DETERMINING SUITABILITY OF HABITAT FOR REINTRODUCTION OF THE WESTERN POND TURTLE (*Actinemys marmorata*) AT FORT LEWIS, WASHINGTON

by

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ABSTRACT

Determining suitability of habitat for reintroduction of the western pond turtle (*Actinemys marmorata*) at Fort Lewis, Washington

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Amphibians and reptiles have experienced a decline coinciding with the degradation of aquatic ecosystems. For decades, environmental agencies have been spending resources restoring threatened species populations and aquatic systems. One such effort is that of the Washington Department of Fish and Wildlife (WDFW) with the western pond turtle (*Actinemys marmorata*, formerly *Clemmys marmorata*) which was historically found from southern British Columbia to Baja, California, but are now endangered over most of their range. The WDFW has a goal of re-establishing five separate populations in the Puget Sound. Fort Lewis, is considered to be a possible suitable habitat for reintroduction because the pond turtle was historically found there. However, recent successive abundance surveys at nine sites did not find a single turtle. The goal of this thesis is to review the causes for *A. marmorata* decline and to examine if suitable habitat for it exists on Fort Lewis. Habitat data (distance to the water, distance to the nearest basking site, canopy cover at ten centimeters, overhead canopy cover, leaf litter depth, distance to the road, bottom substrate type, shoreline accessibility, vegetation type, and presence/absence of south-facing slope) was collected at all nine sites as well as on the site where current reintroduction efforts are focused in Lakewood, Washington and compared in order to determine reintroduction suitability of all the Fort Lewis sites. The data was also compared among sites to determine the best reintroduction candidates. It was hypothesized that Johnson Marsh and Clay Pit habitats on Fort Lewis would be statistically similar to that found at Lakewood, and that Johnson Marsh would be the most suitable of the nine sites due to its size and ecological complexity. A hierarchical cluster analysis of the data revealed that Spanaway Marsh was statistically similar to the Lakewood site habitat (cophenetic correlation coefficient = 0.811, p-value < 0.0001). A ranked comparison of the Fort Lewis locations showed the most suitable reintroduction site to be Clay Pit. Suitable habitat was defined as a site ranked in the upper third for at least three of the habitat characteristics and no more than once in the lowest third in any one of the eight habitat categories. All nine Fort Lewis sites, with minimal alteration, would be potential reintroduction locations. Another promising Fort Lewis habitat, Nisqually Lake, was considered, but not surveyed because it's within the hazardous Artillery Impact Area and study of this area is recommended. Another recommendation for future work arising from this study would be for WDFW to determine the habitat characteristics that are most important in defining a suitable reintroduction site. This thesis also discusses: the possible causes for the decline of *A. marmorata* in Fort Lewis and the current status of restoration efforts at the recovery zone in Lakewood through the efforts of WDFW and the Oregon and Woodland Park Zoos.

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1. Introduction

The western pond turtle (*Actinemys marmorata*, formerly *Clemmys marmorata*) is considered to be an indicator species of both healthy aquatic ecosystems and upland grassland habitat due to its semi-aquatic nature (Animals 1991, Bickham and Smolen 1994, Lamb *et al*. 1995, and Ulsh *et al*. 2000). Their contribution to ecosystems can also be significant. Iverson (1982) found that single species standing crop biomass for turtles, including western pond turtles in California, were consistently among the highest for vertebrates. This finding suggests that turtles have a far higher importance in the ecosystem than is currently understood. The possible ecological importance of turtles makes the decline of *A. marmorata* over most of its historic habitat quite serious. In response to this decline, the Washington Department of Fish and Wildlife (WDFW) developed the *Washington State Recovery Plan for the Western Pond Turtle* in 1999 (Hays *et al.* 1999). The resources and funds budgeted for the recovery of *A. marmorata* every year are relatively small compared to that of other species in Washington State, and depends on availability of state monies. Continued budget cuts threaten continuity of the recovery efforts (Budget 2011).

Currently, only one reintroduction site within the Puget Sound recovery zone, a series of manmade ponds in Lakewood, Washington, is being managed (Schmidt *et al*. 2008). This site was selected as it was already being managed as an urban wildlife park and had the space for an enclosed reintroduction wetland system. The Lakewood site consists of twelve acres within the South Puget Sound Wildlife Area (SPSWA), a 90 acre state owned parcel in Pierce County. Three ponds were constructed from an existing spring seep, native trees and shrubs were planted along the margin, and the entire area was fenced. In the southwest corner, a nesting hill was built from fill and project debris. The first turtles were reintroduced in 1996, and, as of 2008, 145 western pond turtles inhabited SPSWA. Females carry radio transmitters in order to track movements during the nesting season, and eggs are removed from the nests for head-start rearing at the Oregon and Woodland Park Zoos (Future 2007, Schmidt *et al*. 2008, Slavens 2003, and Slavens and Slavens 1998).

To maximize the limited funds for *A. marmorata* recovery, the state might consider using existing suitable reintroduction habitat on federal lands. Fort Lewis, a US army base in Washington State has already allowed WDFW to reintroduce the Oregon spotted frog (*Rana pretiosa*) at one site, Dailman Lake, as part of a pilot project started in 2007 (Barrentine 2009 and Hawk 2010). Since 2008, approximately 2,300 head-started juveniles have been released at the site.

This thesis project examined the potential of Fort Lewis lands as a possible reintroduction site. Fort Lewis is within the historic range of the *A. marmorata*, and works in partnership with WDFW on the recovery and continued success of species such as the Streaked Horned Lark (*Eremophila alpestris strigata*), Oregon Vesper Sparrow (*Pooecetes gramineus affinis*), Western Bluebird (*Sialia mexicana*), Mazama pocket gopher (*Thomomys mazama*), western gray squirrel (*Sciurus griseus*), mardon skipper butterfly (*Polites mardon*), Taylor's checkerspot butterfly (*Euphydryas editha taylori*), and Oregon spotted frog (*R. pretiosa*). Also, land managers at Fort Lewis currently manage plant species beneficial to these animal species such as rare oak savannah, prairie grassland, wetland, and riparian habitats.

There are several aquatic locales on Fort Lewis that would make suitable reintroduction sites for *A. marmorata* with very little alteration. Suitable habitat was defined as a site ranked in the upper third for at least three of the habitat characteristics and no more than once in the lowest third in any one of the eight habitat categories. This could result in a rank summed score as great as 42. The reasoning for this definition of suitability is that it would be prohibitively expensive to alter habitat characteristics in order to make a site suitable, so a site already meeting a greater portion of those criteria would be most suitable for reintroduction. This project investigated suitability of the habitats at Johnson Marsh and Clay Pit and tested if they were similar to habitat found at the Lakewood site that has been identified by the State as suitable for turtle reintroduction based on the site's availability, ecological complexity, size, proximity to dry native oak/prairie uplands, and the ability for WDFW personnel to control access to the site (Hays *et al*. 1999). Of nine historic *A. marmorata* locations on Fort Lewis, Johnson Marsh probably ranks the highest for suitability for reintroduction due to the site's size and ecological complexity. Thus, it was hypothesized that this site would most closely match the characteristics of an ideal *A. marmorata* habitat. Below is background information on the biology and ecology of *A. marmorata*, including information on its decline. Background information on the Fort Lewis site, the selected study locations, and their potential as restoration sites is also presented. Finally, the questions/hypotheses guiding this research are discussed.

1.1. Habitat Requirements and Life History

Actinemys marmorata is a semi-aquatic species found in a wide variety of aquatic habitat types (Hays *et al*. 1999). However, it has very specific habitat requirements. Their home ranges are only 0.62 to 2.47 acres in size, though they are capable of moving distances of up to five kilometers (Holland 1994, as cited in Hays *et al*. 1999). They utilize small, shallow lakes, sloughs, rivers, streams, ponds, and wetlands (Bury 1986 and Hays *et al*. 1999). They prefer locations with slow moving water and an abundance of basking sites.

Basking sites include emergent and submerged vegetation, rocks, sand, downed logs or branches, planks, and even the carcasses of large mammals. Basking is an important behavior needed to maintain their metabolism, development of eggs, to rid themselves of skin parasites, and for synthesis of vitamin D (Lindeman 1999). The prime spots on basking sites are fought over via aggressive behaviors such as biting, mouth gaping, pushing, leg swiping, and climbing atop, with larger turtles most often winning the better positions (Bury and Wolfheim 1973, Lindeman 1999).

Underwater refugia are also important for predator avoidance, and the pond turtle is a very wary species that rarely basks more than a few meters from a potential refuge (Bury and Wolfheim 1973, Hays *et al*. 1999). When scared, a pond turtle will swim rapidly underwater to hide under submerged refugia. These may consist of undercut banks, holes, various sized rocks, or submerged logs or vegetation. If the substrate is soft enough, a turtle may even burrow into the mud for protection.

Pond turtles are dietary generalists that primarily eat aquatic invertebrates and carrion and, occasionally, small fish and frogs (Hays *et al*. 1999). They may also ingest insects from the surface of the water such as grasshoppers or beetles (Bury and Stringer 1992). Pond turtles do not select food based on general availability, but rather, they are opportunistic predators that prefer live prey (Bury 1986). Males tend to eat more live vertebrate prey items than do females, and algae and vegetation make up a greater percentage of the female pond turtle diet. At certain times of the year, females may ingest large quantities of cattail (*Typha latifolia*) or bulrush (*Scirpus* spp.) roots, water lily pods, or alder (*Alnus* spp.) catkins (Hays *et al*. 1999). Bullfrog (*Rana catesbeiana*) tadpoles and adults do not appear to be preyed upon by pond turtles, and this may be due to unpalatable compounds in the skin of the frogs.

Upland habitat is important at all life stages. Gravid females take multiple trips on land before nesting, where they bury themselves in dirt and leaf litter (Reese and Welsh 1997). It is hypothesized that this burial might facilitate thermoregulation and thus benefit pre-ovipositional embryo development. Hatchlings were found to overwinter in their upland nest, after an incubation period of 95-127 days, for up to eight months after the females laid eggs, most likely for protection from predators and winter scouring of waterways at high flow periods (Reese and Welsh 1997). Upland habitat is also critical for overwintering of adults, who leave the aquatic habitat from October through

March or April. These turtles hide under logs, leaves, or bury themselves in mud during this period of hibernation. They prefer sites with 80-90% shrub and tree canopy cover beneath or near Oregon white oak (*Quercus garryana*) (Hays *et al*. 1999).

Individual turtles are slow to sexually mature and can be long-lived. Males can take up to twelve years to mature, and females can take seven years to mature (Hays *et al*. 1999). Although the average life span is unknown, the estimated maximum is 50-70 years, and the longest lived wild pond turtle lived to be 42. Females usually only lay two to thirteen eggs per year between the end of May and early July, and clutch size is positively correlated with female body size (Forsman and Shine 1995). Eggs are laid in upland nests up to 100 meters from the water's edge.

1.2. Distribution and Taxonomy

Historically, *Actinemys marmorata* was found from southern British Columbia south through Baja California, mostly west of the Sierra-Cascade crest (Figure 1; Hays *et al*. 1999). Its presence in Canada seems to be controversial, and if it was present, it may not have been very abundant (Storer 1937). Specimens sent to Canadian museums were not reliably identified, and records are inadequate. An individual *A. marmorata* was positively identified near Burnaby Lake in Vancouver, BC by Ian McTaggert Cowan in 1933, but that is the only record of this species in that area in the late 1930s (Cowan 1938). In Oregon and California, the museum records and availability of fossil evidence are better for establishing the presence of *A. marmorata* (Brattstrom 1953 and 1955, Bury 1963, Crippen 1962, Graf, Jewett, and Gordon 1939, Mosaur 1935, Ruthling 1915, and Storm 1949). These records range from a few jaw bones to preserved complete animals in museums.

Although there is no historic data on the size or dynamics of *A. marmorata* populations in the Columbia River Gorge or Puget Sound areas, there are written accounts of large populations inhabiting Old Fort Lake near Dupont, Washington in the 1860s (Hays *et al*. 1999). Additionally, Native Americans recall stories of gathering turtle eggs at Nisqually Lake, and the Nisqually name for the lake translates to "place where the turtles came from," so it is assumed that *A. marmorata* was locally abundant in the Puget Sound region. Fossils from the Pleistocene strata in south-central Washington indicate a wider range than present distribution (Brattstrom and Sturn 1959). Records indicate that *A. marmorata* were found over much of western Washington, although the majority of records were only single individuals that may have been relocated by humans (Hays *et al*. 1999). It has been proposed that the Puget Sound population was isolated from the Willamette drainage by a pyroclastic event from Mount Rainier about 4,700 years ago (Holland pers. comm., as cited in Hays *et al*. 1999).

Until recently, the pond turtle was taxonomically grouped into the genus *Clemmys* which consisted of four species, *C. insculpta*, *C. guttata*, *C. muhlenbergii*, and *C. marmorata* (Crother *et al*. 2003). However, recent work on the molecular level has supported the assignment of three genera to this group. The genus name *Clemmys* has been replaced with the genera *Actinemys*, *Emys*, and *Emydoidea*. *A. marmorata* is actually a monotypic sister to the other three species.

There are two distinct subspecies of *A. marmorata* (McDowell 1964, as cited in Bickham 1975, Bickham *et al*. 1996, Bramble 1974, Burke, Leuteritz, and Wolf 1996, Frair 1982, Gray 1995, Merkle 1975, and Seidel 2002). Studies on the variations of hemoglobin, sequencing of mitochondrial and nucleic DNA, serum proteins, and shell morphology helped delineate between the subspecies. The northern subspecies, *A. m. marmorata*, is found from the Puget Sound south to the Sacramento Valley, California (Behler and King 1979, Crother *et al*. 2003, and Hays *et al*. 1999). The southern species, *A. m. pallida*, overlaps at the north end of its range with *A. m. marmorata* and ranges from Monterey, California to Baja California Norte. Both subspecies are threatened.

1.3. Causes of Decline

The initial cause of *Actinemys marmorata* population declines was due to commercial collection for the restaurant and pet trades (Hays *et al*. 1999). The South Puget Sound region's populations were extirpated by the 1980s due to habitat destruction and fragmentation, predation by introduced species, environmental toxins, and demographic stochasticity. Only two meta-populations persisted in the Columbia River Gorge area, both less than 120 individuals (Bury and Stringer 1992, Hays *et al*. 1999).

Pond turtles do not thrive in habitats that have been altered by humans (Hays *et al*. 1999). Wetland draining, filling, and development and stream and river damming, dredging, channelizing, and use for irrigation have eliminated suitable habitat over the twentieth century. These actions alter water levels, create physical barriers, decrease basking site availability, and create suitable habitat for non-native species. They may also increase sedimentation and water temperatures and velocities and decrease canopy cover. Grazing by domestic cattle may remove emergent vegetation and modify aquatic and terrestrial habitats. Urbanization decreases upland habitat suitability by decreasing the availability of nesting and overwintering sites. The presence of roads creates physical barriers between aquatic and terrestrial habitats. Habitat destruction and fragmentation makes it difficult, if not impossible, for adults to locate new habitat when occupied habitat becomes unsuitable because habitat is disperse and disconnected.

Introduced species either prey upon pond turtles directly, or carry pathogens to which pond turtles are extremely susceptible (Hays *et al*. 1999). In the case of sports fish, introductions are a direct result of human action. Sunfish, red-eared sliders (*Trachemys scripta elegans*), and snapping turtles (*Chelydra* spp.) compete with pond turtles for prey (Thomson *et al*. 2010). Other introductions, such as bullfrogs (*Rana catesbeiana*) and opossums (*Didelphis virginiana*), are aided by indirect human actions that make habitat more suitable for their occupation (Hays *et al*. 1999). Bullfrogs, naturally found in the eastern US, were introduced to Idaho in the 1890s, and to Oregon in the 1920s and are now found throughout the range of the pond turtle. They prey upon juvenile pond turtles, as well as many other vertebrates. Humans also alter habitat to increase the presence of native predators, such as raccoons (*Procyon lotor*).

People releasing pet turtles have introduced pathogens into the environment of the pond turtle. Pathogens include internal and external parasites and diseases. Leeches (*Placabodella* spp.) are their only known ecto-parasites. In 1930, L. G. Ingles found a new parasite (*Telorchis* sp.) inhabiting the intestines of pond turtles, and seven different species of trematodes and nematodes were found by V. E. Thatcher (1954) to infect pond turtles. A syndrome similar to upper respiratory disease caused a severe decline of the already decimated Klickitat County population in the Columbia River Gorge in 1990, but tests failed to identify the causal agent.

The effects of toxins on pond turtles have not been studied in detail (Hays *et al*. 1999). Diesel spills and Rotenone, a biodegradable compound used to eradicate fish species for fisheries management, have been found to kill turtles. Because of their long lifespan and their tertiary position in the food chain, they may act as bio-accumulators of heavy metals and other toxins. Endocrine mimics may interrupt turtle reproduction or detrimentally skew a population's sex ratio (Daughton and Ternes 1999 and Hays *et al*. 1999).

Due to low recruitment rates, pond turtle populations cannot sustain the increased adult mortality rates caused by human exploitation and increased predation (Hays *et al*. 1999). Late sexual maturity and small clutch sizes in this species put it at greater risk for decline when populations are low. The Klickitat County population in the Columbia River Gorge was moderately adult-biased, with about 80% of the population at adult sizes in 1999. Under normal circumstances, populations are comprised of less than 70% adults, so the Klickitat

County population was thought to be declining prior to human intervention. The Skamania County population was less than 40 individuals in 1994.

1.4. Current Management of the Western Pond Turtle

1.4.1. Legal status

Currently, the pond turtle is listed as Endangered in Washington, a Sensitive Species in Oregon, a Species of Concern in California, a Federal Species of Concern, and is extirpated in British Columbia (Hays *et al*. 1999). The Washington Department of Fish and Wildlife's (WDFW) goal, as written in the recovery plan for the pond turtle, is: "to re-establish self-sustaining populations of *Actinemys marmorata* in the Puget Sound/Puget Trough and Columbia Gorge recovery zones." It requires that at least five populations of more than 200 individuals with no more than 70% adults be established in both the Puget Sound region and Columbia River Gorge (Future 2007).

1.4.2. Current Management Actions

The WDFW began taking steps to intervene in the pond turtle's survival when the remaining Columbia River Gorge populations suffered severe declines from an unidentified pathogen (Hays *et al*. 1999). Current management actions in Washington include habitat acquisition and restoration, captive breeding and head start programs for juveniles, predator removal programs, toxicology research, public education programs, and continued monitoring of population abundance.

Habitat acquisition is probably the most expensive but also most beneficial management activity. Private lands surrounding the Columbia River Gorge habitat were either purchased by WDFW or The Nature Conservancy, or easements were granted by the landowners to ensure that the property would not be developed (Hays *et al*. 1999). Grazing was discontinued at most sites. An artificial habitat was constructed near Lakewood, Washington in the Puget Sound region, consisting of a series of ponds for reintroduction purposes. Enhancement activities include placing more basking sites, removing non-native shrubs and grasses from banks, and planting Oregon white oak (*Quercus garryana*) trees.

The captive breeding and head start programs are the second most important component for continued survival of the pond turtle, and they are the most time intensive management activities. It has been determined that hatchling and juvenile life stages are the most at risk for predation and the most crucial for the continued survival of this species (Hays *et al*. 1999). Therefore, a head start program for juvenile turtles was initiated in 1990, after the unknown pathogen outbreak in Klickitat County. The goal of the program was to give turtle hatchlings a "head start" by raising them at the Woodland Park Zoo to a size that would prevent predation by bullfrogs (*Rana catesbeiana*). This increase in size has been shown to increase survival rate from hatchling to juvenile life stages. Hatchlings were obtained by trapping and equipping females with transmitters in the spring, monitoring the females until they laid eggs, and then placing frames over the nest site to exclude predators and capture emerging hatchlings. Head started hatchlings have been re-released back into Klickitat and Skamania County populations. As of 2002, 620 head start juveniles had been released with a 95% survival rating (Slavens 2003). The most recent releases in July of 2008, brought the total number of released head started juveniles up to almost 1,400, and the survival rate is staying up at about 95% (Future 2007). Some of the latest Columbia River Gorge releases have been equipped with radio transmitters so that scientists can learn more about post-release dispersal.

Two reintroduction sites now exist in the Puget Sound, one in Mason County, and one in Pierce County at the South Puget Sound Wildlife Area (SPSWA) in Lakewood (Schmidt *et al*. 2008). The WDFW still needs three more site to meet their goal of five reintroduction sites in the Puget Sound. The SPSWA site is 90 acres and is owned by WDFW. The project site for the recovery of *Actinemys mormorata* is twelve acres that includes a three acre wetland mitigation site built in 1994 by Pierce County Public Works from an existing spring seep. There are currently plans to increase the size of SPSWA by creating an additional pond complex and providing females with the ideal south facing slope for nesting in order to meet the goal of 200 individuals at this site. The site in Mason County, Goat Ranch Pond, had 22 turtles released there from the head-start program.

The head start program was determined to be neither enough to stabilize Columbia River Gorge populations nor enough to reintroduce populations back into the Puget Sound region, so a captive breeding program was developed among the Woodland Park, Point Defiance, and Oregon Zoos in 1991 (Hays *et al*. 1999). Single adults found throughout the Puget Sound region were captured for captive breeding as they were found. Recent genetic studies have revealed that Puget Sound populations are more closely related to Willamette Valley populations in Oregon, so individuals from this area were used to supplement the captive breeding program. However, the out-of-state stock was only used to refine captive breeding techniques. This program established small populations of less than 40 individuals in various Puget Sound locations from 1990 through 1998 (Figure 3). As of 1997, the Woodland Park Zoo had successfully reared and released 38 captive-reared juveniles, and re-sightings of the marked juveniles indicate that the program is successful. Washington Department of Fish and Wildlife is planning to reestablish populations at more sites in the Puget Sound region, but they are still evaluating which sites would be best suited for reintroduction.

To ensure further survival of juvenile pond turtles, the removal of non-native predator fish and bullfrogs (*Rana catesbeiana*) has occurred in areas with known pond turtle populations (Hays *et al*. 1999). Gigging and fishing to remove adult bullfrogs are effective techniques for reducing negative impacts to turtle populations in small, isolated habitats, and trapping and disposing of bullfrog tadpoles is also employed. Gillnetting and hoop traps are used for non-native sports fish such as bass (*Micropterus* spp.), bullhead (*Ameiurus* spp.), pumpkinseed (*Lepomis gibbosus*), and bluegill (*Lepomis macrochirus*). Efforts to minimize the availability of nesting sites for opossum (*Didelphus virginiana*) and raccoon (*Procyon lotor*) are also underway to limit their predation on pond turtles.

Toxicology research is necessary to understand the types of compounds to which pond turtles are being exposed and what waterborne diseases are present (Hays *et al*. 1999). Careful monitoring of water quality in current pond turtle habitat is beneficial in ensuring that levels of heavy metals and pesticides are not high enough to cause acute toxicity or reproductive failure.

Public education programs on the habitat requirements of *A. marmorata* were developed beginning in 1998 (Slavens and Slavens 1998). These programs provided the general public with information on the dangers of releasing non-native pet turtles into pond turtle habitat and identification guides to help them distinguish between *A. marmorata*, the other native turtle, the painted turtle (*Chrysemys picta*), and introduced turtle species (Hays *et al*. 1999). It was also a goal to begin education programs and materials for public schools.

Abundance surveys were conducted by biologists and trained volunteers at 128 wetlands in 1991, and 88 sites the following year using standardized methodology to locate any remaining unknown populations in western Washington (Hays *et al*. 1999, Slavens and Slavens 1998). The surveys were conducted over the historic range of the turtle, especially at sites with known historic populations. Abundance surveys have been continuously conducted by biologists and volunteers on an annual basis. Trapping, baiting, and artificial basking sites are used to increase the likelihood of visually observing an inhabitant pond turtle. These surveys provide useful information on habitat use, population numbers, and sex ratios.

1.4.3. Future Management and Research

It is critical that WDFW continue their current management actions, as well as take further action to determine upland habitat requirements, identify more, suitable reintroduction sites, establish information management systems and communications among all participants, and evaluate and enforce restrictions designed to protect the pond turtle. This will be difficult to do, as WDFW faced a combined 36.2 percent State General Fund budget cut from the 2007-09 biennium to the 2011-13 biennium (Budget 2011). The other major contribution to the budget comes from recreational license fees, which was predicted to fall short by $10 million at the start of the 2011-13 biennium.

Relatively little is known about the upland habitat requirements of *Actinemys marmorata*. It is understood that they can travel considerable distances in search of nesting and overwintering sites, as well as new aquatic habitat (Reese and Welsh 1997, Hays *et al*. 1999). However, because of their wary nature and the fact that they hide under vegetation and downed logs for extended periods during upland habitat use, much is still unknown. The nesting behaviors of females are equally mysterious (Rathbun, Siepel, and Holland 1992). It is believed that by laying eggs in upland habitat rather than near aquatic habitat may be multi-functional; it could decrease the likelihood of loss due to flooding, be necessary for short incubation times, or decrease the probability of predation by raccoons.

A more recent telemetry study of pond turtles in Trinity County, California found extensive terrestrial activity in adults, especially by gravid females (Reese and Welsh 1997). Pond turtles in Washington may experience very different environmental pressures due to dissimilarities in climate that result in different terrestrial habitat use. It would be safe to conclude, however, that the riparian habitat serves an essential role in the life history of the turtle and should be protected through land acquisition and restoration efforts.

Because this project has numerous stakeholders and agencies involved, it is critical that there is an information management and sharing system available to coordinate efforts (Hays *et al*. 1999). This will assist in local and regional trends and improvement of methodology. Although there is a bimonthly electronic newsletter available online for interested parties, it is not necessarily the most efficient way to share information and large data files (Slavens and Slavens 1998, Slavens 2003).

Currently, harming, harassing, or killing *A. marmorata* or destroying their nests or eggs are prohibited by Washington state law (Hays *et al*. 1999). Regulations on exotic pets need to be more effective in order to prevent the release and establishment of non-native species and their pathogens. It may be possible to distribute information to the public when any pet turtle is purchased.

This project costs about $150,000 to $180,000 per year to meet all tasks, but that is shared among a variety of agencies and stakeholders, and is subject to the availability of funding (Hays *et al*. 1999). This amount is a relatively low cost for a single species conservation, especially when compared to the millions of dollars spent on salmon (*Oncorhynchus* spp.) and the Spotted Owl (*Strix occidentalis*) in Washington each year (Budget 2009). Volunteer resources are also utilized in monitoring, captive breeding and head start programs, and habitat restoration which minimize project costs. State and federal agencies that are involved in the funding of this project include: WDFW, the Washington Wildlife and Recreation Program, the Forest Service, and the US Fish and Wildlife. Weyerhaeuser Company has donated trees for habitat restoration efforts. The Woodland Park, Point Defiance, and Oregon Zoos are involved in the captive breeding and head start programs. The Nature Conservancy and Washington Conservation Corps are also heavily involved in habitat acquisition and restoration for *A. marmorata* in Washington. Many other private organizations contribute funding and volunteers for this ongoing project.

1.5. Fort Lewis

Fort Nisqually was established in 1833, in the area north of the Nisqually River by the Hudson Bay Company for two primary reasons; it served as a site for the booming fur trade and strengthened British claims to the area (Maris 1991). A $2 million bond approved by the people of Pierce County in January of 1917 was used to purchase 61,000 acres which was donated to the federal government for the establishment of a new military base. Thus, Camp Lewis was founded on the land that lies between present-day Olympia and Tacoma, Washington. With the passing of the Housing Program Act of 1926, to create a standing federal military, Camp Lewis was renovated over a period of ten years and renamed Fort Lewis (Figure 2). It was, and still is, used as a training center for recruits, which includes weapons and maneuver training, and it houses the I Corps.

Fort Lewis continued to acquire new land until it grew to its present size of 86,500 acres (McCausland 2001). The majority, 63,000 acres, is used for training, 12,500 acres are used for impact, and the other 10,500 are used for cantonment (Maris 1991). The fort lands include mixed forest (56%), prairies

(20%), oak woodland (4%), ponderosa pine savannah (5%), wetlands (5%), and 27 lakes (Fort Lewis 2004). Lewis falls under the jurisdiction of the Department of Defense's Forces Command (FORSCOM) division of the Department of the Army (McCausland 2001).

1.5.1. Historical Use of Fort Lewis Aquatic Habitats

Fort Lewis' oak savannahs and prairie grasslands provide the military with the perfect setting for a variety of training activities because there is high visibility over long distances and expansive spaces for large maneuvers and airborne operations. Various military and civilian activities occur on the training lands that may impact the habitat. These include large and small ammunition live fire, foot and wheeled vehicle maneuver training, hunting, boating, fishing, dog training, horseback riding, and model airplane flying. Activities that occur against permit regulations include dirt biking, civilian off-road vehicle maneuver, unauthorized horse-back riding, and trash dumping.

Other factors influencing the landscape include industrial and business practices. In 2006, a petroleum product pipeline and fiber optic cable were upgraded and installed through Training Area 15 and Muck Creek. In addition, commercial timber harvesting is permitted in the forests adjacent to wetlands and lakes. These industrial activities can threaten the habitat by trampling native vegetation, introducing exotic species, compacting soil structure, and increasing soil erosion and runoff.

Fort Lewis contains many wetlands and ponds that are among the least disturbed aquatic habitats left in the South Puget Sound region (Bury 1993).

Several herpetofauna studies conducted over much of Fort Lewis in the 1990s found only a few remaining individual pond turtles, and reintroductions have already occurred in nearby locations in Lakewood, Washington (Bury 1993, Bury and Stringer 1992, Carey and Bury 1992, Forrester and Storre 1992). Aquatic habitat at Fort Lewis is not widely used for training, although some sites experience heavy recreational use. Many are surrounded by relatively undeveloped upland habitat because they are active training lands (Bury and Stringer 1992, Bury 1993). According to Bury (1993), several waterways and ponds on Fort Lewis have fair to excellent habitat conditions and the reason for the pond turtle's absence is unknown.

1.5.2. Study Site Selection and Descriptions

Sites were selected from a list of locations that were last surveyed for *Actinemys marmorata* inhabitants in 1992 (Forrester and Storre). Of the ten locations surveyed in 1992, six were initially included in this study: Sequalitchew Lake, Spanaway Marsh, Chambers Lake, Lewis Lake, Nisqually Lake, and Fiander Lake (Figure 4). Clay Pit, Johnson Marsh, Jolly Lake, and Ranger Lake were also included due to the presence of grassland and/or deciduous trees in the surrounding upland habitat. Jolly Lake and Ranger Lake are also at least two and a half miles, as the crow flies, from areas that receive substantial military or recreational activity and had the potential to contain small, previously undetected populations of *A. marmorata*.

Chambers Lake, T18N R2E S23, S26, and S27. Chambers Lake had a water control structure built at the south end in the 1960s to control the water levels of Muck Creek for salmon (*Oncorhynchus* spp.) runs, and it is now a popular fishing spot with many boat launches at the south end (Bury and Stringer 1992). Dense aquatic vegetation at the northern end prohibits access by boat (Forrester and Storre 1992). Water flows through the Muck Creek stream channel, and the water there is much colder (Bury and Stringer 1992). The water is still elsewhere and is generally clear. The lake has 40-80% emergent vegetation cover, which is composed of reed-canary grass (*Phalaris arundinacea*), rushes (*Juncus* and *Luzula* spp.), pond lilies (*Nuphar* spp.), and hardhack spirea (*Spiraea douglasii*). Basking sites are few, mostly small logs under the overhang along the eastern shoreline, so they do not receive much direct sunlight (Bury and Stringer 1992, Forrester and Storre 1992). The upland canopy has scattered deciduous trees on the prairie along the southwestern shore, and elsewhere it is mixed conifer (Bury and Stringer 1992). The upland forest overhangs the water on the southeastern shoreline, the bank is steep in places, and the entire shoreline has dense reed-canary grass up to five meters out from dry land. Signs of other species observed at this site include bullfrog (*Rana catesbeina*), red-legged frog (*Rana aurora*), northwestern salamander (*Ambystoma gracile*) egg masses, Lesser Canada Goose (*Branta canadensis*), Wood Duck (*Aix sponsa*), raptor nests, and a beaver (*Castor canadensis*) dam.

Clay Pit, the confluence of Muck Creek in Training Area 15. Clay Pit lies falls just outside of 13th Division Prairie, one of Fort Lewis' most highly utilized landscapes, and Rogers Drop Zone, the most frequently used drop zone. Training Area 15 is heavily used by Reserve Officer Training Corps for training in the summer months. It is also popular with horseback riders and dog trainers due to its close proximity to the rural town of Roy, Washington.

Fiander Lake, T17N R1E S21. Fiander Lake has been primarily left in a natural state due to its remote location (Bury and Stringer 1992, Forrester and Storre 1992). However, there are two public access points, all located along the northern shore (Forrester and Storre 1992). A third was closed in 2006 by the Fort Lewis Fish and Wildlife Program to facilitate western toad (*Bufo boreas*) migration (Lynch 2011, personal communication). Emergent vegetation covers 10-30% of the lake and consists of cattails (*Typha latifolia*), reed-canary grass (*Phalaris arundinacea*), pond lilies (*Nuphar* spp.), and rushes (*Juncus* and *Luzula* spp.) (Bury and Stringer 1992). The water appears to be very dark and acidic and has a slight current (Bury and Stringer 1992, Forrester and Storre 1992). The mixed conifer upland forest comes to the water's edge on all shores, and the immediate shorelines are dominated by shrub vegetation. Basking logs are abundant around the entire shoreline, and the logs in the northeastern corner are usually in direct sunlight. Bullfrog (*Rana catesbeiana*), Mallard (*Anas platyrhynchos*), and Red-tailed Hawk (*Buteo jamaicensis*) are all present in the area (Bury and Stringer

1992). Extensive flagging in the forest on the lake's eastern side indicates active logging.

Johnson Marsh, T18N R2E S13. Johnson Marsh is a larger, more complex habitat with 60-80% emergent vegetation cover of cattails (*Typha latifolia*), reed-canary grass (*Phalaris arundinacea*), pond lilies (*Nuphar* spp.), hardhack spirea (*Spireae douglasii*), and rushes (*Juncus* and *Luzula* spp.) (Bury and Stringer 1992). There is a water control structure at the southern end, but the marsh remains in a fairly natural state. Other than a slight north to south current in the middle, the water is still and clear with a mud bottom. The bank varies from gentle to steep and is choked with reed-canary grass and cattails in most locations, although several places have grassy banks next to open waters where Canada geese (*Branta canadensis*) have clipped the grass short. There are occasional basking logs throughout the water. The mixed conifer forest comes to within ten meters of the shoreline on the eastern side, and there is open deciduous woodland on the southwestern side. This diverse marsh provides habitat for various fish and snail species as well as bullfrog (*Rana catesbeiana*), red-legged frog (*Rana aurora*), Pacific tree frog (*Pseudacris regilla*), Wood Duck (*Aix sponsa*), Cinnamon Teal (*Anas cyanoptera*), American Coot (*Fulica americana*), Hooded Merganser (*Lophodytes cucullatus*), Pied-billed Grebe (*Podilymbus podiceps*), Great Blue Heron (*Ardea herodias*), lesser Canada Goose (*Branta canadensis*), Mallard (*Anas platyrhynchos*), Red-winged Blackbird (*Agelaius phoeniceus*), and Barn Swallow (*Hirundo rustica*).

Jolly Lake, T17N R1E S9. This natural lake has 70-90% emergent vegetative cover of pond lilies (*Nuphar* spp.), reed-canary grass (*Phalaris arundinacea*), rushes (*Juncus* and *Luzula* spp.), and cattails (*Typha latifolia*), with a notable cattail mat in the middle (Bury and Stringer 1992). The standing water is murky with a muddy bottom. There are a few basking logs along the edge, though they are partially shaded. The upland canopy cover is dominated by mixed conifer trees, and it comes to within less than ten meters of the water's edge. Other species seen in the area include bullfrog (*Rana catesbeiana*), Pacific tree frog (*Psuedacris regilla*), rough-skinned newt (*Taricha granulosa*), and several species of duck.

Lewis Lake, T17N R2E S4 and S5. Lewis Lake is a medium sized lake that attracts a moderate amount of human activity, but its 50 acres still provide some locations with low disturbance (Forrester and Storre 1992). Military activities occur on the southwestern end, there is a practice jump tower on the southwestern shore, and recreation occurs on the north end of the lake (Bury and Stringer 1992). Cattails (*Typha latifolia*), reed-canary grass (*Phalaris arundinacea*), pond lilies (*Nuphar* spp.), and rushes (*Juncus* and *Luzula* spp.) cover 10-20% of the lake, but there are numerous sections of bare shoreline due to human activities (Bury and Stringer 1992, Forrester and Storre 1992). Basking sites are limited, but there are some along the northern and eastern edges. The lake has a current to the north, and the water is still along the edge. The mud and gravel bottom is visible through the clear water. The upland canopy is dominated by mixed conifers and comes to within ten meters of a portion of the shore. Large mouth bass (*Micropterus salmoides*), other fish species, bullfrog (*Rana catesbeiana*), and duck inhabit the area, and a painted turtle (*Chrysemys picta*) was reported in 1991 (Gilbert *et al*. 1991, as cited in Bury and Stringer 1992).

Nisqually Lake, T17N R1E S1 to T18N R1E S9. Nisqually Lake is located in the middle of the Artillery Impact Area (AIA) where a majority of heavy live fire training occurs (Forrester and Storre 1992). This limits human access, so the lake has remained in a fairly natural state. The majority of military disturbance happens at the southern end, but there is no access to the northern end and appears minimally disturbed. Emergent vegetation dominates the shoreline, and aquatic vegetation is abundant throughout. Though there are no basking logs present, vegetative mats could provide basking sites along the western edge. The western end has a gradually sloped bank and receives direct sunlight during the morning and mid-day hours.

Ranger Lake, T17N R1W S27. Although Ranger Lake remains a relatively natural habitat, there is a duck blind in the middle of the lake, and there is a lot of military barbed wire, mortar shells, and smoke canisters from military training activities in the surrounding forest (Bury and Stringer 1992). Emergent vegetation covers about 50-70% of the lake and consists of pond lilies (*Nuphar* spp.), cattails (*Typha latifolia*), rushes (*Juncus* and *Luzula* spp.), reed-canary grass (*Phalaris arundinacea*), and other woody species. There is no bank, the shoreline is almost fully vegetated, and the mixed conifer forest comes almost to the water's edge. The water is still and clear with a mud bottom, and the lake contains a few basking logs, but they are within the canary grass. There are documented occurrences of bullfrog (*Rana catesbeiana*), snail, Mallard (*Anas platyrhynchos*), various species of leech (*Placabodella* spp.), and raccoon (*Procyon lotor*).

<u>Sequalitchew Lake</u>, T19N R2E S19. Sequalitchew Lake is located near the southern end of American Lake and north of Interstate 5 (Forrester and Storre 1992). Although it is heavily used for recreational fishing and military watercraft training, many small coves around the lake are relatively undisturbed by human activity. The relative lack of emergent vegetative cover, only 5-10%, is in part due to the boat put-in locations (Bury and Stringer 1992, Forrester and Storre 1992). In the undisturbed coves, the clear water has little current, and there are an abundance of logs suitable for basking. The mixed conifer forest comes to the water's edge except at the eastern end (Bury and Storre 1992). Other species inhabiting this lake include: painted turtle (*Chrysemys picta*), red-eared slider (*Trachemys scripta elegans*), various fish, bullfrog (*Rana catesbeiana*), Wood Duck (*Aix sponsa*), Canada Goose (*Branta canadensis*), Mallard (*Anas platyrhynchos*), and Pileated Woodpecker (*Drycopus pileatus*). There was also a sighting of an individual *Actinemys marmorata* reported in 1991 in the northeastern cove by Jim Stephenson (Forrester and Storre 1992).

Spanaway Marsh, T19N R2E S32. Spanaway Marsh's history includes being diked and drained for agricultural purposes, as indicated by submerged telephone poles and fencing that show obvious historical flooding (Lynch 2011, personal communication). In 1993, Fort Lewis Fish and Wildlife personnel installed a water control structure to restore wetland function. It is restricted to recreational uses because of nearby bald eagle nests, but it is heavily fished (Bury and Stringer 1992). Cattail (*Typha latifolia*) mats, reed-canary grass (*Phalaris arundinacea*), hardhack spirea (*Spireae douglasii*), pond lilies (*Nuphar* spp.), and other woody species cover 70-80% of the marsh, and the cattail mats make the southern end inaccessible. The water varies from clear to murky and flows through the cattail mats in channels. There are a few basking sites consisting of submerged fencing and woody debris in the deeper north end. The shoreline is almost completely choked with reed-canary grass, except for where the grass on the banks is kept short by geese and fisherman, and in some locations the mixed conifer forest reaches the shoreline. Various fish species, bullfrog (*Rana catesbeiana*), northwestern salamander (*Ambystoma gracile*), Canada Goose (*Branta canadensis*), Mallard (*Anas platyrhynchos*), Pileated Woodpecker (*Drycopus pileatus*), Red-winged Blackbird (*Agelaius phoeniceus*), Barn Swallow (*Hirundo rustica*), and Great Blue Heron (*Ardea herodias*) inhabit the marsh.

Given the dire condition of the pond turtle in Washington State and the current goals of the WDFW to establish three self-sustaining South Puget Sound populations of *Actinemys marmorata*, despite continually reduced budgets, Fort

Lewis' undeveloped oak savannah and prairie grassland habitats offer the best locations for reintroduction and recovery of the species. The focus of this thesis is to determine which sites within Fort Lewis would offer the most suitable habitat for reintroduction and continued success based on the requirements of the species. In order to evaluate nine potential sites on Fort Lewis, two questions were posed: is the habitat at any of the nine Fort Lewis locations significantly different from the habitat at the current reintroduction site in Lakewood, Washington, and of the nine Fort Lewis sites, which ranks the highest as a potential reintroduction site based on ten habitat characteristics (distance to shoreline, distance to basking site, percent canopy cover at ten centimeters, percent overhead canopy cover, leaf litter depth, distance to a road, bottom substrate type, shoreline accessibility, upland vegetation type, and presence or absence of a south-facing slope)? It was hypothesized that the habitat at Johnson Marsh and Clay Pit are statistically similar to the habitat at Lakewood because both Johnson Marsh and Clay Pit provide grassy upland habitat with a gentle slope leading to accessible shorelines. The second hypothesis was that Johnson Marsh would rank the highest of the nine Fort Lewis locations as a potential reintroduction site due to the site's size and ecological complexity. Its ecological complexity would provide more opportunity for basking and predator avoidance while presenting a suitable location for nesting females and overwintering adults.

2. Methods

Prior to all surveys, aerial maps of each study site were constructed using ESRI ArcView© GIS software and Public Works' aerial photographs of Fort Lewis from 2007. These maps were useful in navigating to sites and selecting random starting points for the habitat surveys. Access to each project site was coordinated through Fort Lewis Fish and Wildlife and Area Access passes for all vehicles and surveyors were obtained from Fort Lewis Range Control. On the days of surveys, it was required that observers check in with Range Control to make sure that the desired Training Areas were open to the public and not closed due to training. Due to the highly dangerous Artillery Impact Area surrounding Nisqually Lake, surveyors were never able to gain access to that project site for abundance or habitat surveys. Therefore, that project site was not included in the final analysis for habitat suitability.

There appears to be very few studies of the impacts of US military artillery on animals. The majority of research examines the impacts of underwater sonar Naval testing on marine megafauna, but there is one thesis that looked at the effects of artillery detonated on land at Fort Richardson on the Harbor porpoise (Heenehan 2009). Sparling *et al*. (1998) looked at the effects of white phosphorus, an artillery impact marking compound, on blood characteristics in mallards and found liver and kidney damage attributed to the contaminant. It is likely that artillery impacts would have a negative effect on *Actinemys marmorata*, which is an easily spooked creature. The noise could cause them to abandon basking sites prematurely or abandon the location altogether in search of a quieter locale. The explosions also pose a threat to nests and overwintering turtles.

2.1. Abundance Surveys

Five of the study sites were surveyed by Forrester and Storre in 1992. These included Fiander Lake, Spanaway Marsh, Sequalitchew Lake, Chambers Lake, and Lewis Lake. The other four sites successfully surveyed, Jolly Lake, Clay Pit, Ranger Lake, and Johnson Marsh were included in this study in the recommendation of Joint Base Lewis-McChord Fish and Wildlife personnel, Jim Lynch. Nisqually Lake, originally included in the list of sites for this study and in Forrester and Storre's 1992 study, was excluded due to access restrictions. Its location within the main Artillery Impact Area made it unsafe and inaccessible for this study. If a surveyor were to gain regular access to this site, it would be critical for them to examine the impacts, both direct and indirect, of artillery on the species found in this area. Especially since the AIA is a rare species hot spot containing the Streaked Horned Lark (*Eremophila alpestris strigata*), Oregon Vesper Sparrow (*Pooecetes gramineus affinis*), Mazama pocket gopher (*Thomomys mazama*), mardon skipper butterfly (*Polites mardon*), and the Taylor's checkerspot (*Euphydryas editha taylori*).

Abundance surveys were conducted between May 1st and July 18th, 2009. They were conducted twice at all sites, except for the Clay Pit site due to access constraints. The first surveys were completed between May 1st and June 27th and the second surveys took place at least three weeks later. Surveys began no earlier than 10:30 AM to allow time for the sun to rise above the tree line and begin warming potential basking sites. Surveys concluded no later than 4:30 PM in the early months of the study and 6:30 PM in the later months, as the sun stayed higher on the horizon. This often allowed observers to conduct more than one abundance survey at different sites in the same day. A minimum of one hour was spent at each survey location to allow time for any turtles spooked by the observers' arrival to re-emerge from concealed cover and return to basking activities.

Surveys were conducted from the shoreline at a fixed position from which multiple suitable basking locations were visible. Prior to the start of the abundance survey, a Kestrel thermometer was used to measure and record the starting ambient air temperature. Also noted was the wind speed using the Beaufort wind force scale, the overhead cloud cover percentage, and the time at the start of the survey. Observers sat for a minimum of one hour in relative silence while visually scanning potential basking sites and the shoreline for signs of *A. marmorata* inhabitants; binoculars were also used to scan distant shoreline and basking locations within line of site. During this time, a sketch of the study site was made to include all visible shoreline, basking locations, and vegetation grouped into five categories: emergent vegetation, grass, shrubs, and coniferous and deciduous trees. If any roads or other manmade structures were visible from the observation location, they were also included in the sketch. A list of all other animal species seen or heard during that time, as well as any noteworthy human activity observed other than the surveyors' presence, was compiled. Any turtles observed were identified to species using distinct markings and a copy of

National Audubon Society Field Guide to North American Reptiles and Amphibians (Knopf 1979). Upon concluding the one hour abundance surveys, observers would again measure the ambient air temperature and record it in order to calculate an average ambient air temperature for the hour of survey time.

2.2. Habitat Surveys

Habitat surveys were conducted once for each project location at every site where abundance surveys were conducted. Data at the Fort Lewis study sites were collected from May 1st through June 27th (2009). Habitat data at the Lakewood reference site was collected on September 22nd, when the last of the successful nesting sites were excavated for transport to the Oregon Zoo.

Upon arrival to each of the eight Fort Lewis locations, surveyors would navigate to a randomly selected starting point. The time was noted and the ambient air temperature was measured using a Kestrel thermometer and recorded. The wind speed, using the Beaufort wind force scale, and the overhead cloud cover percentage were estimated and recorded, as well.

The surveyor then performed a random walk to select the first random data plot. The surveyor started facing the water's edge, but then flipped a coin to determine a right or left turn of 90 degrees. After turning, they consulted a prepared random number list of numbers ranging from 1-187. The number corresponded to the number of paces that the surveyor then took in order to arrive at the next point. One-hundred eighty-seven was the predetermined maximum number of paces for the random walk because that is the average distance a gravid female pond turtle will travel from the water's edge for nesting (Holland 1991a, as cited in Hays *et al* 1999). Once at the next point, the surveyor would repeat the coin flipping, turning, and random pace process for a minimum of three iterations. After the third random number of paces, the surveyor would once more flip the coin, turn the appropriate direction 90 degrees, and throw a one-meter surveyor flag over their shoulder. The location of the flag upon landing was the location of the first subplot.

The Universal Transverse Mercator (UTM) position of the subplot was determined using a Garmin eTrex ® Global Positioning System (GPS) unit and recorded. The predominant vegetation type within the surrounding twenty-five meters was recorded by categories of: “conifer/shrub,” “conifer/deciduous,” “grass/conifer” “grass,” “conifer,” and “shrub/grass.” The canopy cover overhead was visually estimated to the nearest percentage as was the canopy cover of the one square meter area centering over the subplot at ten centimeters above the ground. A meter stick was used to measure the leaf litter depth of the subplot to the nearest tenth of a centimeter and recorded.

The location of the nearest water’s edge was also recorded using the GPS unit, and the accessibility to the water was evaluated using a categorical system of “accessible,” “ok,” and “not accessible.” “Accessible” denoted a shoreline with a slope less than twenty degrees and grassy vegetation shorter than one meter. “Ok” shorelines had a slope greater than twenty degrees but less than forty-five degrees entering the water and some shrubby vegetation. “Not accessible” shorelines had a slope of greater than forty-five degrees and/or dense, shrubby vegetation taller than one meter.

The distance to the nearest basking site from the water's edge was measured using a laser range finder, and this distance was later added to the distance between the subplot and the water's edge to get the total distance from the subplot to the nearest basking site. Basking sites were primarily emergent logs and tree branches but also included dense emergent vegetation. The bottom substrate of the aquatic habitat was recorded as "mud," "grassy," or "gravel." Prior to leaving the site, it was noted whether that site had a southern exposed slope, which is most ideal for the development of eggs and overwintering juveniles. Also, the ambient air temperature was again measured and recorded in order to calculate the average ambient air temperature during the survey, in the event that a turtle was seen.

Once all of this data was collected and recorded for the first subplot, the random walk method was again employed, starting from the first subplot, in order to select the subsequent subplots at the location. A minimum of two subplots per study location were surveyed, and more data was obtained as time permitted. Data for each Fort Lewis site was collected once on a single visit. The same data was collected at the Lakewood reintroduction site at four actual nest locations on the day that the eggs from each nest were excavated for transport to the headstart facility at the Oregon Zoo. A total of twenty-seven subplots were surveyed at the eight Fort Lewis study sites, and four subplots were surveyed at the Lakewood site.

Data on the distance from the nearest road to each subplot at the study sites and the nesting locations at the Lakewood reference location were obtained using the same ESRI ArcView© GIS software and Public Works' aerial photographs that were used to make the aerial maps of each study location.

2.3. Data Analysis

The abundance and habitat data were entered into Microsoft Excel © spreadsheets with their corresponding meta-data and notes (Table 1). For the habitat data, distances between subplots and nearest shoreline were calculated using the Pythagorean Theorem, and the distance from the subplots to the nearest basking site were calculated by adding the distance to the shoreline and the distance from the shoreline to the basking site.

Table 1. Habitat data parameters collected at the ten sites.

Parameter	Measurement
Distance to water	Meters
Distance to basking site	Meters
Distance to road	Meters
Canopy cover at 10 cm	Percent cover
Canopy cover overhead	Percent cover
Leaf litter depth	Centimeters
Vegetation type	Categorical
South-exposed slope	Presence/Absence
Shoreline accessibility	Categorical
Bottom substrate	Categorical

2.3.1. Abundance Data Analysis

Since there were no turtles of any species seen at any of the eight Fort Lewis study sites, there is no analysis for that data.

2.3.2. Habitat Data Analysis

To test the first hypothesis that the habitats at Johnson Marsh and Clay Pit are the most similar to the habitat found at the Lakewood site, the means for each quantitative habitat category (distance to basking site, distance to the water, distance to the road, leaf litter depth, canopy cover at ten centimeters, and canopy cover overhead) at each site was calculated, and a hierarchical cluster analysis was performed on the means of the data. A hierarchical cluster analysis separates the locations into groups while looking for similarities between groups within the data. The cluster analysis seeks to minimize within-group variance and maximize between-group variance.

However, the first assumption of a hierarchical cluster analysis is that the data are independent of each so, prior to running the hierarchical cluster analysis, it was necessary to perform a test for correlation among the habitat variables. The test for correlation revealed a strong correlation between "distance to water" and "distance to basking site" variables (correlation coefficient = 0.966), and moderate correlations between "canopy cover at ten centimeters" and both "overhead canopy cover" and "leaf litter depth" (correlation coefficient = 0.517 and 0.683, respectively). Therefore, both "distance to basking site" and "canopy cover at ten centimeters" variables were not included in the hierarchical cluster analysis. The second assumption of a hierarchical cluster analysis is that the data are standardized to minimize variation due to differing ranges or scales of measurement so the distance measurements for the remaining categories (distance to water, leaf litter depth, and distance to road) were all standardized to meters. A

Bray and Curtis ordination was calculated for each of the location pairs to determine how similar each location was to the others. The location with the smallest Bray and Curtis ordination when paired with the Lakewood site is considered most similar to that site.

The qualitative habitat data was converted to ordinal data to again test for similarities between the Fort Lewis sites' habitat data and the Lakewood habitat. For the bottom substrate category, "mud" was given a ranking of one, "grass" was given a ranking of two, and "gravel" was given a ranking of three based on the fact that mud would be the easiest for a pond turtle to seek refuge in, and grass and gravel are subsequently harder to dig through. Shoreline accessibility was given an increasing ranking of one through three for "accessible," "ok," and "inaccessible." Of the upland dominant vegetation type, grassland was the most optimum for nesting and, therefore, received a ranking of one. "Shrub/grass" and "deciduous" were considered of equal quality for overwintering habitat and assigned a rank of two (Van Leuven *et al*. 2004). "Conifer/deciduous" received the next rating of three since there was a high likelihood that oaks were present and pond turtles have a high affinity for habitat containing oak trees. "Grass/conifer," "conifer/shrub," and "conifer" vegetation types are decreasingly desirable and, therefore, received rankings of four, five, and six, respectively. Subplots with south-exposed slopes were assigned a ranking of one, while those without received a zero (Rathbun *et al*. 1992). The converted qualitative data was then averaged for each location and included for a second hierarchical cluster analysis to see if including the qualitative data revealed similarities in habitats that was not apparent when the quantitative data was compared alone.

To test the second hypothesis that of the nine Fort Lewis sites, Johnson Marsh was the most suitable reintroduction site, each site was ranked within each of the eight independent habitat data categories based on the most desirable characteristics for a reintroduction site. The assumption for a ranked summation is that the variables are independent from one another so the categories for "distance to basking site" and "canopy cover at ten centimeters" were removed from the ranking calculation. Within the category for "distance to water's edge," a greater average distance is considered most desirable since fluctuating water levels during the winter threaten the success of nesting. Therefore, this category was ranked from greatest average distance to least average distance to the water's edge, and the location with the greatest average distance received a score of 1.0 for this category, and the location with the least average distance was assigned a score of 9.0. For the category of "overhead canopy cover," it is considered most desirable to have more exposure to sunlight for egg and juvenile development within the nest, so the locations were put in order based on the lowest to highest average percentage canopy cover. "Leaf litter depth" category was ranked from highest to lowest average litter depth because greater litter depth provides female turtles with more material to build their nests. The "distance to road" category was ranked for each location from least to greatest average distance since vehicle maneuvers pose a threat to turtles moving away from aquatic habitats for nesting or overwintering in upland habitat. The qualitative habitat data had already been ranked when it was converted to ordinal data based on most desirable characteristics for each of the remaining four categories of "bottom substrate," "shoreline accessibility," "vegetation type," and "presence of south-facing slope." Each location was ranked lowest to highest based on the averages for each of these four ordinal categories. If locations had the same value for a single category, both locations were assigned the lowest possible ranking. The ranks were then summed for each site for all eight categories, and the site with the smallest overall score was considered the most suitable.

3. Results

3.1. Abundance

Although no *Actinemys marmorata* were detected during any of the Fort Lewis site surveys, this was by no means an exhaustive search for their presence. Limited time and resources allowed only simple stationary visual surveys at no more than two locations per site. Baited traps, artificial basking structures, boat surveys, and snorkel surveys are all possible means to increase the likelihood of detecting the presence of *A. marmorata*, but surveyors were not allowed to leave equipment such as traps or basking structures in place in the military training areas (Forrester and Storre 1992). Additional surveys at these locations may possibly turn up a few individual turtles.

3.2. Habitat

The inclusion of the ordinal data in the hierarchical cluster analysis did not show a dramatic difference from the hierarchical cluster analysis of just the quantitative data habitat data alone, so it will not be discussed further in the results. The results of the hierarchical cluster analysis show that Spanaway Marsh is the most similar to the Lakewood reintroduction site (Bray-Curtis distance = 0.222). The Bray-Curtis distance means that the variance between Spanaway Marsh and the Lakewood site for all variables summed to 0.222. A Bray-Curtis distance closest to zero means that there is more similarity among that particular grouping of locations than in other groupings with greater Bray-Curtis distances.

The results of the rank summation of the habitat data reveal that Clay Pit is ranked as the most suitable of the nine Fort Lewis sites for reintroduction of *Actinemys marmorata* (ranked summed score = 20). Clay Pit's ranked summed score of 20 was the lowest out of the nine Fort Lewis sites, and this is primarily because it ranked first in three of the habitat characteristics: overhead canopy cover, bottom substrate type, and upland vegetation type. It also only ranked in the lowest third for the leaf litter depth category. Jolly Lake would also be considered suitable habitat for reintroduction based on the definition since it ranked in the top one third in at least three habitat categories and no more than once in the lower third ranking for any one category. It had a ranked summed score of 23.

3.2.1. Similarity

The results of the hierarchical cluster analyses reveals that the habitat at Spanaway Marsh was the most similar to the habitat at the Lakewood reintroduction site (Bray-Curtis distance = 0.222, p-value < 0.0001). Clay Pit is the second most similar site when compared to the Lakewood reintroduction site with a Bray-Curtis distance of 0.275. The dendrogram of the cluster analysis shows that Johnson Marsh is, in fact, the least similar site to the rest of the clustered sites (Figure 5). It had a Bray-Curtis distance of 0.774 when paired with the Lakewood site. The dendrogram has a cophenetic correlation coefficient of 0.811 which is the measure of how well the dendrogram represents the similarities of the original distances used to construct the dendrogram. A coefficient of 1.0 is the strongest correlation, but our correlation coefficient of 0.811 is fairly strong.

3.2.2. Suitability

Since some locations were tied in a single category, some categories in the ranked summation had an overall score less than 45, which is the maximum total for a single category given that the sum of the numbers one through nine equal 45. Therefore, the total sum of ranks for all ten categories was 308, not 360. The hypothesis that Johnson Marsh was the most suitable reintroduction site was rejected as it scored 34 points and ranked fifth overall (Table 2). Clay Pit ranked as the most suitable reintroduction site with a total score of 20. Jolly Lake was a close second with 23 points. The least suitable site was Fiander Lake with the highest score of 51.

Clay Pit ranked first in the "overhead canopy cover" category, and it tied for first in the ordinal categories "bottom substrate," "vegetation type," and "presence of a south-facing slope." These first place rankings led to its lowest overall score and overall most suitable ranking.

Table 2. The results of the summation of the rankings for each of the eight categories for each of the nine locations to determine the most suitable reintroduction site. The lowest score indicates the most suitable habitat for reintroduction while higher scores mean those sites are less suitable for reintroduction.

Location	Final Score
Clay Pit	20
Jolly Lake	23
Chambers Lake	30
Lewis Lake	32
Johnson Marsh	34
Spanaway Marsh	35
Sequalitchew Lake	37
Ranger Lake	46
Fiander Lake	51

4. Discussion

The similarity analysis of the habitat data did not support the first hypothesis that the habitat at both Johnson Marsh and Clay Pit would be statistically similar to the habitat at the Lakewood reintroduction site, Clay Pit was the second most similar site after Spanaway Marsh. Also, the second hypothesis that Johnson Marsh would be the most suitable habitat for reintroduction of *Actinemys marmorata* because of its ecological complexity was not supported by the suitability analysis of the habitat data. In fact, Clay Pit was ranked as the most suitable site of the nine locations.

Spanaway Marsh, with its Bray-Curtis distance of 0.222, was the most similar site to the Lakewood site, and fell in the middle of the ranked summation in fifth with a final score of 35. It lies adjacent to Spanaway Lake, a popular recreation spot just outside the boundary of Fort Lewis, and is itself a popular recreational fishing location. However, since the military is already unable to use Spanaway Marsh for training because of the presence of bald eagle nests, they may be more inclined to also restrict recreational use by means of a gated fence in order to protect introduced *A. marmorata*. It does not have a south facing slope for nesting, which would be ideal, but neither does the Lakewood site. The solution for Lakewood is to construct a south facing nesting slope, and this could also work at Spanaway Marsh.

Although the results indicate that Clay Pit is the second most similar site to the Lakewood site and ranked as the most suitable habitat of the nine Fort Lewis sites, it is important to note that its proximity to 13th Division Prairie, the largest contiguous prairie habitat outside of the AIA, and to the towns of Yelm and Roy make it a highly used area for both military training and recreationalists. If there had been a measurement of use included in this analysis, the results may have been different. A solution, utilized at the Lakewood site to keep unwanted people out of the turtles' habitat, would be to completely fence of the portion used by the turtles for basking, feeding, nesting, etc., and restricting access to the site by use of a locked gate. However, this solution is only feasible for the area between the confluence of North and South Muck Creek that is already fenced and off-limits to vehicle maneuvers. The western portion of this site as it is an important active training area and near a main DZ, Rodgers DZ, and could not be fenced-off and locked. Additionally, Clay Pit is staked off with Seibert stakes to prevent vehicles from damaging sensitive riparian zones, but there are authorized fords where large military vehicles are allowed to drive through (Seibert, no date). These concrete hardened fords might appear as optimal basking locations for *Actinemys marmorata* and draw them into hazardous contact with vehicles.

Jolly Lake scored the second highest position for most suitable reintroduction site with 23 points, and was fourth most similar to Lakewood with a Bray-Curtis distance of 0.359. It had the highest average distance from a road which is most favorable, and it had the second highest average leaf litter depth which is necessary for overwintering and nesting. Furthermore, it had moderate overhead canopy consisting of mixed deciduous and coniferous upland vegetation. Although oak/prairie savannah is optimal, a mixed deciduous/coniferous vegetation type can provide the oaks *A. marmorata* prefer to nest near as well as the conifers that will make good basking logs in the near future.

Even though Johnson Marsh actually was the least similar site when compared with the Lakewood reference site and only fell in the middle of the rank summation for most suitable at fifth place with a score of 34, it does merit some consideration as a potential reintroduction site. It ranked second highest in both the "overhead canopy cover" and "vegetation type" categories and already has a south facing slope for nesting. Fencing off a portion of the marsh to restrict access or posting signs to limit access during certain key time periods, such as during nesting, would increase the suitability of this site for reintroduction. Trimming reed-canary grass would also be helpful in increasing the accessibility of the water and basking sites for *A. marmorata*. It may not be most suitable now, but neither was the Lakewood site before it was specifically managed for the success of *A. marmorata*.

Nisqually Lake, while unfortunately excluded from this study due to its hazardous location within the AIA, likely remains the most suitable site for reintroduction. It is surrounded by some of the highest quality upland prairie grassland and oak habitat, has a south facing slope for nesting and is not accessible for recreation or vehicle training. However, the direct and indirect impacts of artillery explosions on *A. marmorata*, and wildlife in general, pose an unstudied and unknown threat to their success. Additionally, it would be necessary for there to exist a legal guarantee that if *A. marmorata* were reintroduced at Nisqually Lake, that any future population declines at that location would not result in closure of the AIA for military training.

If WDFW was able to determine the habitat characteristics that are most important when evaluating a potential site for suitability, it would provide a more accurate assessment of sites and increase the likelihood of success for the recovery of *A. marmorata*. This study was conducted as if all habitat characteristics were equally important, and therefore they were analyzed without a weighted rank summation. Determining the most important characteristics could lead to a prediction model that is more accurate than the simple cluster analysis and rank summation used in this study.

5. Conclusion

It was hypothesized that Johnson Marsh and Clay Pit habitats on Fort Lewis would not be significantly different from that found at Lakewood, and that Johnson Marsh would be the most suitable of the nine sites for *Actinemys marmorata* reintroduction due to its size and ecological complexity. However, the results of the habitat analysis indicate that the habitat at Spanaway Marsh is, in fact, the most similar to the Lakewood site, not Johnson Marsh or Clay Pit. Additionally, Clay Pit is ranked as the most suitable site of the nine Fort Lewis locations based on desired habitat characteristics for *A. marmorata* reintroduction. The difference between the outcomes of the habitat comparison and suitability ranking may be due to the fact that the habitat comparisons between each of the nine Fort Lewis sites and the existing Lakewood reintroduction site does not take into account that the Lakewood site is still undergoing alterations by WDFW to make it more suitable, and the suitability rankings are based on the optimum characteristics for each of the eight habitat categories. The Lakewood site still has further improvements before it can be considered most suitable for *A. marmorata* habitat.

If the military were willing to grant exclusive access to WDFW for either Spanaway Marsh or Clay Pit, on the condition that future population declines would not result in closure of military training, they would be excellent candidates for reintroduction sites. However, since the area west of Clay Pit is a piece of prime training lands, WDFW should consider the already fenced portion of Clay Pit between North and South Muck Creek for reintroduction, which is not extensive in size and limits the possibility of expansion with increasing population size. More remote and less used sites such as Spanaway Marsh and Jolly Lake might make more likely candidates for reintroduction and allow for expansion and improvement. It is important to note that Nisqually Lake was not ruled out nor evaluated in this study, and is already a restricted access location that boasts some of the highest quality upland habitat. It, too, should be considered as a possible reintroduction site for *A. marmorata*.

With a dwindling budget and few undeveloped aquatic and grassland habitats remaining in the Puget Sound, WDFW needs to look at federal lands for potential sites if they are to meet their recovery goals for *A. marmorata*. Fort Lewis holds the largest remaining high quality prairie grassland and oak savannah habitats and already has experience working with state agencies and the Oregon and Woodland Park Zoos on recovery efforts of a semi-aquatic species. Volunteers are already in place to keep bullfrog (*Rana catesbeiana*) populations down in order to minimize the threat to native species.

Although the majority of the historic range of *A. marmorata* is already developed beyond a point of usefulness for these efforts, there are still sites that have been relatively undisturbed and, with minimal effort, would be suitable for reintroduction of the pond turtle and other aquatic wildlife.

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Figure 1. The historic range of the western pond turtle (*Actinemys marmorata*) (Hays *et al*. 1999).

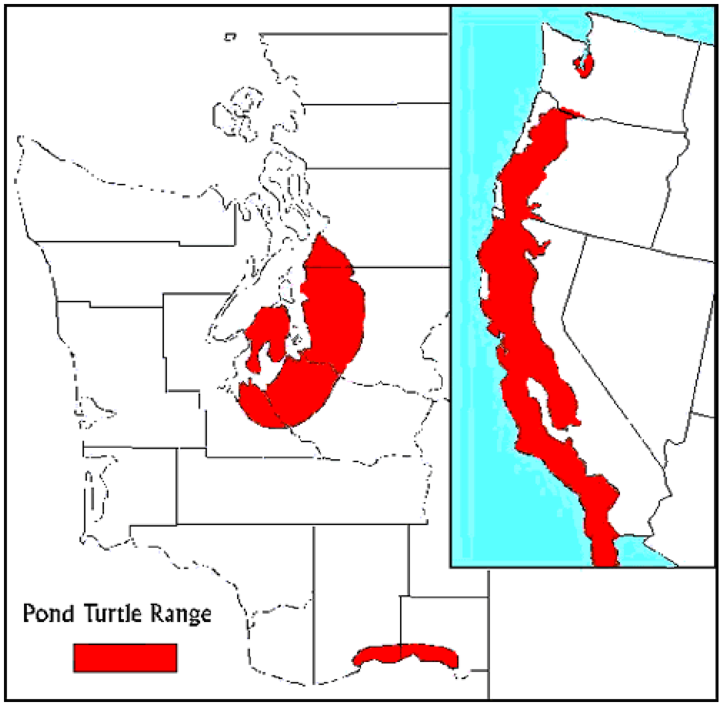

Figure 2. A map of the boundaries of Fort Lewis, Washington and its prairies and oak habitat.

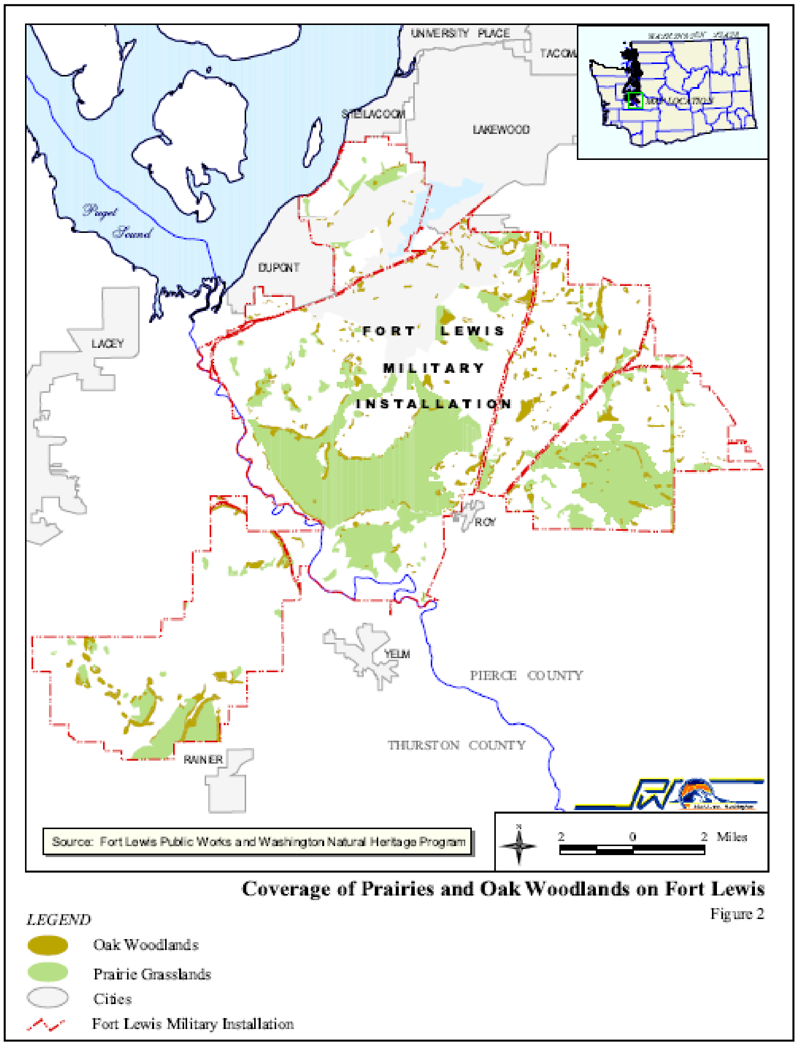

Figure 3. Map of pond turtle reintroduction sites in Washington (Toubman 2001).

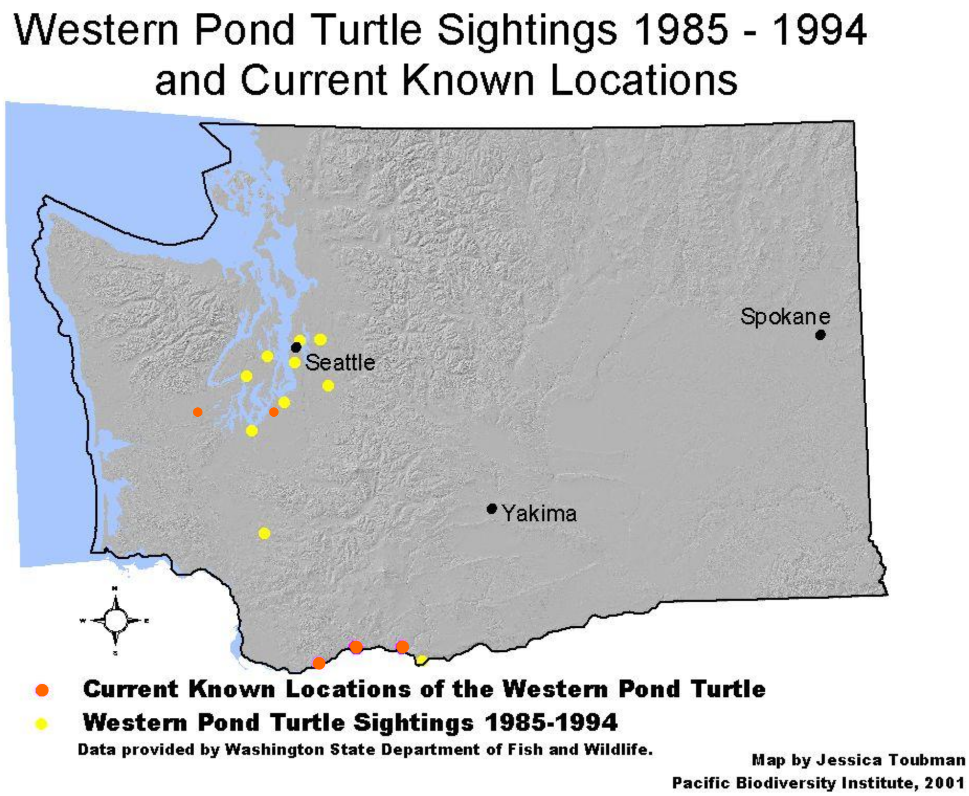

Figure 4. Map of nine Fort Lewis study sites for potential reintroduction.

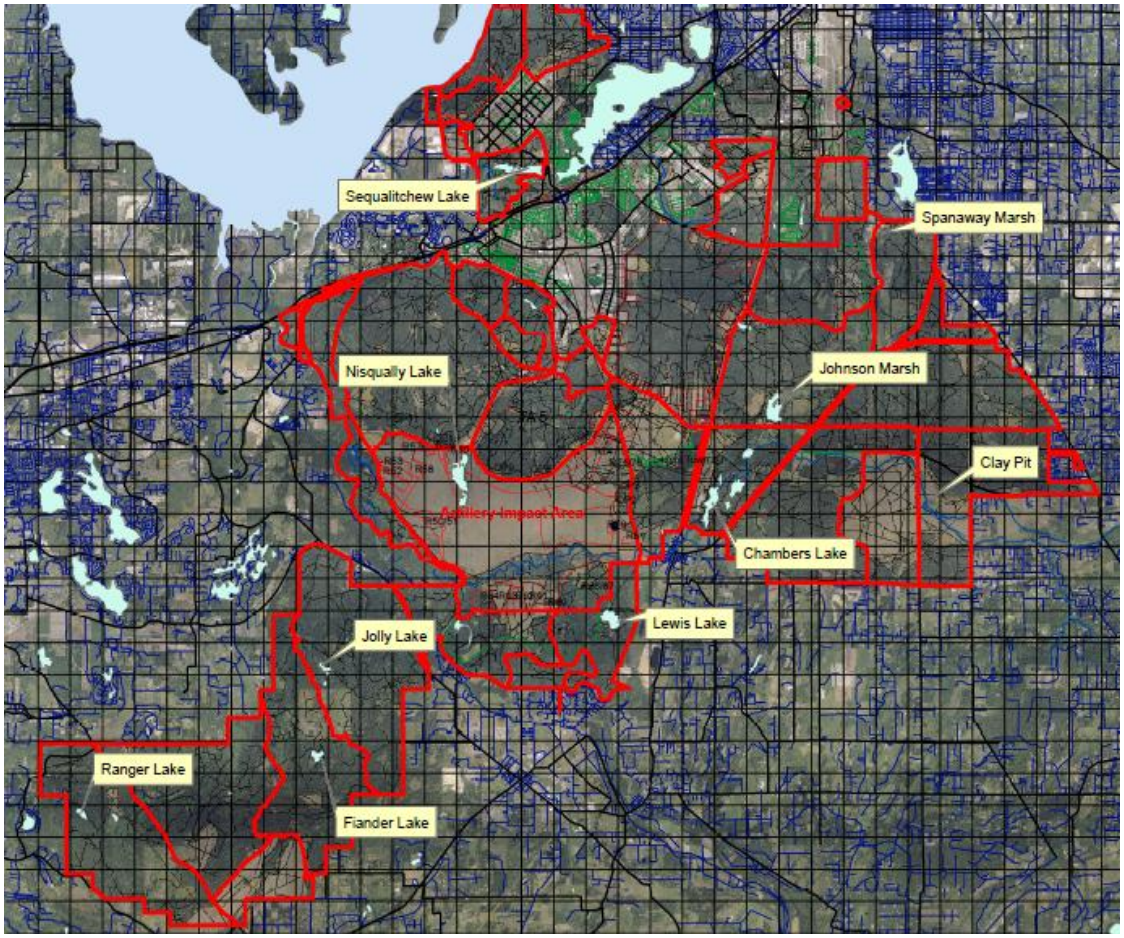

Figure 5. Dendrogram of the hierarchical cluster analysis of the habitat data. Bray-Curtis distances between each location and the Lakewood reintroduction site are included down the left side of the diagram.