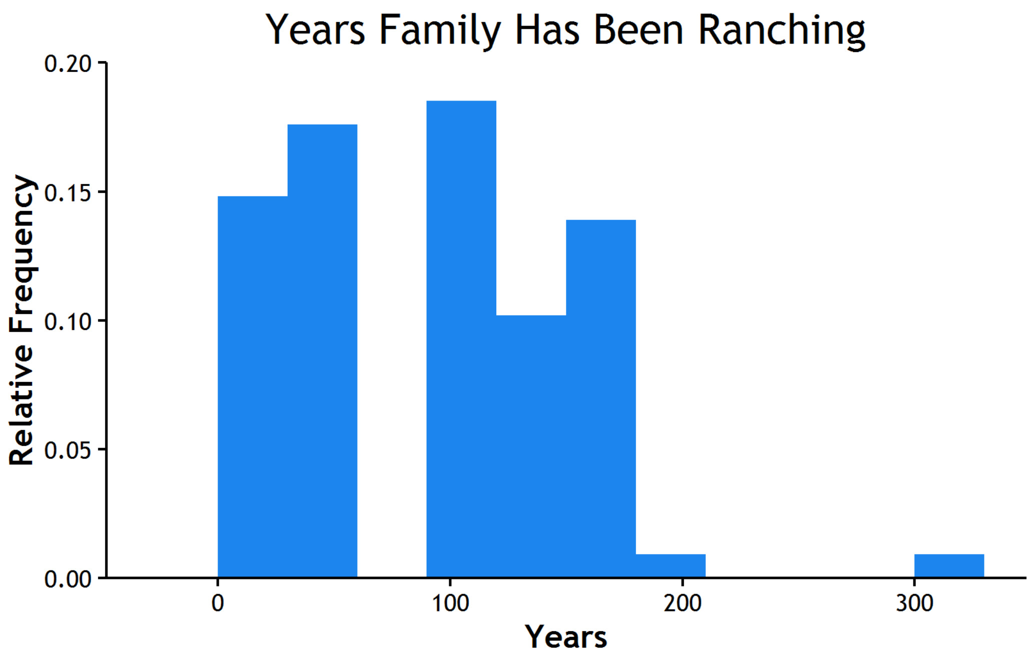

Figure H.4. The self-reported number of years that the respondent's family has been ranching (n=108).

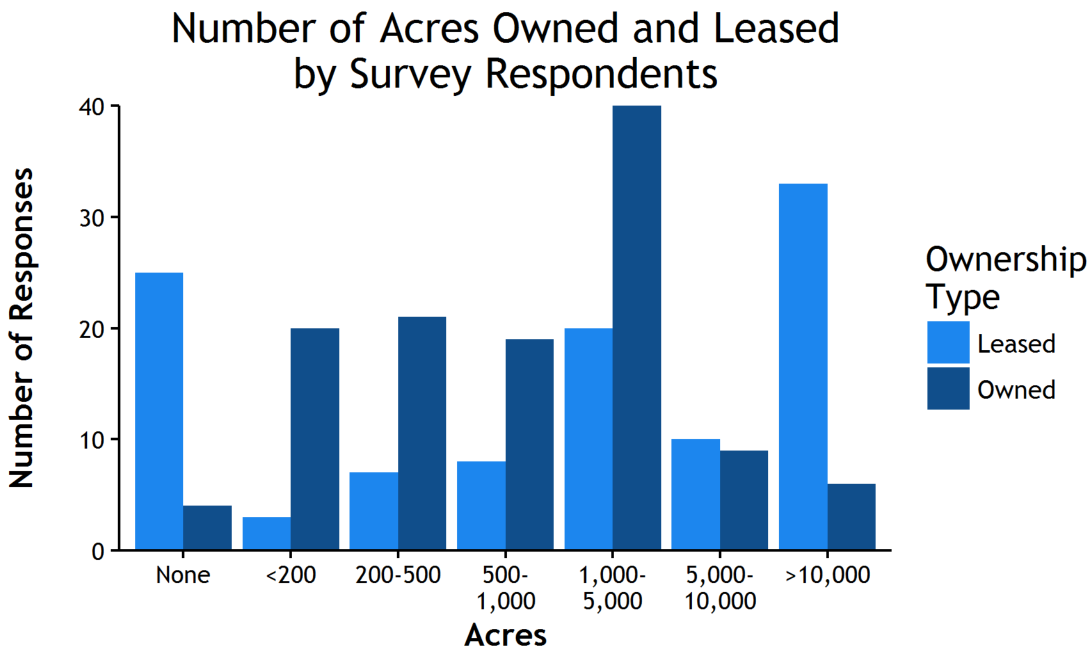

Figure H.5. The number of respondents who lease (light blue) and own (dark blue) acres in Northern California (n=106).

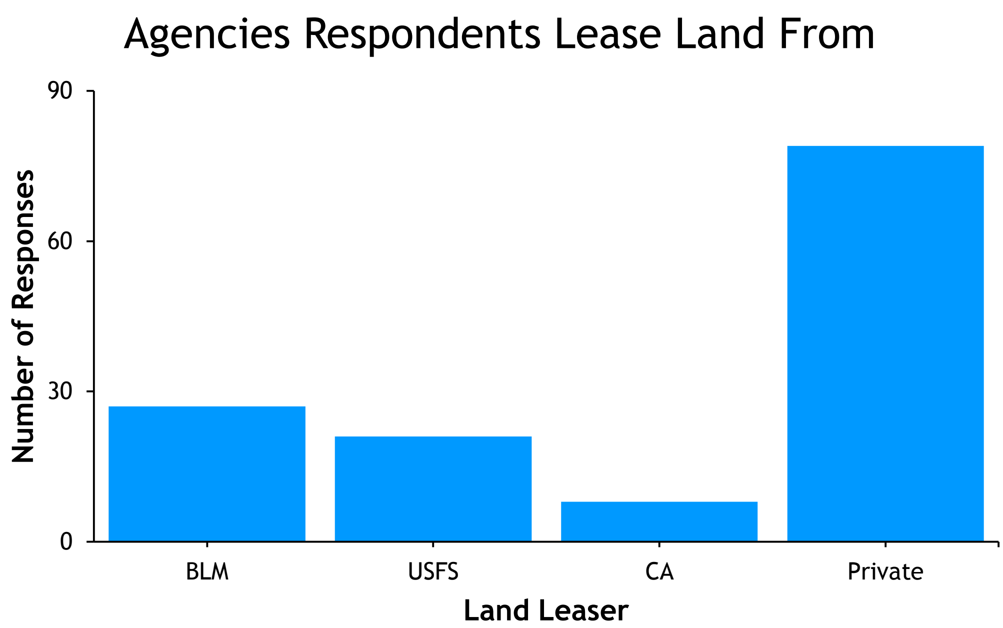

Figure H.6. The number of respondents who lease land from public or private agencies (n=89). Many respondents reportedly lease land from more than one agency.

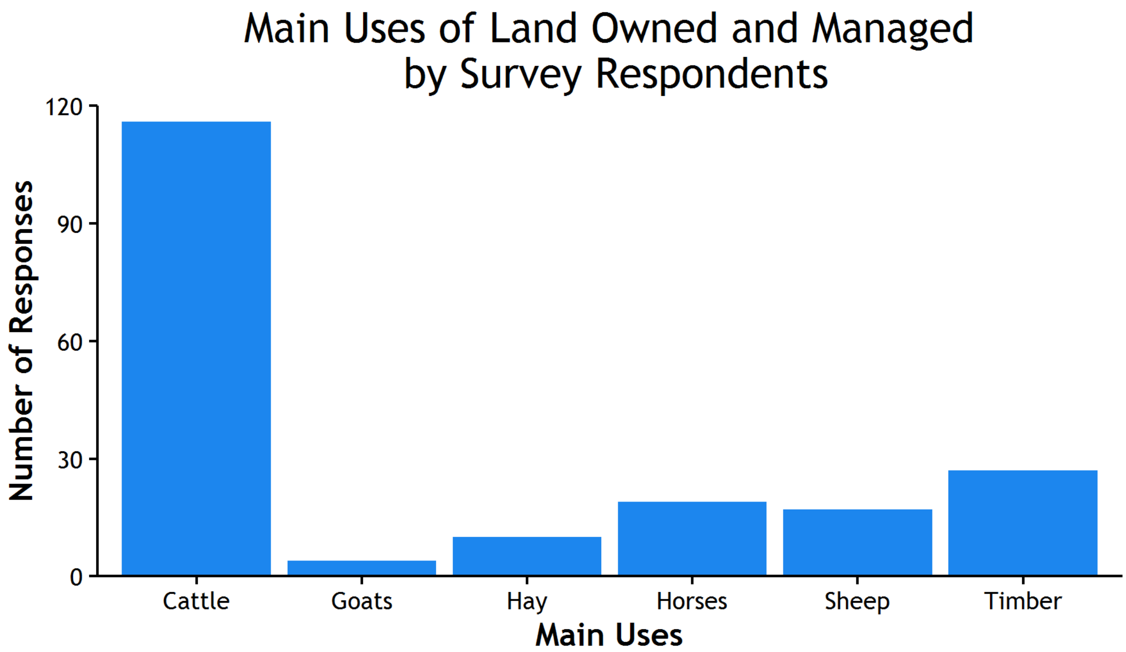

Figure H.7. The number of respondents who use their land for each of these six primary uses (n=122). Many respondents reportedly use their land for more than one use.