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ES 494C
Capstone Final (draft)

Assessing the Suitability of Grey Wolves in Jackson and Klamath Counties

Introduction

Wolves are a considered by many to be a keystone species in ecosystems, meaning they have a wide range of effects when they are part of an ecosystem, and their removal results in great ecological change. Their reintroduction can result in positive impacts on biodiversity and other aspects of ecosystems, although they are often perceived as having a negative impact on humans. With the arrival of new wolves in Oregon, ranchers and farmers in particular are concerned with depredation of livestock, and others are concerned with decreased safety at home and during recreational activities. It is important to determine if an area can feasibly support a growing wolf population, and what positive that population may or may not have.

Understanding the behavior of wolves is key to this, as their behavior determines what impacts wolf reintroduction in Jackson and Klamath County would likely have, and what is needed to maintain any benefits. These needs would include appropriate forest land, ungulate (hoofed animal) populations, and human interference levels. They are some of the general needs, but are each multi-faceted and interconnected. These connections are identified and studied in reviews of previous wolf restoration in both similar and dissimilar habitats to those of the Counties. This range of data from different areas will allow a better examination of preferred habitat, and which would likely benefit most from wolf reintroduction. This is important because some areas may not benefit from wolf introduction, or cannot support a large enough population to have effects.

Literature Review

-Impacts of Wolves on Ecology

Ungulate Suppression

Over browsing of vegetation by deer is a problem which persists throughout the United States. Often, the only plant species to survive are those which the deer cannot eat, and those which regenerate and reproduce quickly (Levy). Many tree seedlings and herbs such as ginseng suffer the most. Some species such as hay-scented fern are not eaten by deer. This has caused the species to grow from around three percent of ground cover to thirty percent in areas with heavy deer browsing (Levy).

One of the most famous studies on wolf reintroduction focused on the trophic cascade effect that occurred with the presence of wolves in Yellowstone National Park (Smith, et al). Trophic cascade refers to the suppressive effects large predators have on their prey, and how that affects other organisms on the food chain. In this study, much of the focus is around ungulate suppression. It highlights how this promotes growth of aspen and willow saplings, which are slightly uncommon but very ecologically important in the area. Wolf reintroduction appears to have positively impacted these populations, and they also found that practically every species was affected by an increase in wolf numbers, with many suggested positive effects, and little to no negative ecological effects. In the conclusion of this study the researchers claim that they are confident that wolf introduction will change the functions in yellowstone ecosystems, and result in trophic cascade throughout the region (Smith, et al). These results have prompted an increased awareness of and interest in wolf reintroduction, especially concerning whether or not this is applicable elsewhere.

A study in the great lakes region highlights the importance of doing research in an area different to Yellowstone. The authors decide to study the heavily forested region of Wisconsin between Lake Superior and Lake Michigan. This study differed in that instead of examining an area before and after wolf reintroduction, it selected various sites with different wolf concentrations and then examined size, coverage, and reproduction of three herbaceous understory species, Polygonatum pubescens, Clintonia borealis, and Trillium grandiflorum (Bouchard, et al). They ranked the sites as: no wolf impact, low wolf impact, and high wolf impact. low wolf areas were defined as having wolf presence for 4-6 years, and high wolf areas had wolf occupation for 12-13 years (Bouchard, et al). This is a possible limitation, as there may be other factors influencing each area such as ungulate density, terrain, rainfall, and soil composition.

This study found that understory herbs in areas with high wolf impact had significantly larger mean leaf coverage area, when compared to both low impact and no impact areas. Low impact areas saw lower levels of plant growth and reproduction when compared to areas with no wolf activity, which initially surprised the researchers, although they then state that their hypothesis was faulty, as wolves will select locations already containing high deer densities (Bouchard, et al). This means that areas with recent wolf reintroduction were areas that had recently been heavily grazed by ungulates. However, this information makes the progress of the high impact areas even more significant, and gives a better picture of impacts after wolf introduction (Bouchard, et al). The researches state that effects in the area are not as notable as those seen in Yellowstone, concluding that trophic cascade may not be as important in the area. They also note that herbs in the dense forest do not grow as fast as saplings in forest-meadow boundaries, so much more time is needed to actually determine if trophic cascade is playing an important role (Bouchard, et al).

Methods of introduction also need to be taken into account, it seems the most important aspect is the population size of the reintroduced wolves. In the article *Wolves Will Not Provide Small-Scale Ecological Restoration*, the authors argue against a proposal to use intensely managed, small scale, pack restoration methods, as it has limited ecological impact. An important point they bring up is that the most effective methods use the reintroduction of multiple large predators if the goal is to reduce overpopulation of ungulates, as well as the benefits of full-scale reintroduction (Belant, Jerrold L., Layne G. Adams.) Increased human conflict may arise from larger populations needing to be maintained. Wolf populations also act more sporadically when occupying fenced in, intensely managed restoration efforts. While these efforts may bring some ecological change, the do not fully facilitate ecosystem recovery, given the scale of influence wolves would naturally have (Belant, Jerrold L., Layne G. Adams.)

Effects on Mesopredators

Mesopredators are mid-level carnivores which both prey upon other animals, and are prey themselves, they are typically very adaptive in food selection and acquisition. Many of these animals in the United States, such as coyotes, had historically been preyed upon by wolves (Ripple, et al). Coyotes in particular also compete for the same prey types, because of obvious advantages of wolves, their presence leads to the absence and avoidance by coyotes. The removal of wolves from their environment has caused a large increase in mesopredator numbers, which in turn affects the ecology of vast regions previously home to wolves. Despite control efforts, there are more than a million coyotes now in the West (Ripple, et al). While the coyote may have ecological importance, when it is the top predator in an area, it is often devastating to a wide range of other animals (Ripple, et al).

In order to reduce a coyote population it is estimated that seventy-five percent or more of the breeding population be removed. Currently, the Animal Damage Control agency only removes 18-29% in cooperating states. Critics argue that because of this, the control program is doomed to fail, and is a waste of money, with the average coyote kill costing taxpayers 1,000 dollars (Henke). There have been numerous attempts to eradicate portions of coyote populations, many of which show positive growth for deer and rabbit populations, but also an occasional lack of biodiversity (Henke). While human enacted coyote suppression can help protect endangered species, it can be done more effectively with wolf presence, as it does not leave a gap in the predator role (Ripple, et al).

-Preventing and Compensating Livestock Depredation

Preservation and restoration of wolves has only recently been seen as a priority by the public and conservation agencies. Historically, people have killed wolves for fur, protecting their livestock, to maintain or increase populations of wild ungulates, disease control, and fear (Musiani, Paquet). The perception often remains that ranchers and farmers should be able to kill wolves on or near their property, and government agencies will often have hunting programs alongside successful restoration programs. While it was previously mentioned that wolf reintroduction can bring revenue to state parks, there is still debate on whether wolves on public and private land can be both beneficial to the ecosystem and not encroach too extensively on human actions.

Livestock Depredation Factors

A study in Northern Italy, aimed at determining factors which influence wolf predation of livestock, finds that some key factors are population numbers of wild ungulates, population and organization of reintroduced wolves, and the distance wolves would have between human populations (Imbert, et all). It also discusses the importance of preventative methods and non-lethal control. The degree to which these factors affect results is seen in the difference between a country like Greece, which has very low ungulate populations and very high livestock predation, and Germany, which has high ungulate numbers and electric fences, and subsequently very low rates of wolf predation (Imbert, et all).

Related to this is the importance of having an ecosystem which can support more pack-based wolf populations, as lone wolves are more sporadic and will roam large areas. These lone wolves are often young dispersing to form new packs, but disturbances in packs can also cause adults in a pack to separate. These disturbances include killing by humans, and low food availability (Imbert, et all). This is important information to consider when regarding culling of wolves. In terms of livestock protection, culling refers to killing undesirable animals, or otherwise removing them from an area.

Prevention Methods and Effects

One study found that wolf predations of livestock increased 4 percent for sheep and 5 to 6 percent for cattle in years subsequent to wolf culls. While they may deliver immediate protection for livestock, in the long run, culls will both destabilize wolf populations, and increase their impacts on livestock(New Research… Wolf Culls). Using strychnine to poison wolves is perhaps the most destructive on ecology and biodiversity, because it often kills non-target, low population animals such as wolverines and fishers, as well as numerous scavenger birds and other animals(Proulx, et al). The authors hope for more organizations and agencies in the United States and Canada to condemn its use.

The article *Gray Wolf Restoration in the Northwestern United States* applies the Yellowstone reintroduction to a human context. This study took place throughout Montana, Idaho, and Wyoming, the states which Yellowstone occupies. They found the Yellowstone area was affected by $1,888 to $30,470 in potential livestock losses. The increase in visitor expenditure estimated at $23 million, and the existence value (perceived value) of wolves at $8.3 million. Predictions for the central Idaho area were similar. Their conclusions found the wolves to populate areas quicker, have less costly damage to livestock than expected, and more economic benefits for the States than expected. The article also examined losses to hunters and benefits specifically to National Park areas like Yellowstone (Bangs, et al). These findings show that the states have an excess of increased revenue needed to account for farmers losses, which they have been doing since 1987, and also enough for large scale prevention methods of livestock protection.

So far the Fish and Wildlife Service and USDA Wildlife Service use the following methods in the area: Light and siren devices, often triggered by radio-collared wolves, the use of guard animals, flagging and fencing, providing agency personnel to guard and maintain areas, harassing and relocation of wolves, providing supplemental food to wolves that establish dens in livestock areas, research using electronic collars to discourage wolves from attacking livestock, providing livestock producers radio monitoring devices to know when wolves were near their livestock, and helping to provide alternative grazing land to reduce wolf encounters(Bangs, et al).

This research shows that not only is livestock predation less of an issue than predicted in the United States, but that there are numerous methods of minimizing the risk even further, and the funds to do so.

Perceptions

Despite this potential for human-wolf interaction to work smoothly, public perception of wolves remains around 50% positive, placing them as one of the least liked animals. Factors which increase likelihood of negative perception include age and involvement with livestock. Sheep producers in particular have a 70% disfavor. In contrast, people described as highly educated about wolves have a 72% positive view of wolf reintroduction(Black, Rutberg). This study continues to cite statistics for Michigan, where wolf perception is lowest, and wolf presence is highest. It finds that 7% of Michigan residents are intolerant of wolves, these residents are represented by three groups that are nearest to wolf habitat: Upper Peninsula residents, livestock growers, and hunters(Black, Rutberg). Positive views of wolves increases with access to management tools such as compensating livestock loss, state removal of wolves, and farmer removal of wolves. As a result, 78% of farmers and 76% of all other residents claim satisfaction with available management tools (Black, Rutberg). This shows the importance of making sure management tools not only compensate losses, but also help to keep wolves away from private land. The study also mentions the importance of wolf education, but notes that the majority of people who partake in it are already wolf enthusiasts, and that programs need to broaden their audience(Black, Rutberg).

-Adjusting to Existing Models and Predicting Suitable Management or Study Areas

While wolf populations once occupied areas in the majority of the United States, success rates and positive effects of both deliberate and natural recolonization vary depending on many factors (Miladenoff). GIS regression models are often used. In the northeastern United States, data from northwest packs was used to create regression models. As previously discussed, prey density is a major factor to wolf pack success, accounting for seventy-two percent of variance in wolf density (Miladenoff). However, there are many factors which ultimately determine if wolves are suitable in an area. They found that deciduous forests and land-cover agriculture are negatively associated with maintaining wolf packs, as is small scale private land. Mixed conifer-deciduous and coniferous wetlands are positively associated with stable wolf populations (Miladenoff). Road density is also a major factor, as it is a general indicator of wolf-human interactions. The majority of packs preferred road densities lower than .45km per square kilometer (Miladenoff). There are overlaps in many areas with poor habitat due to human presence, but also large populations of ungulates, which gives both a higher ecological need for wolves, as well as favorable amount of food resources. However, these areas have higher occurrence of human-wolf interaction and this could cause issues (Miladenoff).

Comparing the prior GIS data to new wolf populations in the North East showed that wolves were doing more favorably than predicted, but stayed true to relative predicted success in different areas. What this determined is that there could be potential for multiple large, interconnected, high wolf density areas. This interconnectedness shows great probability for a stable population in the northeast (Miladenoff).

Research in the great lakes region found similar results, but also focused on which areas of restoration would limit interactions between ranchers and wolves. The researchers developed a model to predict wolf predation on livestock. In this study, pasture land and high deer density were found to increase likelihood of livestock depredation when combined with low amounts of cropland, coniferous forest, herbaceous wetland, and open water(Edge, et al). While the prediction model this study used was not entirely accurate, it highlights the importance of determining factors which could predict depredation events (Edge, et al).

There have been successes in adapting and expanding models to fit the Northwest, and I will be using multiple which have had prior success. In this way I can get closer to an accurate but not necessarily precise suitability range.

Project Goal

This project will attempt to extrapolate current and future grey wolf suitability, and likely interactions with the environment and human populations in Jackson and Klamath counties. This will be done using an ArcGIS raster analysis to show variables such as potential and past wolf habitat, ungulate habitat, vegetation type, and human interference. This will help in identifying areas which may both benefit and be benefitted by wolf populations, as well as what habitats and ranges wolves will likely occupy in higher density. Many wolf suitability models assume far less human interaction than actually occurs. This model attempts to show where and why these interactions are likely to happen. This model incorporates ungulate behavior, based on migration, as a predictor of wolf behavior.

Methodology

Determining variables and working with raw data

Proximity to ungulate migration routes is one factor which is highly useful. Data for ungulate densities only showed densities over large areas, which was not as helpful. Despite being used in many other models, this will be replaced with proximity to ungulate migration. This is done because its possible this miscalculation of wolf behavior explains why wolves have not been avoiding road dense areas as often as other models predict. (see map1)

> The layer which shows migration routes is recoded to show only high and low importance. The high importance areas are then buffered at 5, 10, and 15 miles. Each of these are given decreasing values, which represent relative importance. The importance values are 5, 3, and 2 respectively. This is because if a wolf pack is occupying area within 5 miles of these migration routes, it is far more likely to hunt only mostly in these

routes. In this way, the importance value factors in where wolves will likely have available prey and thus also likely avoid livestock interaction.

These buffer zones are then converted to raster data

A vegetation index was used determine forest type, sensitive habitat, and urban and agriculture land. This data had to entered manually, through use of an index which corresponded to landsat data from 2012. Species and land types of high importance were given their own layers (see map2), approximately 30 species and forest types were identified in the area using detached metadata. Once the highest value regions were identified and separated, the rest of the land cover types and species were given importance values ranging from 0 to 3. These values were used to form 3 classifications of forest type, as seen in map4.

These dominant species were given importance values based on whether they are preferred by wolves or not. Wolves generally prefer mixed coniferous and coniferous forests, and avoid deciduous forests and lower elevation agriculture land. Importance values of 0 to 5 were given.

Buffer zones around sensitive habitat were created, and given importance values of 5. These areas represent where wolves are highly likely to have a positive impact of the environment. By showing these regions as highly suitable, it can help highlight areas that could be observed to confirm the effects of wolves.

A separate 5 mile buffer around agriculture was created and made a layer with 0 importance, so that the map would reflect that wolves around agriculture is not suitable. However, in an agriculture zone where there is proper forest nearby, habitat benefitted by wolf presence, relatively low road density, and ungulate migration, the map may show somewhat high wolf suitability, but will still not show it as ideal habitat. This better reflects what actual wolf behavior has been. In this way, the model shows areas which may be problematic for livestock owners.

Urban areas and dense agriculture are given 0 importance and do not allow summation of positive factors such as migration routes, because wolves will generally not follow deer directly through, for example; central point, OR.

This data was converted to raster.

Road density is a related factor involved in wolf suitability. Data on km of road/km was available, and was reclassified into low, medium, and high densities. Road density is proving to show moreso where wolves and humans will interact, rather than where wolves will avoid. (see map3)

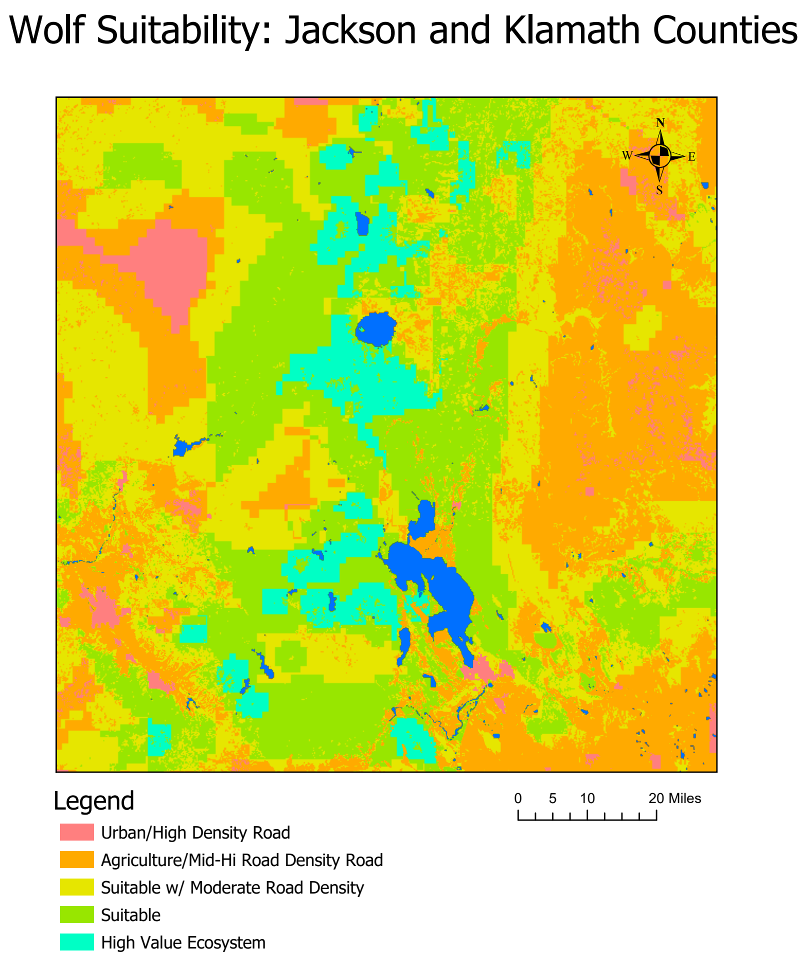
Low densities are areas such as sky lakes wilderness and the protected areas around crater lake, and were given an importance value of 5. Moderate road densities generally showed where there were multiple two way highways, suburbs, farmland, and heavily recreated areas and were given an importance value of 2. High road densities are denser suburbs and down town areas, and are given 0 importance value.

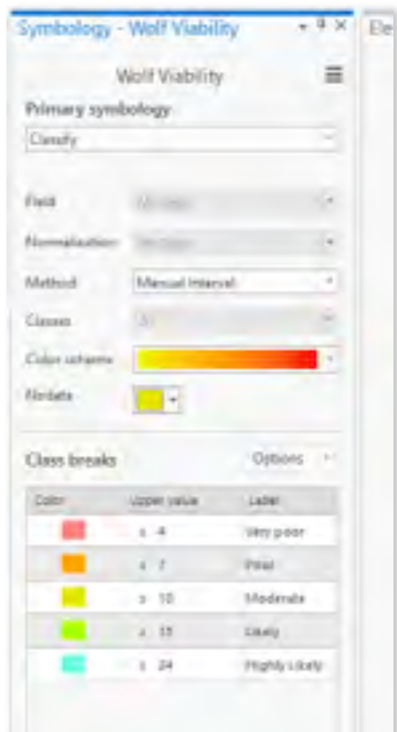
In each raster layer, missing data is all converted to 0. This is done so that a summation of the layers can be added. For example, the layer showing subalpine grassland by default has no data for any area outside of those areas.

A weighted summation was done using the previously described layers, however, the weights all remain at one. This is done because the importance values assigned earlier represent the weights. This was done because, for example, instead of weighting the entire coniferous forest layer the same, each specific forest type, such as ponderosa dominant, could be given its own value. In this way, nuanced data was able to be used, without having an additional 20 or so layers to work with. If the same nuances were desired through a simple weighted sum, each specific forest type would need its own weighted layer. This example applies to the other layers described as well.

Results and Analysis

(see appendix for supplementary maps)





The result is a model showing values from 0 to around 25. The maximum importance available in this model is 35, so an index could be achieved by dividing each value by 25.

As values approach 10, it means that there are factors which indicate either habitat wolves will likely occur, or are benefitted from them, but also areas with high human presence, and this indicates possible conflict areas. As values pass 15, it indicates that there are multiple sensitive areas nearby, with very suitable habitat and low road density. These overlap with known wolf activity areas, along with some protected areas. These values were translated to more easily digested descriptive text, though there is much more to interpret. The following analysis assumes that wolf behavior will adhere to this model.

There is much suitable land in the cascade range, with some of the highest values occurring south of Crater lake and through the sky lakes wilderness area. These areas have a lot of snowmelt and subalpine meadowland, which provides key habitat for many species. Ungulate migration links also pass through these areas, so there is high potential for over browsing of sensitive species. As drought years increase, these areas become more prone to encroaching coniferous stands. However, these areas may expand as wildfires become more frequent in these higher elevations. It is important to the ecology that burned areas are able to support sensitive pioneer species and grasslands. There are even trees such as aspen, which can be found on the eastern cascade range, though mostly in very small, old groves, which rely on disturbances and riparian zones. It is likely that they once occupied a larger range, and may once again if enough disturbances such as severe fires, floods, and landslides occur. In these large expanses of coniferous trees, deciduous understory, pioneer, and riparian species are key to sustaining healthy ungulate populations. Wolves in these areas should help protect from over browsing, and destruction of riparian zones. They do not necessarily have to reduce ungulate populations to do so, rather just by keeping them on the move, one specific area cannot be decimated.

Grey wolves have already been spotted and occupied loose ranges in the sky lakes wilderness area, so the model is accurate in that sense. Whether it will continue to predict wolf behavior is not known. Areas which are marked as suitable but with high road density, that occur close to suitable land and high value ecosystems, there is more likelihood of human wolf interaction. This seems particularly problematic around Ashland, and in grazing land to the East of Medford. There is a pocket of white oak-shrubland in this area as well, and as wolves do not prefer this forest type, it may provide some sort of a buffer to their influence. The northern and western side of Klamath falls and the wildlife sanctuary are also areas where one might expect continued human wolf interaction. The northern side in particular has rather high road density, and only moderately suitable forest, yet there was known wolf activity across a very large swathe of land. (wolf regions shown in map1, road densities in map3)

There have been recurring attacks near boundary butte, a peak between Medford and Crater Lake. The rancher had problems through 2016, and successfully implemented deterrents for two years, only for the wolves to become accustomed to them, and continue livestock attacks. A total of 11 livestock animals, and 2 guard dogs have so far been lost. The reason that this area has been experiencing a higher occurrence of livestock depredation may be explained by the raster analysis. It is noticeable when looking at map4 and map5 together, that despite suitable and high value habitat in the region, aspects such as agriculture and road density cause a pocket of low total suitability. This pocket breaks up a relatively continuous swathe of highly suitable land around Crater Lake and moving south. There is also a wildlife corridor utilized by multiple ungulate species, which passes just north of boundary butte. These together mean that wolves are likely to utilize this northern part of boundary butte for hunting, but upon moving south will enter dense human areas over a very short distance. Fragmented wolf-suitable areas, and human activity areas pose the highest risk for human-wolf interaction. (map4, map5)

As wolf populations increase over the next decade, it is rather likely that protections on them will be removed. Keeping corridors for wolf movement, and maintaining healthy grazing lands, are going to be some of the most important aspects of reducing human-wolf interraction. Studies such as this can help prepare for managing the wolf populations and preventing culling of the animals. This is important because surviving members of the pack often act more erratically, particularly younger males.

-Observation of Ecologically sensitive sites

There is still much work to be done to see if the model accurately predicts wolf suitability in addition to identifying species which are positively benefitted by their presence. To explore how this might be done, I went to one of the ecologically important zones.

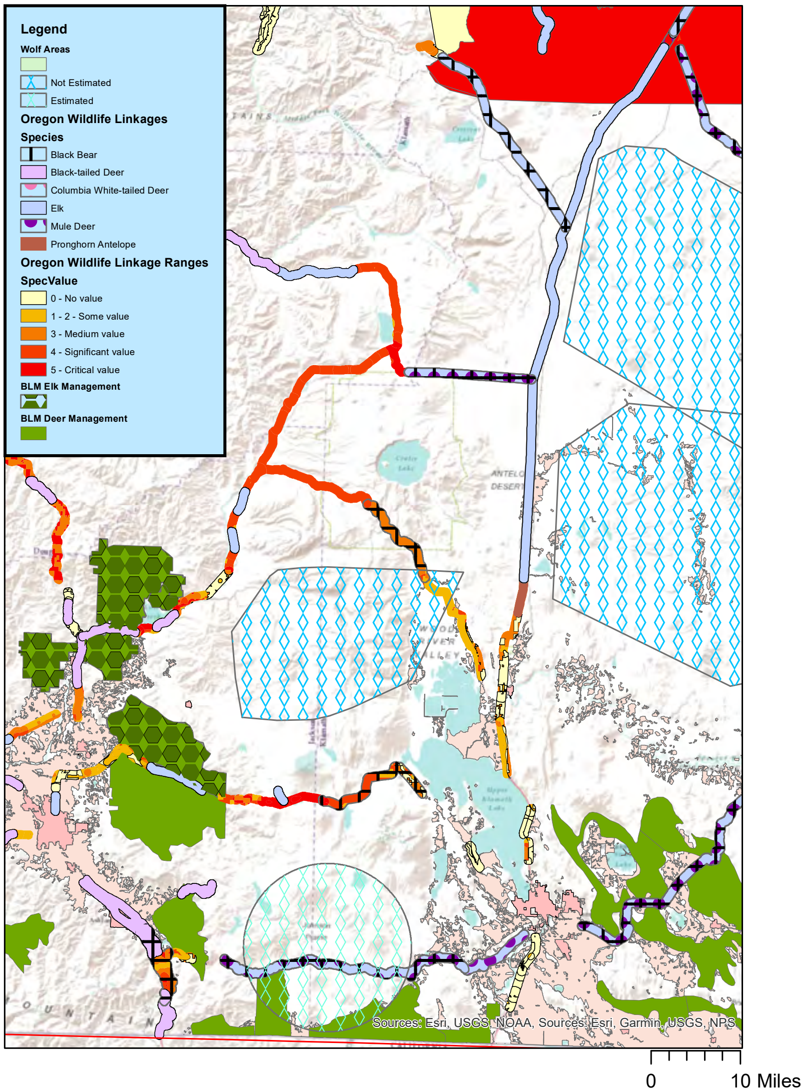
Sites with Aspen trees were noted when in the field in this area. Their growth perimeters were mapped using a GPS, as well as information about height, other vegetation, and notes on survivability along the perimeter at different points. If the models do in fact point to this area as likely to support wolves well, then these perimeters and point information will be updated to map4. If another area is determined to be likely of greater value, then similar observations will be done. Visiting the region in map6 did provide useful experience at seeing how map features such as dotted palustrine environments were indicative of browsing areas and sometimes sensitive species.

Conclusion

Wolves are returning to the area, and understanding where wolves can potentially benefit the environment and how people will react to their return is useful to management efforts and policy making. This information can be applied to wolf culling, the effects of removing them from the Endangered Species List, and how to manage forests to discourage livestock predation. Since the killing of the alpha wolf in particular can cause offspring to roam and attack livestock, in a de-listed future, hunting could be restricted in areas with more human density. Additionally, wolf restoration projects could use this type of GIS map to identify potential areas of wolf restoration. Doing a more intensive field survey would be very helpful in improving the maps functionality. Analyzing future geospatial data will also provide evidence of the long term change that is often associated with wolf presence, and so I hope to keep this research ongoing.

Appendix
-Maps
-map1

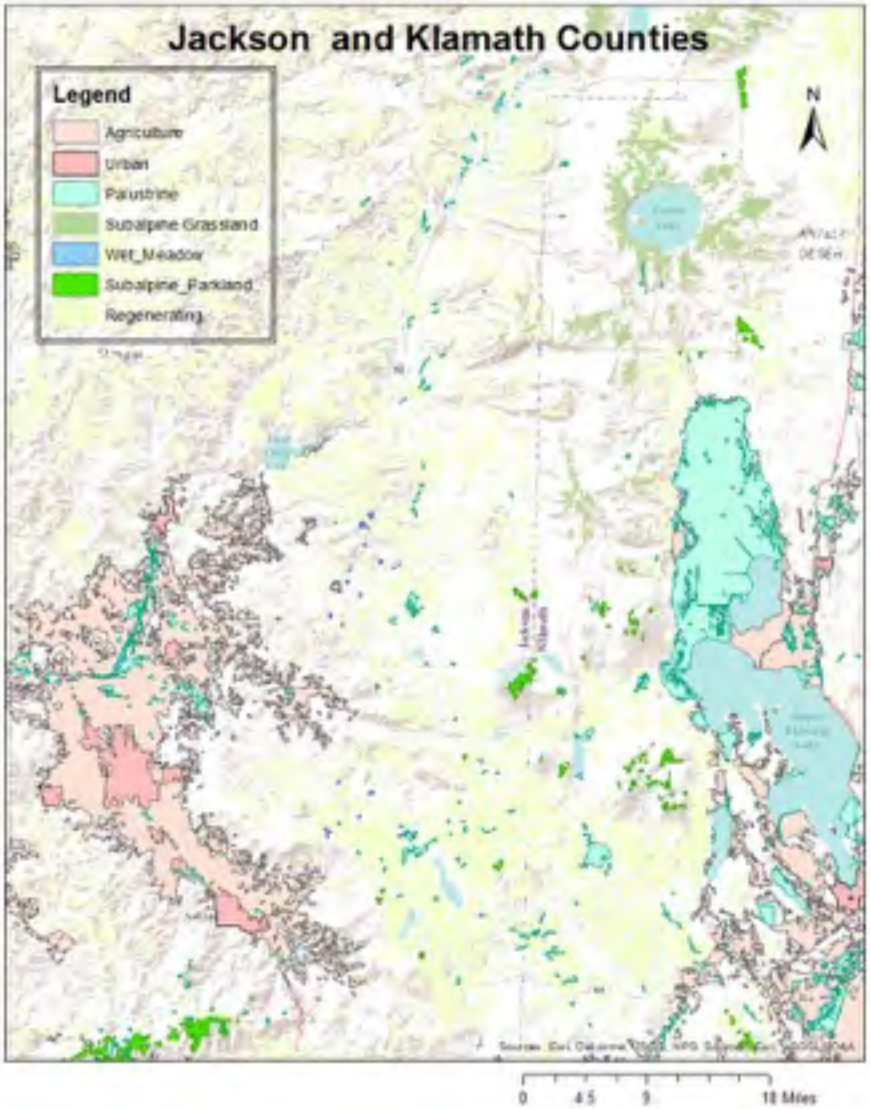
Known Wolf Regions and Mammal Migration Links



Map1 contains the raw data used to determine values in the ungulate migration layer.

Known wolf activity areas are also shown here.

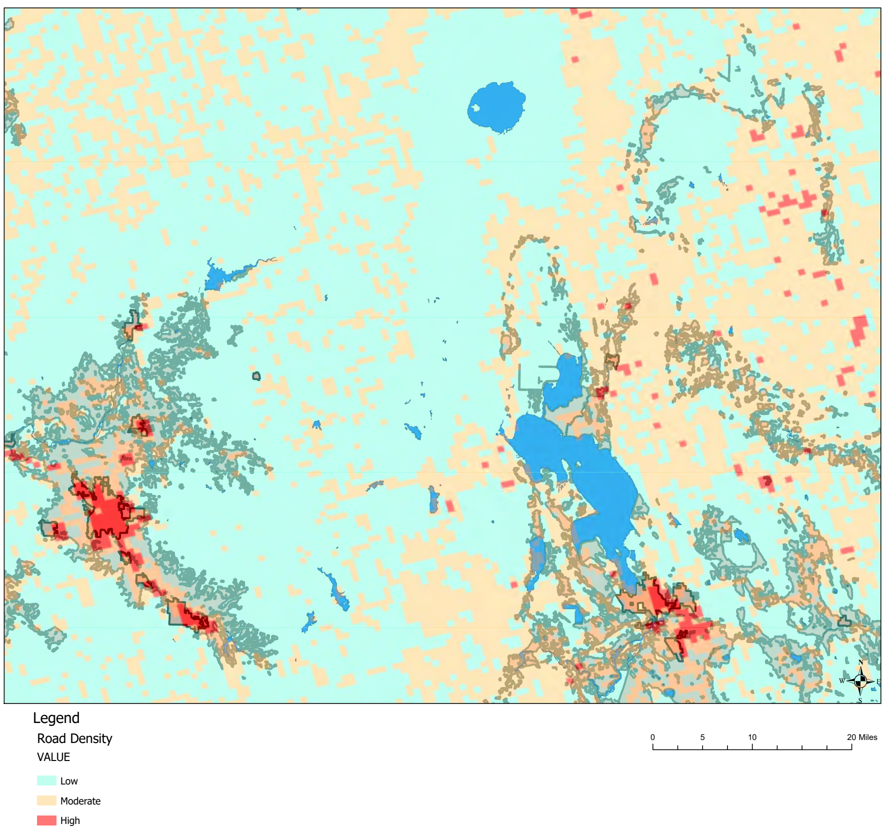
-map2: Land Cover



Map2 contains forest, agriculture, and urban cover data for predictive modeling. It is also very useful in identifying pockets of meadowland and easily over browsed areas, which provide ideal study areas.

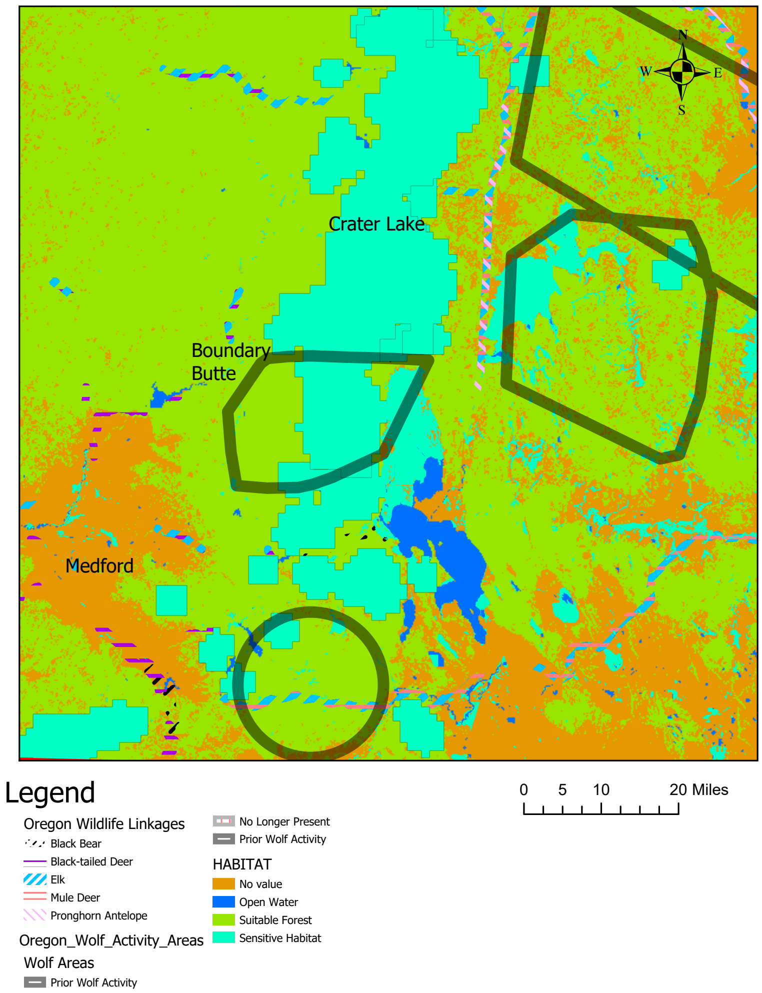
-map3

Jackson and Klamath Counties: Road Density



-map4

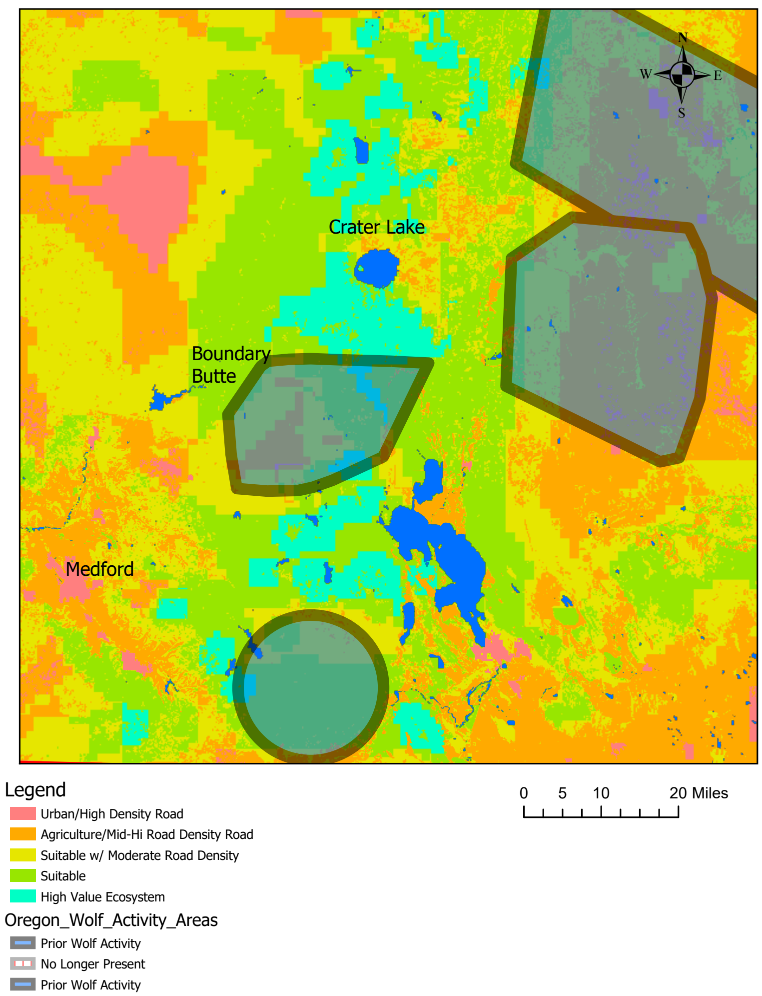
Wolf Suitability: Jackson and Klamath Counties



When paired with map5, map4 highlights how suitable forest and high value ecosystems can occur within high road densities, and how this may cause more human interaction.

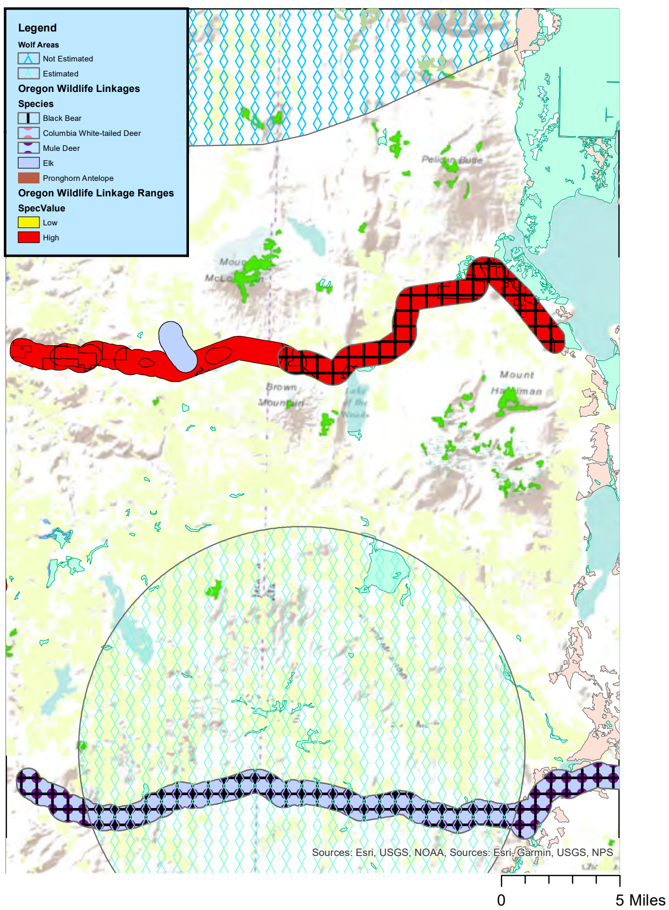
-map5

Wolf Suitability: Jackson and Klamath Counties



-map6

Selecting a Study Region



This is an area of particular interest, as it is between prior known wolf packs, and is heavily trafficked by both black bear and multiple ungulate species. It is also somewhat isolated from intense human activity. While this project does not attempt to study the real effects in this region, it does show ideal areas for doing so.

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