Strategizing Critical Habitat Restoration for Military Bases: An Exploration of Prairies on Joint Base Lewis-McChord

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A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Landscape Architecture

University of Washington

2021

Committee:

Daniel Winterbottom, Chair

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Program Authorized to Offer Degree:

Landscape Architecture

University of Washington

Abstract

Strategizing Critical Habitat Restoration for Military Bases: An Exploration of Prairies on Joint Base Lewis-McChord

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The decline of ecological habitats has led to the increased listing of endangered species (Haddad et al., 2015). U.S. military installations require complex environments to train soldiers for a variety of missions, and surrounding development has resulted in bases becoming harbors of critical habitat and endangered species (Schultz, 2016). The thesis explored the relationship between conservation and the military by examining a military base currently hosting critical habitat and listed species. I studied critical prairie habitat in the Southern Puget Sound and three at-risk prairie species (Taylor's Checkerspot Butterfly, Mazama Pocket Gopher, and Streaked Horned Lark) residing on Joint Base Lewis-McChord (JBLM). I defined habitat parameters for prairie restoration that would target all three species simultaneously using species recovery

goals. I then outlined four options for habitat restoration that could be used as starting points in determining the feasibility of future prairie restoration on JBLM.

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ACKNOWLEDGEMENTS

There are so many people in my life who helped me along the way that I am truly grateful for. I would first like to thank my parents for always being there for me and helping me when I need it, and I am forever indebted to what you have done for me. I want to thank my thesis committee, Daniel Winterbottom and Julie Johnson, for guiding me in this process and making sure I stayed on track. I also want to thank the whole Department of Landscape Architecture for being so communicative during this crazy time and ensuring we kept moving towards our academic goals. I would name all of you, but that list would be extensive…

To those of you who took time out of your day to answer a student's email about a project, I would have been lost without input from each of you. Ed Moreen, Harry Craig, and Christopher Cora, thank you for each going above and beyond to get together on a call, indulge me with information, and provide me with resources. Stu Watson, Amanda Bennett, Steven Krueger, and everyone else I reached out to and spoke with, thank you for your guidance.

I would like to thank my OCS Class in the Army National Guard. We all had our personal struggles to contend with and so much work to get done, but we were able to come together as a team and support each other. All of you were a huge help in me making it this far. "By The Numbers!"

Finally, I would like to thank my friends for supporting me in this process, and for being able to rejuvenate me when I had free time. You all motivated me to keep going whether I ever told you directly or not, and I would not have gotten this far without you all.

1. Introduction

Human Expansion, Ecological Reduction

The evolution of our early hominid ancestors into our current *Homo sapiens* form has been traced back to Africa somewhere between 200,000-300,000 years ago. It took them quite some time to leave Africa and move elsewhere, which has been dated between 70,000-100,000 years ago. The initial spread and population growth was slow as it took approximately 200,000 years for the human population to reach 1 billion. After this milestone, it only took another 200 years until the human population exploded around the globe to reach our current population of approximately 7.8 billion people (*Biodiversity*, 2021). This massive increase of population has led to the coinciding spread of land use by humans as well as increased human resource consumption, resulting in the consequential decline of habitats and wildlife populations. According to the World Wildlife Federation's (WWF) Living Planet Index, the agglomerated populations of several categories of wildlife (mammals, fish, and others) has declined by an average of approximately 60% from 1970 to 2014 (Charlton, 2018). This reveals how the acceleration of human population growth and spreading land use has negatively impacted ecosystems collectively and are likely to continue doing so without intentionally implementing mechanisms to prevent it.

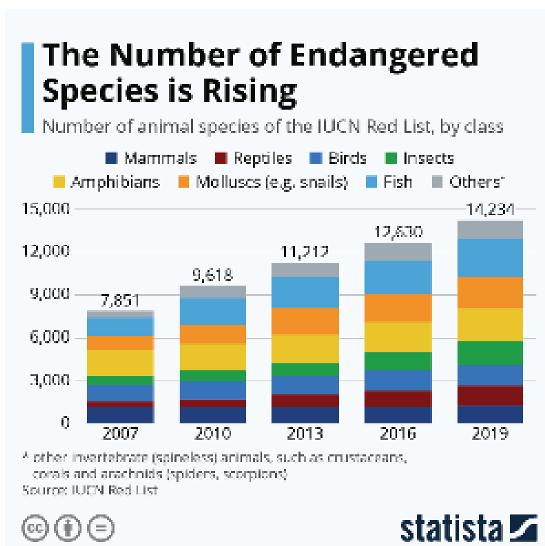


Figure 1.1. Graph shows the number of endangered species on the International Union for Conservation of Nature (IUCN) red list over time and by class. Graph taken from (Buchholz, 2020).

Stopping the degradation of natural systems is not simply to preserve the aesthetics and uniqueness of nature. Natural systems provide us with numerous benefits and are necessary for our survival. We rely on ecosystems functioning properly for our access to water, clean air, food, medicine, and a whole array of imperative life-sustaining elements. This adds significant importance to conservation efforts. According to the USDA, “conservation is the careful maintenance and upkeep of a natural resource to prevent it from disappearing” (Wray, 1976). It is not only the numerical totals of habitat and species that are important, but the complex functioning of varied interconnected systems. Natural systems have been evolving since before the introduction of humans and have become intricately balanced. Species that vanish from a system can initiate a ripple effect on a system’s ability to sustain itself, leading to disruptions in other systems. This is the primary reason the Endangered Species Act (ESA) was enacted in 1973, and its induction has been significant for conservation across ecosystems (*Endangered Species Act* | *Overview*, 2020).

Warfare Ecology

Conflicts between humans have likely been constant since our inception. The earliest reliable evidence of group violence was found in a place called Nataruk located in Kenya, where remains dating back somewhere between 9,500 and 10,500 years ago have been found. The skeletal remains found contained blunt head trauma through a cracked skull and obsidian spear tips lodged in two of the skeletons (Stetka, 2016). Technology and strategy have evolved since then, creating an entirely indistinguishable style and sophistication of warfare from our ancestors.

Wars are highly variable in scale, type, purpose, and the externalities they cause depending on what was done and who was involved. In a paper by Machlis and Hanson titled “Warfare Ecology”, they create a “taxonomy of warfare” in which they outline and try to define key elements involved in warfare along a cyclic timeline. They break warfare down into 3 stages: preparations, war, and postwar activities. They briefly describe activities that occur during the various stages and they go into detail about ecological impacts that typically occur during each stage (Machlis & Hanson, 2011). The breadth of “warfare ecology” is beyond the scope of this thesis, but it is important to note that warfare is a continuous chain of events that affect each other. This thesis is not focused on how stages of warfare positively or negatively affect ecological systems (pollution, disturbance, etc.), but more specifically explores military training in relation to the widespread degradation of ecological systems.

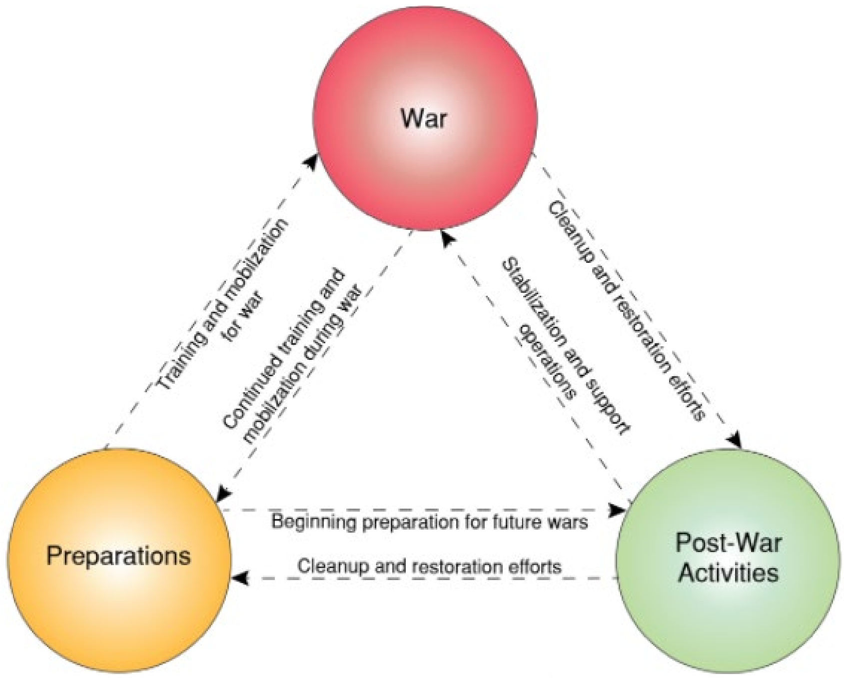


Figure 1.2. Diagram shows relationship between the three stages of warfare as described by (Machlis & Hanson, 2011)

Military Bases and Critical Habitat/Listed Species

The Department of Defense (DoD) has established many military installations across the United States, originally placing them in areas that were fairly isolated (Schultz, 2016). They manage approximately 25 million acres of land, and 420 of those are comprised of 500 or more acres of land (Dalsimer, 2016). Because of the military's influence globally and the complexities they must face, the location of domestic installations were key in initial planning. It was important to set up bases where there was adequate space to conduct realistic and high-quality training, and installations were usually constructed in isolated locations. However, the growth and spread of people and development over time has led to gradual encroachment of these once-remote military bases. At the same time, the area required for quality military training has been substantially increasing as technology has advanced and strategies have evolved (Schultz, 2016).

Encroachment has become a common issue for domestic military installations. It can hamper training activities while also affecting neighboring civilian populations. Adjacent communities may experience issues such as excessive noise from training that can be highly disruptive. This problem that affects both the military and communities generated a need to involve military bases into local and regional planning (Schultz, 2016).

Figure 1.3. Image of U.S. Marine Corps' Futenma Air Station in Okinawa Prefecture, Japan. Image taken from (*Marine Corps Air Station Futenma*, 2013)

Development does not happen on military bases without the permission of those in charge of the installation. Bases have strong boundaries with restricted access and federal penalties to those who trespass without granted access (*United States v. Apel*, 2014). Restrictions of base access are to maintain security needs. Also, base "buffers" have been created to mitigate neighboring civilian encroachment, providing the military with more space between their training activities on-base and close by communities. Both restricted access and buffer creation for military installations have safeguarded military lands from outside development and kept development to the surrounding areas (*Protecting Endangered Species on Military Lands: Successful Species Recovery*, 2004).

As noted above, increasing population and higher resource consumption have resulted in decreasing habitats and populations of various species. Because military lands have been shielded from outside development, the plant and wildlife species within them have also been protected from outside expansion (*Protecting Endangered Species on Military Lands: Successful Species Recovery*, 2004). DoD managed lands now contain the highest density of endangered and imperiled species compared to any other federally managed land, and the DoD has assumed responsibility of managing and protecting approximately 400 threatened and endangered species across their installations (Dalsimer, 2016). Twenty-four at-risk species are actually endemic to military bases (Lee Jenni et al., 2012). The DoD is responsible for approximately 1/8th of the land that the U.S. Forest Service manages, but the number of endangered species on their lands is about equal to that of the Forest Service (Benton et al., 2008). Military training areas (MTA's) including places like artillery ranges and bombing release areas have high numbers of endangered species due to their large sizes, minimal habitat fragmentation by roads and rail, and the occurrence of frequent dynamic disturbance events that maintain disturbance-reliant landscapes (Ellwanger & Reiter, 2019).

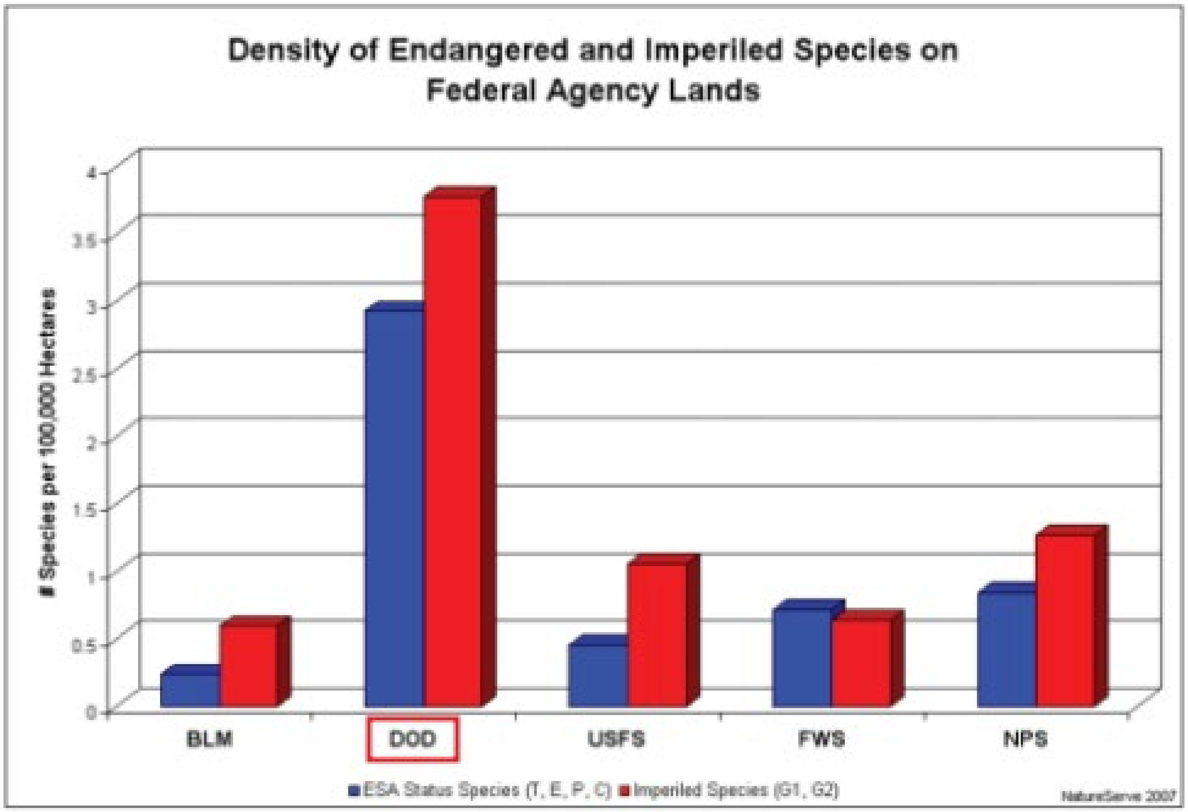


Figure 1.4. Graph shows the number of endangered or imperiled species per 100,000 hectares by federal land manager. Graph taken from (Dalsimer, 2016).

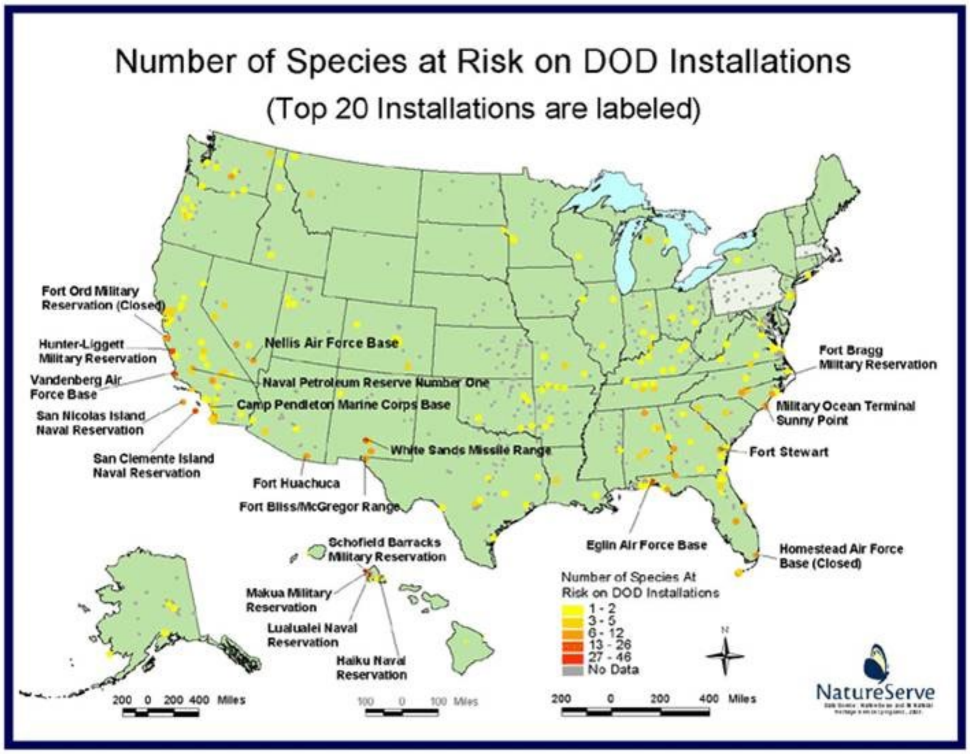


Figure 1.5. Map shows locations of U.S. military bases and the number of at-risk species per base. Map taken from (*Species at Risk on DoD Installations*, 2011)

Military and Conservation

The DoD manages approximately 26.9 million acres globally, 8.8 million of which are in the United States (Gorte et al., 2013). They consist of some of the highest quality preserved landscapes in the United States. The biodiversity on military installations serves well to increase the resiliency of their landscapes from major disturbances, helping to maintain continuity of training and preparations for missions. Variable natural landscapes also provide the military with a wide array of realistic natural landscapes to use for training purposes (Benton et al., 2008). The instruction from the DoD pertaining to these lands is as follows:

"The principal purpose of DoD lands, waters, airspace, and coastal resources is to support mission-related activities. All DoD natural resources conservation program activities shall work to guarantee DoD continued access to its land, air, and water resources for realistic military training and testing and to sustain the long-term ecological integrity of the resource base and the ecosystem services it provides.... DoD shall manage its natural resources to facilitate testing and training, mission readiness, and range sustainability in a long-term, comprehensive, coordinated, and cost-effective manner" (Gorte et al., 2013).

The DoD falls under the ESA and other laws and regulations that require them to perform tasks and stay compliant with various natural resource requirements (*Protecting Endangered Species on Military Lands: Successful Species Recovery*, 2004). One main piece of legislation in place is the Sikes Act of 1960, which requires the Secretary of Defense to "carry out a program to provide for the conservation and rehabilitation of natural resources on military installations" (NMFWA, 2004). The conservation of natural resources on military installations has evolved over time since the passing of the Sikes Act, and in 1989, a directive was issued requiring all installations to create an Integrated Natural Resources Management Plan (INRMP) which initiated a new and more comprehensive approach for these installations to manage their natural resources. INRMP's must involve coordination with federal and state authorities, which not only helps with planning and strategizing but also allows the military to tap into outside resources that those organizations can provide. The military has built relationships with many organizations over the years including the U.S. Fish and Wildlife Service, state agencies, the Forest Service, and The Nature Conservancy (Benton et al., 2008).

Barriers to Ecological Restoration on Military Bases		
Natural	Military Readiness	Requirements and Restrictions from other Entities
Specific habitat/wildlife requirements	Training necessity	City, County, State, Federal
Infrastructural impediments	Training quality	DoD's own internal requirements
Location of existing habitat	Training continuity	Tribal Agreements
Invasive species	Unexploded Ordinance	Neighboring communities

Table 1.1. Table shows a consolidated list of barriers to ecological restoration on military bases by category.

Opportunities for Ecological Restoration on Military Bases		
Protection from Encroachment	Target Species Present	Federal and State Agency Cooperation
Surrounding urban development	Critical Habitat	U.S. Fish and Wildlife (USFW)
Agriculture	Threatened and Endangered Species (TES)	Environmental Protection Agency (EPA)
Civilian human activity	Combining efforts to restore both habitat and wildlife	State Department of Fish and Wildlife

Table 1.2. Table shows a consolidated list of opportunities for ecological restoration on military bases by category.

The military's coordinated environmental efforts with other agencies have paid dividends in many cases. A pioneer effort in the evolution of military land management took place on Ft. Bragg, which focused on the declining longleaf pine (*Pinus palustris*) forests in the Southeast United States. Longleaf pine has declined by approximately 97%, leaving less than 2 million acres out of what used to be approximately 90 million acres. Ft. Bragg was established in 1918 when the forest was still widespread throughout the region, but now it holds a significant amount of the remaining pine forests within its boundaries. The red-cockaded woodpecker is a focal species of the longleaf pine ecosystem that was also originally widespread but experienced decline alongside its forest habitat. A combined effort between the leaders on Ft. Bragg and a Department of Defense Fish and Wildlife service team led to strategies being developed that promoted suitable management approaches for the longleaf pine forests, as well as relaxed training restrictions on the base. Over time, encroachment of increasing development put further pressure on the military to meet the woodpecker recovery goals, and so the DoD entered an agreement with the Nature Conservancy and the U.S. Fish and Wildlife Service with authority under the Sikes Act called the Fort Bragg Private Lands Initiative (PLI). The Nature Conservancy could now purchase land from those willing to sell it using DoD funding and their own, and the military could access that land for compatible training exercises (Benton et al., 2008). This dual-purposed agreement is one example of the DoD working with other governmental agencies to meet training needs and to implement strategies to achieve species recovery goals.

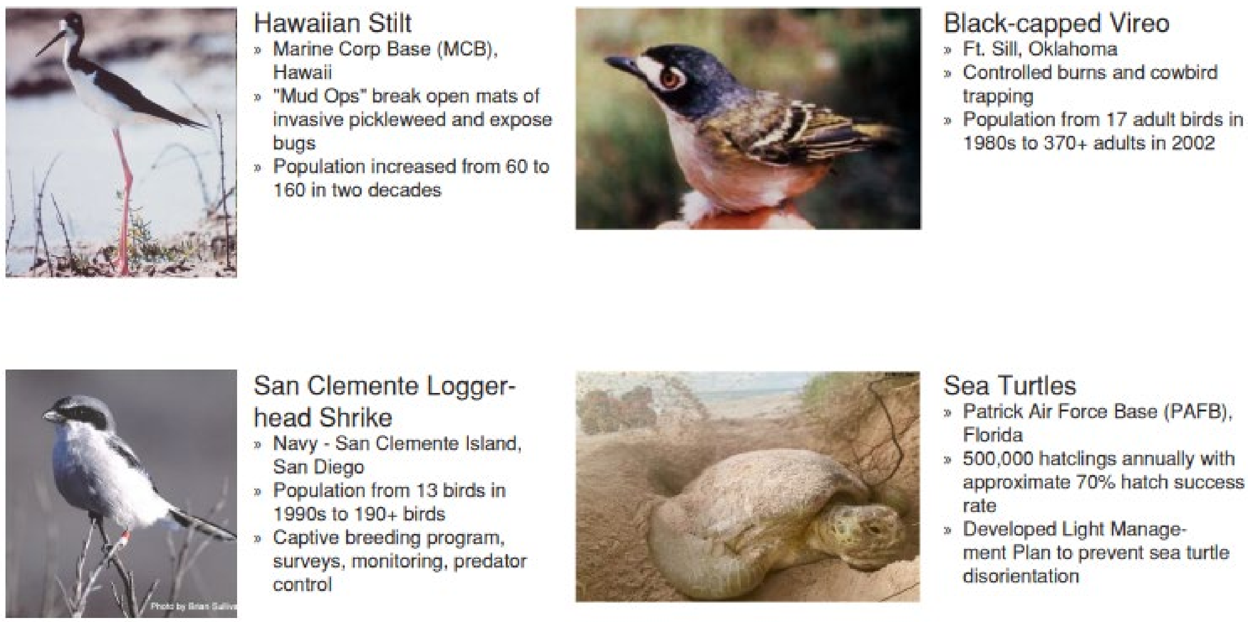


Figure 1.6. Figure shows a few examples of species the military has worked to help across the U.S. Information and images taken from (Benton et al., 2008), (*San Clemente Loggerhead Shrike*, 2019).

Thesis Goals

The dwindling number of critical habitats and coinciding year-over-year increase of endangered species is a major cause for concern, especially as the human population and ensuing resource needs are projected to continue increasing into the future. Ecosystem degradation negatively affects us directly in many ways, which creates an imperative for more planning and implementation of conservation and restoration efforts. The sheltering of habitats on military installations has resulted in the preservation of high-quality landscapes filled with remnant habitats and a high density of endangered species, and areas surrounding many bases are becoming increasingly populated which is furthering this island effect. The U.S. military is already highly active in environmental work, and their efforts combined with interagency cooperation have led to many successful precedents. However, this issue is still prevalent and is a topic worth investigating.

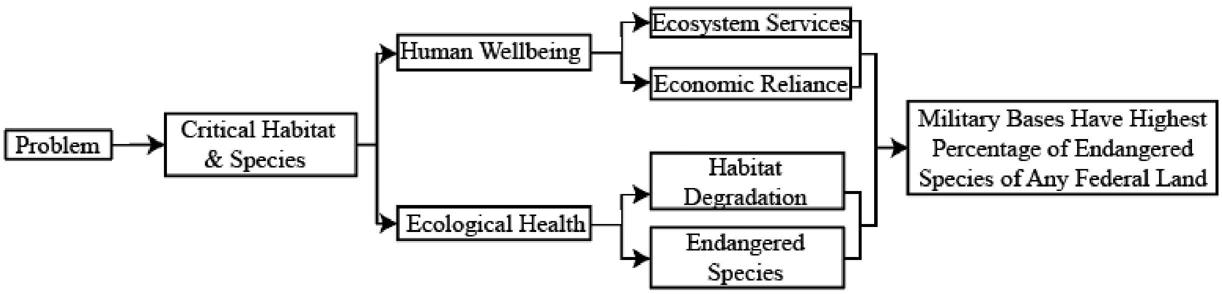


Figure 1.7. Diagram shows a basic framework for the importance of military bases in relation to habitat and species.

For this thesis, I am interested in learning what can be done about furthering conservation and restoration efforts knowing that military installations are host to a variety of declining habitats and species while also harboring their own needs. Selection of a military base containing critical habitats and at-risk species allows me to explore this relationship between ecology and the military in more depth. Habitat restoration is highly case-specific and there is not a single path forward that will achieve the recovery goals required to restore or improve all ecological systems, but there are starting points that can act as a generalized guide. The processes I used to make decisions for ecological restoration in this thesis are based on this guide (Miller & Hobbs, 2007).

1. Selection of Location & Habitat for Restoration
2. Identification of Target Species or Group of Species
3. Reference Habitat Nearby or Historical Presence of Target Habitat
4. Habitat Parameters for Target Species
5. Cost/Benefit Analysis of Ecological, Financial, and Social Costs

To narrow down the scope of this project into something manageable with my limited timeframe, I selected a local habitat type and military installation based on where I currently live. Joint Base Lewis-McChord (JBLM) hosts the largest remaining prairies in the Southern Puget Sound, making this site an ideal candidate. Research into the prairie ecosystem showed that there are three focal species under survival pressure due to degradation of regional prairies: the Taylor's Checkerspot Butterfly, Mazama Pocket Gopher, and Streaked Horned Lark. I outline each species' needs and habitat requirements to define restoration parameters, aiming to create conditions that would be suitable for all three species simultaneously to try maximizing usage of acreage and minimize repurposing of military lands.

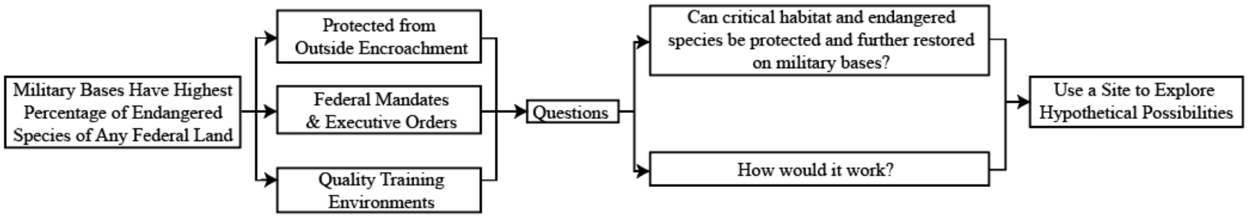


Figure 1.8. Diagram shows how military bases have their own needs despite holding a significant number of endangered species on their lands. Selection of a site was deemed effective to explore this further.

2. Joint Base Lewis-McChord (JBLM)

History

The Nisqually Tribe had historically occupied and maintained the area that JBLM occupies today, and there is a long history of transformation that occurred between initial European settlement and what JBLM has become today. In 1833, Ft. Nisqually was established by Hudson Bay Company with the intention of becoming established in the western fur trade, but soon shifted into sheep and cattle production. Fescue in the prairies was ideal for grazing, which led to gradual expansion of this business model. As more settlers moved to the area and development expanded, land parcel allocation and the spread of land use continued to increase. Slowly, parcels became more subdivided as the population kept increasing until the onset of World War 1, where eligible voters agreed to the establishment of a military reservation in the county. This 70,000 acre allocation of land was the inception of Ft. Lewis (Perdue, n.d.).

Ft. Lewis began as a small 1,100 acre Army installation when it was first created, and there were people still living on the 70,000 acre land allocation after the agreement was made (Perdue, n.d.). It was originally termed “Camp Lewis” until the first brick barracks were constructed between 1926-1927. Expansion continued and further military development was necessary to meet growing installation needs. In 1938, an 1,800-acre Army airfield named Gray Army Airfield was constructed, providing Ft. Lewis with air capabilities (JBLM PAO, 2017). Shortly after its construction it was renamed McChord Field, and in 1947 McChord Field became independent from Ft. Lewis with the inception of the U.S. Air Force. The Air Force then renamed McChord Field into McChord Air Force Base (AFB) (U.S. Army, n.d.). Growth of military size and capability on these military installations eventually led to units being deployed from these locations into war, first starting with the Korean War around 1950 and continuing intermittently through the present day (JBLM PAO, 2017). Ft. Lewis and McChord AFB maintained their function and value to the military, and eventually they became unified as Joint Base Lewis-McChord in 2010 after the evaluation and recommendation in 2005 by the Base Realignment and Closure (BRAC) Commission (Hancock et al., n.d.).

Present Day

JBLM is a 414,000-acre installation that comprises two locations. The western location is 90,000 acres in size consisting of Ft. Lewis and McChord AFB. It is situated north of Olympia, WA and south of Tacoma, WA. The eastern location is Yakima Training Center (YTC) which is approximately 324,000 acres in size and is located just north of Yakima on the east side of the Yakima River (Hancock et al., n.d.). This thesis is focused on the western location and the critical prairie habitat on that installation. For this thesis, JBLM will only reference the western location, whereas YTC will be in reference to the eastern location.

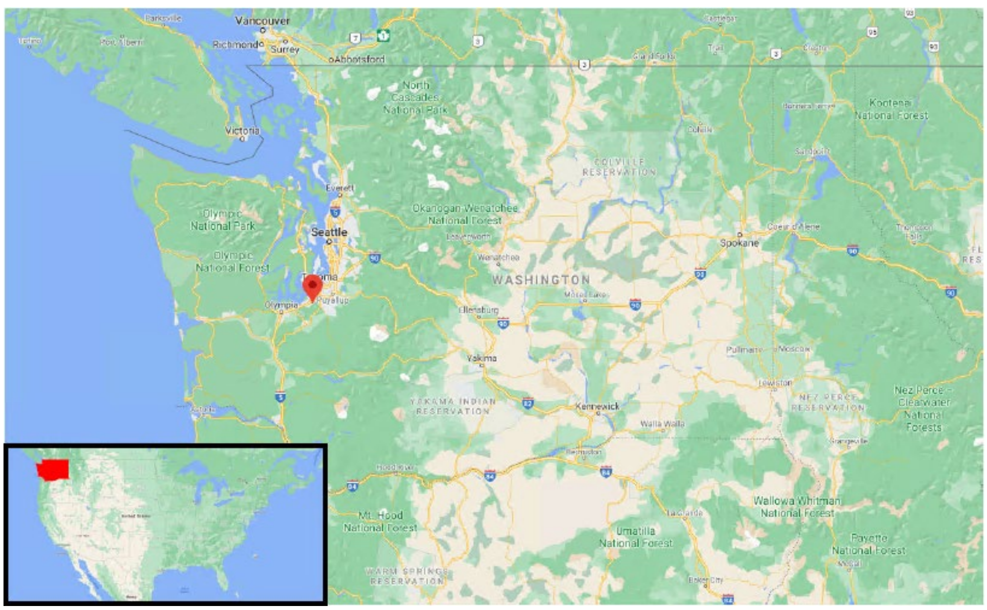


Figure 2.1. Map shows the western location of JBLM. Map taken from Google Maps.

JBLM is the largest military installation on the west coast, divided into approximately 10,000 acres of cantonment and 80,000 acres of training areas and ranges. This installation serves over 150,000 people and has a major economic impact on the State of Washington (AECOM, 2015). An economic base impact study conducted by University of Washington Tacoma’s Center for Business Analytics estimated the annual economic impact of JBLM is approximately $8.3 billion on the South Puget Sound. Bill Adamson from the South Sound Military and Community Partnership (SSMCP) stated, “The study demonstrates the critical importance of JBLM in maintaining a stable regional and state economy” (Burkhardt, 2018).

The 2005 recommendation of the BRAC Commission listed Ft. Lewis as the #1 Power Projection Platform (PPP) in the Army, and it is only one of fifteen PPPs designated by the Army. This is because of its ability to feed, house, train, and mobilize units in comparison to other installations. It also contains or has access to strategic seaports, strategic aerial ports (McChord AFB as one), a strategic railway corridor, and a strategic highway network. As the military shifts its capabilities to become more adaptable and modular to deal with "irregular warfare", JBLM is well-suited to handle a variety of evolving scenarios (Hancock et al., n.d.).

Environmental Work

JBLM's environmental focus has developed significantly over the past 100 years. They are now deemed a leader in sustainability and environmentalism in the military, and the amount of work they have accomplished and continue to do is representative of that. There are many groups that perform environmental roles on JBLM such as the Center for Lands Management (CNLM), U.S. and State Fish and Wildlife, JBLM's own Fish and Wildlife, Cascade Prairie Oak Partnership (CPOP), the Integrated Training Area Management (ITAM) team in conjunction with Range Control, the Environmental Protection Agency (EPA), and more. It is a complex web of roles and relationships that has led to JBLM becoming a premier environmental military installation.

One example of work being done on JBLM is forest management. Forest management first began on Ft. Lewis in 1960 to try and increase Douglas fir (*Pseudotsuga menziesii*) populations. Its original strategy was to promote even-aged stands of forests, but the forestry program grew over time to become what it is today (Perdue, n.d.). The mission statement of the JBLM Forestry Branch is as follows: "The mission of the Forestry Branch is to provide good stewardship of the forested training lands of Joint Base Lewis-McChord by ensuring the continued existence of a healthy forest that supports military training, sustains native plants and animals, and benefits local communities." The Forestry Branch Management Plan goes into detail about the kinds of work they do and the strategies they use to achieve their goals. One of their primary focuses is the presence of threatened and endangered species. There are two forest-dwelling species on JBLM that are listed by the IUCN, those being the Northern Spotted Owl (*Strix occidentalis caurina*) and the Western Gray Squirrel (*Scirius griseus*), and the Forestry Branch has had to navigate their decision-making to attend to those species. They also need to have some concern with listed prairie-dwelling species because of forest-grassland margins (Forestry Branch & Directorate of Public Works, 2017).

Work is also being conducted off JBLM to assist with critical habitat and listed species requirements on JBLM. Sentinel Landscapes Partnership, formed in 2013, is a collaboration between the DoD, United States Department of Agriculture (USDA), and United States Department of the Interior (DOI). Their mission statement is as follows: "The Partnership's overarching goals are to strengthen military readiness, bolster agricultural and forestry productivity, conserve natural resources, and increase access to recreation." They work with private landowners around military installations, essentially aiming to implement conservation projects on these lands and providing federal assistance to these landowners to do so. Strategies are catered to each installation involved with the Sentinel Landscapes Partnership. For JBLM, they have been working towards the recovery of endangered species, implementing prairie management strategies, and have conducted restoration and management efforts off-base. Approximately 570 acres of prairie habitat have been restored or maintained through work conducted by the WA Department of Fish and Wildlife and the Partners for Fish and Wildlife Program, and a full-time wildlife biologist has been hired to continue the work being done for species recovery for prairies. The Sentinel Landscapes Partnership is currently protecting almost 20,000 acres and has under 80,000 acres enrolled in their program (Sentinel Landscapes, 2020).

3. Southern Puget Sound Prairies

Prairie Background

Prairies and grasslands were prolific in the Southern Puget Sound area prior to European settlement. They grew on the glacial outwash soil found throughout the region and require full sun and frequent disturbance to be maintained. Native grasslands in the region have significantly declined over the past several hundred years, and documented historical amounts vary. One estimate states that 180,000 acres may have been present in the region prior to settler changes to the landscape through development and agricultural expansion. Along with loss of prairie habitat, remaining areas have become fragmented and resulted in isolated populations, further reducing populations through extirpation and inbreeding. It is estimated that approximately 95% of original prairie habitat has been converted to other uses or been overgrown by woody vegetation due to the lack of fires. The remaining Southern Puget Sound native grassland community type is primarily made up of the Idaho Fescue-White-top Aster Community which is generally dominated by Idaho fescue (*Festuca idahoensis*) somewhere between 30-70% of the total community (Potter, 2016).

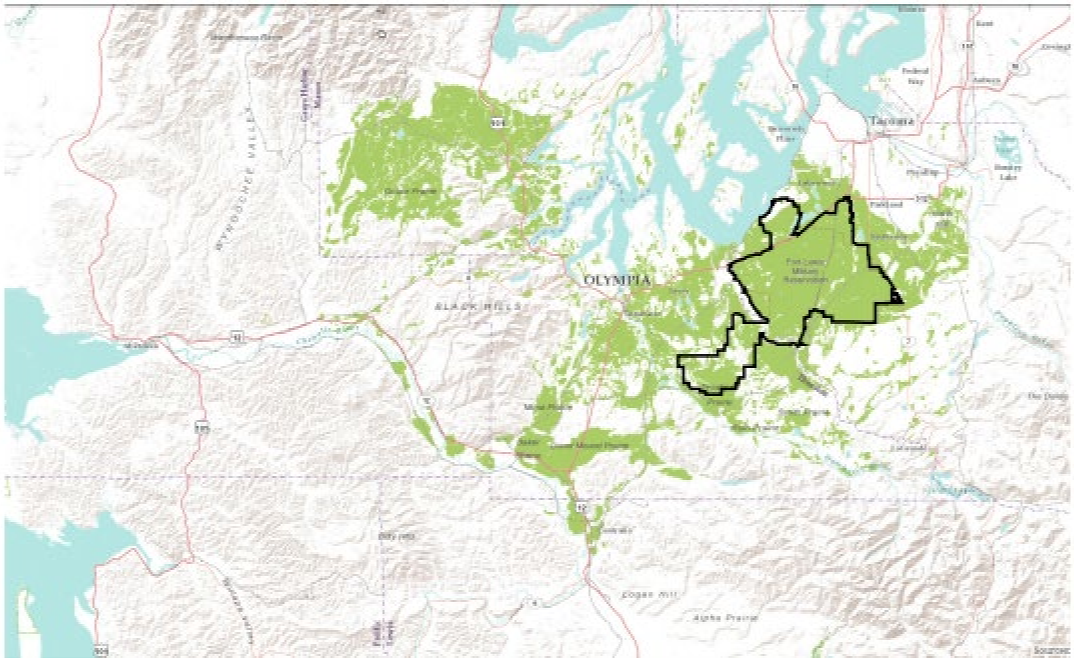


Figure 3.1. Map shows the historical prairie extent in the Southern Puget Sound. The black outline is the present-day boundary of JBLM. Base map taken from (U.S. Fish and Wildlife, n.d.)

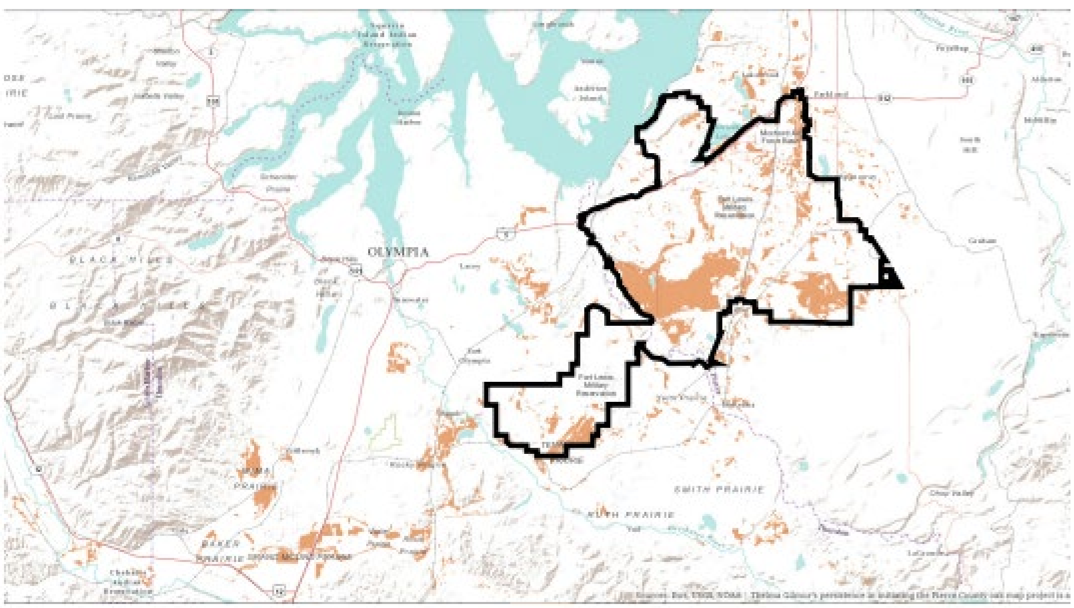


Figure 3.2. Map shows the current prairie extent in the Southern Puget Sound. The black outline is the present-day boundary of JBLM. Base map taken from (U.S. Fish and Wildlife, n.d.)

Records from Hudson's Bay Company during the first settlement of Europeans in the Puget Sound indicate that prairie fires were a yearly occurrence. The Nisqually Tribe relied heavily on the prairie ecosystem for food, and this supports the claim that fires were intentionally set to maintain the prairie ecosystem. Bracken fern rhizomes and camas bulbs were commonly used, and these species were prolific in historical prairies. Fire also does not destroy underground bulbs but only eliminates the aboveground growth, and furthermore it may have acted as a trigger to rhizomatous growth to increase the spread of species like bracken fern. Fire is also beneficial for forbs by increasing the likelihood that seeds will reach the soil and germinate by removing dead vegetation (Perdue, n.d.).

The primary invasive species that affects the proliferation of Puget Lowland grasslands is Scotch broom (*Cytisus scoparius*). Scotch broom is a non-native shrub that thrives in open sun and undergoes rapid growth, commonly forming monocultures as high as 10 feet tall. Seeds remain viable in the soil for decades after storage, and plants can survive mechanical treatments if the stem and root systems remain intact. The Forestry Branch on JBLM has the long-term goal of exhausting the seed bank of Scotch broom, and implements mechanical, chemical, and fire treatments to continually fight against mature and newly germinated specimens. This species directly impacts training on JBLM by preventing movement of troops and vehicles, limiting visibility, and increasing the danger of fire by significantly increasing the fuel load. It also impacts grasslands by outcompeting grassland species, creating shade for shade-intolerant grassland species, and altering the soil chemistry. There are several other invasive species that are present on JBLM that are of concern, as well as the possibility of other noxious weeds that are under watch for potential future establishment onsite, but Scotch broom poses the biggest threat to the prairie ecosystem (Forestry Branch & Directorate of Public Works, 2017).

Taylor’s Checkerspot Butterfly (*Euphydryas editha taylori*)

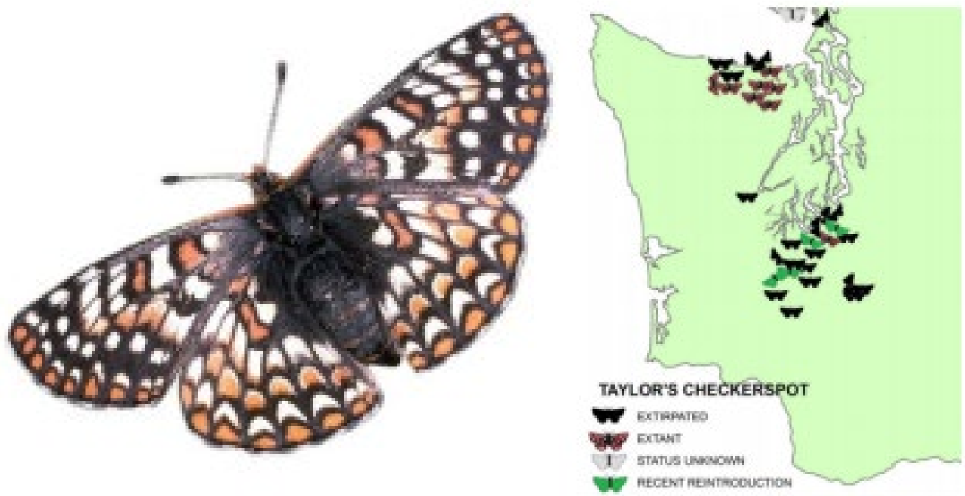


Figure 3.3. Image is a photograph of the Taylor’s Checkerspot Butterfly from (Johnson, 2010). Map designates extirpated, extant, status unknown, and recent reintroduction locations of this species taken from (Potter, 2016).

The Taylor’s Checkerspot obtained its Endangered status in WA state in 2006 and became federally listed as Endangered in 2013. It is endemic to the Pacific Northwest and used to be found as far north as Vancouver Island in British Columbia and as far south as the Willamette Valley in Oregon. Documented distribution included 45 locations in Washington State and 80 total locations in western Washington, Oregon, and British Columbia. It now resides in only 11 locations with 8 being in Washington State, 1 in British Columbia, and 2 in Oregon. In Washington, one of the sites is located on JBLM while the remaining seven are in Eastern Clallam County. In 2006, the Washington Fish and Wildlife Commission listed this species as endangered, and it was eventually federally listed by the U.S. Fish and Wildlife Service in 2013 (Potter, 2016). The Taylor's Checkerspot is a medium-sized butterfly with a wingspan of approximately 2.25 inches. The wings are a mixture of orange/red, cream, and black and it is the smallest subspecies of Edith checkerspot butterflies. This species is assumed to be sedentary, meaning it is unlikely it moves long-distances during its year-long life cycle and thus is observed in the same places. It has also been found to be clustered in distribution within the habitat they occupy (U.S. Fish and Wildlife Service, n.d.-c).

The Taylor’s Checkerspot Butterfly produces one brood per year, and adults emerge in the spring. This is when males begin to become territorial and search for mates, while females begin to lay eggs on host plants. Flight lasts from between 10-14 days, and eggs hatch within around 9 days of laying. Larvae emerge and typically form five instars (larval development stages) where they are shedding their skin and creating new skin several times for growth until they enter diapause and go dormant sometime between June through early August depending on local conditions. They burrow in various places like underneath rocks, logs, or within ground-nesting bee tunnels before entering diapause as their host plants are no longer suitable for their dormancy period. Larvae awaken post-diapause during winter to begin feeding, and during this process they may only move up to ten meters a day while feeding and searching for pupation sites. During movement they are protected by vegetative concealment and chemical production from their host food plants (Kronland & Martin, 2015; U.S. Fish and Wildlife Service, n.d.-c)

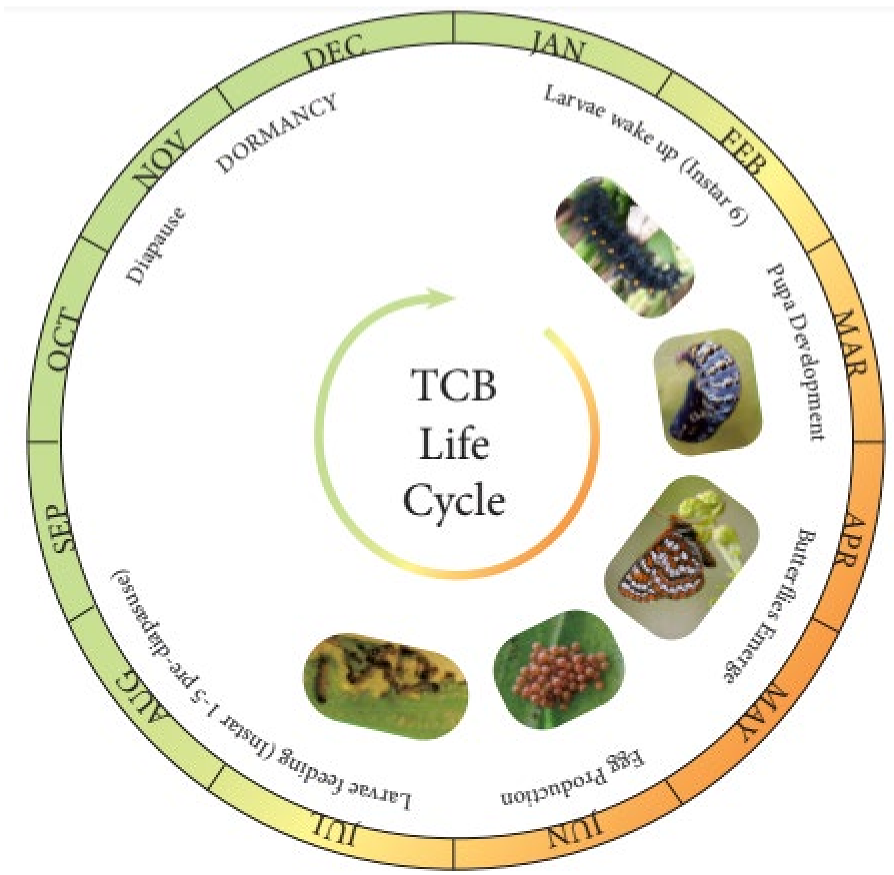


Figure 3.4. Diagram shows the life cycle of the Taylor's Checkerspot Butterfly (labeled TCB in this diagram).

Habitat for the Taylor's Checkerspot is variable as they have been found to inhabit short grasslands/prairies, meadows, coastal bluffs, dunes, montane meadows, forest clearings, forest road edges and forest balds. The lone cluster of Taylor's Checkerspots in the Southern Puget Sound is found within a prairie. The two main factors for continual reproduction, feeding, and the re-introduction of this species are the presence of host plants and nectar sources. Tied to its loss is the decline of lowland grasslands and native forbs through increasing development and the surge of non-native forbs and shrubs. They have specific dietary needs during both their larval and adult stages and require specific host plants for egg laying and dormancy. Observed prairie species for nectar consumption include common camas (*Camassia quamash*), Puget balsamroot (*Balsamorhiza deltoidea*), and nineleaf biscuitroot (*Lomatium triternatum*) as well as sea blush (*Plectritis congesta*) found in upland forest balds. Plants used for egg-laying include English Plantain (*Plantago lanceolata*) typically found on forest edges and roadsides, and harsh paintbrush (*Castilleja hispida*). Food sources for larvae are broader and include multiple plant families. Some examples are the Broomrape (*Orobanchaceae*) and Speedwell (*Veronica* spp.) families, and other plants include sea blush and blue-eyed Mary (*Collinsia grandiflora, parviflora*) (D. Stinson, 2005).

Mazama Pocket Gopher (*Thomomys mazama*)


Figure 3.5. Image is a photograph of the Mazama Pocket Gopher from (Washington Department of Fish and Wildlife, 2013). Map designates current known sites of this species taken from (U.S. Fish and Wildlife Service, n.d.-a).

Endemic to the western United States, the Mazama pocket gopher obtained its Threatened status in WA State in 2006 and was federally listed as Threatened in 2014. It is located only in western Washington, western Oregon, and northern California. This species received a federal candidate status in 2001 and was later listed as “threatened” by WA state in 2006. Four subspecies of the Mazama pocket gopher were proposed to be additionally listed in 2012 (D. W. Stinson, 2020).

The Mazama pocket gopher is a member of the Geomyidae, or New World subterranean rodents. They are 6-9 inches in length, and they have fur-lined external pockets on both sides of their mouth, hence the naming choice of pocket gopher. Mazama refers to Mount Mazama, which was a volcano that exploded approximately 6,000 years ago to create Crater Lake. Fur color varies among different subspecies, but they are usually some shades of brown. Most of their life is spent living underground except for when they need to gather food, which they store into their pocketed cheeks and then move back underground. They then move the food into caches within their tunnels where food is accumulated and stored for later periods. Their bodily structure is tubular, making them well-suited for moving through underground tunnels. Their claws are long and they can move dirt efficiently, and they also use their claws and their teeth to get at the root systems of plants (D. W. Stinson, 2020).

Mazama pocket gophers live somewhere between 1-2 years, and they reach full mating maturation at 1 year. Females produce litters only once per year and are only pregnant for less than 3 weeks before giving birth to an average of five pups. This species prefers well-drained, easily crumbled soil, resembling glacial outwash soils deposited in the Puget Sound. They prefer burrowing in their underground system of burrows, and do not like high-density clay soils due to their moisture levels and tightly bound textures. They are generally solitary and will reside in the same place over time, unless soil conditions change and they need to move (D. W. Stinson, 2020).

Loss of prairie-like habitat and the fragmentation of prairies are the main concerns surrounding the Mazama pocket gopher. Isolated populations are vulnerable to genetic problems and natural events that could lead to their extirpation from an area, and it is unlikely that nearby populations will repopulate an empty area due to their sedentary nature and the obstacles that sit between them and other prairie habitat such as roads and unsuitable ecological types. They also have to deal with predators while migrating, making chances low that migration will occur successfully on their own (D. W. Stinson, 2020).

Streaked Horned Lark (*Eremophila alpestris strigata*)

Figure 3.6. Image is a photograph of the Streaked Horned Lark from (Moning, 2015). Map designates current known nesting sites of this species taken from (U.S. Fish and Wildlife Service, n.d.-b).

The streaked horned lark obtained its Endangered status in WA state in 2006 and became federally listed as Endangered in 2013. It is a ground-dwelling passerine endemic to the Pacific Northwest. It used to extend as far north as British Columbia and as far south as the Willamette Valley in Oregon, but much of its total population has been extirpated over time. It can now be categorized into three regional groupings, those being the Puget lowlands, Washington and Oregon Coast, and the Willamette Valley (Oregon Fish and Wildlife Service, n.d.). It is the only native lark in North America among 76 localized species, of which there are 24 horned lark subspecies differentiated by size and color. According to surveys of singing males in 2015, it is estimated that there are 147 pairs across the 17 known breeding locations in WA state. Transect data showed that the population appears stable at known nesting sites, but that males may be starting to outnumber females for a few potential reasons. Predation, human-related disturbance, and inbreeding due to high site fidelity are all areas of concern when looking at the streaked horned lark (D. W. Stinson, 2016).

The streaked horned lark has a dark brown back and yellow on the underparts. It is slightly distinguishable from other lark species based on minor color differentiation. Male streaked horned larks are somewhat larger than females in body size and wingspan, and they are also slightly different in plumage color. This species is distinct from the lark species in its breeding range as it resides in the Puget lowlands and the coast, whereas others are more suited to alpine environments. This species prefers wide-open spaces without trees and minimal shrub vegetation. They are a ground-nesting species and have adapted to reside in a variety of habitats including grasslands and prairies, coastal dunes, wetland mudflats, grassland edges, grazed pastures, and other open, minimally vegetated types of terrain. Wintering habitat is generally the same as nesting habitat (Oregon Fish and Wildlife Service, 2020). When establishing territories, males typically avoid sites that are shrub-dominant, sod-like in grass structure, and non-native perennial forbs. Females choose nest sites with a higher vegetation density and higher amounts of perennial forbs. Much of the streaked horned lark habitat has been lost to human development and lack of frequent fires.

The migration pattern for streaked horned larks in the Puget lowlands is generally to move south into Oregon for winter and to move back to the Puget lowlands for breeding and nesting. Winter and breeding habitat are alike, both being mostly empty of shrubs and trees made up of mostly bare ground. During both seasons, streaked horned larks are primarily granivorous, except for nestlings who feed exclusively on insects (Oregon Fish and Wildlife Service, n.d.).

4. Restoration Parameters for Multiple Target Species

Species Basic Needs

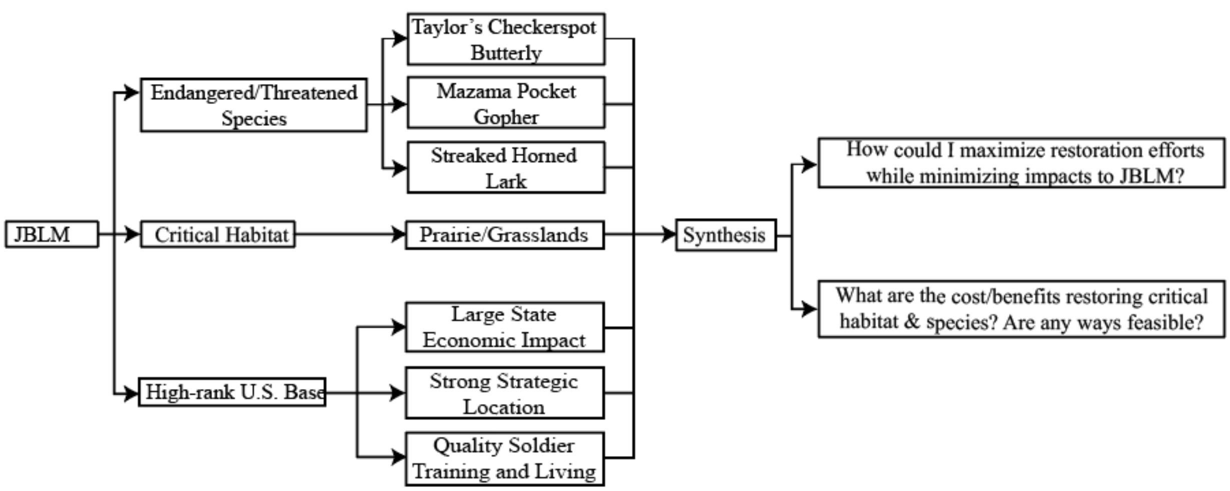
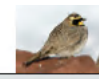


Figure 4.1. Diagram shows how JBLM has ecological needs while also being a quality military base. Putting these together led to questions about strategies to address both simultaneously on JBLM.

Adequate habitat restoration to meet each of the discussed species recovery goals is likely both space and cost consumptive (Miller & Hobbs, 2007). Training on military installations also requires significant space for operation. This led me to approach the restoration of critical prairie habitat and each of these species by trying to develop an "ideal" prairie habitat that contains all necessary elements that each species requires with the goal of maximizing land use and minimizing costs. Using the information I gathered across all three of my target prairie species, I cross-examined their needs and habitat requirements to create refined prairie restoration parameters.





Prairie Item	Taylor's Checkerspotted Butterfly	Mazama Pocket Gopher	Streaked Horned Lark
Food	Highly Selective	Not Selective	Somewhat Selective
Habitat	Highly Selective	Somewhat Selective	Highly Selective
Soil	Not Selective	Highly Selective	Somewhat Selective
Edge Presence	Not Selective	Somewhat Selective	Highly Selective

Table 4.1. Table shows categorized species needs and associated ratings for each target species.

I first took the information that I gathered and created simplified categories based on major factors for each species. I then incorporated a rating system for each category of "Highly Selective", "Somewhat Selective", and "Not Selective" that apply to that species based on what they require for their desired habitats.

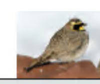
1. Food: The Taylor's Checkerspot Butterfly requires very specific plant species for food consumption at various life stages, making this a crucial factor in its inhabitable prairie composition. The Mazama Pocket Gopher consumes a wide variety of foods based on what is currently available to it in the area and does not require a specific palette. The Streaked Horned Lark requires a mixture of seed dispersing grasses for granivorous adults and a selection of insects for their young but is not documented as being particular on which species it prefers.
2. Habitat: The Taylor's Checkerspot Butterfly does inhabit a wide variety of grassland types, but the plants that it requires for egg-laying and larval dormancy are highly particular. The Mazama Pocket Gopher is primarily reliant on their preferred soil composition (glacial outwash or similar) being present. It is flexible with other habitat factors. The Streaked Horned Lark requires that the grassland habitat they inhabit is wide-open and free of edges. This means that small patches surrounded by forest are unlikely to attract it, even if all their other conditions are met.
3. Soil: The Taylor's Checkerspot Butterfly does not utilize the soil for its lifecycle, and it is only reliant on the plants present. The Mazama Pocket Gopher requires that the soil be

gravelly, loose, and well-draining. It will move away from soil types that have increased water retention or finer-grained soil particles and is reluctant of flooding. The Streaked Horned Lark nests in bare patches within grasslands, but I did not find if it was highly particular about the exact composition of the exposed soil it nests in.

4. Edge Presence: The Taylor's Checkerspot Butterfly has documented nests near forest/prairie edges on JBLM, which shows it is not concerned with edge presence. However, it is very unlikely to cross over forest edges in search of new habitat. The Mazama Pocket Gopher is also unlikely to cross over habitat edges, unless forced to do so with increased water retention or flooding of their current inhabited territory. The Streaked Horned Lark avoids edges entirely and requires wide-open landscapes.

Once these basics were established, I gathered more specific information that would further define habitat restoration for each species and reveal any overlapping or distinct challenges with restoration. My aim was to understand how my target species move within their habitats, how large their habitats need to be, the seasonality of species vulnerability, any specific goals outlined by the Washington Department of Fish and Wildlife for these species' recovery, and the threats that each of these species face.





Prairie Requirement	Taylor's Checkerspotted Butterfly	Mazama Pocket Gopher	Streaked Horned Lark
Dispersal Distance	< .56 acres	< .07 acres	4-20 acres
Patch Size	> 50 acres	> 10 acre small patches > 250 acre cores	> 300 acres (can include non-prai-rie as long as it is open)
Seasonal Restriction	March-June	March-June	February-August
Goal (Washington Department of Fish and Wildlife)	15-20 habitat patches 250 adults seen in a single-day survey over 5 years within a >/= 50 acre patch	Multiple connected cores and small patches supporting >/= 1000 gophers for 20 years	Increase egg hatching rates Reduce human impacts to nesting sites
Threats	Habitat loss and fragmentation Habitat succession Invasive species	Lack of habitat corridors Habitat quality Food availability Weather extremes	Habitat loss and fragmentation Human activities Inbreeding (lack of connectivity) Low fecundity

Table 4.2. Table shows specific categories for restoration of each target species.

1. Dispersal Distance: Each of these species has a low distance of dispersal. The Streaked Horned Lark's dispersal distance is only higher than the others because younglings find new nest sites, but adults exhibit high site fidelity once nest sites and territories are established (Duggan et al., 2015).

2. Patch Size: Habitat patch sizes vary between each species. The Taylor's Checkerspot Butterfly requires 50 or more acres to sufficiently stabilize populations within a single habitat patch. Mazama Pocket Gophers require 10 acres or more for small patches that they can use temporarily, but they require large 250-acre cores (large patches) for a stable habitat. Streaked Horned Larks require 300 acres of wide-open land, but not all of this must be restored grassland. Airports have been successful habitats for this species because they typically have grasslands surrounding them and they are required to be very open to improve aircraft visibility (Duggan et al., 2015). 250 acres appears to be the minimum amount of prairie required for habitat restoration for all three species as long as adjacent land is wide open and adds up to 300 total acres.
3. Seasonal Restriction: Each of these species undergoes important life events around the same time, making their overarching time span of vulnerability February to August.
4. Goal (WA Dept. of Fish and Wildlife): The Taylor's Checkerspot Butterfly and the Mazama Pocket Gopher have more explicit goals outlined, each aiming to have more habitat patches, sufficient sizes for those patches, and to hit population goals. The Streaked Horned Lark has a vague goal, which is reliant upon biologist monitoring and nest and egg identification and tracking. All goals aim for population increases.
5. Threats: Each species has threats that pertain to them, but they mostly overlap with one another. Habitat loss, fragmentation, lack of connectivity, and quality are the four primary qualities that the design aspect of restoration needs to address. Remnant or restored habitat patches must also have restricted access to some extent, preferably using the seasonality of the species as shown above.

Species Habitat Patch Design

Once I outlined the basic needs each species required, I worked to develop a habitat patch design that would target the needs and behavior of each species. I parameterized the size, shape, and edge type for what a habitat patch needs to look like, and then inserted more specific characteristics that each species require that can overlap with each other in a single design.

1. Size: The size of a habitat patch will determine both the amounts of interior habitat and edge habitat present, otherwise called edge to interior ratio (E:I ratio). The larger that a habitat patch is, the more interior habitat it will contain and the less edge habitat, meaning it has a low E:I ratio. The smaller a habitat patch is, the more edge habitat it will contain and the less interior habitat, meaning it has a high E:I ratio (National Resources Conservation Service, 1999). Edge habitat separates multiple distinct types of habitat from each other, and can be a transitory habitat of its own (Beck, 2013). For my target prairie species, they are reliant on interior prairie habitat, and far less likely to use

transitory habitat separating grasslands and forests or wetlands. This means larger habitat patches are more suitable for my target species than scattered smaller patches.

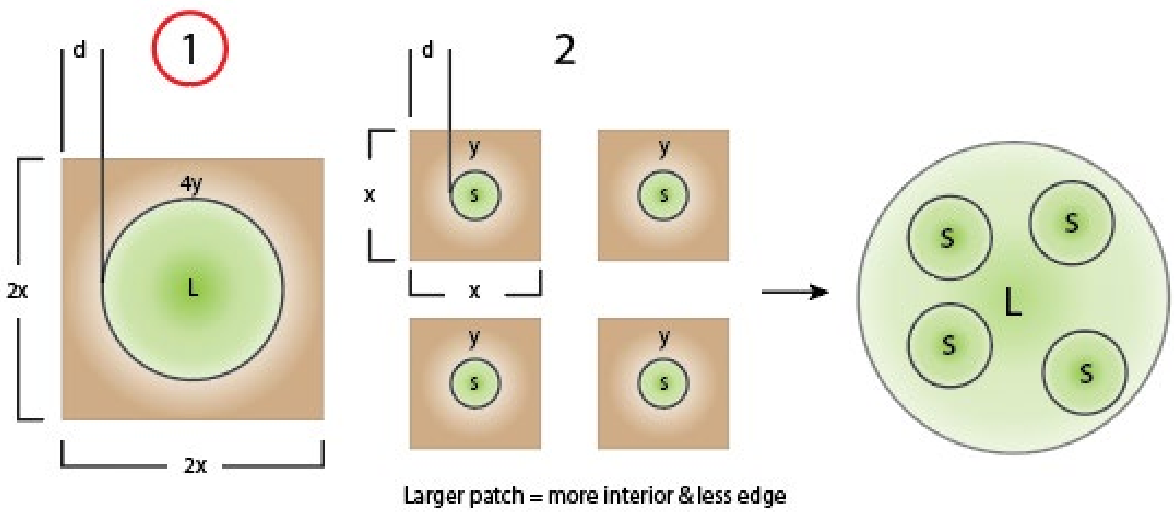


Figure 4.2. Patches 1 and 2 both take up the same amount of total area, but the interior habitat of Patch 1 is much greater than Patch 2, and the edge habitat of Patch 2 is much greater than Patch 1. Patch 1 was selected as preferable. Images derived and reworked from (Dramstad et al., 1996).

2. Shape: The shape of a patch can determine some of the ecological processes that occur within a habitat patch. Compact patches with smoothed edges will have a lower E:I ratio than convoluted patches, but misshapen convoluted patches will have higher resilience to different disturbance events. A convoluted shape could also promote interaction with other patches compared to an isolated circular patch (Beck, 2013). For my target species, both a low E:I ratio and high connectivity are preferred in recovery efforts to increase population sizes and promote interbreeding among separated populations (Duggan et al., 2015). This means that the shapes of my patches need to maintain a suitable size of core, while also stretching outward to connect to other remnant or newly restored patches if possible.

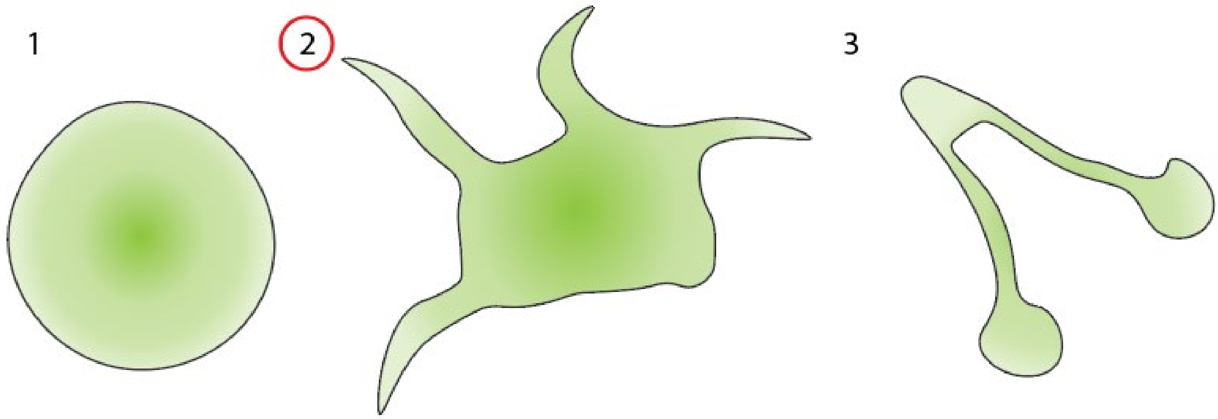


Figure 4.3. Patch 1 is a compact patch with smooth edges. Patch 2 is a partially compact patch with some convolution, including connective strands. Patch 3 is a convoluted patch with weak cores and high connectivity. Patch 2 was selected as preferable. Images derived and reworked from (Dramstad et al., 1996).

3. Edge: Edges of patches result in different ecological outcomes depending on how they are formed. Microclimates are formed by how shade, sun, moisture, and other elements all interact in their placement, and this can create a variable habitat along the edge that supports a higher diversity of species, including species that are primarily suited for edge conditions. Hard edges act as a barrier and promote movement of species in either habitat along the edge rather than across it. Convoluted edges encourage more movement of species across edges as the diversity of plants and animals increases (Beck, 2013). For my target species, I am not concerned with increased diversity of species and habitats but am solely focused on increasing the target prairie internal habitat. Hard edges can also be used to funnel species along an edge to ideally move towards another patch with a genetically varied population, potentially increasing genetic diversity and reducing inbreeding (Duggan et al., 2015).

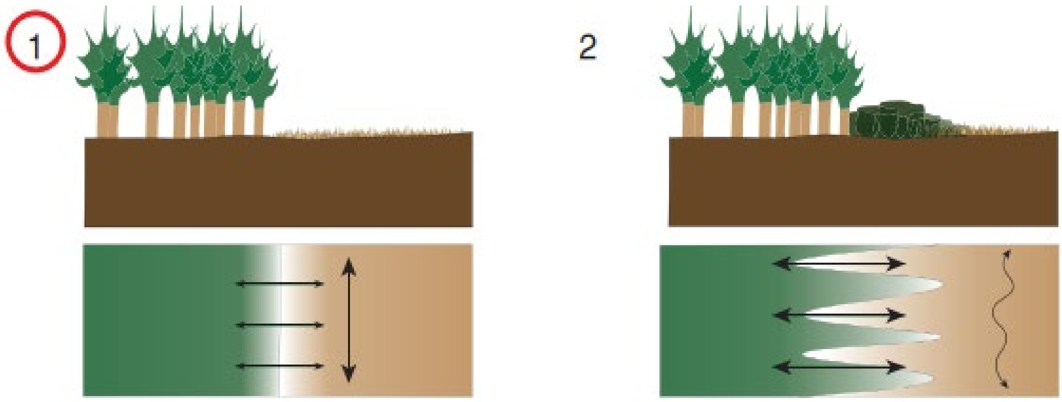


Figure 4.4. Edge 1 represents a hard edge, showing minimal transitory species in the edge habitat and strong movement along the edge. Edge 2 represents a convoluted edge with a higher propensity for shrub and other edge species. Edge 1 was selected as preferable. Images derived and reworked from (Dramstad et al., 1996).

Idealized Patch Design

I used all the information gathered above and used them as restoration parameters in designing an "ideal" habitat patch that could hypothetically host all 3 species simultaneously. There was no evidence showing that these species require a certain distance from each other, but that they only require their own resources to be present on a site.

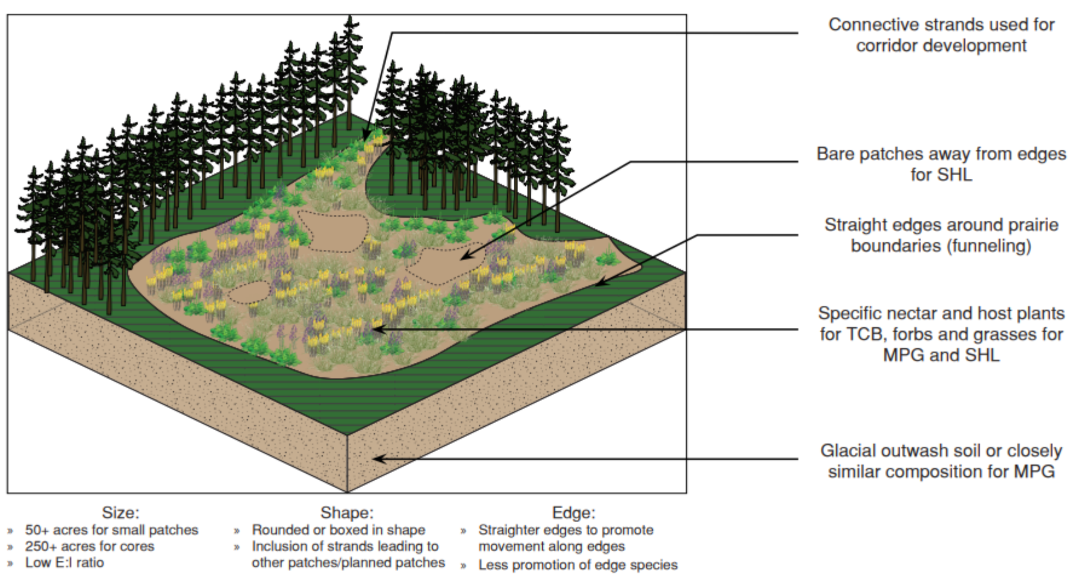


Figure 4.5. Diagram shows specific landscape elements required for an all-encompassing habitat patch for the three target species.

This habitat patch includes the basic elements that were ranked for each species, as well as the size and shape that it should be to be most effective to meet the goals of restoration. The patch must include species that the Taylor's Checkerspot Butterfly needs for its life cycle needs, including harsh paintbrush, English plantain, common camas, and the full plant palette if possible. Food for the Streaked Horned Lark and Mazama Pocket Gopher should coincide with plants for the Taylor's Checkerspot Butterfly. Bare patches for Streaked Horned Lark nesting must be included in patch implementation and likely maintained over time. The soil for restoration needs to be glacial outwash or equivalent for the Mazama Pocket Gopher to live in the patch.

Smaller habitat patches should be 50 acres or more to support the Taylor's Checkerspot Butterfly and the Mazama Pocket Gopher. This will likely be too small for the Streaked Horned Lark unless it is located next to a large, wide open area devoid of forest, but these patches can support the other two species. Large habitat patches should be 250 acres at minimum to create population-sustaining cores for all three species. The Streaked Horned Lark may need more acreage for its proliferation, so ideally these cores could be 300 or more if there are no adjacent open areas. Patches should be a mix of the circular compact and the convoluted patch shapes and should include strands that extend outward towards other prairie habitat patches if present. Edges on habitat patches should be as straight as possible and avoid unnecessary convolution, maintaining a low E:I ratio and promoting movement along edges rather than across them.

Habitat Corridors

According to the National Resources Conservation Service (NRCS), a corridor is "A linear patch that differs from its surroundings" (National Resources Conservation Service, 1999). Corridors have shown efficacy in experimentation. One project revealed that connected patches of the pine-savannah system contained 14% more species than unconnected patches. They can also reduce the amount of time that it takes for species to colonize habitat patches compared to colonization of patches that are isolated (Damschen et al., 2019). Corridors can function in several different ways. For target prairie species recovery on JBLM, there is one primary function and two secondary functions that prairie corridors could serve. The primary function for prairie corridors should be to act as a "conduit", or to convey movement of genetics, seeds, and organisms of critical prairie habitat and target prairie species from one habitat patch to another. The two secondary functions of prairie corridors could be for them to act as both "sinks" and "sources". Its function as a sink would be to retain target prairie species between patches, which would increase the efficacy of corridor implementation beyond the function of being a conduit for movement. Its function as a source would be to take retainment of species further and also promote reproduction of target species within the corridor (National Resources Conservation

Service, 1999). These two secondary corridor functions are not expected based on my research but could still be possible. There are potential negative effects of corridors, such as increased predator activities, conveyance of invasive species, pests and diseases, and micro-habitat changes (Hilty et al., 2020). This could potentially be mitigated by strategic maintenance, but this is beyond the scope of this thesis and will not be included in any assumptions.

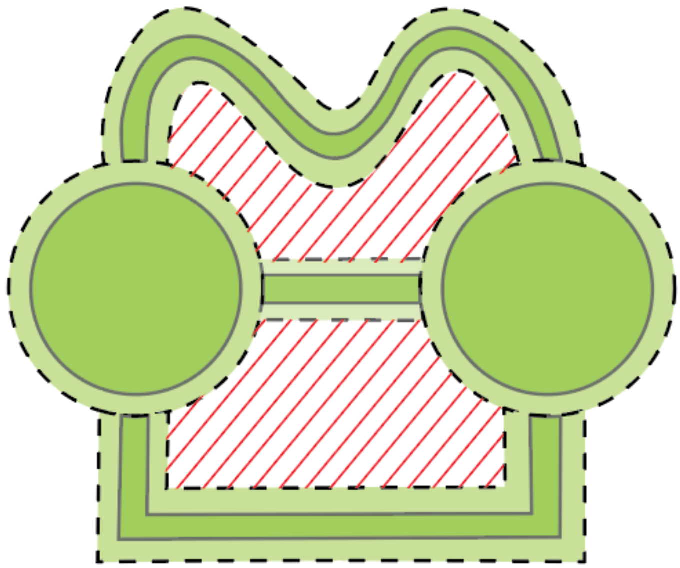


Figure 4.6. Diagram shows two patches and optional shapes of corridor implementation. Green represents the target habitat, light green represents transitory edge habitat, and the red lines represent barriers.

Because of the military activities that need to occur on JBLM, the most sensible approach to habitat corridor implementation is the “Least-Cost” model. The least-cost model is estimating the surface area of least resistance from one patch to another, whether by shortest distance, lowest cost, or both. There are barriers present on JBLM such as restricted areas and other critical habitats such as wetlands and the Northern Spotted Owl designated habitat, and for this thesis they are assumed to present excessive costs. There are also other critical species on JBLM, and the incorporation of their locations are beyond the scope of this thesis.

In addition to utilizing the least-cost model, I needed to determine specific parameters for habitat corridors. At a minimum, I wanted to achieve a conduit function for corridors, but to also consider the corridor size needed for them to act as sinks and sources. I took the same resource parameters that I used for habitat patches and assumed that they would suffice for corridors as well. The main characteristic that I still needed to define was how wide corridors needed to be. As discussed earlier, the Mazama Pocket Gopher requires at least 10 acres of prairie habitat for a habitat patch (approximately 200 meters x 200 meters). The Taylor’s Checkerspot Butterfly requires approximately 50 acres (approximately 447 meters x 447 meters), but this species has been noted to reside near forest edges. My assumption because of this is that the width of corridors is not as important to the Taylor's Checkerspot Butterfly as much as the acreage is, meaning they likely do not require a corridor to be 447 meters in width. Research on the Streaked Horned Lark found that the probability of locating this species increased significantly as it became further away from an edge, with the most occurring 150 meters or further away from an edge (Anderson & Pearson, 2015). Because corridors contain at least 2 edges, one on either side, this means that the distance from either side would have to be a minimum of 150 meters, making the minimum width of corridors for the Streaked Horned Lark 300 meters. Synthesis of this information gave me a minimum width of 300 meters for habitat corridors to support all three target prairie species.

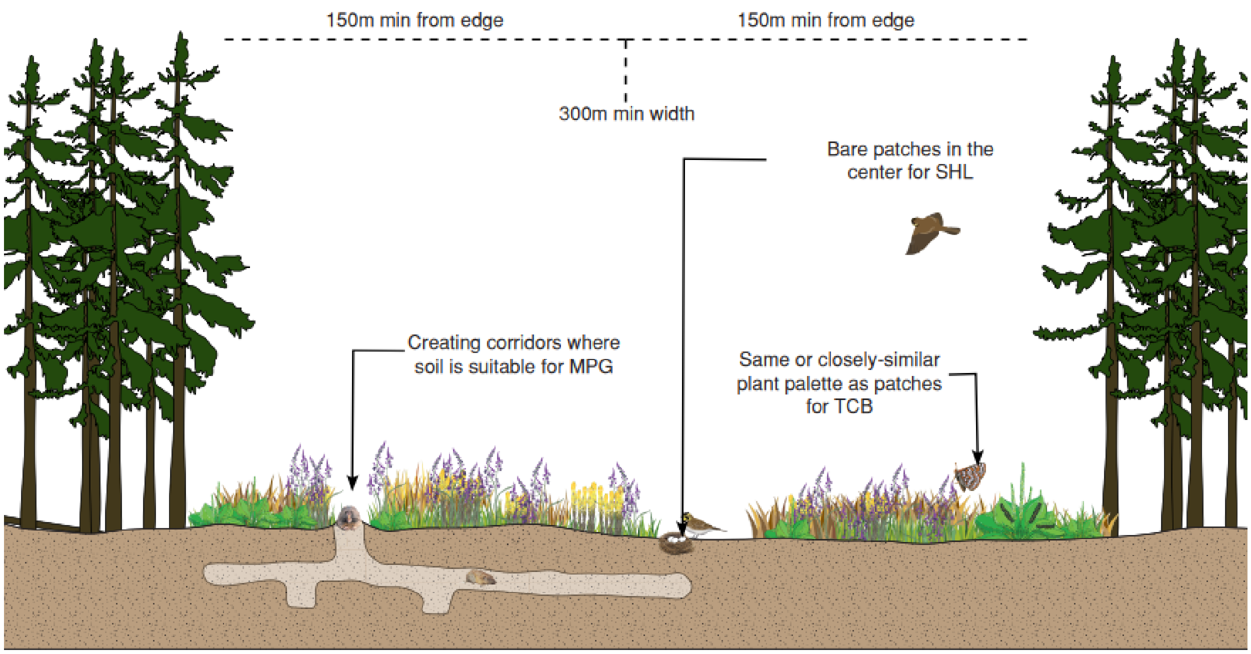


Figure 4.7. Section shows assumed landscape and width characteristics of corridor habitat for target species. SHL is Streaked Horned Lark, TCB is Taylor's Checkerspot Butterfly, and MPG is Mazama Pocket Gopher.

Expansion

Expansion is the utilization of existing habitat patches and using them as a starting point to create larger patches. Although expanding an existing habitat is not a requirement for restoration, it does provide a reference set of resources that could spread into the restored version (Miller & Hobbs, 2007). Also, each target species has a required amount of habitat for them to be willing to nest or establish territories, and this method is a way to minimize additional costs and space requirements by activating underutilized habitat. This is important to mitigate interference into military activity while meeting restoration needs.

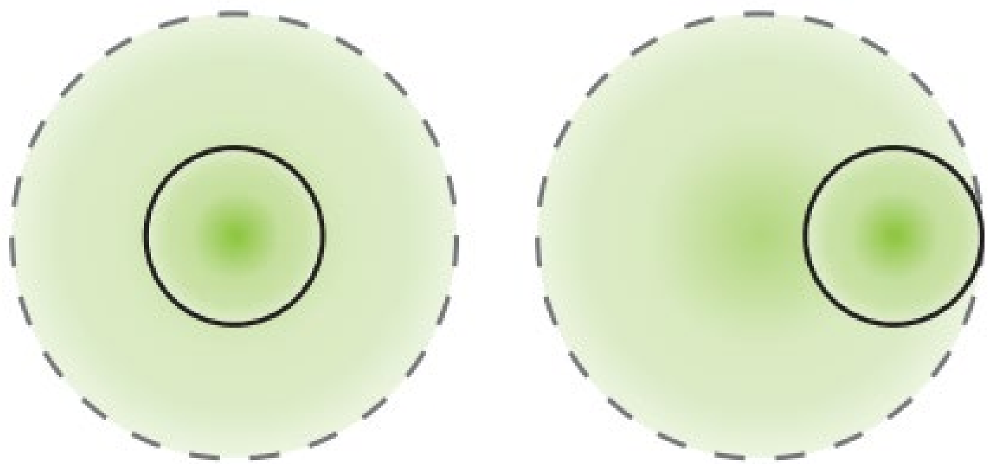


Figure 4.8. Diagrams show how existing habitat (solid line) can be expanded (dashed line) in various ways, not required to start from the center. Diagrams adapted from (Dramstad et al., 1996).

5. JBLM Site Analysis

Ecology

JBLM's contains a wide array of ecologies that have changed over time. Currently, it is approximately 55% dry and wet conifer forest, 24% grassland, 9% urban, 3% water, and the rest is a mix of various forest and grassland combinations that include fir, pine, oak, and savannah mixes (Forestry Branch & Directorate of Public Works, 2017). Because of the similarities between many of the subcategorized ecotypes, I grouped habitat types together into forested, grassland (also shrubland, oak and pine), and wetlands and water. As mentioned earlier, the Northern Spotted Owl is one of the several other listed species on this site that are not prairie related. The Northern Spotted Owl has a designated forest area on JBLM for their hopeful introduction, which has also been outlined on my map. Designated area has not been marked for the locations of Western Gray Squirrel. Also present in the wetland areas are Water Howelia (*Howelia aquatilis*) and the Oregon Spotted Frog (*Rana pretiosa*), both of which are also federally listed species. Wetlands have been deemed off-limits for my thesis.

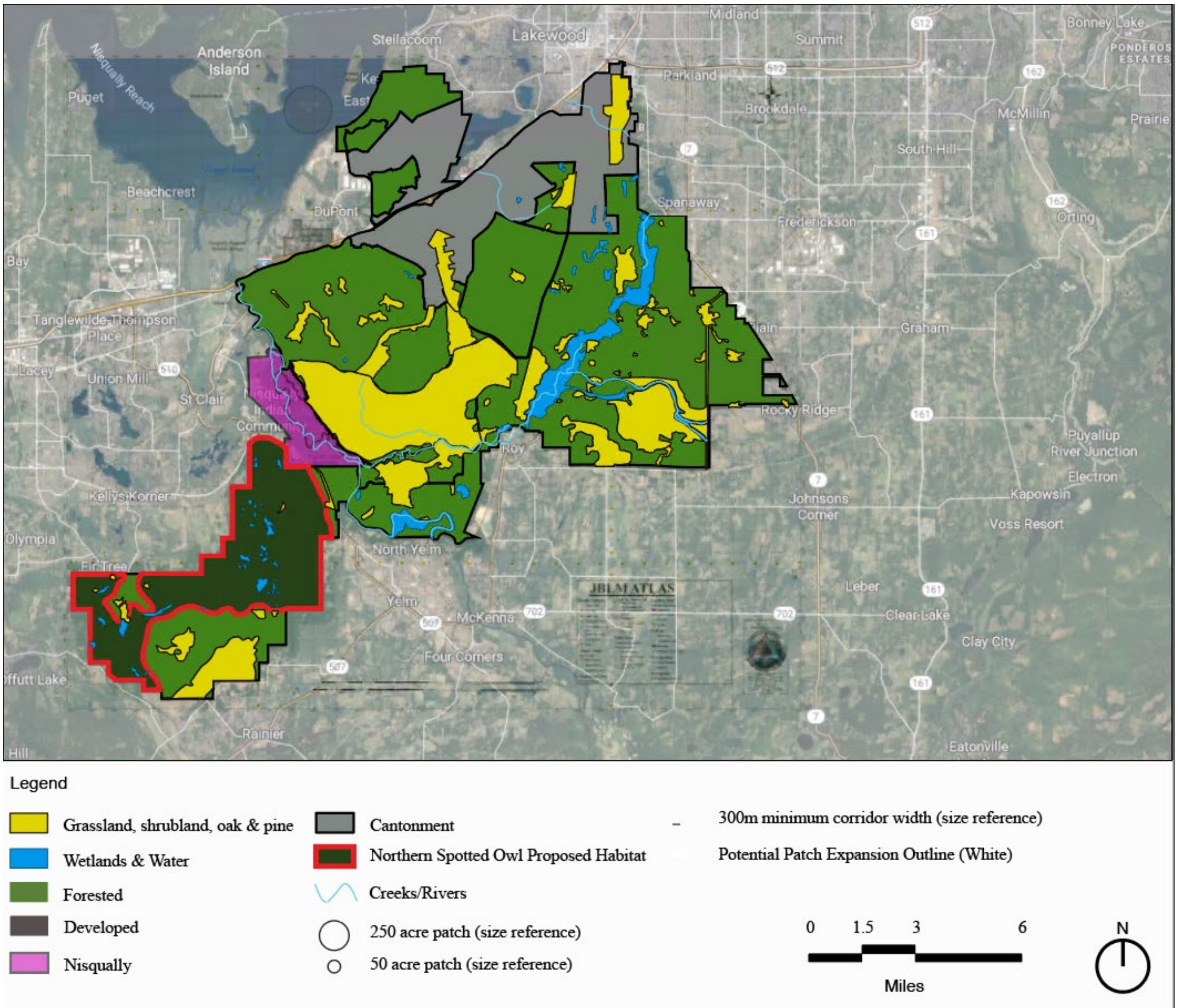


Figure 5.1. Map shows generalized habitat types and features on JBLM. Aerial map taken from Google Maps and base atlas taken from (Talbot, 2018).

Land Use

JBLM is a highly complex installation with many functions and land use designations. I spent substantial time trying to find ways to sort land use into specific categories that I could use for my thesis, but the information was too much and ended up being beyond the scope of this thesis. Instead, I simplified land use into broad categories: Training Areas, Impact Areas, Infrastructure, and Nisqually land.

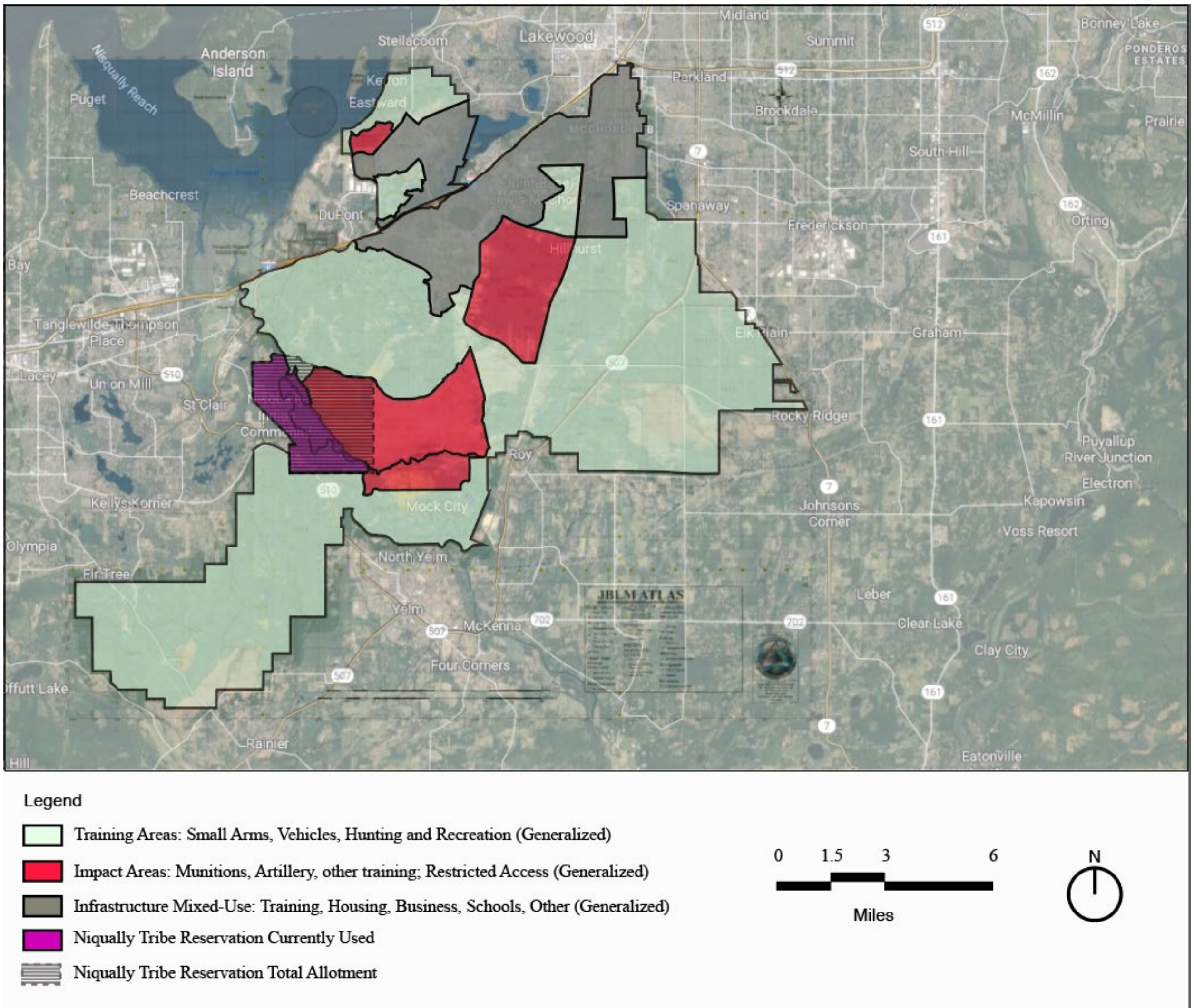


Figure 5.2. Map shows generalized land use on JBLM. Aerial map taken from Google Maps and base atlas taken from (Talbot, 2018).

Species and Training Restrictions

It is interesting to look at ecology and land use together while examining where the species currently reside on JBLM, as well as how that relates to land-use restrictions. The Streaked Horned Lark is located on two airfields as well as on the 91st and 13th Division Prairies. The Taylor's Checkerspot Butterfly has two small clusters on the 91st Division Prairie. The Mazama Pocket Gopher is located on the periphery of the 91st Division prairie and just south in the South Impact Area, as well as in the Johnson Prairie and the Upper and Lower Weir Prairies in the southwestern corner of JBLM. The commonality between all three of these species and their locations is that there is some form of restriction of land use occurring whether it is seasonal or year-round. There appears to be a direct correlation between the presence of species and training restrictions, albeit training such as munitions and artillery fires have the effect of creating disturbance events that can maintain critical prairie habitat. Duggan et.al also predict that management techniques such as Scotch broom removal and year-round training restrictions would lower habitat risk for the target prairie species (Duggan et al., 2015). This is an interesting component that I was unable to incorporate further into my thesis due to my limited time frame and the overwhelming complexity of trying to understand training activities, types and purposes of restrictions, and how it all connects to ecology. However, it is important to make note of this to illustrate a potentially crucial element to ecological restoration on military installations.

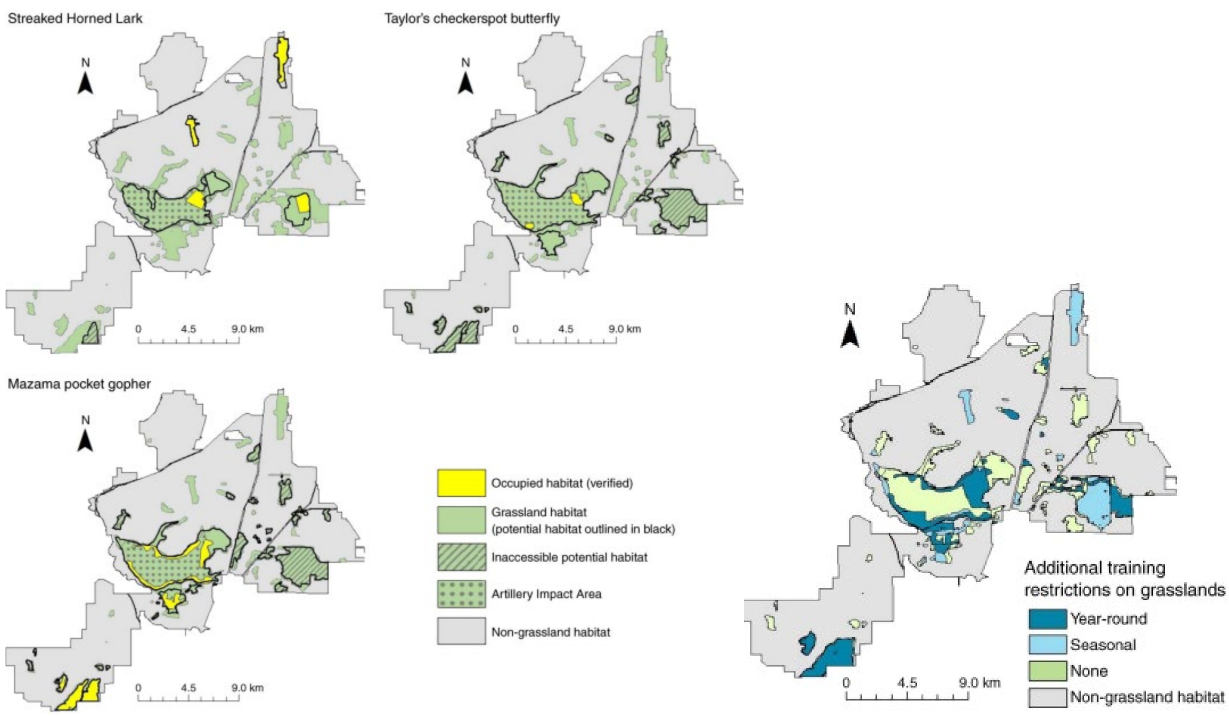


Figure 5.3. Maps show grassland habitat compared to non-grassland habitats on JBLM. The three maps on the left show the occupation area of each species, the Artillery Impact Area, and inaccessible grassland habitat. The map on the right shows areas with year-round restrictions, seasonal restrictions, and no restrictions to training. Maps taken from (Duggan et al., 2015).

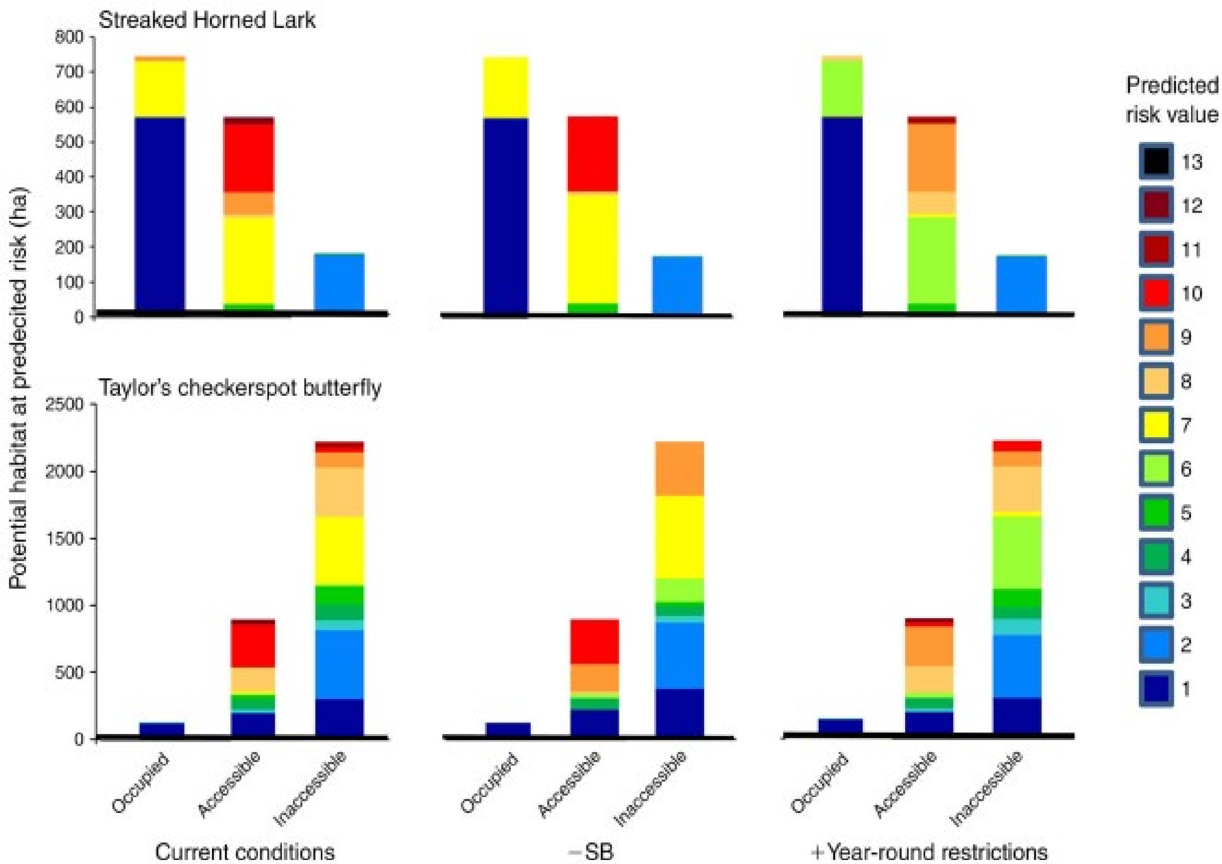


Figure 5.4. Figure shows the changes in risk for occupied, accessible, and inaccessible habitat for the Streaked Horned Lark and the Taylor's Checkerspot Butterfly when implementing no change, removing Scotch broom (SB), and implementing year-round restrictions. Figure taken from (Duggan et al., 2015).

Soil

42% of soils on JBLM are glacial outwash, and 58% of soils were formed underneath the historic grasslands. 31% of soils are formed under forest vegetation and are moderately well drained, showing that forest habitat may still contain usable soil for prairie habitats if forests were removed and prairie habitat installed (Forestry Branch & Directorate of Public Works, 2017).

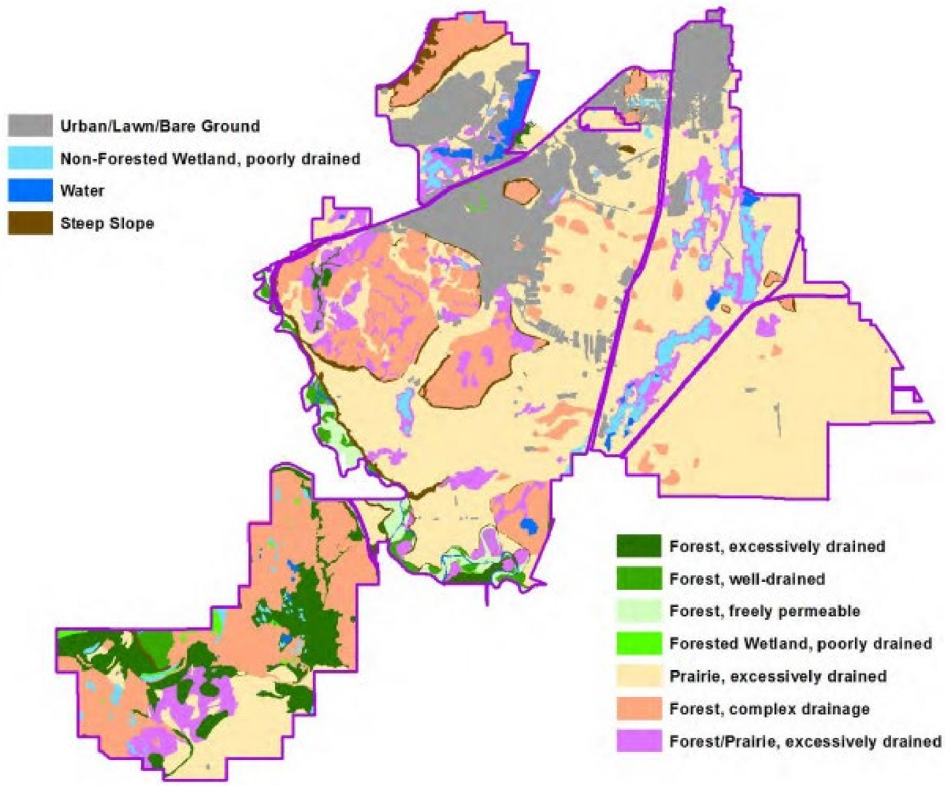


Figure 5.5. Map shows various soil types on JBLM. Map taken from (Duggan et al., 2015).

To examine soil characteristics more specifically, I utilized soil survey data provided by the NRCS and narrowed it into JBLM. I created a polygon outlining all of JBLM south of I-5 to gather soil information. I did not include the portion of the installation north of 1-5 because there is no prairie currently located there and restoration would have to start without reference prairie habitat. I had to zoom in a certain extent to get soil categorizations to become visible on the survey map. I then panned all around JBLM and took screenshots at this same zoom level and collaged screenshots together to make a rough but full map. Once the collage was finished, I downloaded the full soil survey as a PDF from the NRCS and created a basic outline of each soil category that was present on JBLM in the soil survey. This included the soil name, soil label, parent source material, hydrologic soil group, and drainage. Because prairies were established on glacial outwash soil, I used those characteristics as a baseline to infer whether other soil types would be sufficient to host future prairies. Also, I used the collaged soil survey map combined with Google Earth to visually identify which kinds of ecologies were supported by each soil type with the goal of finding which soil categories were suitable for prairie habitat. I did not have access to the site, so I could not confirm locations of ecologies in person and there may be inaccuracies. This combined process led me to create a basic ranking system for each soil category, rating them as Good, Fair, Poor, or Not Feasible.

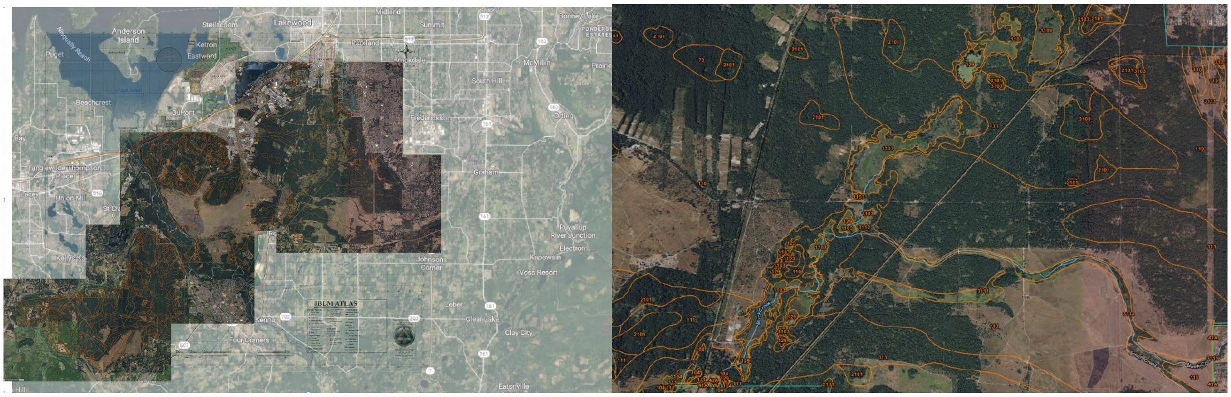


Figure 5.6. Map on the left is a collage of NRCS soil survey data of JBLM. Image on the right is a zoomed-in example of the map survey information. The survey map was taken from (Natural Resources Conservation Service, n.d.). Aerial base map taken from Google Maps and from (Talbot, 2018).

Soil Name	Soil Label	Parent Source Material	Hydrologic Soil Group
Alderwood gravelly sandy loam (8-15%)	2	Glacial drift and/or glacial outwash over dense glaciomarine deposits	B
Everett very gravelly sand loam (0-8%)	32	Sandy and gravelly glacial outwash	A
Everett very gravelly sandy loam (8-15%)	33	Sandy and gravelly glacial outwash	A
Indianola loamy sand (0-5%)	46	Sandy glacial outwash	A
McKenna gravelly silt loam (0-5%)	65	Glacial drift	D
Nisqually loamy fine sand (0-3%)	73	Glacial outwash	A
Norma fine sandy loam (0-3%)	75	Alluvium	A/D
Pilchuck loamy sand (0-3%)	84	Alluvium	A
Puyallup silt loam (0-3%)	89	Alluvium	B
Semiahoo muck (0-1%)	104	Herbaceous organic material	B/D
Shalcar muck (0-2%)	105	Herbaceous organic material over glacial drift and outwash	C/D
Skipopa silt loam (3-15%)	108	Glaciolacustrine deposits	D
Spanaway gravelly sandy loam (0-3%)	110	Glacial outwash	A
Spanaway gravelly sandy loam (3-15%)	111	Glacial outwash	A
Water, fresh	129	N/A	N/A
Urban land-Spanaway complex (0-2%)	992	Glacial outwash	A
Urban land-McChord complex (0-2%)	993	Glacial drift	A
Urban land	994	N/A	N/A
Steilacoom-Yelm complex (0-2%)	1100	Silty glacial lacustrine deposits	B/D
Fluvaquents-Water complex (0-1%)	1102	Alluvium	A/D
Semiahmoo-Water complex (0-1%)	1103	Herbaceous organic material	B/D
Yelm-Steilacoom-Everett complex (0-30%)	1105	Glacial outwash	A/D
Snoqualmie loamy fine sand (2-8%)	1106	Alluvium	A
McChord-Everett complex (0-3%)	2100	Alluvium	A
McChord-Everett complex (3-15%)	2101	Glacial drift	A
McChord-Everett complex (15-30%)	2103	Glacial drift	A
Everett-Spanaway complex (3-15%)	3100	Glacial outwash	A
Xerorthents (30-100%)	3103	Glacial drift	A
Everett very gravelly sandy loam (2-40%)	3106	Glacial outwash	A
Indianola-Yelm complex (0-30%)	3110	Glacial outwash	A/D
Spana-Spanaway-Nisqually complex (0-2%)	3111	Glacial outwash	B/D
Everett-Spanaway-Spana complex (0-30%)	3112	Glacial outwash	A

Figure 5.7. Image is a screenshot from Microsoft Excel of NRCS soil survey information (Natural Resources Conservation Service, n.d.). Shown information is Soil Name, Soil Label, Parent Source Material, and Hydrologic Group.

Drainage	Primary ecology supported onsite	Prairie Currently on Soil Type?	Quality of Soil for Prairie
Moderately well-drained	Forest, prairie	Yes	
Somewhat excessively drained	Forest, Forest clearing, edge conditions	Possibly	
Somewhat excessively drained	Forest, Forest clearing, edge conditions	Possibly	
Somewhat excessively drained	Forest	No	
Poorly drained	Forest	No	
Somewhat excessively drained	Prairie/grassland, prairie edge	Yes	
Poorly drained	Forest	No	
Somewhat excessively drained	Edge of Water/wetlands, Forest	No	
Well drained	Edge of Water/wetlands, Forest	No	
Very poorly drained	Wetland	No	
Very poorly drained	Forest, wetland	No	
Somewhat poorly drained	Forest, Forest edge	No	
Somewhat excessively drained	Prairie, forest	Yes	
Somewhat excessively drained	Prairie, forest	Yes	
N/A	Water	No	
Somewhat excessively drained	GAAF Airfield	Grassland (Yes)	
Moderately well drained	Cantonment	No	
N/A	Cantonment	No	
Somewhat poorly drained	Forest, Forest clearing, edge conditions	No	
Very poorly drained	Wetland edge, Forest edge	No	
Very poorly drained	Wetland, wetland edge, ponding	No	
Moderately well drained	Forest, forest clearing, forest edge	No	
Somewhat excessively drained	Forest, forest clearing, forest edge	No	
Moderately well drained	Forest, Forest clearing, edge conditions	Possibly	
Moderately well drained	Forest, grassland, forest clearing, edge conditions	Yes	
Moderately well drained	Forest, grassland, forest clearing, edge conditions	Yes	
Somewhat excessively drained	Forest, grassland, forest clearing, wetland edge, forest edge	Yes	
Somewhat excessively drained	Forest, grassland, forest clearing, wetland edge, forest edge	Yes	
Somewhat excessively drained	Forest	No	
Moderately well drained	Forest, Forest clearing, edge conditions	No	
Somewhat poorly drained	Wetland edge	No	
Somewhat excessively drained	Forest, Forest clearing, edge conditions	Yes	

	Good
	Fair
	Poor
	Not feasible

Figure 5.8. Image is a screenshot from Microsoft Excel of NRCS soil survey information and associated ranking system (Natural Resources Conservation Service, n.d.). Each soil category received a ranking of Good, Fair, Poor, or Not Feasible as soil suitable for prairie restoration.

Most soil categories on JBLM received a rating of Fair or Good based on the compositional comparison. Soil categories that received a Good rating had prairie currently existing on them, showing that they are clearly capable of hosting prairie habitat. Those soil categories that received a Poor rating were typically ranked C or D for Hydrologic Group, and identification on the map revealed that they were usually located in wetlands or on the buffers of wetlands. Those that received a Not Feasible rating were usually located where water was pooling or in areas of cantonment. Overall, most forest areas appear feasible to install prairie habitat if existing vegetation and timber are removed. The areas to avoid are wetlands, which I have already deemed off-limits due to the presence of wetland critical species and unknown wetland requirements that may impede restoration in those locations.

6. Restoration Approaches

Concepts of Restoration

Ecological restoration in relation to military installations is highly case-specific and requires in-depth, multilayered planning to address the needs of various involved parties. My species and habitat research and JBLM site analysis provided me with basic guidelines about what prairie restoration requirements are, what is needed to recover the three at-risk prairie species, and where restoration could possibly happen on JBLM. With these defined goals and site parameters, I began to think about the various ways that restoration could be conducted on and off JBLM. I used my research of other military restoration examples and created 4 broad categories of options that could be used to try and meet restoration goals while also considering the military's needs. I also considered the effects that each option would have on restoration effectiveness and military readiness. These options are hypothetical in nature and are not indicative of strategies that would work due to many missing factors in my analysis.

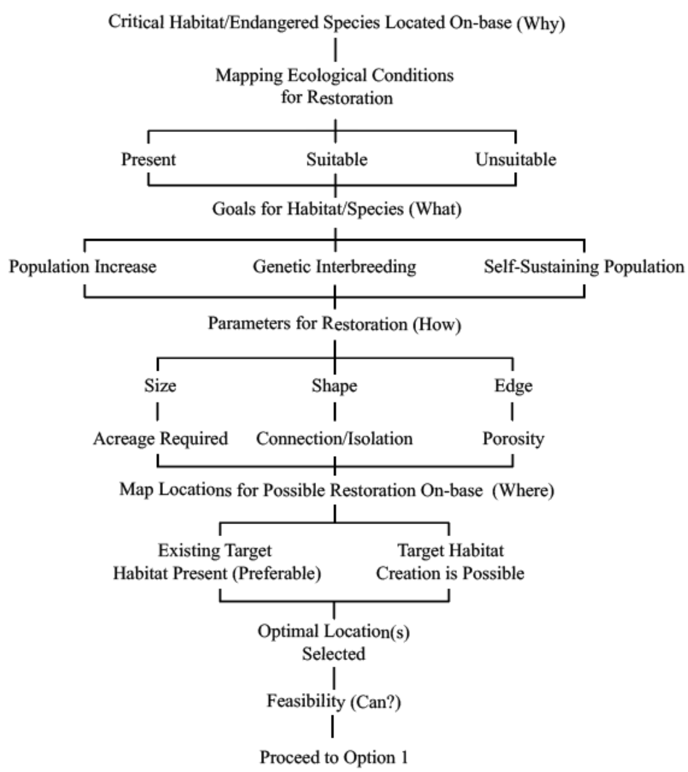


Figure 6.1. Diagram shows my conceptual framework for habitat restoration on military installations. Diagram leads to Option 1 as the first option to be considered in the restoration process.

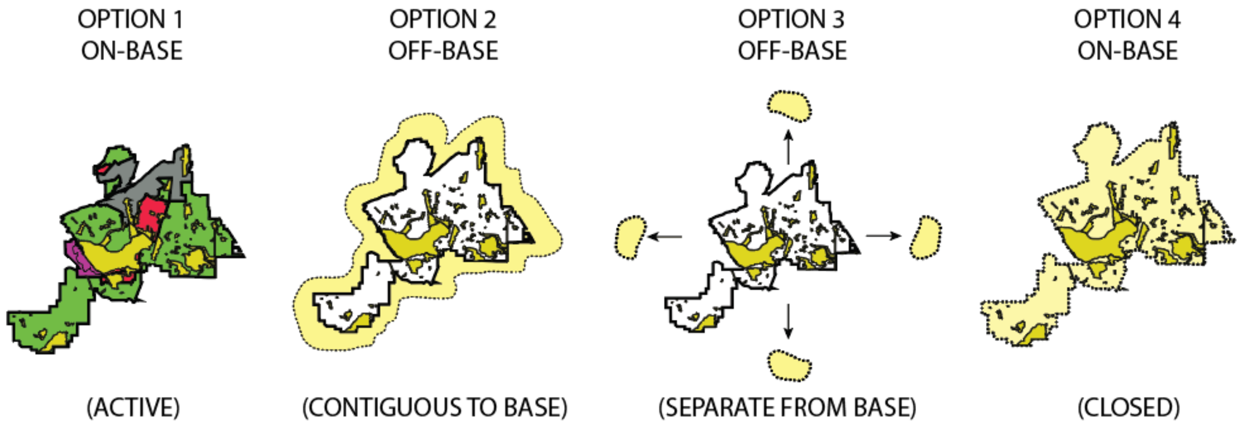


Figure 6.2. Diagram shows the concept of prairie habitat restoration behind several restoration options. From left to right, Option 1 is On-base (active), Option 2 is Off-base (contiguous to base), Option 3 is Off-base (separate from base), and Option 4 is On-base (closed).

Option 1: On-base (active)

The first option is to try and conduct ecological restoration on a military installation while the installation is still fully operational. The goal with this approach is to balance military training needs with habitat restoration and species recovery. Utilizing the existing prairies on-base would provide ideal reference habitat to be used as a source of seeds and species, and some underused patches could be activated by increasing their acreage or strategizing restrictions to land use to create future host sites for target species. Also, the base remaining open would allow for military training to continue on the installation, although the amount of restoration and the locations for restoration are paramount factors that will likely determine how training is affected. The restriction of training does play a role in species prevalence as noted earlier, which may or may not be possible depending on what training needs to be done, what space or habitat types are needed, and if that training could occur anywhere else to still meet training requirements. Also, limiting restoration to occur within the base would likely prevent any need to interact or negotiate with neighboring entities as restoration is being handled internally.

However, there are several tradeoffs in keeping restoration on-base while the base is still active. One is that there will likely be a strict limitation on how much prairie can be restored based on the installation's training needs, meaning that species recovery needs may not be possible to be met on-base even if some restoration occurs. Also, limitations in restoration may prevent multiple strategies from being implemented, preventing a complete approach to species recovery from being realized and leaving gaps in what was accomplished.

Option 1	On-Base (Active)
Pros	Cons
1. Utilize existing prairies	1. Limit to prairie restoration
2. Training continues	2. Connectivity and patch size increases may not both be able to happen. Possible one or the other mentality.
3. No impact to outside entities	

Figure 6.3. Diagram shows the pros and cons of selecting Option 1 as the restoration approach.

Because most of the forested habitat appears to have suitable soil requirements for prairie habitat, most of the land could technically be altered into prairie given that restoration aligns with the installation's training needs and does not interfere with critical forest species. This creates a wide array of possibilities that could be hypothetically implemented. To start, I used the habitat map I created and categorized prairie patches as large habitat cores of 250 acres or more, small habitat patches of 50 acres, and patches smaller than 50 acres which are considered too small. I then mapped locations for both potential habitat corridors and example areas where habitat could be expanded into larger patches. For habitat corridors, my goals were to link habitat cores together and to activate underused habitat patches by utilizing them in my corridor layout, and I used the least-cost approach to create a web of connections throughout JBLM. For habitat expansion, my goals were to expand small habitat patches to activate them and to expand cores where possible to incorporate smaller patches. Once I completed layouts for each, I combined the two to show an optimized version where patches are interconnected to increase species conveyance and patches are larger to host new populations.

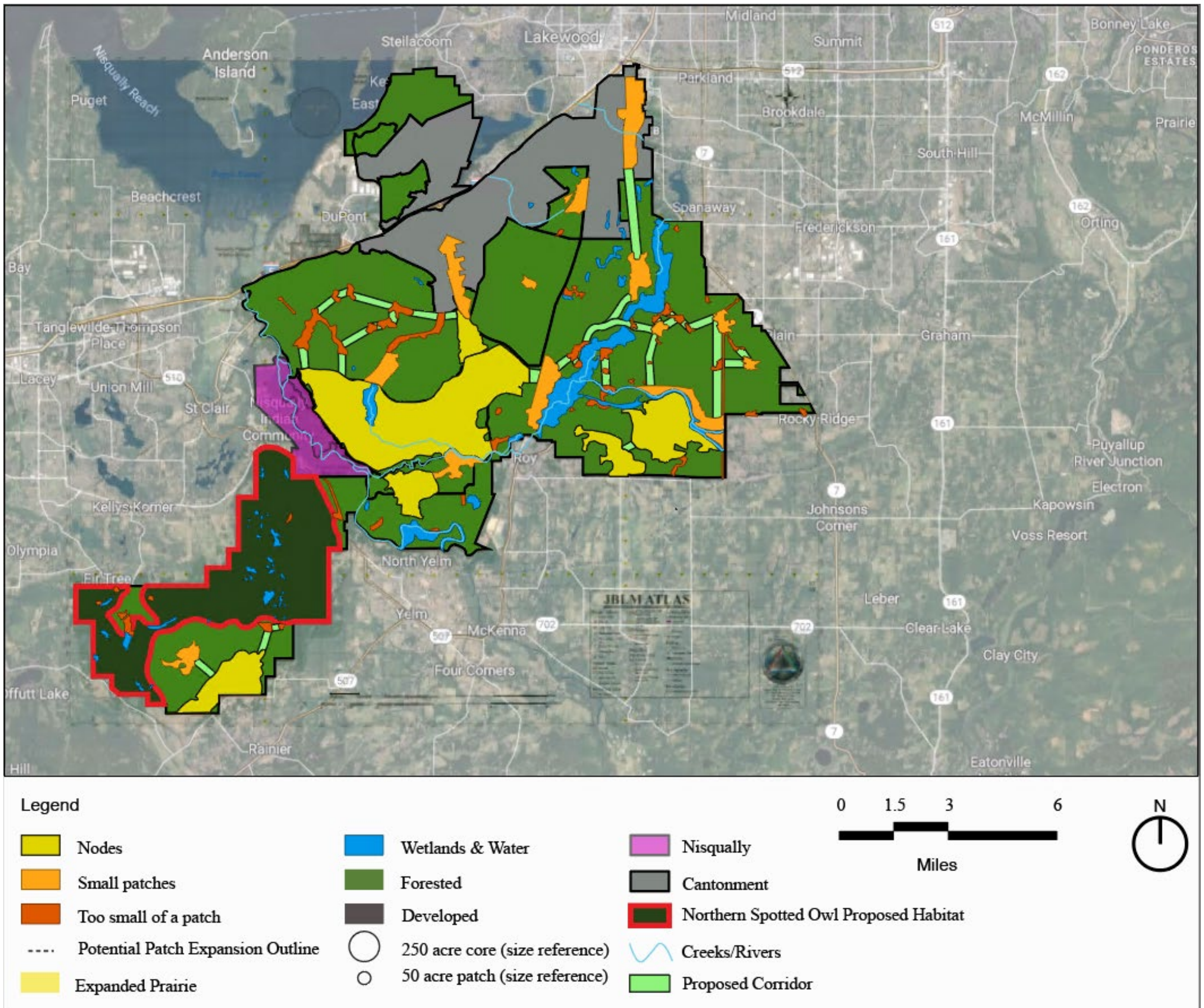


Figure 6.4. Option #1 plan shows the potential layout of habitat corridors using the least-cost approach, utilizing existing patches. Aerial map taken from Google Maps and base atlas is from (Talbot, 2018).

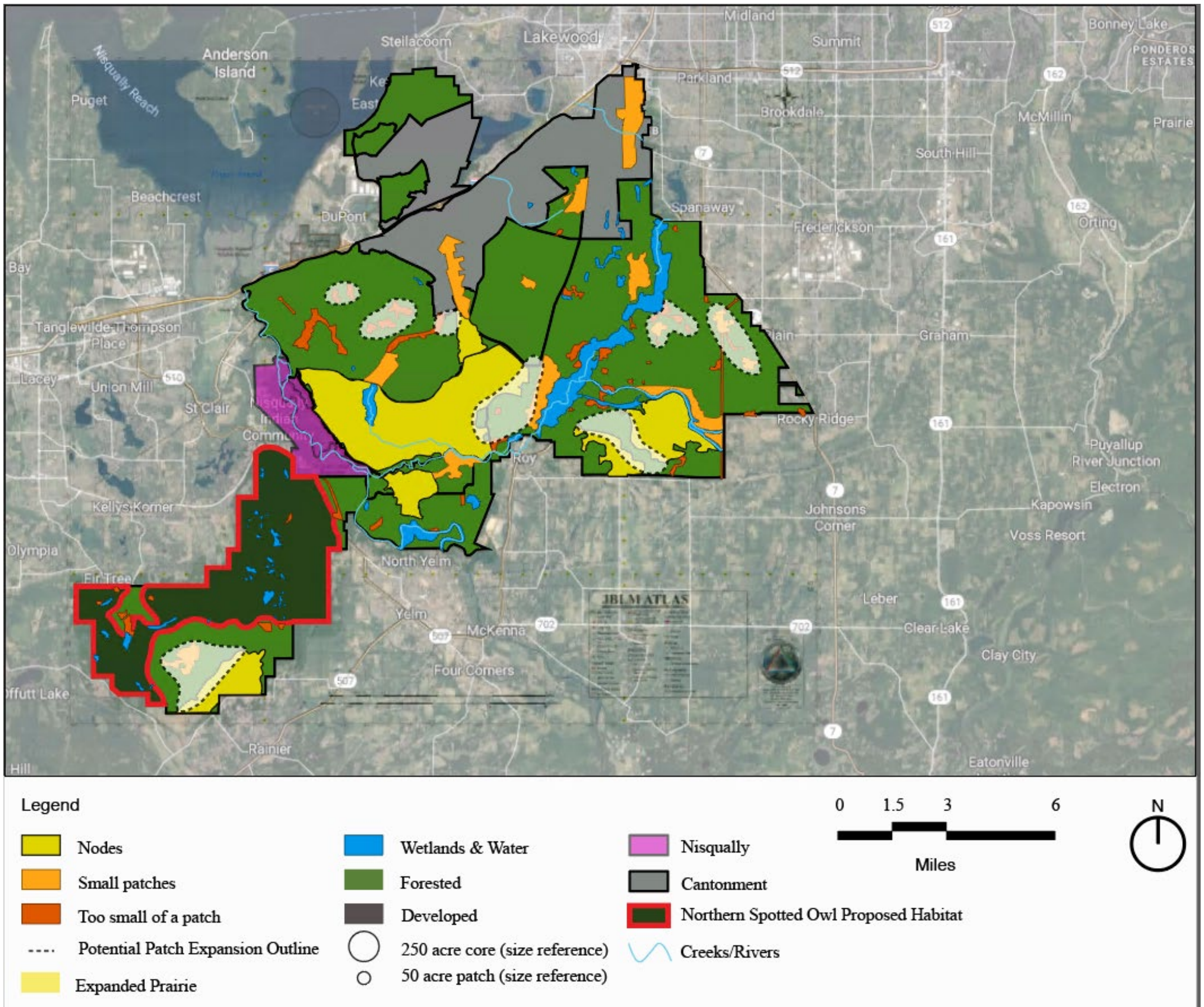


Figure 6.5. Option #1 plan shows a selected potential layout of habitat expansion, utilizing existing habitat patches. Aerial map taken from Google Maps and base atlas is from (Talbot, 2018).

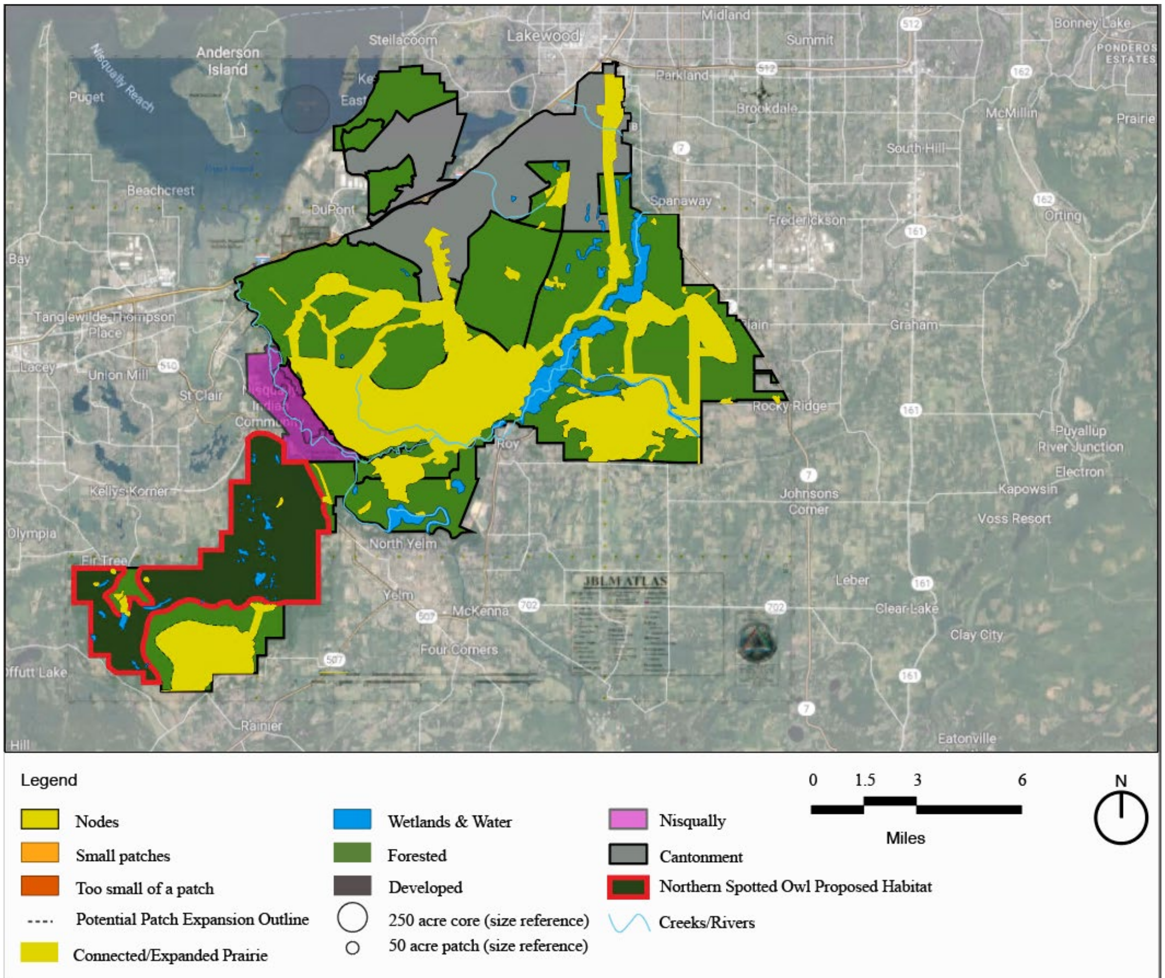


Figure 6.6. Option #1 plan shows a full combinatory approach of corridor and expansive restoration if all selected potential corridors were developed, and selected reference habitat patches were expanded. Aerial map taken from Google Maps and base atlas is from (Talbot, 2018).

The layouts I selected are not as refined as what would be necessary for actual implementation of habitat restoration. The purpose of my layout was to reveal key areas that could be considered in an actual project and to explore the scale of such an implementation. I am missing crucial elements that would further define exactly what could be done and what is feasible for on-base restoration. To lay out some missing pieces, I created decision matrices that are a conceptual walkthrough of questions that might be considered when attempting to actualize a restoration project on an installation. For my matrices, I split Option 1 into two parts, Option 1A and Option 1B. Option 1A concerns itself with the interference of training requirements when implementing habitat restoration, while Option 1B is concerned with conflicting critical habitats and at-risk species that may be in the same locations as proposed restoration.

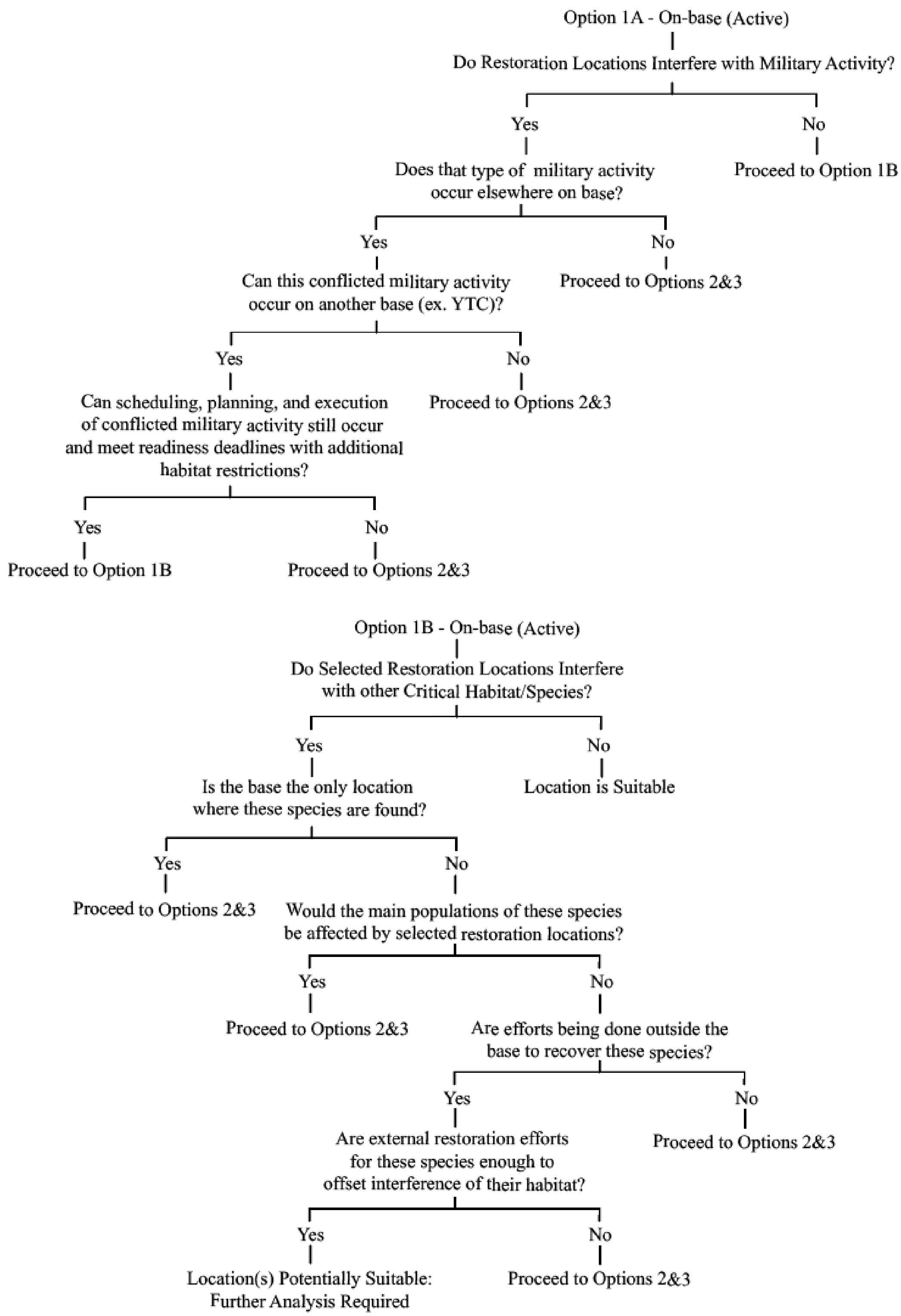


Figure 6.7. Diagram is the decision matrix for Option 1. Option 1 is split into 1A for military training and 1B for conflicting critical habitats and at-risk species.

Overall, the combined layout of habitat corridors and expanded habitat patches on JBLM may be sufficient to meet all three species recovery goals if a significant amount of those restored lands had both training restrictions and continuous management. However, the amount of land that this would consume is several thousand to tens of thousands of acres, and this would likely be a major hindrance to military training if pursued unless a significant portion of training was relegated to another installation such as YTC. Therefore, if habitat restoration were to be more realistically pursued on JBLM while the base is active, planners would need to settle with meeting a fraction of recovery goals only implementing minimalistic prairie restoration where possible and leaving most of the prairie restoration to be conducted off-base.

Option 2: Contiguous to Base

Option 2	Off-Base (Contiguous to Base)
Pros	**Cons**
1. Minimizes negative impact to training	1. Limitations to land selection
2. Prairie on-base may be useable	2. Land already purposed. Would need to purchase and re-purpose
3. Lifts restrictions on military	3. Training restrictions may stil be required if along base edge

Figure 6.8. Diagram shows the pros and cons of selecting Option 2 as the restoration approach.

The second option is to restore prairie contiguous to JBLM. This option is more prevalent than moving away from JBLM because it would be preferable to connect future restoration to the large reference prairie patches located on JBLM. Moving off-base could be beneficial to military activity on JBLM by helping to meet critical habitat and species recovery needs, lifting some of the burden off the installation and potentially lifting restrictions in place. Restoration next to the base could also assist in creating a buffer that would mitigate military and civilian disturbance. However, this strategy limits the availability of land selection to locations tangential to JBLM and to land where prairie is extending to the installation boundary. Also, the land is already allocated to other owners such as private landowners and counties or towns, which means negotiation and purchase agreements would need to be made. Finally, there may be no benefits to JBLM training restrictions even if land is re-purposed for restoration depending on the context of selected locations and acreage.

There are four locations along the boundary of JBLM that could gain partial access to 91st Division Prairie, 13th Division Prairie, and the Lower Weir Prairie, all of which are currently owned by private landowners or other towns. Contested parcels are located within Spanaway, Roy, Yelm, and Rainier. Spanaway and Yelm are located within Pierce County while Yelm and Rainier are in Thurston County. Examining and selecting each parcel and developing a subsequent financial estimate is beyond the scope of this thesis, but I found rough numbers for county land prices that could paint a picture of potential costs. The average price of farms, ranches and other land for sale in Thurston County is $986,597 (Land Watch, 2021b), and the average price of farms, ranches, and other land for sale in Pierce County is $562,302 (Land Watch, 2021a). Parcel properties vary wildly depending on location and seller, but in general, a few acres of land in either county range in the hundreds of thousands of dollars, and parcels 50 acres or more enter the multi-million-dollar range. This price tag also says nothing about the quality of the land in association to prairie habitat being installed there but referencing the historical Southern Puget Sound prairie map indicates that there is a high likelihood that much of the land in these parcels have been prairie once before.

I circled the four contiguous locations on a Google Earth screenshot and inserted 50-acre habitat patch and 250-acre habitat nodes as reference sizes to show the scale of what would be needed to make an impact on the three target species recovery needs. I then zoomed-in on the Roy connection only to illustrate the size requirements from a magnified point of view. A 50-acre patch may consume only a few parcels of land depending on the sizes of parcels that are selected and purchased. However, creating a 250-acre habitat core is a significant task that would require heavy negotiation and purchasing of many parcels all adjacent to one another. The cost is likely high, and a cost/benefit analysis would need to be conducted to see if this is feasible with available funds. Finally, I inserted a 300-meter-wide habitat corridor using the least-cost model as a reference. Inserting a habitat corridor in a straight line would likely intersect many parcels along the way, and thus more detailed corridor planning would be required for parcel selection if connectivity becomes an additional goal.

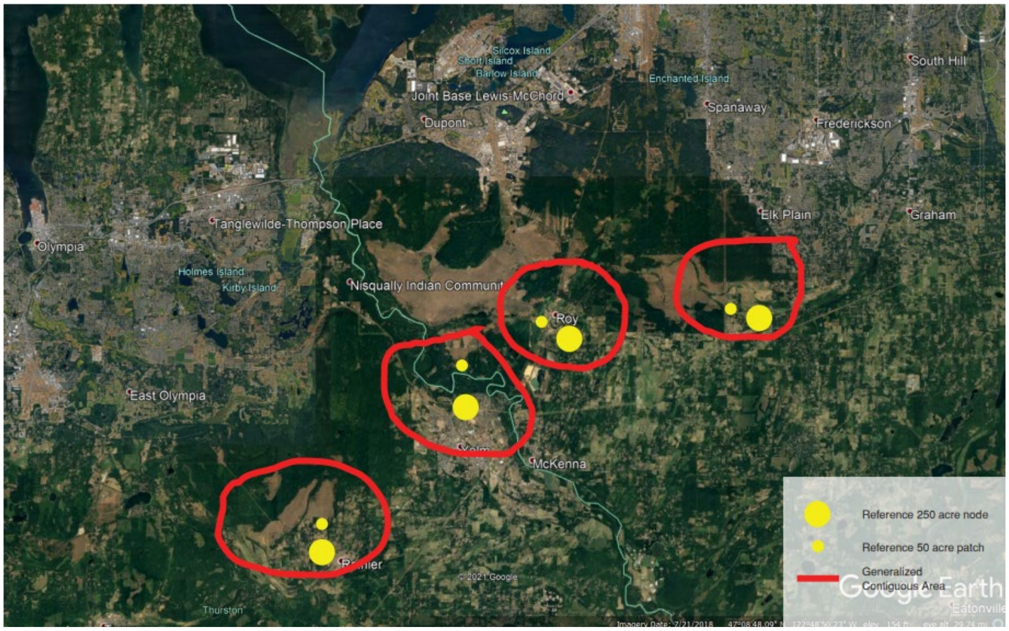


Figure 6.9. Red circles on the map indicate locations where prairie extends outward towards the installation boundary and meets neighboring parcels. Small yellow circles represent 50-acre habitat patches and larger yellow circles indicate 250-acre habitat nodes. Aerial map taken from Google Earth.

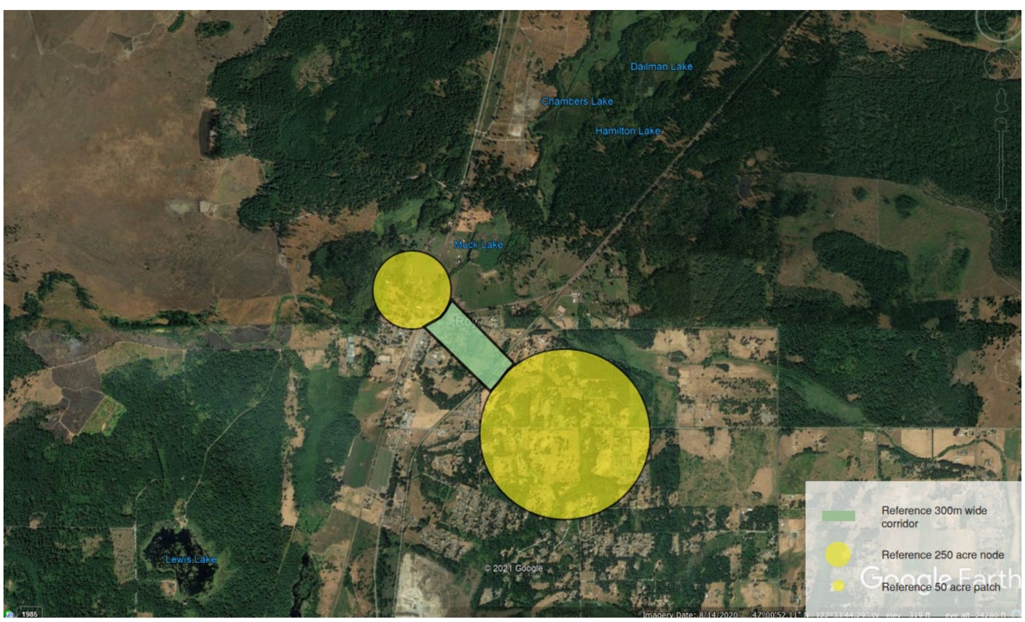


Figure 6.10. Small yellow circle represents a 50-acre habitat patch, and the large yellow circle indicates a 250-acre habitat node. The green strip represents a 300-meter-wide habitat corridor. Aerial map taken from Google Earth.

Option 3: Separate from Base

Option 3	Off-Base (Separate from Base)
Pros	**Cons**
1. Land selection more flexible	1. Purchased land only effective if grouped together, limiting land selection
2. Potentially lifts restrictions on military	2. Land already purposed. Would need to purchase and re-purpose
3. No negative impact on military training	3. Largest remaining prairies in Southern Puget Sound not being utilized

Figure 6.11. Diagram shows the pros and cons of selecting Option 3 as the restoration approach.

The third option is to select lands away from JBLM to implement prairie restoration. The benefits are similar in some respects to Option 2, primarily regarding the potential for beneficial impacts on restrictions of military training. Parcel selection is also more flexible because they do not need to be directly adjacent to JBLM. However, this restoration approach ignores the remnant prairies on JBLM, leaving high-quality and high-acreage reference habitat unused. There is the option of trying to utilize other scattered remnant prairie habitat in the area, or to start restoration from scratch. The largest remaining reference prairie habitats outside of JBLM include the Mima Prairie, Grand Mound Prairie, and Rocky Prairie, all located southwest of JBLM and separate from each other. Investigating the composition, ownership, and restoration work done on these prairies is beyond the scope of this thesis, but these could be suitable reference locations for off-base restoration.

As mentioned earlier in this thesis, JBLM Sentinel Landscapes Partnership has been conducting habitat restoration off-base, focusing on the recovery of endangered species. Some of the work they have done has been in the remnant prairies listed above, meaning there is likely potential for future work to be conducted there. More specifically, there are multiple small plots of Taylor's Checkerspot Butterfly critical habitat among their collection of restoration work, which has resulted in increased populations of the species as well as some lifted restrictions on JBLM (Sentinel Landscapes, 2020). This partnership has seen significantly increased overall funding over the past decade and this provides insight to the available budget for parcel purchasing. However, I do not have information on how exactly the budget is being used.

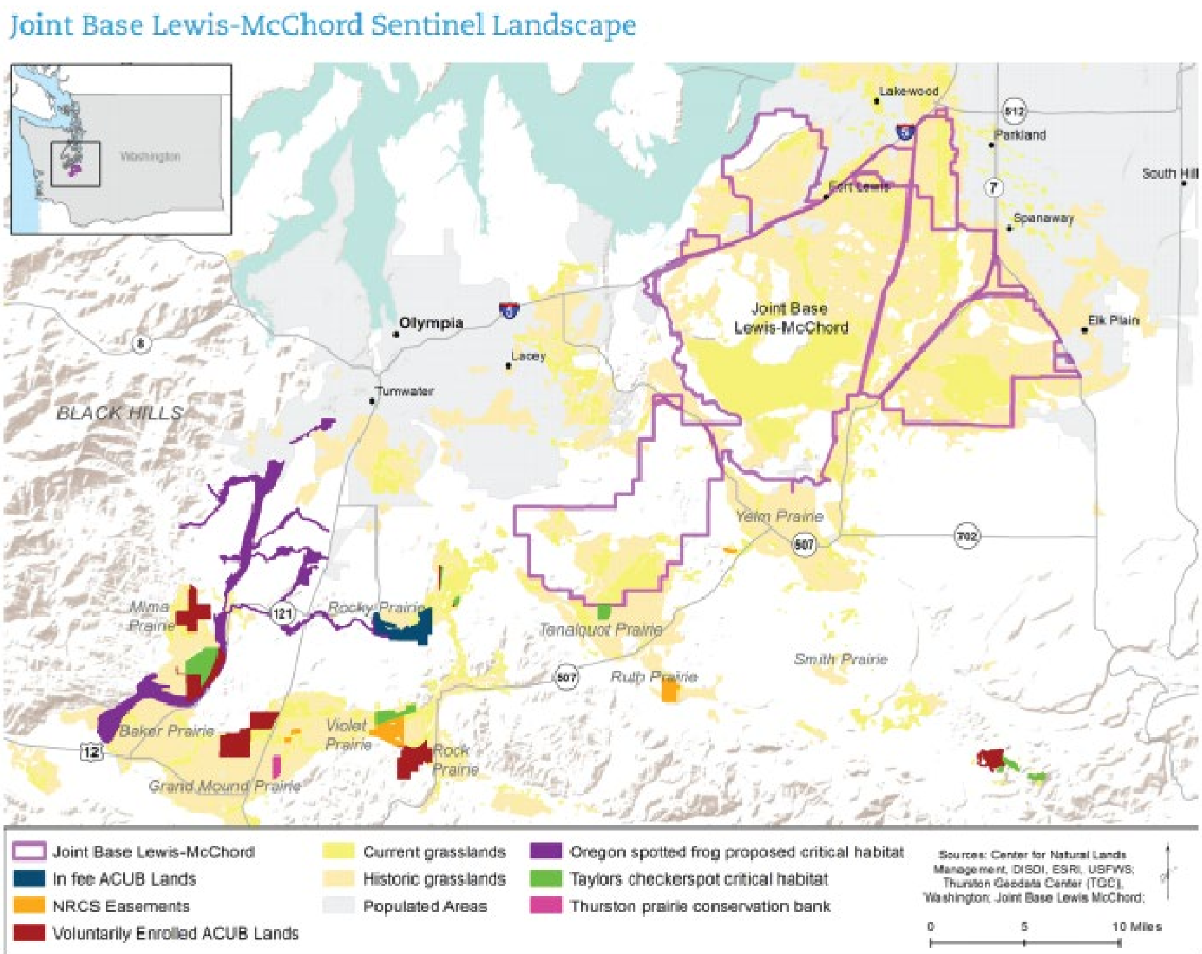


Figure 6.12. Map shows the locations of JBLM Sentinel Landscapes Partnership restoration work. Map taken from (Sentinel Landscapes | Joint Base Lewis-McChord, n.d.)

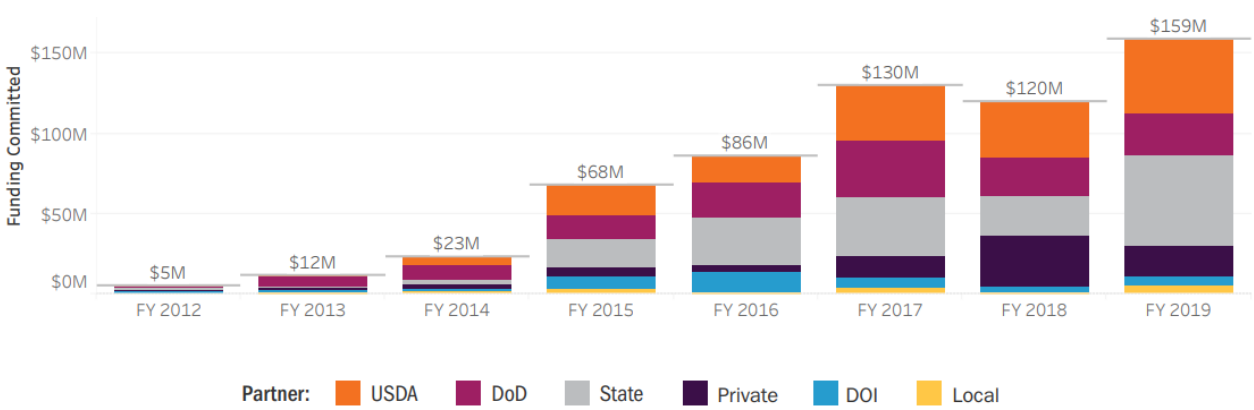


Figure 6.13. Bar graph shows the JBLM Sentinel Landscape total funding by partner from FY 2012 to FY 2019. Figure taken from (Sentinel Landscapes, 2020).

Options 2 & 3

These two approaches have similarities and differences between each other, but their premise is the same. If restoration cannot be conducted directly on JBLM due to inadequate feasibility, the next step is to move off-base in search of restoration sites. Both require similar processes to reach a conclusion, so I created a combinatory conceptual framework of these processes. Options 2 and 3 are also not mutually exclusive but can be combined to restore habitats adjacent to and away from JBLM simultaneously if that is the most feasible solution.

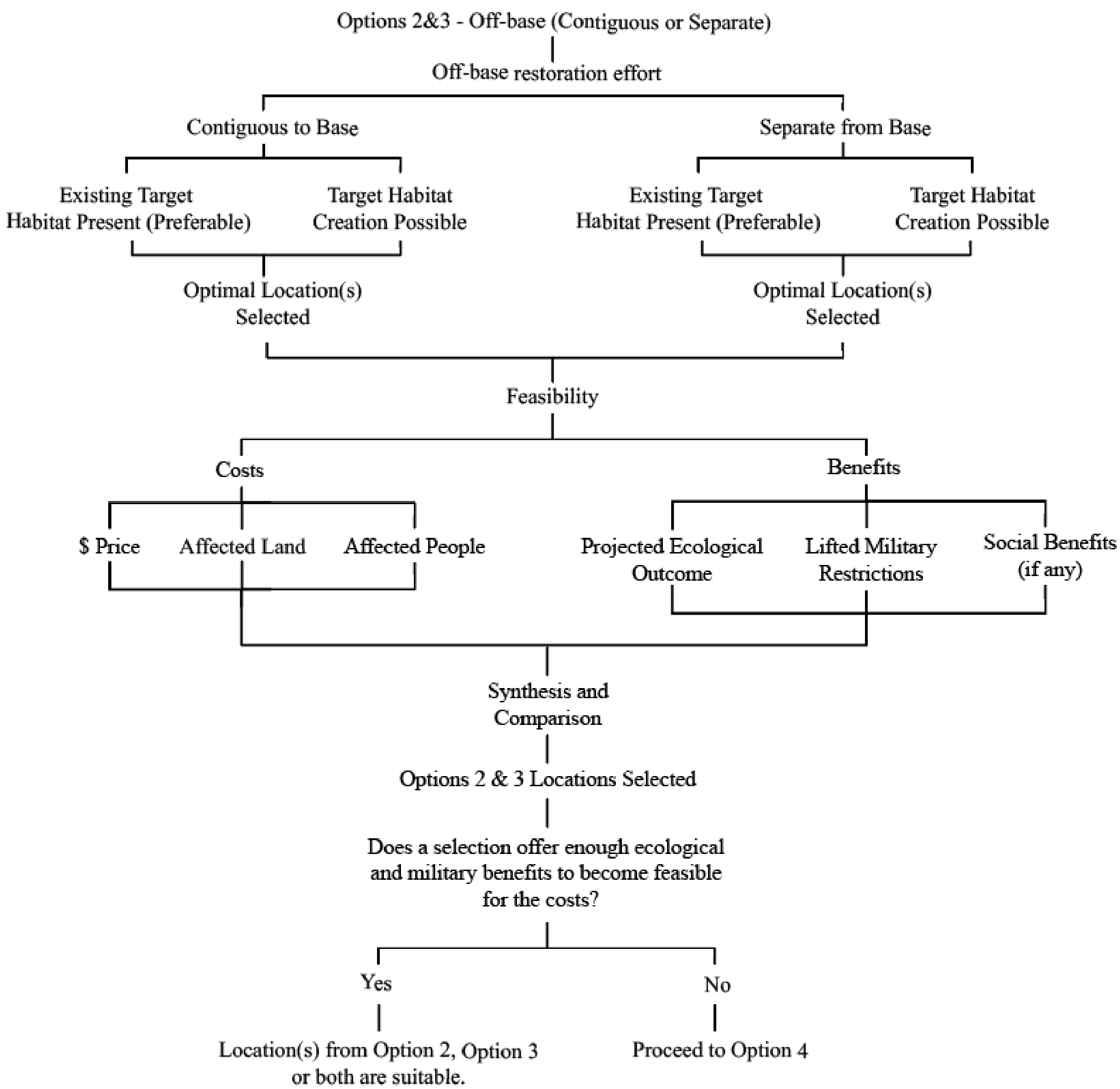


Figure 6.14. Diagram is the decision matrix for Options 2 and 3.

Option 4: Off-base (Closed)

Option 4	On-Base (Closed)
Pros	**Cons**
1. Potential maximization of restoration efforts	1. Military readiness hindered overall with base closure
2. Utilize existing prairies	2. Land might not be re-purposed for restoration

Figure 6.15. Diagram shows the pros and cons of selecting Option 4 as the restoration approach.

The fourth and last option is to consider habitat restoration if JBLM were to close and move its operations elsewhere. This is extremely unlikely to occur due to the high installation PPP rating, the strategic location, its annual economic impact, and the quality of training and living that occurs here as explained earlier in this thesis. However, in the unexpected case that JBLM were to become a BRAC site in the future, the potential for prairie restoration could be significant. Because most of the forested areas have established themselves over suitable prairie soil, hypothetically most of JBLM that is not urban or wetland could be changed into prairie habitat. The historical prairie map supports this. There are still other at-risk forest-dwelling species present on JBLM that need to be accounted for, however, adding complexity in determining which forested areas would be ideal for prairie restoration. The exact specificity of potential prairie mapping was not conducted in this thesis due to time and access constraints, so instead I simply overlaid all the forested area on JBLM, except for the designated Northern Spotted Owl habitat, as potential prairie. I left this as a loose concept only to display the magnitude of potential that this site holds if redirected into restoration.

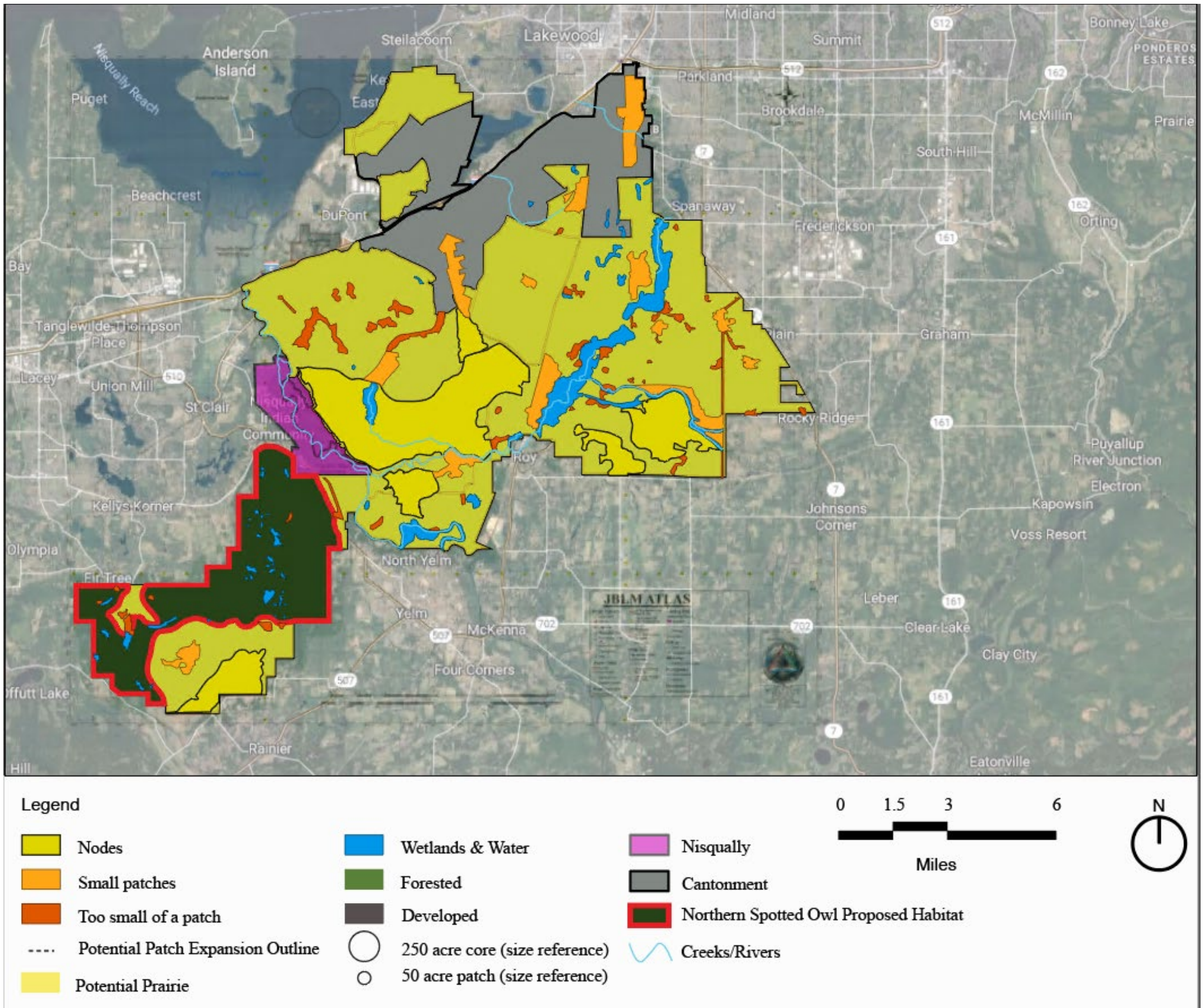


Figure 6.16. Option #4 plan shows maximized potential for prairie habitat restoration using soil suitability Excel categorization for prairies. It also shows current prairie patches by category. Aerial map taken from Google Maps and from (Talbot, 2018).

If fully realized, approximately two-thirds or around 60,000 acres of JBLM could be prairie, and this would multiply the total prairie in the Southern Puget Sound by several times. However, this is assuming that the primary goals of this site would become ecological in nature. A more likely scenario for a BRAC site is that a wide array of players including federal, state, county, city, and community would all want some portion of this site to apply directly to their needs. It is a highly complicated process that takes a long time to plan and execute. A conceptual BRAC design for this site would be an extensive project of its own, so I created a simple framework of how planning may go for a BRAC site.

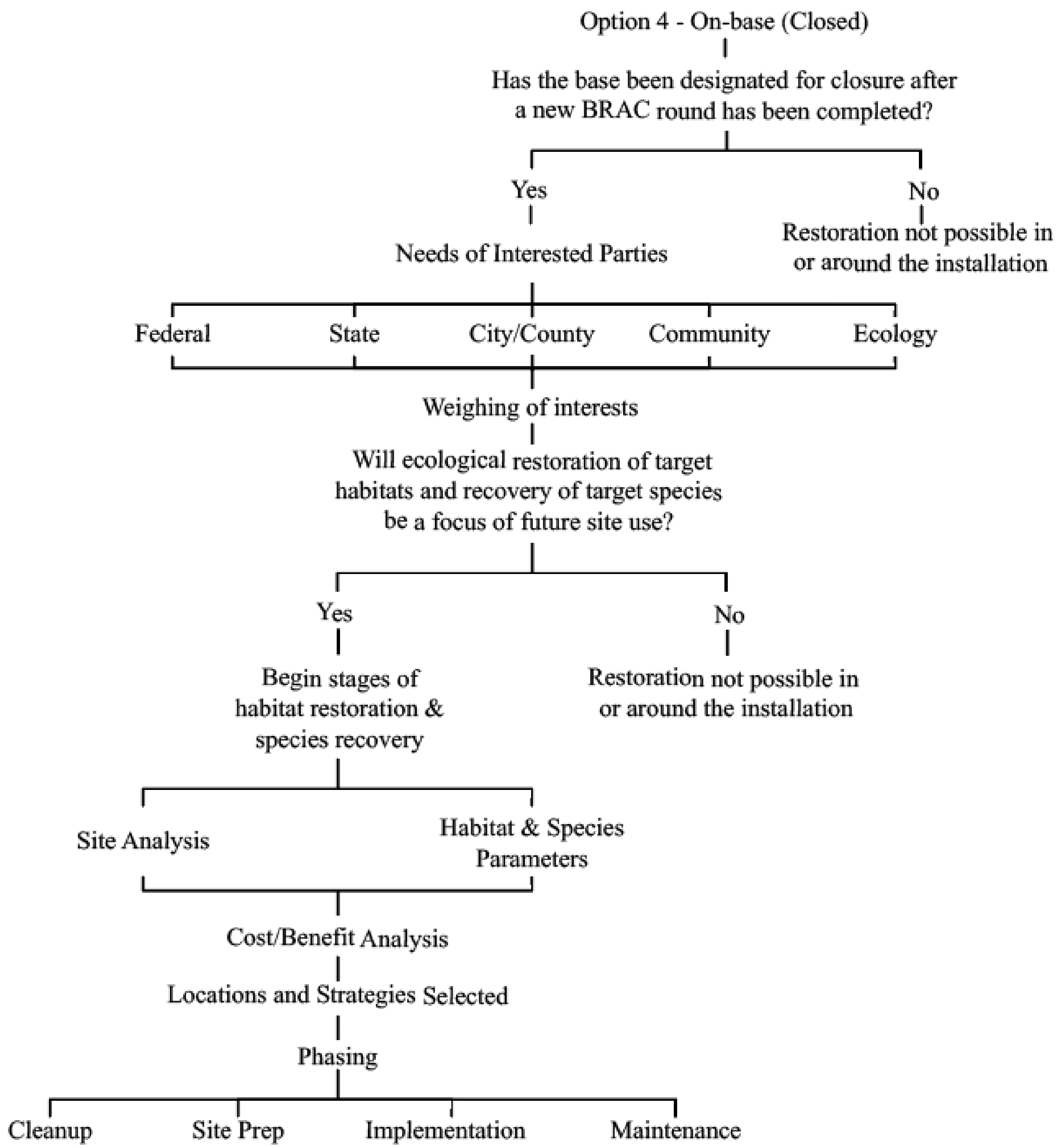


Figure 6.17. Diagram is the decision matrix for Options 2 and 3.

The restoration planning process would be like what was described throughout the bulk of this thesis, but it may not necessarily be a focal concern of a BRAC. Restoration may not even occur at all in some cases. For JBLM, the presence of critical habitat and listed species would likely make ecological restoration a concern, but the extent of how far that would go is unclear. It is doubtful that any valuable prairie habitat would be removed due to federal and state prevention, but additional prairie restoration, as well as a thorough maintenance and management regime, are not guaranteed. There are a lot of unknowns about this option, but it is still worth consideration.

The Naval Air Station (NAS) is one example military installation that eventually became a BRAC site. It was established in 1929 in Sand Point, next to Lake Washington. Its naval function changed over the years until in 1973, the Navy surplused a good portion of the property. Part of it was allotted to the National Oceanic and Atmospheric Administration (NOAA), part of it was distributed to the City of Seattle, and part of it was retained by the Navy to continue providing logistical services. The portion received by the City of Seattle was repurposed in 1977 into what is now Magnuson Park, a 198-acre park comprising habitat restoration, material reuse, sports playfields, and social gathering areas. The rest of the facility that was retained by the Navy was closed and repurposed after the Defense Base Closure and Realignment Act of 1990 (Naval Facilities Engineering Systems Control, n.d.). This project shows a division of recipients and how the recipients decide the purpose for their portion. In this case, ecological restoration was a major piece in the creation of Magnuson Park, but it is not necessarily always the case.

7. Conclusion

Summary

The four restoration options that I explored in this thesis all contain their own set of benefits and drawbacks. Each option was examined only at the surface-level to get a general understanding of potential solutions for critical prairie habitat in relation to JBLM. Certainly, each of these options can be explored at a greater depth than I have been able to do. For Option 1-On-Base (Active), the habitat corridor layout and expanded existing prairie patches are just examples of how it could be conducted, but a rigorous site analysis would be required to be more precise. The combination of habitat corridors and expanded habitat patches that I presented in my layout should be sufficient in size and spread to recover the three target prairie species, but there may be far more efficient ways to meet restoration goals. For Options 2-Off-Base (Contiguous) and Option 3-Off-Base (Separate), a thorough cost vs. benefit analysis is required to really figure out which parcels outside of JBLM are the premier locations for habitat restoration, and whether the amount of parcels available are enough to make an ecological impact. For Option 4-On-base (Active), the complexities involved in a military installation closing and being reallocated for other purposes are extraordinary, but the likelihood of this happening at JBLM are slim. There has been discussion of another BRAC round taking place in the future to select and strategize the closure of more military installations, and there is a strong chance that one or more of those installations have ecological issues that would need to be addressed. The restoration approach used in this thesis could present a logical precedent for how restoration could be conducted on future closing installations if restoration is an objective.

Options 1-3, where the interventions are shown on-base and off-base with the base remaining active, do not need to be mutually exclusive and ideas from each can overlap as seen fit after planning and strategizing. Options 2-4, with Option 4 being base closure, also do not need to be mutually exclusive. These options are strategies that can be interwoven with each other at various scales, all of which is dependent upon the individual site in question and its needs. Going through the rigor of this thesis exemplified the complex web of challenges unique to each installation, and JBLM is a prime example of a site with seemingly innumerable factors to be addressed. Solutions need to be carefully curated, using the knowledge of various experts and inputting the interests of various involved parties who ideally would all deliberate to come up with a balanced and fair solution. Ecologies, the military, communities, municipalities, and state and federal governments all have a marked interest at a balanced outcome, and this is a deeply stake-heavy topic that is rarely discussed in the field of Landscape Architecture.

Limitations

There were many barriers preventing me from maximizing the depth of my investigation in this thesis. The first was limited access both to information and to the site itself. There is a substantial amount of information publicly available and published by the military, JBLM, and other federal agencies pertaining to site and environmental information about JBLM. However, there are much finer-grained details that I was unable to gather that would have allowed me to explore this thesis more deeply and more specifically. These restrictions to information are in place for a reason, so it would be up to those involved with the installation itself and future projects to be able to gain access and make a fully-fledged analysis. Limited site access was also an issue, one I expected since military installations have restricted access for security reasons. However, this prevented me from being able to access prairies and gain a first-hand understanding of the habitat targeted for my thesis.

Another major limitation was time. The relationship between ecology and the military is far more complex than I expected. It took many months to sift through the research and be able to narrow and focus on my subject. I was only able to explore high-level concepts without really testing implementation feasibility. However, the "Options" built into this project could be used in the future to explore these ideas further.

I also encountered limitations for specific site factors and considerations. I did not map out the locations of other at-risk species that may have been affected by my Option 1 layout. I also did not account for topography or soil chemistry, both of which could have been major players in determining where prairie restoration was possible. These factors might have more thoroughly defined the locations, shapes, and directions of habitat corridors, and would have affected the way I chose to layout expanded prairie patches. I also did not consider social factors. The Nisqually Reservation may have played a more major role in deciding strategies had I had more time to delve into how various players affect how restoration may be implemented. Neighboring communities and parcel purchasing were also acknowledged, but not defined to any further degree. Finally, I did not account for a maintenance plan for restoration. I was able to define parameters of prairie restoration that would attract and ideally host all three target prairie species, but the longevity of restored prairie is also highly important because of its desired disturbance regime. Entities working with JBLM are already managing a significant amount of land, but the maintenance of prairie corridors and a much higher total acreage of prairie may or may not be tenable.

Reflection

I sit in an interesting, dual position that led me to undergo this thesis. On one hand, I have an ecological background, and on the other hand, I am a member of the US military. Both personas desire their own outcomes, and both face barriers in achieving them. In my intermediary position, I wanted to explore this dichotomous relationship to uncover links that exist between the two, and thus to hopefully learn more about myself.

Prior to entering the Landscape Architecture program, I spent several years involved in the horticultural realm. I have done several restoration projects large and small, I worked in a nursery for a time, I started gardening at home, and I spent approximately two years as a landscape maintenance worker and a pruner. This gave me a general understanding of how restoration worked, and the strategies involved in developing and executing a restoration project. I did not feel like focusing on restoration would be much of a challenging topic when deciding on a thesis topic since I had done plenty of it already, but I did not leave it off the table.

The same time I entered the Landscape Architecture program, I enlisted in the Army National Guard. I wanted to pursue a higher meaning, something beyond my own personal goals. I also wanted to become a stronger and more capable person like many of my family members have become through their service. I had previously thought that the military world and my pursuit of becoming a landscape architect were entirely separate from each other, but that was only until I tried to put them together.

This project revealed to me that things may overlap and interrelate in ways that you would not see by staring at them from the surface. It was difficult to hone in at first as I was trying to understand this previously unknown relationship. My thesis was constantly changing as the digital stack of articles and papers I was reading continued to increase. I felt as though every time I was about to lock in on a topic relating the two, more information would appear that would catch my attention and move me in a different direction. That is when I found some interesting articles on the dwindling prairie habitat in the Southern Puget Sound and how most of the remaining habitat was on JBLM. I found this to be interesting and eventually created this thesis project.

Overall, this thesis essentially became an introduction into what could become many different projects. I was unable to provide definitive solutions for how to restore prairie habitat, but I was able to identify numerous factors that would play a role in that process and lay out generalized restoration approaches. Every time I tried to enter a design mindset, I would end up finding another factor that would pull me back out so I could try to figure out how to address it. This kept happening until I realized the absolute breadth of this subject, and I had to settle with a broadened version of my original intent. However, what did spawn out of this process was an understanding that this issue of critical habitats and installations is not singular, and how there are many installations running into similar ecological conundrums. I have not seen work from other Landscape Architects on this subject nor have I had conversations about it prior to this year, but I think that this subject is fascinating and that others may think the same once they see it for what it is.

Bibliography

AECOM. (2015). *Joint Base Lewis-McChord Joint Land Use Study*. https://cms.cityoftacoma.org/Planning/JLUS APZ Overlay/JBLM JLUS Existing Conditions Report - final.pdf

Anderson, H. E., & Pearson, S. F. (2015). Streaked Horned Lark Habitat Characteristics Streaked Horned Lark Basics. *Center for Natural Lands Management, Washington Department of Fish and Wildlife*, *April*. https://cascadiaprairieoak.org/wp-content/uploads/2015/04/Streaked-horned-lark-habitat-characteristics_April-2015.pdf

Beck, T. (2013). An Ever-Shifting Mosaic: Landscape Ecology Applied. *Principles of Ecological Landscape Design*, 209–233. https://doi.org/10.5822/978-1-61091-199-3_9

Benton, N., Ripley, J. D., & Powledge, F. (2008). Conserving Biodiversity on Military Lands: A Guide for Natural Resources Managers. In *Conserving Biodiversity on Military Lands: A Guide for Natural Resources Managers*.

Biodiversity. (2021). Population Matters. https://populationmatters.org/biodiversity

Buchholz, K. (2020). *Number of Threatened Species is Rising*. Statista. https://www.statista.com/chart/17122/number-of-threatened-species-red-list/

Burkhardt, J. (2018). *Putting a Number on the Impact of JBLM*. University of Washington Tacoma. https://www.tacoma.uw.edu/news/article/putting-number-impact-jblm

Charlton, E. (2018). *We've lost 60% of wildlife in less than 50 years*. World Economic Forum. https://www.weforum.org/agenda/2018/10/weve-lost-60-of-wildlife-in-less-than-50-years

Dalsimer, A. A. (2016). *Threatened and Endangered Species on DoD Lands*. DoD Natural Resources. https://denix.osd.mil/nr/archive/archived-documents/threatened-and-endangered-species-on-dod-lands/

Damschen, E. I., Brudvig, L. A., Burt, M. A., Fletcher, R. J., Haddad, N. M., Levey, D. J., Orrock, J. L., Resasco, J., & Tewksbury, J. J. (2019). Ongoing accumulation of plant diversity through habitat connectivity in an 18-year experiment. *Science*, *365*(6460), 1478–1480. https://doi.org/10.1126/science.aax8992

Dramstad, W., Olson, J. D., & Forman, R. T. T. (1996). *Landscape Ecology Principles in Landscape Architecture and Land-Use Planning*. Harvard University Graduate School of Design, Island Press and the American Society of Landscape Architects.

Duggan, J. M., Eichelberger, B. A., Ma, S., Lawler, J. J., & Ziv, G. (2015). Informing management of rare species with an approach combining scenario modeling and spatially explicit risk assessment. *Ecosystem Health and Sustainability*, *1*(6), 1–18. https://doi.org/10.1890/EHS14-0009.1

Ellwanger, G., & Reiter, K. (2019). Nature conservation on decommissioned military training areas – German approaches and experiences. *Journal for Nature Conservation*, *49*(May 2018), 1–8. https://doi.org/10.1016/j.jnc.2019.02.003

Endangered Species Act | Overview. (2020). U.S. Fish and Wildlife Service. https://www.fws.gov/endangered/laws-policies/

Forestry Branch, E. D., & Directorate of Public Works. (2017). *Forest Management plan*. U.S. ARMY JOINT BASE LEWIS-McCHORD WASHINGTON. https://www.sttas.com.au/sites/default/files/media/documents/plans/FMP_May_2018_published.pdf

Gorte, R. W., Vincent, C. H., Hanson, L. A., & Rosenblum, M. R. (2013). Federal land ownership: Overview and data. *Federal Land Ownership: Elements and Considerations*, 1–30. https://fas.org/sgp/crs/misc/R42346.pdf

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., Lovejoy, T. E., Sexton, J. O., Austin, M. P., Collins, C. D., Cook, W. M., Damschen, E. I., Ewers, R. M., Foster, B. L., Jenkins, C. N., King, A. J., Laurance, W. F., Levey, D. J., Margules, C. R., … Townshend, J. R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, *1*(2), 1–10. https://doi.org/10.1126/sciadv.1500052

Hancock, S., Burnett, W., Eckert, J., Greif, J., Helms, M., Fix, D., Hyjek, S., Stegenga, K., Fix, M., Ripetta, K., & Lowenberg, M. G. (Ret. . T. (n.d.). *Retaining and Expanding Military Missions: Increasing Defense Spending and Investment*. Denny Miller Associates Hyjek & Fix, Inc. https://www.ofm.wa.gov/sites/default/files/public/legacy/reports/mil_report.pdf

Hilty, J., Worboys, G. L., Keeley, A., Woodley, S., Lausche, B. J., Locke, H., Carr, M., Pulsford, I., Pittock, J., White, J. W., Theobald, D. M., Levine, J., Reuling, M., Watson, J. E. M., Ament, R., & Tabor, G. M. (2020). Guidelines for conserving connectivity through ecological networks and corridors. *IUCN*, *30*. https://doi.org/10.2305/iucn.ch.2020.pag.30.en

Johnson, C. (2010). *Butterfly Restoration Project*. http://www.swanlake-preservation.org/butterflyrestoration.html

Kronland, B., & Martin, A. (2015). Prairie Habitat Management Joint Base Lewis-McCord 2014 Annual Report. *Center for Natural Lands Management*, *April*. https://cascadiaprairieoak.org/wp-content/uploads/2015/04/PrairieHabitatAnnual_2014_FINAL.pdf

Land Watch. (2021a). *Pierce County, WA Land Information*. CoStar Realty Information, Inc. https://www.landwatch.com/washington-land-for-sale/pierce-county#:~:text=Internal data from LandWatch records,for sale here is %24582%2C995

Land Watch. (2021b). *Thurston County, WA Land Information*. CoStar Realty Information, Inc. https://www.landwatch.com/washington-land-for-sale/thurston-county#:~:text=LandWatch data lists over %2463,for sale here is %24986%2C597

Lee Jenni, G. D., Nils Peterson, M., Cubbage, F. W., & Jameson, J. K. (2012). Assessing biodiversity conservation conflict on military installations. *Biological Conservation*, *153*, 127–133. https://doi.org/10.1016/j.biocon.2012.05.010

Machlis, G. E., & Hanson, T. (2011). Warfare Ecology. *NATO Science for Peace and Security Series C: Environmental Security*, *113*(8), 33–40. https://doi.org/10.1007/978-94-007-1214-0_5

Marine Corps Air Station Futenma. (2013). CNN. https://www.cnn.com/2013/12/27/world/gallery/marine-corps-air-station-futenma/index.html

Miller, J. R., & Hobbs, R. J. (2007). *Habitat Restoration—Do We Know.pdf*. *15*(3), 382–390. http://millerlab.nres.illinois.edu/pdfs/Habitat Restoration - Do We Know What We're Doing.pdf

Moning, C. (2015). *Horned Lark*. Macaulay Library. https://www.allaboutbirds.org/guide/Horned_Lark/media-browser

National Resources Conservation Service. (1999). Part 614.4 Conservation Corridor Planning at the Landscape Level. *National Biology Handbook*, *August*.

Natural Resources Conservation Service. (n.d.). *Web Soil Survey*. https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Naval Facilities Engineering Systems Control. (n.d.). *Former Naval Station Puget Sound at Sand Point*.

NMFWA. (2004). The Sikes Act. *National Military Fish and Wildlife Association Government Affairs Committee*, 11. papers2://publication/uuid/B4383F1D-0EBA-44A7-88BD-7B3C5ABFC0F9

Oregon Fish and Wildlife Service. (n.d.). *Streaked horned lark*. U.S. Fish and Wildlife Service. https://www.fws.gov/oregonfwo/articles.cfm?id=149489450

Oregon Fish and Wildlife Service. (2020). *Streaked horned lark*. U.S. Fish and Wildlife Service. https://www.fws.gov/oregonfwo/articles.cfm?id=149489450

PAO, J. (2017). *Timeline: From Camp Lewis to Joint Base Lewis-McChord*. Northwest Military. https://www.northwestmilitary.com/guides/online-newspapers/2017/08/timeline-from-camp-lewis-to-joint-base-lewis-mcchord

Perdue, V. (n.d.). Land-Use and the Fort Lewis Prairies. *The Nature Conservancy of Washington*, *Cascade Pr*. https://cascadiaprairieoak.org/documents/LandUseandFtLewis.pdf

Potter, A. E. (2016). *STATE OF WASHINGTON Periodic Status Review for Taylor ' s Checkerspot*. Washington Department of Fish and Wildlife. https://wdfw.wa.gov/sites/default/files/publications/01798/draft_wdfw01798.pdf

Protecting Endangered Species on Military Lands: Successful Species Recovery. (2004). U.S. Department of Defense and U.S. FIsh and Wildlife Service. https://denix.osd.mil/nr/threatenedendangeredandatriskspecies/federallylisted/factsheets/fact-sheet-successful-t-and-e-species-recovery-dod-u-s-fish-and-wildlife-service/

San Clemente Loggerhead Shrike. (2019). The Institute for Wildlife Studies. http://www.iws.org/species_loggerhead_shrike.html

Schultz, J. (2016). Preparing for Duty State Policy Options to Sustain. *Military and Veterans Affairs*. https://www.ncsl.org/Portals/1/Documents/Military_Veterans/PreparingDuty_Revised_120616.pdf

Sentinel Landscapes. (2020). *2020 SENTINEL LANDSCAPES ACCOMPLISHMENTS REPORT*. USDA. https://sentinellandscapes.org/media/0rukteuq/2020-sentinel-landscapes-accomplishments-report_final_28jul20.pdf

SENTINEL LANDSCAPES | Joint Base Lewis-McChord. (n.d.). *SENTINEL LANDSCAPES*. United States Department of Agriculture. https://hccc.wa.gov/sites/default/files/resources/downloads/Sentinel Lands JBLM_091515.pdf

Species at Risk on DoD Installations. (2011). Nature Serve.

Stetka, B. (2016). *Prehistoric Carnage Site Is Evidence of Earliest Warfare*. Scientific American. https://www.scientificamerican.com/article/prehistoric-carnage-site-is-evidence-of-earliest-warfare/

Stinson, D. (2005). Washington State Status Report for the Mazama Pocket Gopher, Streaked Horned Lark, and Taylor's Checkerspot. *Washington Department of Fish and Wildlife*, *July*. https://wdfw.wa.gov/sites/default/files/publications/00390/draft_prairie_species.pdf

Stinson, D. W. (2016). Periodic Status Review for the Streaked Horned Lark. *Washington Department of Fish and Wildlife*, *June*, 28. https://doi.org/10.13140/RG.2.1.4107.0960

Stinson, D. W. (2020). Mazama Pocket Gopher Recovery Plan and Periodic Status Review. *Washington Department of Fish and Wildlife*, *August*. https://wdfw.wa.gov/sites/default/files/publications/01449/wdfw01449.pdf

Talbot, K. (2018). *JBLM Atlas V2*. https://home.army.mil/lewis-mcchord/application/files/6715/5372/2770/JBLM_Atlas_v2.pdf.

U.S. Army. (n.d.). *JOINT BASE LEWIS-MCCHORD*. https://home.army.mil/lewis-mcchord/index.php/about/history

U.S. Fish and Wildlife. (n.d.). *Introducing... The Mazama Pocket Gopher*. https://www.arcgis.com/apps/Cascade/index.html?appid=a99553093e5a45b183c18e8cf0762176

U.S. Fish and Wildlife Service. (n.d.-a). *Species Fact Sheet Mazama pocket gopher Thomomys mazama (ssp. couchi, douglasii, glacialis, louiei, melanops, pugetensis, tacomensis, tumuli, yelmensis)*. https://www.fws.gov/wafwo/species/Fact sheets/MazamaPocketGopher_final.pdf

U.S. Fish and Wildlife Service. (n.d.-b). *Species Fact Sheet Streaked Horned Lark Eremophila alpestris strigata*. https://www.fws.gov/wafwo/species/Fact sheets/streakedhornedlarkfinal.pdf

U.S. Fish and Wildlife Service. (n.d.-c). *Taylor's Checkerspot Butterfly*. https://www.fws.gov/wafwo/articles.cfm?id=149489655

United States v. Apel. (2014). Casetext. https://casetext.com/case/united-states-v-apel-2.

Washington Department of Fish and Wildlife. (2013). *Mazama Pocket Gopher (Thomomys mazama)*. Puget Sound Institute, University of Washington. https://www.eopugetsound.org/articles/mazama-pocket-gopher-thomomys-mazama

Wray, J. D. (1976). What does conservation mean. *Journal of Biological Education*, *10*(3), 115. https://doi.org/10.1080/00219266.1976.9654071