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Best Management Practices for the Conservation of Western Pond Turtle Populations in California

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This Master's Project

Best Management Practices for the Conservation of Western Pond Turtle Populations in California

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Abstract

This project provides insight into western pond turtle (*Actinemys marmorata*) population health at sites in three states on the western part of the United States. Washington, Oregon and California have identified the western pond turtle as endangered, a critical and a species of special concern in that respective order. Washington has implemented a recovery plan for western pond turtles and Oregon has established best management practices for the conservation of native turtles. California has yet to establish any guidelines for the conservation of western pond turtles. This species is endemic to the western United States and has been suffering from declining populations since the late 1800s. The factors that have contributed to the decline in western pond turtle numbers include: historical commercial food use, habitat destruction and fragmentation by water diversions, urbanization and agriculture, non-native species interactions, fire, drought, and flood which are increased by climate change due to anthropogenic activity. Reptiles in general do not do well with high disturbance rates in their environment, due to their slow movements. Western pond turtles have also been afflicted by different diseases, such as a respiratory illness that decimated one-third of the population in Washington and shell disease that has been affecting populations in Washington, Oregon and California. Exposure to diseases is proliferated by contact with released pet turtles, as captive turtles contain different bacteria. The western pond turtle sites analyzed are in the Columbia Gorge and South Puget Sound in Washington, Willamette Drainage in Oregon and sites in Lake County, San Diego County and Yolo County in California. These sites were analyzed through a combination of data from peer-reviewed, unpublished literature and government agency reports. The purpose of this research is to determine the effectiveness of management plans and strategies used for the recovery and conservation of western pond turtle populations, with an emphasis on head-starting programs, non-native species removal, habitat restoration and enhancement. The results will be analyzed by looking at historical data and more recent results in relatively the same area to determine if the western pond turtle populations have increased or decreased at those sites, in order to best allocate resources and prepare management plans for the conservation of western pond turtle populations in California. The recommendations being propose are surveying and monitoring, collaboration, habitat restoration/enhancement, non-native species removal, head-start programs and land acquisition. The analysis between sites in Washington, Oregon and California showed some progress but requires further research.

Introduction

Western pond turtles (*Actinemys marmorata*) are a species of freshwater turtle native to the state of Washington all the way down to Baja California, Mexico (Figure 1). They have been classified as an endangered species in Washington State since 1993 (Washington Department of Fish and Wildlife 1993), a species of sensitive-critical concern in Oregon (Oregon Department of Fish and Wildlife 2008) and a species of special concern in California (Wright et al. 2008). They are also listed as a species of special concern by the U.S. Fish and Wildlife Service (Rosenberg et al. 2009). There were thought to be only 250-350 individuals left in Washington in the 1990s.There are many factors that have contributed to the decline of the western pond turtles in its past range; such as exploitation for commercial food; degradation, depletion and fragmentation of habitat; and interspecific relationships with non-native species (Hays et al. 1999). These factors, coupled with the vulnerability of juvenile western pond turtles and their delayed reproductive age, have brought disastrous consequences to the western pond turtle populations.

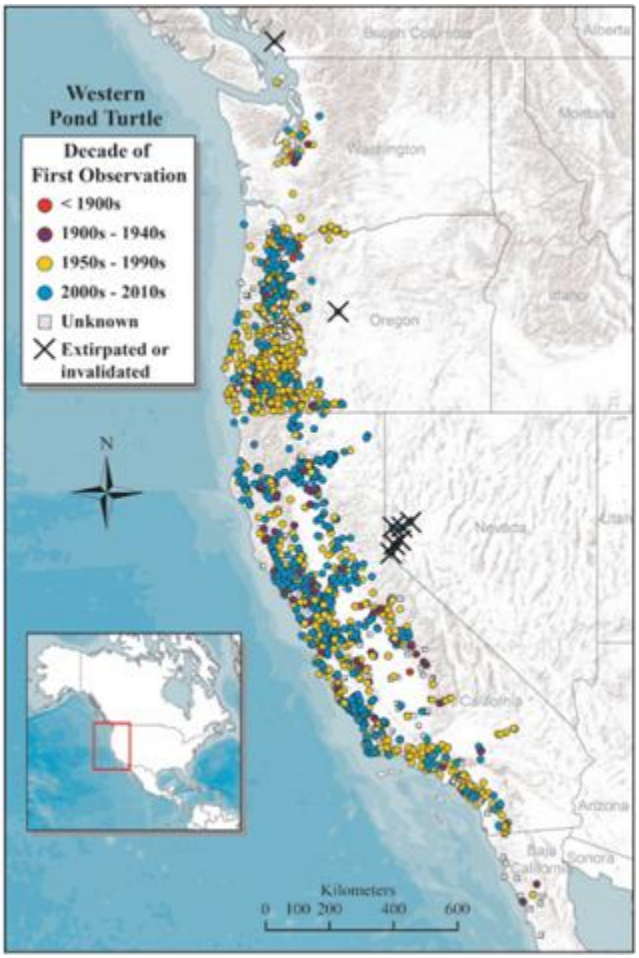

Figure 1. Western pond turtle range from Washington to Baja California, Mexico. X's describe areas where turtle have been extirpated (Canada and Oregon) or introductions (Nevada) have occurred (Barela and Olson 2014).

Taxonomy

Western pond turtles are in the family Emydidae (Bury et al. 2012). In 1841 western pond turtles were first identified as *Emys marmorata* by Steilacoom and later in 1852 by Baird and Girard (Baird and Girad 1852). The name *Clemmys marmorata* was later used by Strauch in 1862. The genus name is presently interchanged *Emys* and *Actinemys* and thus can be seen in both forms (Washington Department of Fish and Wildlife 2013, Siedel et al. 2017). Through genetic evaluation two subspecies of western pond turtles have arisen. The northwestern pond turtle (*Emys marmorata marmorata*) which lives from Washington to the Central Valley of California and the southwestern pond turtle (*Emys marmorata pallida)* that inhabits the Central Valley to Baja California. However they are still considered the same species, and known as western pond turtles (Gray 1995, Spinks and Shaffer 2005). Other names that are associated with western pond turtles are: pacific pond turtle, pacific mud turtle or mud terrapin (Smith 1895, Seelinger 1945, Bettlehiem 2005).

Natural History

Species Description

Western pond turtles are considered medium sized turtles, adults reach 160-241 mm while hatchlings are 25-31 mm in carapace length (dorsal side of shell) (Bury et al. 2012). They are sexually dimorphic, females tend to have smaller heads, less pointed snouts, taller and rounder carapaces, and thinner tails as compared to males (Figure 2). Colors can also vary geographically and by age, with slight variations in carapace color from black to dark green, the carapace may also be marked with dark mottlings or be unmarked. The plastron (underside of shell) is a cream to yellow color and may possess mottlings. The coloration of the head and neck also vary by sex, geography and age (Holland and Bury 1998, Ernst and Lovich 2009). Males will usually have a light yellow patch under their throat. Females tend to have dark prints or rosette rings called paisley print. These prints are permanent throughout their life. Males get darker with age and juveniles are a brown-olive color and have very visible mottlings (Hays et al. 1999).

Figure 2. Life stages of western pond turtles as well as male and female physical attributes (Bettlehiem 2011).

Habitat Requirements

Western pond turtles can be found in streams, rivers, lakes, ponds, urbanized bodies of water and brackish water. They prefer to inhabit the slow moving currents of rivers and streams, staying close to the river bank and backwaters where there are sufficient basking sites and refugia (Reese and Welsh 1997). They tend to stay away from areas that have high woody vegetation as it produces too much shade. They are omnivores and opportunists; western pond turtles do not have the muscles required to swallow outside of water, they are restricted to an aquatic diet consisting of aquatic plants, invertebrates, amphibians, fish and carrion (Stebbins 1972, Nussbaum et al. 1983).

Nesting occurs from May through July and females may travel more than 100 meters away from a body of water to nest. Females prefer to nest on sandy banks next to a body of water or open grassy areas with availability to sunlight. About 12 weeks after females have laid their eggs, hatchlings will emerge from their eggs (Holland 1994). Each female may produce between 1 to 13 eggs in a clutch more than once a year however that is uncommon (Ernst and Lovich 2009). Hatching success is dependent on the weather, if it gets too cold than this could lead to hatching failure (Ewart et al.1994). Western pond turtles are temperature sex dependent, meaning that at higher incubation temperatures the ratio of females to males will be greater (Ewart et al. 1994, Geist et al. 2015). Juvenile survivorship is low until they reach their reproductive years at about 10 years old (Holland 1994, Bury and Germano 2008). Western pond turtles are a long-lived species and can live up to 50 to 70 years (Gibbons and Semlitsch 1982, Geist 2019).

Western pond turtles have other important uses for land consisting of emergent basking, aestivation, and overwintering (Holland 1994). Turtles will leave the water to bask in the sun, a behavior called emergent basking. This will usually take place on logs, rocks, emergent vegetation, or on water banks (Hays et al. 1999). Emergent basking is essential for turtle thermoregulation, metabolism, digestion, reproduction and growth (Lovich et al. 2017). It is also crucial for females to produce viable eggs. Emergent basking is most prominent in March through July due to a Mediterranean climate (Nordby 1992). This means that summers will be warm and dry and winters will be cold and wet (Verkaik et al. 2013). Another land use is aestivation, which is a form of hibernation and a technique that turtles use during the really hot part of the year or in times of drought; they prefer to burrow in uplands (Lovich et al. 2017). Overwintering on the other hand is a technique used to conserve energy starting in the Fall through cold seasonal events. The ideal environment for overwintering would be dense clumps of deciduous trees or shrubs (Reese and Welsh 1997).

As discussed above, uplands are required for vital western pond turtle behaviors and growth stages; emergent basking, aestivation, overwintering and nesting. The home range for adult western pond turtles differs between sexes. Males will have a home range of about 1 hectare away from their aquatic habitat, while the home range for females will consist of approximately 0.3 hectare (Bury and Germano 2008). Juvenile western pond turtles emerge from their nests in the spring and will have a home range of about 0.4 hectare (Bury and Germano 2008). Western pond turtles tend to prefer elevations no higher than 1500 meters above sea level (Holland 1994). Western pond turtles can tolerate water temperatures of 1-38°C (Holland 1994).

Protection under the Law

Western pond turtles in Washington are protected under WAC 232-12-29, Appendix A, Section 404 of the Federal Clean Water Act (regulates discharge in the environment in Columbia Gorge) and are a species of special concern for the Pacific Ecosystem Office of the U. S. Fish and Wildlife Service. The goal for the recovery management plan in Washington is to establish self-sustaining populations of western pond turtles in the Puget Sound/Puget Trough and Columbia Gorge zones (Figure 3) (Hays et al. 1999). This would be accomplished through the recovery plan which consists of; 1. habitat acquisition, 2. habitat enhancement, 3. surveys, 4. interagency survey plan, 5. toxicology research, 6. capture breeding, 7. head start programs, 8. predator removal, 9. habitat use research and 10. reintroduction (Hays et al. 1999).

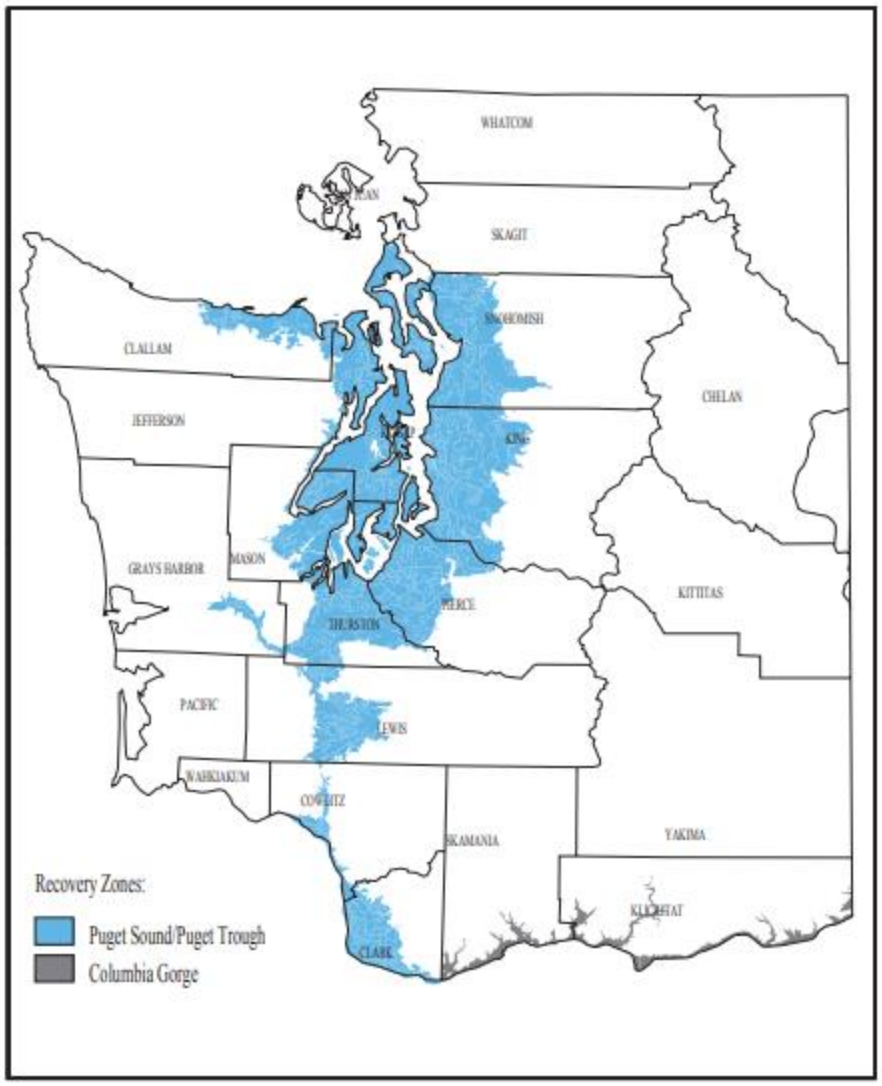

Figure 3. Recovery zones for western pond turtles in Washington State. Blue represents South Puget Sound and grey represents the Columbia Gorge (Hays et al.1999).

In Oregon western pond turtles are a species of sensitive-critical concern and thus have established best management practices to be implemented depending on certain factors. Under the Oregon Sensitive Species Rule OAR 635-100-0040, individuals are not allowed to possess, remove or harm western pond turtles (Rosenberg et al. 2009). Best management practices are dependent on scientific research and aim to relieve negatively impacting factors. However a very important note to make is that best management practices (BMPS) do not necessarily comply with all federal, state or local laws. The best management practices for Oregon's conservatory strategy of native turtles consist of; 1. create and enhance habitat for Oregon's native turtles, 2. avoid direct modifications to water bodies and waterways, 3. avoid altering hydrology of and causing increased sedimentation rates into water bodies, except for short-duration actions that are linked to habitat restoration efforts, 4. avoid or minimize disturbance from public access or other human activities, 5. provide native vegetation buffers around wetlands and other water bodies, 6.

utilize seasonal “no-entry” restrictions to minimize human-related disturbances, 7. provide permanent conservation ownership or easements to protect the site in perpetuity (Oregon Department of Fish and Wildlife 2015).

In California the western pond turtle has been identified on two landscape management plans as a “focal species” in CALFED Ecosystem Restoration Program and as a “species of special concern” in the California Comprehensive Wildlife Conservation Strategy (Wright et al. 2008). Other protections that are allocated to species of special concern are through the California Environmental Quality Act (CEQA; California Public Resources Code §§ 21000-21177). CEQA requires state and local agencies to identify any significant impacts that a project might have on the abiotic and biotic environment. Mitigation or avoidance of actions are required if impacts to the environment are identified (California Department of Fish and Wildlife 2019a). Due to western pond turtles being a species of special concern, it is illegal to take or harm them (California Department of Fish and Wildlife 2015). The California Department of Fish and Wildlife, has not established a species specific management plan for the western pond turtle (L. Patterson, California Department of fish and Wildlife, pers. comm. 2019).

Historical Range in California

Historically the western pond turtle range in California has been along the coast, inhabiting slopes and drainages. There have also been established populations in desert drainages of the Mojave River and at the Andreas Canyon (Stebbins 1995). They can also be found in drainages in central California, west of the Cascade Range and the Sierra Nevada. Overlap of the two subspecies can be seen in the Central Valley area of California (Seeliger 1945). The number of western pond turtles has significantly decreased; however, even with such low numbers they can still be found in 90% of their historical range in California (Jennings and Hayes 1994).

California makes up most of the western pond turtle range, providing a variety of habitats. The climate in California can be characterized as Mediterranean. Seasonal signaling or phenology is important for organisms and their life histories, which are dependent on heterogeneous cycles over time (Walther et al. 2002). This allows organisms to know when food will be most available and when it is time to reproduce or migrate. These cycles have allowed native organisms to co-evolve and establish trophic levels that determine inter and intraspecific relationships in that environment (Knight et al. 2005).

Factors Affecting Western Pond Turtle Populations

Past Human Consumption

Western pond turtles were consumed as food in the late 1800s to the 1930s by humans. Due to the fact that western pond turtles do not reach sexual maturity until about the age of 10 years, populations would suffer from low recruitment (Heppell et al. 1996). When population numbers decrease and individuals are spread out over long distances, the risk of extirpation is very high. In the 1980s average annual sales in the San Francisco markets for western pond turtles had been recorded to have reached $18,000 (Smith 1895). In 1895 between 24,000 and 47,115 terrapins were sold in the San Francisco area for about $3 to $5 per dozen (Bettlehiem 2005). It is now illegal to consume or trap western pond turtles in all states that they inhabit.

However the many years of harvesting exploitation greatly impacted the dynamic structure of western pond turtle populations reducing fecundity, in other words inhibiting population growth.

Disease Outbreaks

In Washington where the population of western pond turtles is endangered, disease outbreaks such as a respiratory infection and shell disease have devastated the western pond turtle populations even further. In 1990 a respiratory infection killed one-third of the population (Holland 1994). A form of shell disease arose in the Washington area in 2003 and Oregon in 2014. Usually, shell disease is associated with captive turtles and could be an indication of bad water quality (Washington Department of Fish and Wildlife 2016). Water toxicology research was conducted in Klickitat County, Washington; the reports had determined that the lake had higher levels of aluminum than the surrounding ponds (Landis and Storch 1991). However, the levels of aluminum were not high enough to cause any harm. The toxicology report indicated that there was nothing significantly wrong with the water quality meaning there was no evidence of chemical contamination at the site (Hays et al. 1999). The causes of diseases in western pond turtles have not been discovered yet (Landis and Storch 1991**)**. However captive turtles have been known to spread many diseases (Holland 1994).

The study of disease in California on western pond turtle populations was first conducted in 2013; through a collaboration of the University of California Davis School of Veterinary Medicine, California Department of Fish and Wildlife Investigations Lab and U.S. Fish and Wildlife Service. Western pond turtles from all over the state were examined and pathogens were identified (Silbernagel et al. 2013). Other species of non-native turtles, like the red-eared slider (*Trachemys scripta elegans*), were also examined to compare pathogens. This was done to eliminate the possibility that non-native turtle introductions were the cause of disease in native turtle species. The researchers found that both native and non-native turtles carried *Mycoplasma* spp. This bacterium causes respiratory illness. The study also showed that there was a higher prevalence of the disease in southern California. Water quality may be a factor in the spread of pathogens.

Water Diversions

Water diversions are an anthropogenic effect that has contributed to the destruction of wetland habitat and has also taken its toll on the western pond turtle populations. When wetlands are filled in for industrial and agricultural use, this reduces basking and nesting ground sites. Dams that redirect water limit the geographic range and mobility of western pond turtles, isolating populations even further (Hays et al. 1999). The Reclamation Act of 1902 facilitated these water diversions in many states (Moyle and Randell 1998).

Fragmentation of waterways can have negative effects, for instance creating dams can change the seasonal thermal regime flow and can disturb the signaling of life history events for many native organisms (Reese and Welsh 1998, Poff and Zimmerman 2010). The difference in size, growth and fitness on individuals can be seen in western pond turtle populations living on free-flowing and dam-regulated forks on the Trinity River in northern California. In regulated, forks the water temperature can become colder than normal due to hypolimnetic release. The hypolimnetic layer is the bottom layer of a body of water; it is usually cold in temperature and

can vary in oxygen levels. Colder temperatures suggest that turtles living in the regulated fork grow slower, male relative mass was decreased but female mass did not decrease. The reason behind the stable relative mass of the females was attributed to a higher use of food resources due to colder temperatures. Also compared to the free-flowing fork there were fewer gravid females, meaning less females carrying eggs (Ashton et al. 2015).

Urbanization

Urban waterways present several challenges for western pond turtle populations. Factors responsible for the decline in the western pond turtle populations due to urbanization are reduced sites for land uses (emergent basking, aestivation, overwintering, reproduction and nesting), predation of eggs and hatchlings, and interspecific competition with non-native turtles (Congdon et al. 1994). Increased encounters with the human population put western pond turtles at risk of harm by pets, subsidized predators and road traffic (Mitchell and Klemens 2000, Ashley and Robinson 1996). Subsidized predators include raccoons (*Procyon lotor*), rats *(Rattus* spp.), skunks (*Mephitis mephitis*), coyotes (*Canis latrans*) and pets like dogs (*Canis lupus familiarus*) (Spinks et al. 2003). In California landscaped areas with irrigation systems have negatively affected hatching success of western pond turtle eggs, due to excess moisture (Spinks et al. 2003).

Recreational Activity

Another example of western pond turtle habitat disturbance by humans can be seen in California. Recreational activities can have negative impacts on western pond turtle habitat and population success. Urbanization and the increase of human populations have taken their toll on optimal native habitat (Spinks et al. 2003). A study in the San Francisco Bay Area found that human activity such as hiking, biking, fishing, boating and motor vehicles in western pond turtle habitat can greatly decrease emergent basking (Nyhof and Trulio 2015). The site for this study took place near Moffett Naval Air Station, where western pond turtles have found refuge in a heavily altered water channel. This canal is in close proximity to the newly opened San Francisco Bay Trail. Human disturbance may have a greater effect on western pond turtles that other non-native turtles due to their wariness (Bury et al. 2012).

Agriculture

California has filled in much of its wetlands to accommodate agricultural crops and livestock. The impacts of agriculture on western pond turtles and other aquatic organisms can be clearly seen in the Central Valley in California (Meyer et al. 2016, Germano and Bury 2001). The San Joaquin River has been altered with water diversions, implemented to support agriculture and livestock activity. California has lost approximately 90% of its wetlands in the Central Valley. Farming has greatly impacted wetlands by using floodplains for crops and building dams and levees, fragmenting the San Joaquin River (Frayer et al. 1989). If livestock are not fenced out of a watershed they will trample, introduce excess nutrients and compact the soil around the body of water (Riensche et al. 2019). These actions impact western pond turtle populations by destroying natural habitat, impacting diet and polluting with excess nutrients and chemicals.

Non-Native Species Interactions

Other factors that contributed to the decline in western pond turtle populations are introduction of non-native species like the American bullfrog (*Lithobates catesbeianus*), sunfish fish (*Lepomis* spp), largemouth bass (*Micropterus salmoides*), red-eared sliders (*Trachemys scripta elegans*) and other species. Bullfrogs and warm-water fish have greatly impacted the survival rate of hatchling and juvenile western pond turtles (Hays et al. 1999). This has had profound effects on western pond turtle populations because of their low numbers, isolation and delayed maturity age. Other interspecific interactions are competition for food and habitat with non-native turtle species, fish, birds and garter snakes (Holland 1985).

In California the western pond turtles are being displaced by urbanization and the non-native red-eared slider turtle (*Trachemys scripta elegans*) (Ernst and Lovich 2009). Red Eared sliders are native to southern United States and northern Mexico. The red-eared slider was first introduced by the food industry and then became the preferred turtle species for a pet in the United States (Kraus 2009). This facilitated the species' movement from the south of the United States to many other parts of the nation. Once the turtle becomes too difficult to take care of, the owners will release them into the environment creating an ecological imbalance in that habitat (Kraus 2009). Presently in California, the red-eared slider has invaded the western pond turtle's habitat (Lowe et al. 2000, Pearson et al. 2015). The red-eared sliders are generally larger in size, more aggressive and have more resilient eggs, allowing for a high hatching rate in different environments (Spinks et al. 2003). At basking sites especially, in situations with high turtle populations inter- and intra-specific aggressive behaviors may take place (Bury and Wolfheim 1973). The addition of a non-native more aggressive and more resilient turtle in western pond turtle habitats can only lead to population declines (Figure 4).

Figure 4. Non-native species interactions, western pond turtle in center surrounded by red-eared sliders in Lake County, CA. Photo by Kathleen Scavone. (Scavone 2019)

Drought and Fire Impacts

The impacts of drought on western pond turtle populations were studied in the Central Valley in California on the San Joaquin Experimental Range of the U.S. Forest Service in the western foothills of the Sierra Nevada between the years 2009 to 2015 (Purcell et al. 2017). The effects of drought on western pond turtles can lead to starvation, dehydration, decreased movement and increased predation. During a drought, ponds and waterways can completely dry up, affecting western pond turtle natural behavior. Drought can negatively affect western pond turtle populations by eliminating their diet (Holland 1994). As discussed previously, western pond turtles are omnivores but have a mostly aquatic diet. Radio telemetry was used to follow the movement of 20 adult western pond turtles. Using the Palmer Drought Severity Index (PDSI), which is a measure of relative dryness calculated with present temperature and precipitation data, western pond turtle survivorship was assessed (Figure 5). Purcell et al. (2017) found that over time the mortality number of adult western pond turtles was 9 out of the 20. Concluding that consecutive years of drought leads to high mortality of adult western pond turtles. Drought can also affect recruitment for mating especially in isolated populations leading to a higher possibility of extirpation.

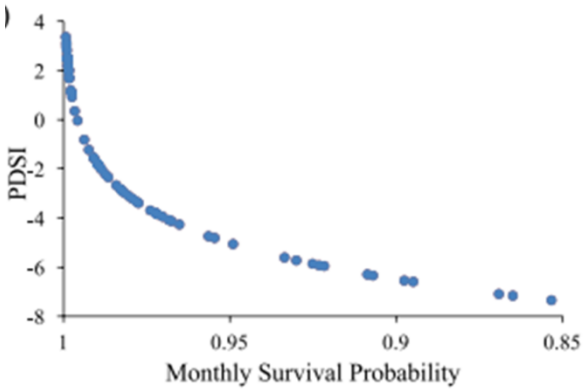

Figure 5. The relationship between Palmer Drought Severity Index and the monthly survival probability of western pond turtles in the Central Valley (Purcell et al. 2017).

It is especially important to note with the climate change trend in California, that western pond turtles are susceptible to wildfire impacts. The negative effects on western pond turtle populations have been documented in southern California after a wildland fire in 2013 that impacted Elizabeth Lake. Data were collected on water quality, demographic structure and short-term survivorship of the population (Lovich et al. 2017). After a fire, the water quality decreases in different ways: lower levels of dissolved oxygen; high salinity; increase in pH; increase dissolved ammonia, nitrate and soluble reactive phosphorus; and increase in sedimentation. While few western pond turtle survivors were found, it seemed that larger adult individuals survived better than hatchlings and juveniles as no remains were found. Short-term survivors can be identified as they will possess burns on shells and limbs. Injuries due to fire greatly decrease the likelihood of survival of an individual. Coupled with habitat destruction and fragmentation will cause turtles to be sedentary or will significantly decrease movement. Due to burn injuries and habitat fragmentation turtles are restricted from moving away from the affected area. Turtles will ultimately starve to death due to the elimination of their food source. When wildfire burnt areas are faced with drought, the negative effects on western pond turtles are higher. During a drought aquatic habitats will dry up, the evaporation of water will leave behind a white mineralized layer. A white mineralized layer will form on the turtles preventing thermoregulation during emergent basking (Figure 6). Mortality from predation also increases as turtles are easier targets on terrestrial habitats (Leidy et al. 2016).

Figure 6. Western pond turtle carcass at Elizabeth Lake (Los Angeles County, CA) in 2015. Due to years of drought and fire, a white mineral layer coats the bottom of the lake due to water evaporating (Lovich et al. 2017).

Flood Impacts

Flooding can have severe consequences for western pond turtles as the filling in of shallow pools used as microhabitat for western pond turtle hatchlings and juveniles can occur, (Ashon et al. 1997). The use of dikes and water diversions for agriculture and industry again impact western pond turtle habitat. Turtle nests are especially susceptible to excess moisture lowering hatching success. Western pond turtle eggs absorb extra moisture and may burst, which can yield the egg non-viable (Feldman 1982, Spinks et al. 2003).

Objective of this Study

Both Washington and Oregon have established either a species-specific management plan or best management practices for the conservation of western pond turtles. California is the only state where this native turtle does not have established conservation guidelines even though it is a species of special concern. In this paper the question; Are the management techniques that Washington and Oregon have established, succeeding in the recovery and conservation of western pond turtle populations? With a focus on head-start programs, non-native species removal and habitat restoration/enhancement, lead to a more efficient recovery of western pond turtle populations? In order to support the application of best management practices for the

conservation of western pond turtle populations in California, scientific peer-reviewed, unpublished literature and government agency reports will be used to determine the best management practices for California. The conservation of western pond turtle populations is important because it is the only native freshwater turtle in California and one of two turtle species endemic to the west coast (Reese and Welsh 1997, Ernst and Lovich 2009). They are part of the food web that supports native species. Whether western pond turtles are prey or predator, they are part of a feedback trophic system that will create cascades in their environment and change interspecific interactions.

Methods

For this paper peer-reviewed, unpublished literature, government agency reports and personal communications with specialists in the field were used to compare and support claims to best management practices implemented by Washington and Oregon State for the conservation of western pond turtles.

These management practices were inferred by the following two peer-reviewed papers.

- Washington State Recovery Plan for the Western Pond Turtle (Hays et al. 1999).
- Guidance for Conserving Oregon's Native Turtles including Best Management Practices (Oregon Department of Fish and Wildlife 2015).

Comparisons conducted between Washington, Oregon and California state, in order to assess whether conservation efforts for Washington and Oregon are increasing the western pond turtle populations. This was done by using historical or past population surveys. Recovery efforts started in Washington in 1990 and then followed in Oregon. Then looking at population surveys conducted after 1990 to see if population numbers have changed. The number of head-starting turtles will also be presented and used to display changes to population demographic structure and if their presence gives rise to sustainable populations by increasing recruitment along with habitat restoration. Using data from a study conducted by Barela and Olson (2014) on western pond turtle habitat mapping in the northwestern United States, an analysis of the data was produced to obtain more knowledge of land ownership of western pond turtle sites. This could be a key component in conservation in California for the implementation of management practices. I also reached out to specialists in the field, in order to get more insight on the topic but also to fill in some of the information gaps.

Results

Management Background

Table 1. A comparison of Washington and Oregon's management practices for the recovery of western pond turtles (generated from Hays et al. 1999 and Oregon Department of Fish and Wildlife 2015).

Washington State Recovery Plan	**Oregon General Best Management Practices**
1. Habitat acquisition	1. Create and enhance habitat for Oregon's native turtles
2. Habitat enhancement	2. Avoid direct modifications to water bodies and waterways
3. Surveys	3. Avoid altering hydrology of and causing increased sedimentation rates into water bodies, except for short-duration actions that are linked to habitat restoration efforts
4. Interagency survey plan	4. Avoid or minimize disturbance from public access or other human activities
5. Toxicology research	5. Provide native vegetation buffers around wetlands and other water bodies.
6. Capture breeding	6. Utilize seasonal "no-entry" restrictions to minimize human-related disturbances
7. Head start programs	7. Permanent conservation ownership or easements to protect the site in perpetuity
8. Predator removal	-
9. Habitat use research	-
10. Reintroduction	-

For Washington State the two recovery regions that were analyzed are the Columbia Gorge and south Puget Sound (Figure 3). South Puget Sound is in the northwestern part of Washington bordering Canada, while the Columbia Gorge is in the southern part of Washington bordering Oregon. With the recovery regions being on opposite sides of the state, this will give a more concise opinion of what is happening in the state. Within these recovery zones, there are sites that have been studied and have implemented a recovery plan for the endangered western pond turtle. In the Columbia Gorge the sites consist of Sondion, Bergen, Pierce National Wildlife Refuge (NWR) and Beacon Rock. In south Puget Sound the sites are; Pierce County and Mason County.

This recovery management program has been a collaboration between many agencies. The Washington Department of Fish and Wildlife is the lead agency and has been given funding to do this research for conservation by the Woodland Park Zoo (Seattle, WA) and the Oregon Zoo (Portland, OR). The Center for Wildlife Conservation (Seattle, WA) has been the primary funding source for the captive breeding and the head start program. Volunteers were very important to this research and expenses for equipment and volunteer activities were provided by a grant from the Washington Department of Fish and Wildlife Aquatic Lands Enhancement Account. Non-governmental agencies have also provided funds like the Woodland Park Zoological Society, Foley/Frischkorn Wildlife and Conservation Fund, and the Western Aquatic Turtle Education and Research. Even though Western pond turtles have not been classified as endangered under the Federal ESA, the U.S. Fish and Wildlife Service has provisioned funds under the Endangered Species Act Section 6. The ESA, Section 6 allocates federal money to states and counties to operate conservation management plans (Hays et al. 1999).

The process of head-starting starts with obtaining western pond turtle eggs at recovery sites and incubating eggs at head-starting facilities such as through collaborations with universities and zoos. The eggs are incubated at higher temperatures in order to produce more females (Ewart et al. 1994). Once the hatchlings are born they are maintained at an optimal water temperature of about 22 ˚C and basking sites at about 27˚C, with a high protein diet, clean water and functional habitat design (Dallara 2011). The purpose of head-starting facilities is to help grow healthy western pond turtle juveniles and release them into the wild, when they are more able to compete and avoid predation by other species in their environment (Heppell et al. 1996).

The site established in Sondino, resides in Klickitat County. This site encompasses 80 hectares and is owned and managed by the Washington Department of Fish and Wildlife. This site has a pond complex, and upland habitats. The western pond turtle population at this site is also one of two naturally occurring populations in the state. The population estimates at this site have used a mark-recapture trapping technique (Hallock et al. 2017).

At the Bergen site in Skamania County, the site consists of 80 hectares owned by U.S. Forest Service and 26 hectares of privately owned land. The site has been determined as good western pond turtle habitat it includes an extensive lake, pond and wetland complex within a forest and pastureland environment. The second naturally occurring population of western pond turtles inhabits this site (Hallock et al. 2017).

The Pierce National Wildlife Refuge (NWR) site is owned by U.S. Fish and Wildlife Service and is located in Skamania County. Due to its optimal western pond turtle habitat which includes a complex of creeks, ponds, sloughs and adjacent upland habitat; turtles were reintroduced to this site in 2000 (Hallock et al. 2017).

Beacon Rock State Park is also found in Skamania County, this site is a very interesting habitat for western pond turtles and includes a mitigated wetland and other aquatic bodies. This site is managed by the Washington State Parks and Recreation Commission. It originally did not have a naturally occurring western pond turtle population, but 204 turtles have been introduced from 2007- 2017 (Hallock et al. 2017).

In Pierce County the western pond turtle site occurs within 36 hectares owned and managed by the Washington Department of Fish and Wildlife. These 36 hectares are managed for urban wildlife and western pond turtles have their own habitat which encompasses 4.9 hectares and includes a 1.2 hectares of mitigated wetland and adjacent grasslands. Western pond turtles were introduced to this site in 1996 (Hallock et al. 2017).

Finally the site in Mason County includes a shallow 8 hectares pond that has other aquatic environment around it. The site is on Washington Department of Natural Resources land and experiences disturbances due to management for timber production and recreational use. Head-started turtles were releases until 2013 at this site. Visual emergent basking surveys were conducted from 2005-2013 (Hallock et al. 2017).

Oregon has collaborated with the recovery plan for Washington State; however, Oregon itself does not have any recovery zones as of this moment. Head-starting programs are not popular in Oregon, there was a head starting pilot at one point but no monitoring was conducted (S. Barnes, Oregon Department of Fish and Wildlife, pers. comm. 2019). However, Oregon has developed best management practices for the conservation of western pond turtles that serve as guidelines that are not technically enforced under the law. For the purpose of measuring western pond turtle populations at Oregon sites, the region of the Willamette Drainage will be analyzed. The two zones analyzed were Benton County and the Umpqua Region. The reason these locations were chosen is because the Willamette Drainage is connected to the Columbia Gorge in Washington.

One of the sites in Benton County is the East Thornton Lake Natural Area. This site was purchased by the city of Albany, OR in 2010 and designated about 10.9 hectares of property for the conservation of native species (Figure 7). The landscape can be described as riparian forest and upland oak savanna. In 2011 the Oregon Department of Fish and Wildlife awarded a grant to the Albany Parks and Recreation Department to manage invasive weeds and develop a native turtle management plan. A collaboration with the Oregon Wildlife Institute was initiated in order to improve the habitat for western pond turtles and western painted turtles (*Chrysemys picta*). The site is surrounded by human residential area, which brings turtles in contact with humans and vehicles. The lake also experiences reoccurring algal blooms in the summer due to excess nutrients, most likely from run-off from residential gardens. Non-native macrophytes, like the Brazilian elodea (*Egeria densa*) are present, which have impacts on turtle natural habitat and recreational activities. A lack of emergent basking sites was also documented, with only 10 large

logs and mowed grass at residential sites. Non-native species were identified at the site as carp (Family *Cyprinid*), largemouth bass (*Micropterus salmoides*), western mosquitofish (*Gambusia affinis*), yellow bullhead (*Ameiurus natalis*), yellow perch (*Perca flavescens*) and bullfrogs (*Rana catesbeianus*) (Vesely 2014).

Figure 7. Western pond turtle restoration sites in East Thornton Lake Recreational Area (Benton County, OR) (Vesely 2014).

The other sites in Benton County that are being analyzed in this paper are OR 022 W and OR 002 U. The site OR 002 U was located on a 2.5 hectares lake. No other information was available on these sites other than population morphological surveys (Holland 1994).

The Umpqua Basin in Oregon is one of the historical places where western pond turtles inhabit ponds and rivers. It is 1, 208, 100 hectares and has varied sea levels up to 1827 meters. The Umpqua Basin also has 5 provinces consisting of the Coast Range, Klamath Mountain, Western Cascades, Willamette Valley and other (Figure 8). This land is owned by the U.S. Forest Service and Bureau of Land Management (Rosenberg et al. 2009). For the purpose of this paper, south Umpqua was the focus of population assessment. South Umpqua is bordered by the Klamath Mountains and Western Cascades. The river flows are extreme compared to the river flows of the other three drainages (Horn and Gervais 2018).

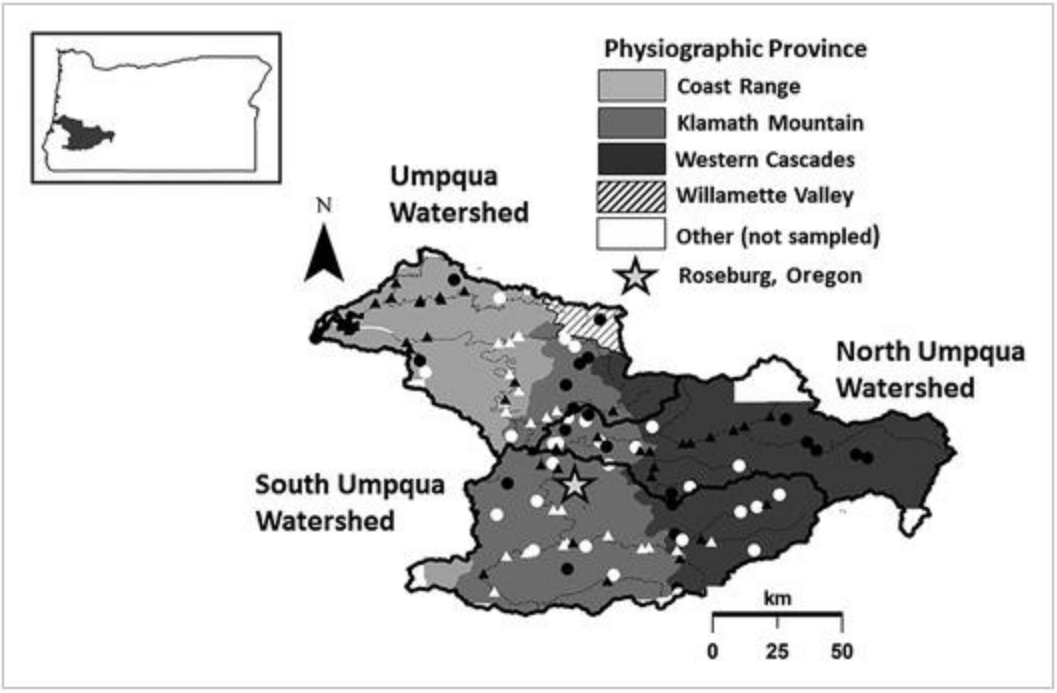

Figure 8: Umpqua Basin drainage (Douglas County, OR) with three distinct watersheds (Horn and Gervais 2018).

In California there are no assigned recovery regions for western pond turtle populations as the species has not been listed as threatened or endangered. However, head-start pilots and habitat restoration projects are being conducted by non-governmental agencies in collaboration with the California Department of Fish and Wildlife (Geist et al. 2015). The sites analyzed in California were Boggs Lake in Lake County, the University of California Davis Arboretum Waterway in Yolo County and Sycuan Peak Ecological Reserve in San Diego County. These sites were chosen due to the similarity in management practices which consisted of head-starting programs, non-native species removal and habitat restoration/ enhancement. The results will give interesting knowledge into how western pond turtle populations react to management strategies in northern and southern regions in California.

Dr. Nicholas Geist's Lab at Sonoma State University is leading the way for conservation of western pond turtles at Boggs Lake in Lake County, California. The North Bay Western Pond Turtle Project was initiated in 2008 by Dr. Geists's research. The North Bay Western Pond Turtle Project is a collaboration between Sonoma State University, California Department of Fish and Wildlife and head-starting facilities at the San Francisco and Oakland Zoos. Every year approximately 30-40 head-started western pond turtles are released back to the native site (San Francisco Zoo 2017).

Boggs Lake Ecological Reserve is the site where The North Bay Western Pond Turtle Project releases its head-started turtles (Figure 9). This site is located in Lake County and is co-owned and managed by the Nature Conservancy and California Department of Fish and Wildlife. This reserve includes 18.6 hectares; Boggs Lake is an upland vernal pool which is a habitat for

endemic flora and Fauna species. The reserve is used for recreational purposes like; Fishing, birdwatching and wildlife viewing (California Department of Fish and Wildlife 2019b).

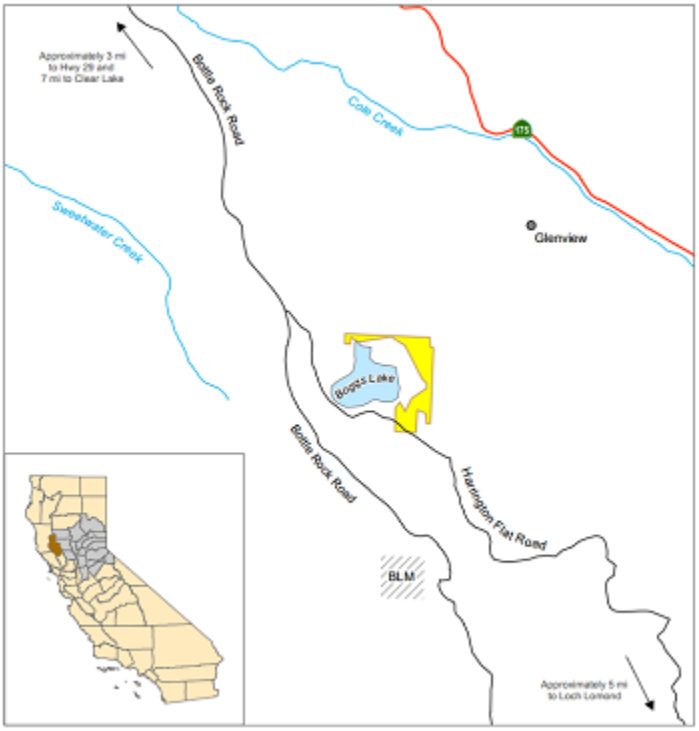

Figure 9. Boggs Lake, located in Lake County, CA is a vernal pool (California Department of Fish and Wildlife 2019b).

The University of California Davis Arboretum Waterway is inhabited by a western pond turtle population, research on demographics and factors affecting them have been studied since 1996 (Spinks et al. 2003).The Arboretum has an approximate surface area of about 4 hectares, has an average depth of 1 meter and has an average of 15 meters wide. A paved walkway encircles the arboretum at the campus. There was also non-native vegetation planted along with an irrigation system (Spinks et al. 2003). Observations of a declining western pond turtle population in the waterway and sightings of non-native turtles in 1996 triggered this investigation. For the assessment of the western pond turtle population, turtles were captured, marked and measured; and non-native species were removed. Due to the decline in population at the time a head-starting program was initiated, which released 31 juveniles into the Arboretum. The Arboretum has under-gone restoration work, providing better emergent basking sites (Spinks et al. 2003, Lambert et al. 2019).

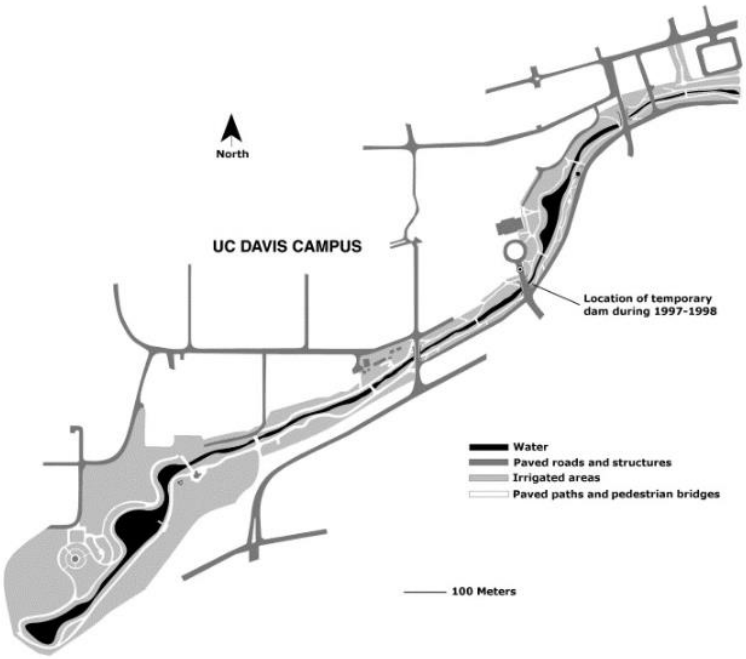

Figure 10. University of California Davis Arboretum Waterway (Yolo County, CA) (Spinks et al. 2003).

San Diego County has implemented a Management Strategic Plan Area that was designed by the San Diego Management and Monitoring Program for the San Diego Association of Governments (SANDAG). SANDAG, through the collaboration with the U.S. Geological Survey, identified Sycuan Peak Ecological Reserve as essential habitat for western pond turtles (Brown et al. 2012). The management practices used for this restoration area started in 2009 and consisted of a head-start program and removal of non-native species such as the American bullfrogs (*Lithobates catesbeianus*), African clawed frogs (*Xenopus laevis*), sunfish (*Lepomis* spp.), largemouth bass *(Micropterus salmoides*), and crayfish (*Procambarus* spp.). The San Diego Zoo served as the head-starting facility for this project. Ten head-started juvenile turtles were released and then fitted with radio transmitters to determine movement and health. Surveys were conducted from 2013-2015 by the U.S. Geological Survey (Brown et al. 2015).

The site at Sycuan Peak Ecological Reserve is based on the Sweetwater River (Figure 11). It can be found about a kilometer below Loveland Dam. The vegetation found in the uplands is mostly sage shrubs, chaparral surrounded by riparian zones. The river banks consist of rock and sand with exposure to the sun. Six pools were chosen based on western pond turtle survey trapping. These six pools provide the most suitable habitat in the reserve for western pond turtles. Pools 1-3 are the lower pools which are made up of boulders and rocks with open canopy, deeper pools and plenty of basking sites and foraging sites. The upper pools 4-6 are made up of sand and gravel bottoms, emergent vegetation, have less sun expose and seasonal drying (Brown et al. 2015).

Figure 11. Western pond turtle site in Sycuan Peak Ecological Reserve (San Diego County, CA) (Brown et al. 2015).

Land Ownership of Western Pond Turtle Habitat

California contains almost 40 times more western pond turtle sites than Washington and a little less than one and a half times more sites than Oregon (Figure 12). Although California holds the most western pond turtle sites of the three states, it has not established a management plan for the species.

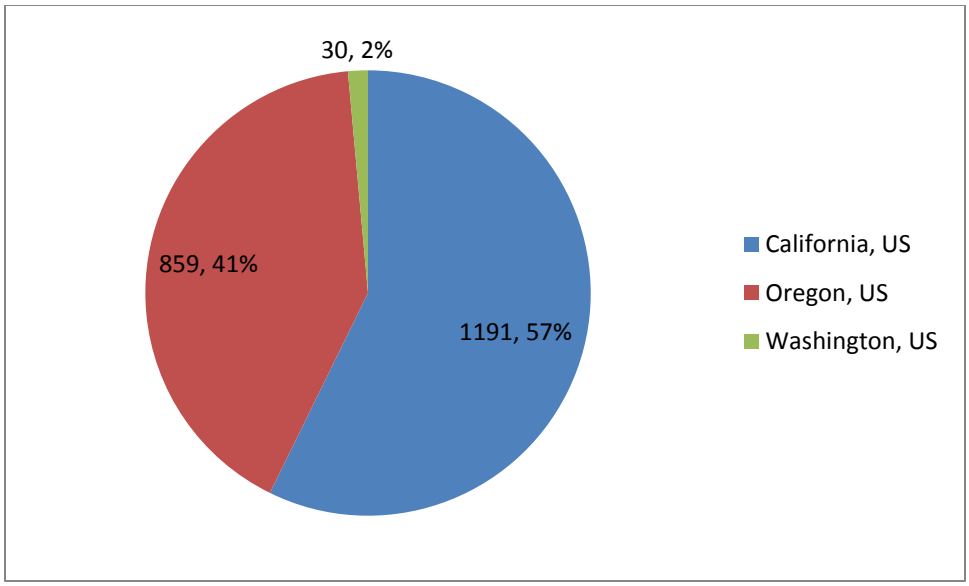

Figure 12. The percentage and number of western pond turtle sites in each respective state of California (n=1191), Oregon (n=859) and Washington (n=30) (Data from Barela and Olson 2014).

An essential component of the management of western pond turtle sites is land ownership as the implementation of management plans, especially those that have to be followed under the law, are not always accepted by residential and industrial property owners. The Forest Service is the agency that owns the most number of western pond turtle sites; followed by the Bureau of Land Management, Department of Defense, National Park Service, U.S. Fish and Wildlife Service and then Bureau of Reclamation (Table 2).

Table 2. Western pond turtle habitat owned by United States federal agencies. A unique site defined as being isolated while a cluster site having another site(s) within 500 meters (Barela and Olsen 2014).

Land ownership	Unique	Clusters	Total (%)
Bureau of Land Management	89	26	115 (5.5)
Bureau of Reclamation	14	0	14 (0.7)
Department of Defense	44	7	51 (2.4)
Forest Service	301	65	366 (17.5)
US Fish and Wildlife Service	32	1	33 (1.6)
National Park Service	33	2	35 (1.7)
Non-federal land	1341	141	1482 (70.7)
Total	1854	242	2096

Washington Assessment

The two recovery zones in Washington for western pond turtles are the Columbia Gorge and south Puget Sound. The Columbia Gorge is in the southern part of Washington bordering Oregon. While south Puget Sound is in the northwestern part of Washington. Eight counties were

surveyed in 1993, showing the age demographic in western pond turtle populations in each respective county (Table 3). The counties within the Columbia Gorge are; Skamania, Klickitat, and Clark. The counties within south Puget Sound are as follows; King, Pierce, Kitsap, Thurston and Mason. In Skamania County with high numbers of painted turtles the number of both adult and juvenile western pond turtles decreases compared to Klickitat County where there are less painted turtles. In sites where red-eared sliders are present, western pond turtle numbers are non-existent or low. Competition may be taking place at these sites due to the high number of turtles in the area (Bury and Wolfheim 1973).

Table 3. Western pond turtle population demographics in Columbia Gorge and South Puget Sound, Washington for 1993 (Compiled from Nordby 1992) (Washington Department of Fish and Wildlife 1993).

County	Sites surveyed	Sites with pond turtles	Adult pond turtles	Juvenile pond turtles	Painted turtles	Red-eared Sliders
Skamania	39	10	23	2	288	
Klickitat	6	2	33	8	4	
Clark	15	0			150	
King	14	1	1		5	5
Pierce	7	0				7
Kitsap	5	1	1		3	
Thurston	1	1	1			
Mason	1	0				
Totals	88	15	59	10	450	12

South Puget Sound contains two recovery sites, while the Columbia Gorge contains four recovery sites (Hays et al. 1999) (Table 4). The information here is very important to take note, recovery efforts in Washington began in 1990, head-start releases at these sites took place from 1991-2015. The number of head-started turtles at these sites is also presented with a minimum of 204 to a maximum of 558 juvenile head-started western pond turtles released.

Table 4. Head start release numbers in Washington from 1991–2015 (Hallock et al. 2017).
1 Schmidt and Tirhi (2015), 2 Murphie and Skriletz (2014), 3 Holman et al. (2014), 4 Bergh and Anderson (2015).

Recovery Zone	Site	Year recovery site was established	Total head-starts released
South Puget Sound	Pierce County[1]	1996	427
South Puget Sound	Mason County[2]	2005	325
Columbia Gorge	Sondino[3,4]	Remnant	558
Columbia Gorge	Bergen[3]	Remnant	333
Columbia Gorge	Pierce NWR[3]	2000	353
Columbia Gorge	Beacon Rock[3]	2007	204

It is important to track and monitor head-started turtles that have been released, to determine the impacts they are having on populations. This will give insight into management

practices and efforts that have been implemented to produce viable western pond turtle populations. The western pond turtle population in Klickitat County in 2005 was recorded to be 288 (Figure 13). Recovery sites in both the Columbia Gorge and south Puget Sound were surveyed. A significant increase in numbers of western pond turtles occurred from 1993 to 2005. The western pond turtle population in Klickitat County increased with the addition of 247 head-started turtles. While Pierce County had a non-existent population in 1993, in 2005 western pond turtle were recorded at 66 with the introduction of head-started tutles. Pierce NWR is located in the Columbia Gorge Recovery Region, but populations were not measured in 1993, however in 2005 the population was recorded at 114.

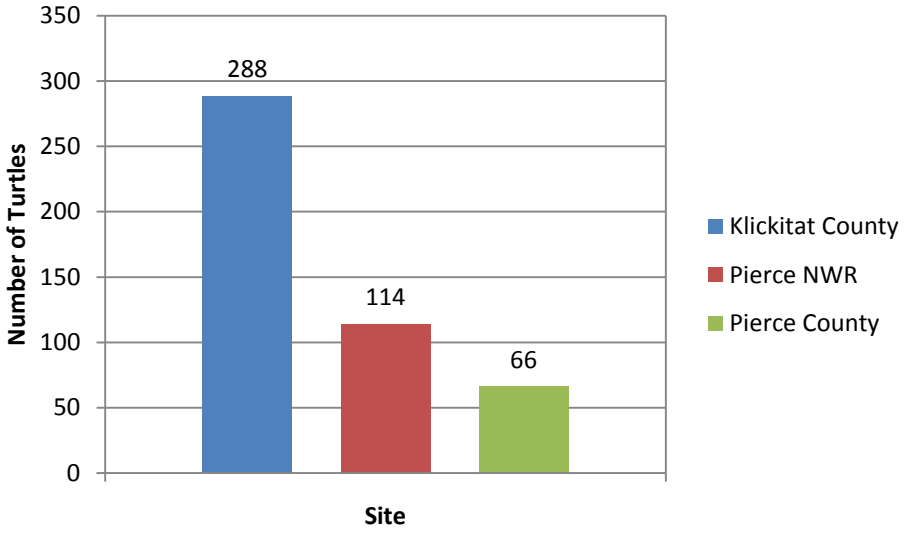

Figure 13. Western pond turtle populations in recovery regions of Washington in the Columnia Gorge- Klickitat County and Pierce NWR and South Puget Sound- Pierce County in 2005 (Data from Van Leuven et al. 2005, Holman et al. 2015, Schmidt and Tirhi 2015).

Pierce County in south Puget Sound had a western pond turtle population of zero and head-start release totaled 427 in 2015. The impacts on the western pond turtle population in Pierce County, were monitored from 2003 to 2015 (Figure 14). The correlation coefficient R^2 of 0.69 indicates that the correlation is strong and that the western pond turtle population is increasing. This suggests that the management practices taking place at the Pierce County site had a positive effect on western pond turtle population growth.

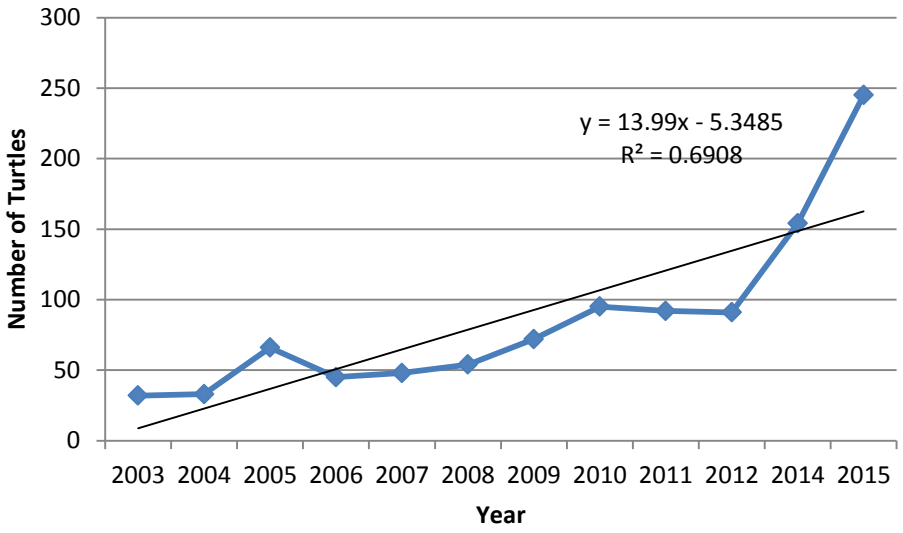

Figure 14: The data show an increase in western pond turtle population from in Pierce County, located in the South Puget Sound recovery zone between 2003-2015 (Data from Schmidt and Tirhi 2015).

Although Pierce County has had great success with its western pond turtle population, sites in Sondino, Bergen, Pierce NWR and Mascon County have not had the same success (Figure 15). All the sites except Sondino have had positive growth trends until a certain point. After this point a negative growth trend is depicted. These results merit more research. The site in Sondino in a special site as western pond turtles are acquired and translocated from this site, as it is one of the naturally occurring populations in Washington (Hallock et al. 2017). But if we look closely at the population trend in Sondino there seems to be an indication of a slight recovery in 2015 but more information is necessary in order to determine a trend.

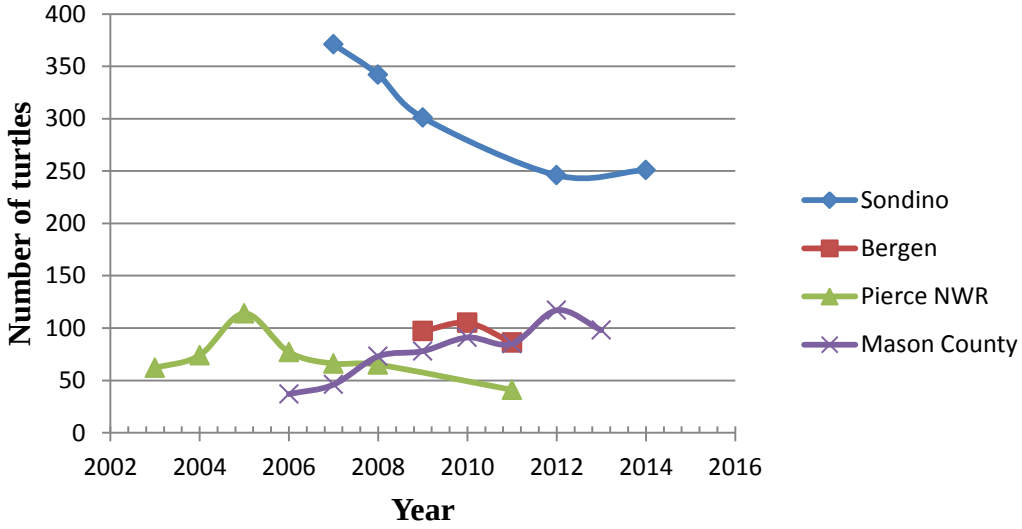

Figure 15. Trends in size of western pond turtle populations at four sites in Washington (Data from Murphie and Skrilletz 2014, Holeman et al. 2015).

The magnitude at which head-start programs effect western pond turtle populations has not been established, however the hope is that head-start program will increase recruitment and create sustainable western pond turtle populations. Demographic structure is important to account for in western pond turtle populations as well as head-started released turtles. The number of head-started turtles has been identified at three sites Klickitat County, Skamania County and Pierce NWR (Table 5). In Klickitat County only 46 of the western pond turtles are not head-started, in Skamania County 10 are not head started and in Pierce NWR all of the turtle in the population are head-started. In is important to note as well the number of adult females at each site as population size depends heavily on reproductively mature female numbers.

Table 5. Western pond turtle numbers and identity at sites in the Columbia Gorge for 2005 (Van Leuven et al. 2005).

Location	# turtles	# head starts	# adult females
Klickitat County	288	242	29
Skamania County	88	78	5
Pierce NWR	110	110	0
Total	486	430	34

Predation is one of the leading factors in the decline of western pond turtle recruitment. Bullfrogs are voracious predators towards juvenile western pond turtles. At sites with bullfrogs present the number of turtles < 120 mm in carapace length decline, while the turtles that are >120 mm in carapace length increase due to lack of bullfrog predation (Figure 16). The carapace of the adult populations in Klickitat County, Washington are much larger compared to the carapace size of Oregon populations. This is due to bullfrogs driving western pond turtle morphology to be larger as only the large juveniles will survive predation during their most vulnerable stage.

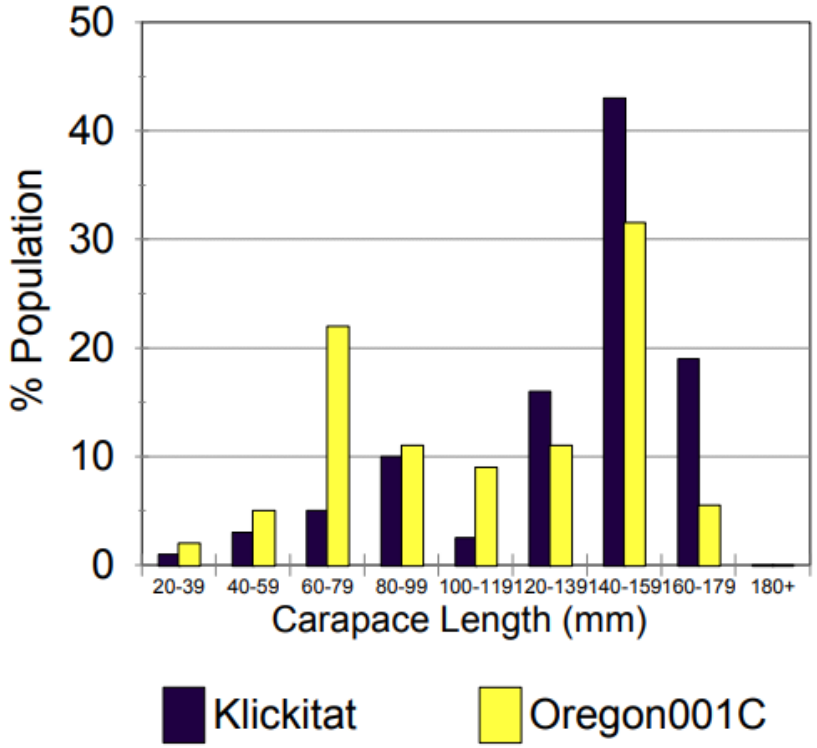

Figure 16. Western pond turtle morphological size difference in Klickitat County, OR with bullfrogs present,(n = 84), 1987-90 and in Oregon site 001C with bullfrogs absent,(n = 54), 1991 (Hays et al. 1999).

Oregon Assessment

Oregon is the second state in the western part of the United States with the most western pond turtle sites (Figure 12). Western pond turtles inhabit the Willamette Drainage (Holland 1994). Benton County, Oregon exists within the Willamette Drainage. A historical western pond turtle population at OR 022 W is demonstrated to have a population of 68 individuals during 1954-1959 (Figure 17). The carapaces of the individuals were measured, which represents a higher adult based population with no hatchlings and possibly a very low number of juveniles. This population demographic structure, with low hatchlings and juveniles, may indicate a present and future lack of recruitment. The data are skewed to the right indicating that the majority of the individuals are adults, based on their large carapace. The Washington State Recovery Plan for western pond turtles states that in order for a population to have sustainable recruitment, at least 70% of the population must be adults and the rest juveniles (Hays et al. 1999).

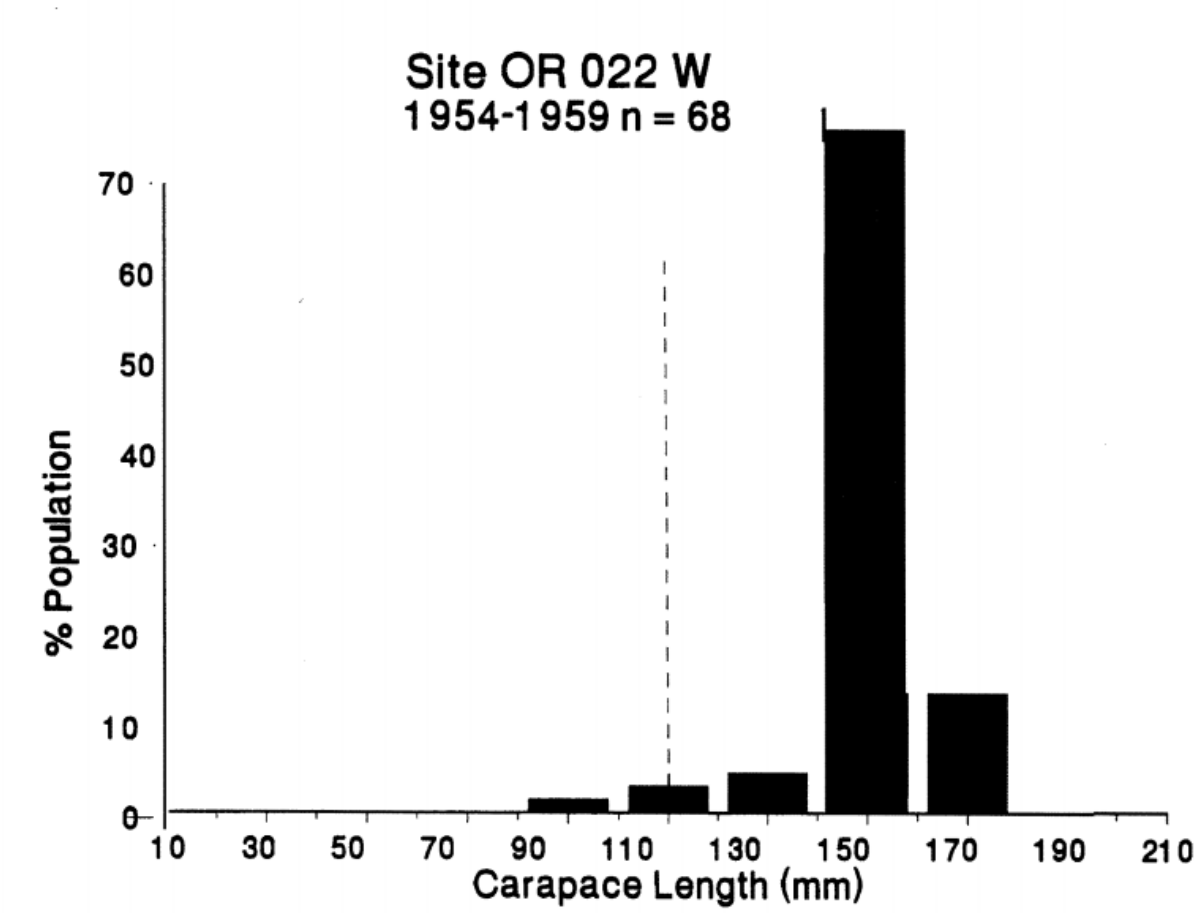

Figure 17. Historical population of western pond turtles and carapace size comparison of individuals at site OR 022 W in Benton County, OR. Western pond turtle adults were classified as > 110 mm carapace length, represented by dotted line (Holland 1994).

At the OR 002 U site in Benton County, the population of western pond turtles has a more symmetrical size distribution and thus has a demographic population that is ideal for sustainable populations (Figure 18). It is interesting to note the difference between sites and western pond turtle inhabitants especially when sites are in the same county. Also when turtle populations are skewed to the right, turtles tend to be older giving way to the notion that reproduction, nesting, hatching success, hatchling and juvenile survivorship may be at risk.

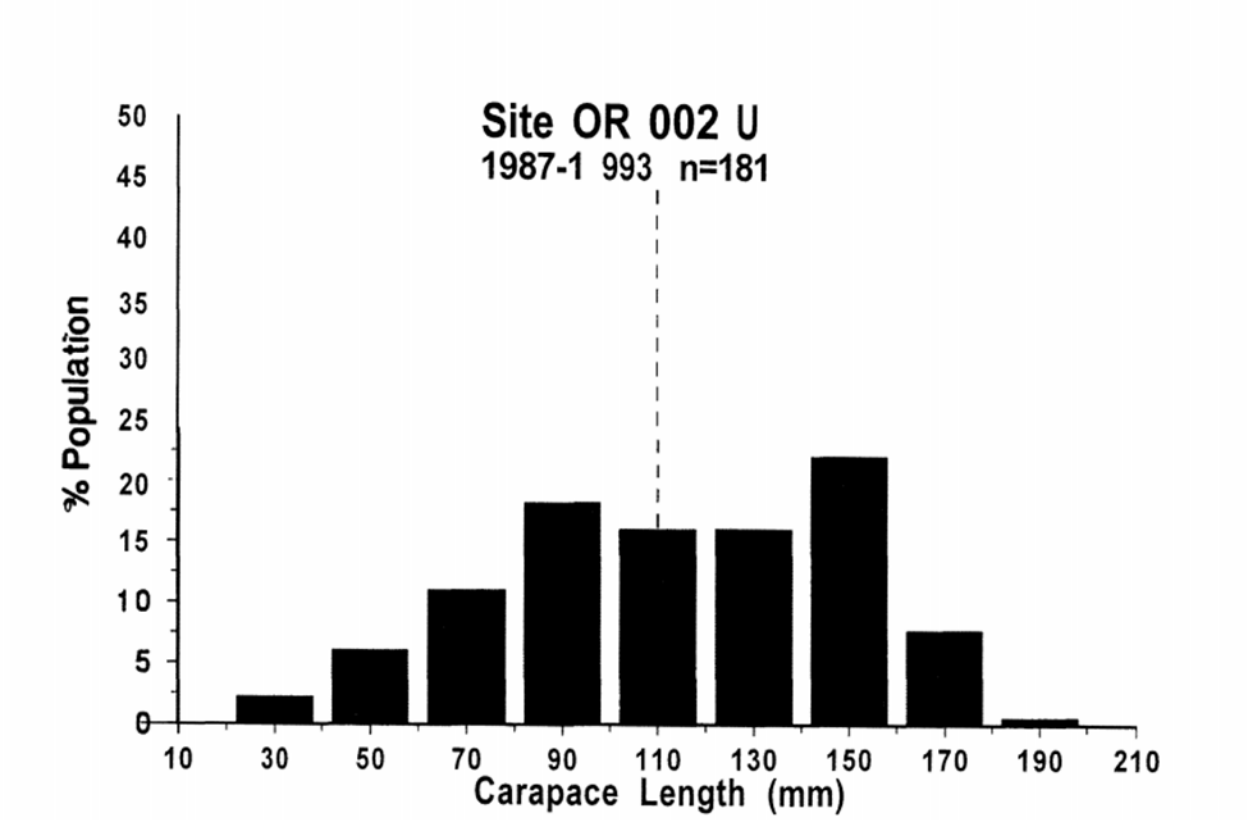

Figure 18. Historical population of western pond turtles and carapace size comparison of individuals at site OR 022 U Benton County, OR. Western pond turtle adults were classified as > 100 mm carapace length, represented by dotted line (Holland 1994).

Another location in Benton County is The East Thornton Lake Natural Area. Oregon has two native freshwater turtles which are the western pond turtle and the western painted turtle. The co-existence between these two native turtles needs to be further researched. At this site western painted turtles seem to be prospering over the western pond turtle (Table 6). The red-eared slider numbers a very low at this site, thus not a major competitor for western pond turtles. There was also a near equal sex ratio between males and females.

Table 6. Western pond turtle populations compared to western painted turtle and red-eared slider populations at East Thornton Lake Natural Area in Benton County, Oregon (Vesely 2014).

Species	Males	Females	Total
Western Painted Turtle	23	9	32
Western Pond Turtle	3	2	5
Red-Eared Slider	1	0	1

Like Benton County, Douglas County resides in the Willamette Drainage. It is southeast of Benton County approximately a distance of 230 km. The Umpqua National Forest is in

Douglas County which is one of the historical places where large populations of western pond turtles exist (Holland 1994). In Douglas County there were sites with very little recruitment (Figure 19).

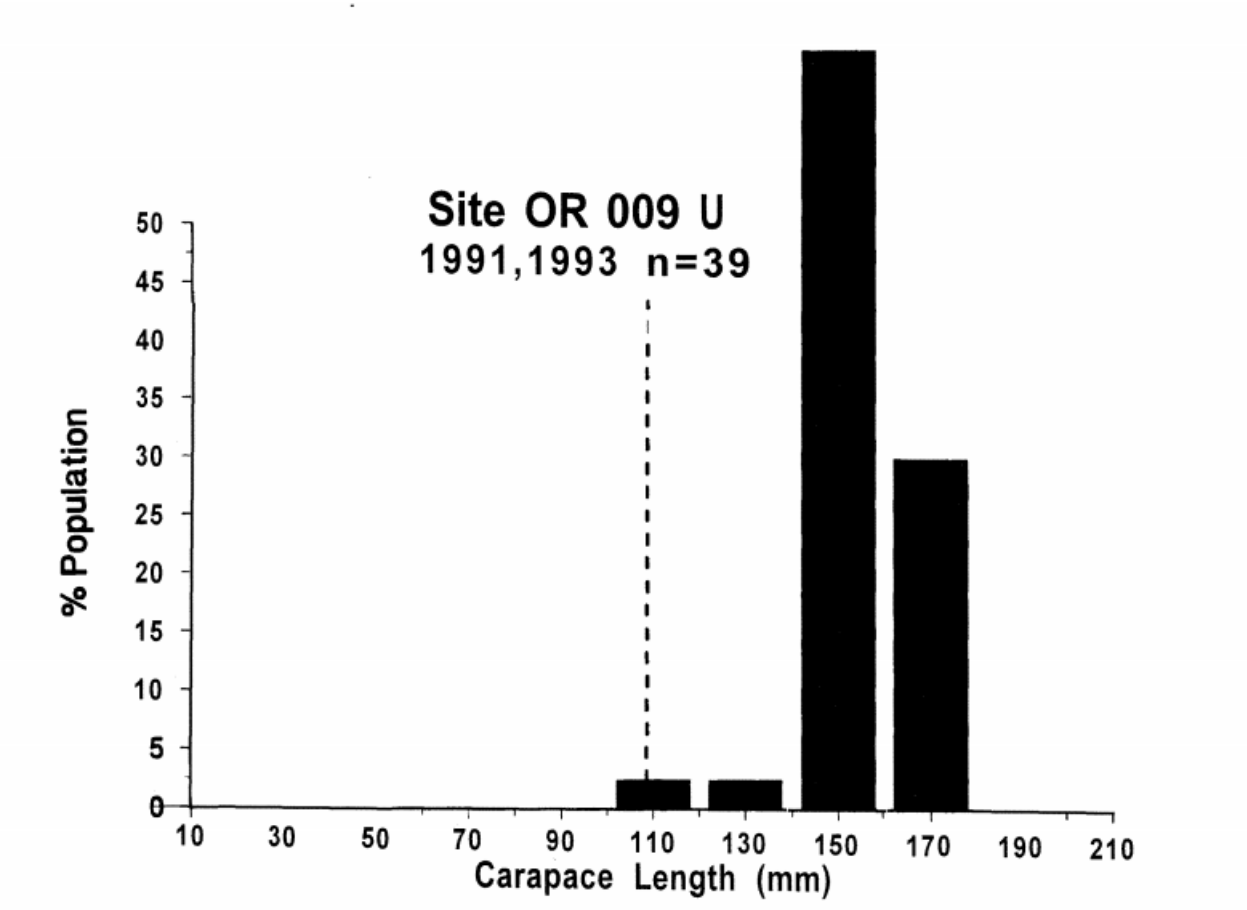

Figure 19. Population demographic structure of historical western pond turtle populations in Site OR 009 U, Douglas County, OR. Western pond turtle adults classified as > 110 mm carapace length, represented by dotted line (Holland 1994).

The Umpqua drainage is a historical habitat for the western pond turtle (Holland 1994). Western pond turtle populations in the Umpqua Drainage were surveyed and monitored to determine what their habitat preferences were (Horn and Gervais 2018). The results found more western pond turtle individuals located in rivers than ponds (Figure 20).

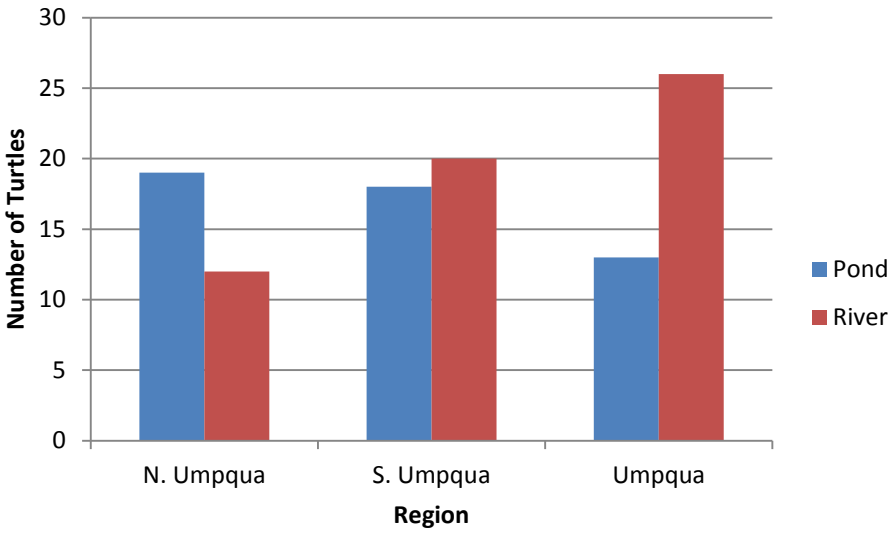

Figure 20. Western pond turtle numbers recorded along rivers in 1999 and in ponds in 1999 and 2000 through the months of April–September. The N. Umpqua is n= 19 in ponds and n= 12 in rivers. In S. Umpqua n=18 ponds and n= 20 rivers. Finally in Umpqua n= 13 ponds and n= 26 rivers (Data from Horn and Gervais 2018).

Another study was conducted in 2009 in south Umpqua and population numbers were fairly similar to the study conducted in 2018 (Germano and Bury 2009) (Table 7). A difference of 6 individuals between 9 years seems to promise a form of stability for the western pond turtle population in the south Umpqua River Region. The survey in the 2009 study also reveals the percentages of demographic structure of the south Umpqua population, revealing a fairly stable population.

Table 7. Willamette Drainage located in Oregon, western pond turtle population numbers and demographic structures (Germano and Bury 2009).

Site	*N*	Juveniles	Adults	Young	Old
Ponds and Reservoirs					
Yoncalla	60	18.3	81.7	3.3	36.7
Cooper	24	12.5	87.5	12.5	66.7
Alligator	32	21.9	78.1	3.1	71.9
Carmine	50	46.0	54.0	36.0	12.0
Blue Bluff	39	35.9	64.1	30.8	20.5
Rawlins	83	57.8	42.2	20.5	19.3
Streams and Rivers					
Cow Creek	65	16.9	83.1	4.6	43.1
Jackson Creek	56	30.4	69.6	8.9	58.9
South Umpqua	32	25.0	75.0	9.4	46.9
Jenny Creek	53	28.3	71.7	3.8	73.6

California Assessment

Northern California is recorded to have a higher population density of western pond turtles than southern California (Brattstorm 1988, Brattstorm and Messer 1988, Holland and Bury 1998, Bury et al. 2012). Nevertheless the Western Pond Turtle Project in Northern California pioneered by Dr. Nicholas Geist, has developed an head-starting program in collaboration with other agencies. Approximately 30 to 40 western pond turtle head-juveniles are released into Boggs Lake, Lake County each year since 2008. There is a strong positive correlation, supported by an R^2 value of 0.95 with regards to female western pond turtle numbers in Lake County from 2009 - 2011 (Figure 21). With a higher number of females available for recruitment the hope is that the western pond turtle population will increase.

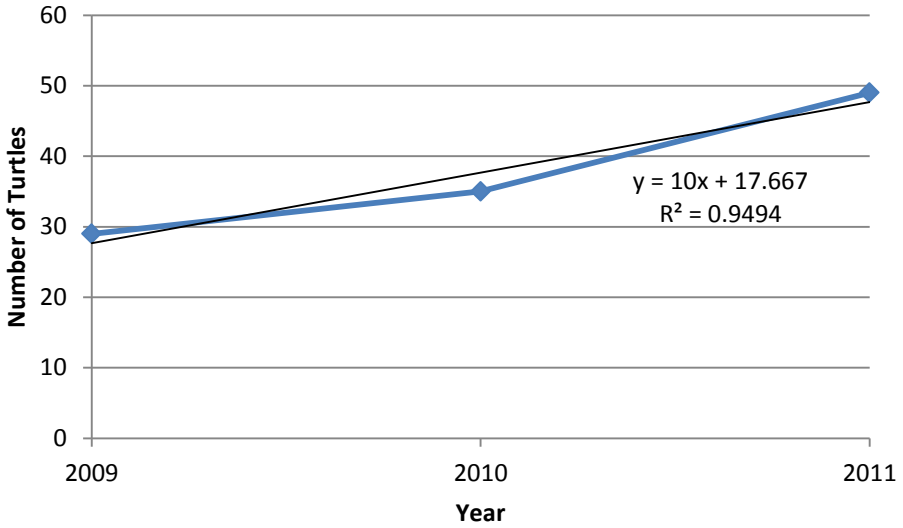

Figure 21. Number of female turtles between June 3rd and July 3rd 2009, 2010 and 2011 in Boggs Lake, Lake County, CA **(**Data from St. John et al. 2012).

At the University of California Davis Arboretum Waterway, the western pond turtle population in 2001 was projected to be about 76 individuals. Of those 76 western pond turtle 45 were non-head-started while 31 were head-started. The population survey in 2019 did not identify the turtles as non-head-started and head-started. A comparison can only be made between the numbers of western pond turtles present (Figure 22).

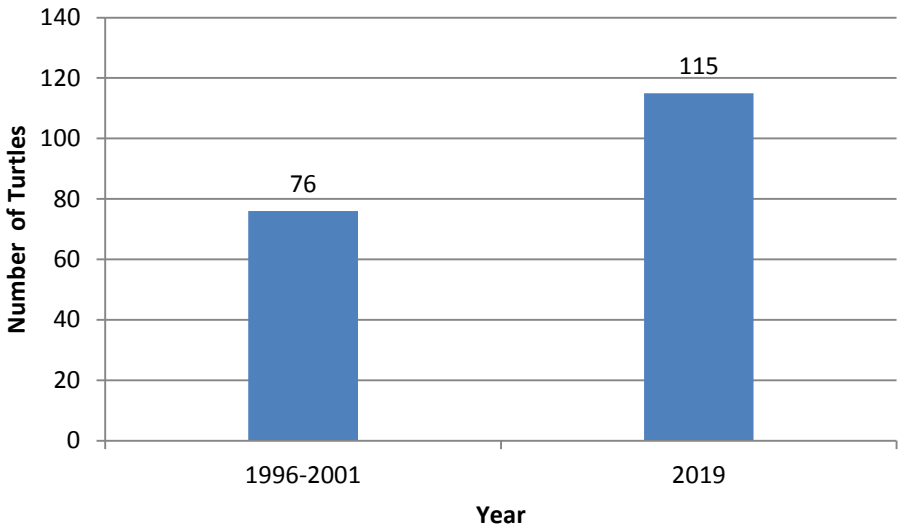

Figure 22. The western pond turtle population at the UC Davis Arboretum Waterway (Yolo County, CA) (Data from Spinks et al. 2003, Lambert et al. 2019).

Boggs Lake has implemented a head-start approach, which is promising due to the site residing in a protected reserve. Other western pond turtle habitats may not have that protection and may experience disturbances. The dilemma of western pond turtle habitat destruction and fragmentation is still taking place. Although western pond turtle sites are found in both northern and southern California, southern California western pond turtles are declining at a more rapid rate (Holland and Bury 1998, Bury et al. 2012). Western pond turtle sites have been in decline since the 1960s in Ventura County to the Mexican Border (Figure 23). The graph shows decreasing western pond turtle sites in southern California, represented by a negative slope and an R^2 of 0.71 relating to a strong correlation.

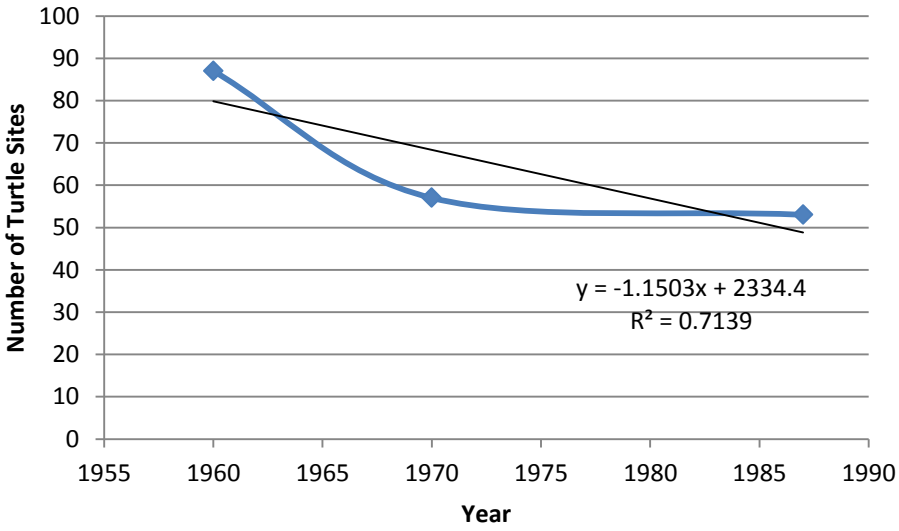

Figure 23. Trend in western pond turtle sites in southern California between 1960-1988 (Data from Brattstrom 1988, Brattstrom and Messer 1988).

Furthermore, the southern California County that holds the most western pond turtle sites is Los Angles, followed by San Diego, Orange, Western Riverside and Southwestern San Bernardino (Figure 24). Southern California does not have many sustainable western pond turtle populations and as factors that negatively affect population increase, western pond turtles will be more at risk of extirpation.

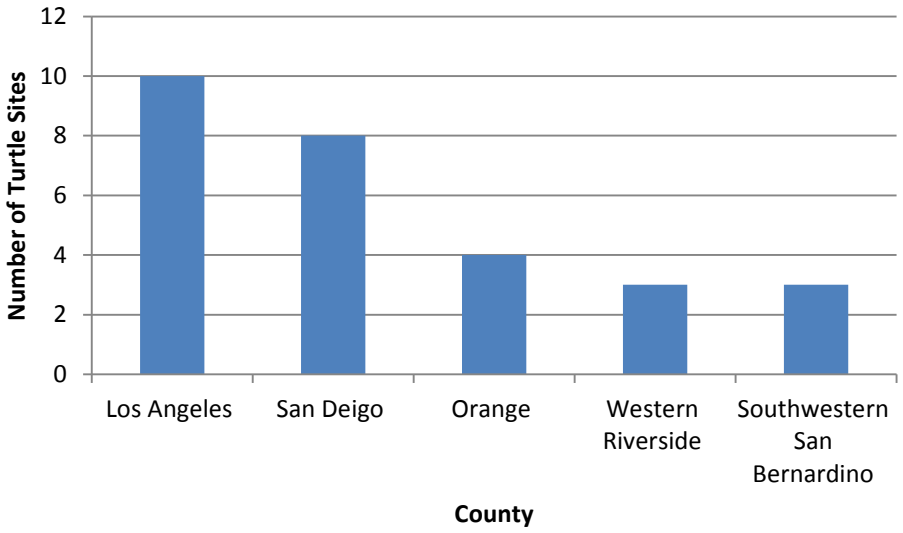

Figure 24: Western pond turtle sites in southern California counties (Data from Brattstrom 1988, Brattstrom and Messer 1988).

The county of San Diego is taking measures to mitigate negative impacts on western pond turtle populations by using head-start programs, non-native species removal and habitat enhancement. A western pond turtle population has been surveyed twice, once in 2002 through 2003 and another time in 2015 (Figure 24). Five head-started turtles were released in July 2013 and another five were released in July 2014. At the end of the study in 2015 all the head-started turtles were still alive (Brown et al. 2015). The head-started turtles would have been around four years old when they were released. Meaning that the head-started turtles may not have contributed to the increase in population by reproducing. However non-native species were removed at this site and could have contributed to hatchling and juvenile survivorship and an increase in the population.

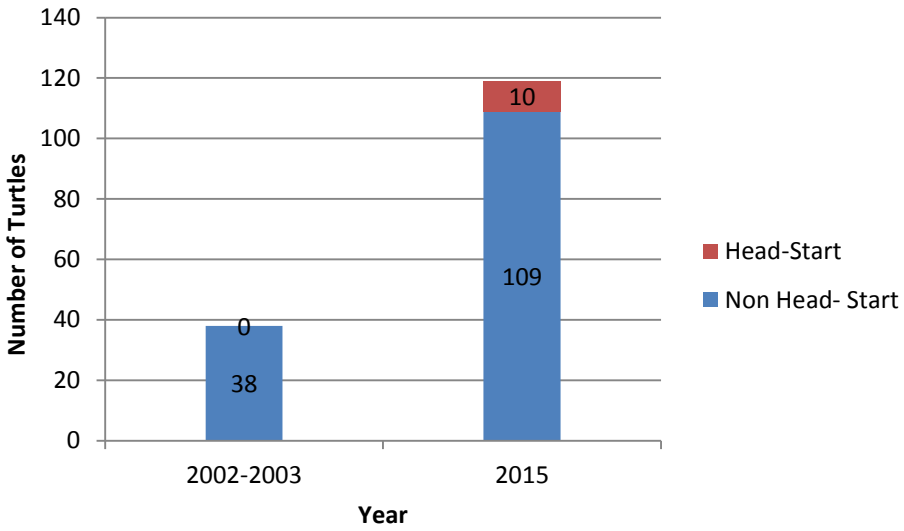

Figure 25. Western pond turtle numbers at Sycuan Park Ecological Reserve (SPER) (San Diego County, CA) from 2002-2015 (Data from Madden-Smith et al. 2005, Brown et al. 2015).

The sites from Washington, Oregon, and California have been compared based on whether head-start programs, non-native species removal and habitat restoration/ enhancement were implemented as management practices and what the population trends were at each site (Table 8). There are varied combinations of practices and results that correspond to western pond turtle population growth trends. The information for some of the sites is missing, consistent surveying is vital to determine the effects of management practices.

Table 8. A comparison of different sites in Washington, Oregon and California and their use of head-start programs and non-native predator removal and the effect on western pond turtle populations. The ✔s mean that the practice is in use, the ✗s mean the practice is not in use and the – s means information is not available.

State	Recovery Zone	Site	Head-start Program	Non-native Species Removal	Habitat Restoration/ Enhancement	Population Trend
Washington (Hays et al.1999, Van Leuven et al. 2005, Holman et al. 2015, Schmidt and Tirhi 2015, Hallock et al. 2017)	Columbia Gorge	Sondino	✔	✔	✔	Negative
	Columbia Gorge	Bergen	✔	✔	✔	Negative
	Columbia Gorge	Pierce NWR	✔	-	✔	Negative
	Columbia Gorge	Beacon Rock State Park	✔	-	✔	-
	South Puget Sounds	Pierce County	✔	✔	✔	Positive
	South Puget Sounds	Mason County	✔	-	✔	Negative
Oregon (Holland 1994, Germano and Bury 2009, Vesely 2014, Horn and Gervais 2018)	Willamette Drainage	East Thornton Lake	✗	✔	✔	-
	Willamette Drainage	Benton County	✗	✗	✗	Negative
	Umpqua Drainage	South Umpqua	✗	✗	✗	Positive
California (St. John et al. 2012, Spinks et al. 2003, Lambert et al. 2019, Madden-Smith et al. 2005, Brown et al. 2015)	Lake County	Boggs Lake	✔	✗	✔	-
	Yolo County	UC Davis Arboretum Waterway	✔	✔	✔	Positive
	San Diego County	Sycuan Peak Ecological Reserve	✔	✔	✔	Positive

Discussion

There were varying results in population growth trends in each state and thus a clear relationship between management practice implementation of non-native species removal, head-start programs and habitat restoration/enhancement is not clearly seen (Table 8). It is necessary to explain that even though Washington has not met the recovery objective of establishing at least five populations of >200 pond turtles, composed of no more than 70% adults, there has been progress (Hays et al. 1999, Hallock et al. 2017). Washington was the state that implemented the three practices the most and upon further inspection, it is necessary to accumulate more data to fully determine how non-native species removal, head-start programs and habitat restoration/ enhancement have effected western pond turtle populations. There are certain factors that might contribute to the negative population trends in Washington such as disease outbreaks in 2003 and 2012 as well as population survey obstacles or errors that may have resulted in negative population growth trends (Figure 15) (Washington Department of Fish and Wildlife 2016, Hallock et al. 2017).

The analysis of the state of Oregon's best management practices for the conservation of native turtles was not fully explored. Information on practice implementation of western pond turtle management is not reported to the Oregon Department of Fish and Wildlife or any other agency (S. Barnes, Oregon Department of Fish and Wildlife, pers. comm. 2019). This is a major obstacle as the progress and effectiveness of these best management practices cannot be measured in Oregon. The sites that were analyzed in this paper for the state of Oregon were mostly managed prior to 2015 except for the site in south Umpqua. It is important to note that the management agency for south Umpqua was never determined. Thus these sites were not representative of the best management practices established by the Oregon Department of Fish and Wildlife (Table 7, Figure 20). There is a resistance for the state of Oregon to use head-start programs as a best management practice, even though the Oregon Zoo is in collaboration and facilitates a head-start program for the Washington western pond turtle recovery plan (Hays et al. 1999, Rosenberg et al. 2009).

California has experimented with non-native species removal, head-start programs and habitat restoration/enhancement. These management practices have produced positive outcomes (Spinks et al. 2003 and Brown et al. 2015). The management pilots in the state have used applied conservation to help western pond turtles before their populations decrease further and are listed as an endangered species (San Francisco Zoo 2017). If no management is conducted with western pond turtles in California and they are classified as an endangered species, their numbers might not recover or take a long time to recover like in Washington. California contains the greatest number of western pond turtle sites and should be proactive in the management of the species (Figure 12). To lose the only freshwater native turtle species in California would be tragic as western pond turtles are integral for their habitat.

Surveying is one of the practices that needs to be consistent and done as accurate as possible. The most common techniques for surveying western pond turtle populations have been net trapping, visual surveys and radio-transmitter monitoring. In Washington, the Interagency Western Pond Turtle Working Group has set standards in the correct techniques that should be used for inventorying and monitoring western pond turtles (Barkhurst et al. 1997, Bury

2012).Visual surveys are difficult to conduct due to turtles retreating due to their timid behavior (Rosenberg et al. 2009). Due to the difficulty of conducting surveys on western pond turtles errors may occur, different techniques may also be employed making comparisons of population data unreliable (Williams et al. 2001).

In Washington past population surveys conducted identified suitable reintroduction sites (Nordby 1992). Habitat research was conducted in Skamania County and areas in the south Puget Sound region and found that they share similar abiotic conditions. With this data, characteristics for suitable western pond turtle habitat were identified. Radio-transmitter monitoring was used to research land use and determine the level of intervention needed at a site. Land use monitoring will shed knowledge into how western pond turtles are using their habitat. Monitoring will identify if more emergent basking sites are needed, if aquatic micro-habitats are present, if the vegetation surrounding the sites is adequate, if soil is adequate for nesting, if uplands are accessible, if water quality is adequate, if non-native species are present, if western pond turtles are staying on the protected sites. This is important information to have as intervention can take place depending on the need for the population at each site, reducing the financial expenses (Lambert et al. 2019). Movement and of western pond turtle land uses such as aestivation, nesting and overwintering need to be further researched.

Due to western pond turtles being listed as an endangered species in Washington there has been more follow through with surveys to assess the progress of the recovery plan (Hays et al. 1999, Hallock et al. 2017). This is the reason why there is more data available on western pond turtle populations in Washington at specific sites over the years. Oregon is in the process of identifying management regions and will designate priority conservation areas for western pond turtles within each region as part of the Western Pond Turtle Range-Wide Conservation Coalition's Management Strategy (S. Barnes, Oregon Department of Fish and Wildlife, pers. comm. 2019). Research in California on western pond turtles also holds promise to finding new suitable habitats through surveying and monitoring especially in southern California (Figures 23, 24) (Abel, 2010, Brown et al. 2015, Nerhus 2016).

Different levels of habitat restoration/enhancement can take place for western pond turtles such as, planting native vegetation, installing human made rafts or logs, creating paths to uplands, creating nesting sites, creating under bridges, fencing protected area, avoiding water diversions, and avoiding water contamination (Hays et al. 1999, Oregon Department of Fish and Wildlife 2015).

To convince private landowners to comply with regulations that would benefit endangered species, but at the same time limit land use, is a difficult task. If the land is not purchased the management practice implementation process will take longer and be more difficult. The purchase of land would enable a rapid implementation of management practices followed by unlimited access and permanent protection (Hays et al. 1999, Decker et al. 1996, Rosenberg et al. 2009). Multiple government agencies already own western pond turtle sites (Table 2). This could prove to work in favor of management implementation.

Washington has managed to successfully increase the western pond turtle populations by its management implementaion. Most of the western pond turtle sites are owned by a

government agency. The Washington Department of Fish and Wildlife purchased habitat land and is the lead management agency for most of the sites. After the department purchased the Sondino site in Klickitat County, they discontinued grazing and helped reduce or cease grazing activity upland and adjacent to wetlands owned by private landowners.

Once grazing was discontinued at the Sondino site, the grass become overgrown, tall and thick. The studies concluded that western pond turtles preferred to move in the tall dense grass. The criteria for optimal western pond turtle habitat was established as; a complex of small ponds near sea level, abundant emergent basking sites, isolated by at least one half mile from busy roads and other centers of human activity, isolated from large bodies of water and streams, emergent vegetation and a mud bottom, abundant invertebrate and larval amphibian prey, few or no non-native predators like largemouth bass and bullfrogs, diversity of upland habitats, including open, grassy areas for nesting and dense clumps of deciduous trees or shrubs for overwintering (Hays et al. 1999).

Measures were also taken to ensure that head-started turtles were successful in Washington at the recovery sites. The first location for the reintroduction of western pond turtles was the recovery site in Pierce County (Hays et al. 1999). This decision was made due to the fact that the Washington Department of Fish and Wildlife owned the property, so management implementation would be easier. The ponds seemed to be a suitable environment for the western pond turtles; it provided a permanent water body, free of non-native species and the lakeside was surrounded by open grass. Appropriate measures were taken to keep the turtles safe, the property was fenced all the way around; and the turtles were enclosed in an area of about 4.9 hectares. Some of the turtles were equipped with radio- transmitters on their carapace in order to monitor behavior, growth and survival (Hays et al. 1999). The western pond turtle population in Pierce County is one of the more successful sites with a head-started program in Washington (Figure 14).

At the site in East Thornton Lake Natural Area four goals were identified to conserve the western pond turtle population 1. identify the baseline population size and prepare long-term approach for monitoring, 2. continue recruitment success by identifying and protecting nesting sites, 3. increase and improve basking sites, and 4. identify negative impacting factors to native turtles in Thornton Lake (Vesely 2014). Management plans should encourage the public to share in the responsibility of the conservation of a species among state agencies, non-governmental organization and local government, this is important for successful results (Pinkerton 1999). The collaboration allows for open communication in East Thornton Lake in Oregon, where the community is involved in the conservation of turtles in a highly residential and recreational area. It is critical that managing agencies and scientist are involved in interpreting the best management practices and guidance is given to the public. The need for guidance occurred when, a non-native aquatic vegetation called Brazilian elodea *(Egeria densa)* prospered at this site until a coalition of landowners contracted with a commercial pesticide applicator to remove the elodea from the lake. Aquatic herbicides fluridone, diquat dibromide and dipotassium endothol were used to treat the non-native aquatic plant. The effects on fish, invertebrates and aquatic species can be negative at higher than recommended doses (Washington State Department of Ecology 2001).

The removal of non-native predators in Washington such as bullfrogs and warm water fish has been done opportunistically, adult bullfrogs, tadpoles and egg masses have been removed while surveys have been conducted, sunfish have been gill-netted and removed (Hays et al. 1999). Bullfrogs have caused changes in morphological size distribution in western pond turtle populations (Figure 16). Western pond turtle morphological measurements in Klickitat Washington are larger than that of the populations in Oregon were bullfrogs are absent. The effects of non-native predators can also be seen in California at the Sycuan Peak Ecological Reserve site. Western pond turtle hatchlings were observed a short time after removing non-native predators (Brown et al. 2015). The population growth at this site is telling of the negative impacts non-native species can have on western pond turtles (Figure 25).

The head-start programs conducted in Washington and California introduced western pond turtle juveniles that were past their most vulnerable stage back into the wild. Vulnerability to predation is one of the top reasons western pond turtle populations have low recruitment of hatchlings and juveniles (Heppell et al. 1996). This is represented by populations with the presence of larger western pond turtle adults with very few or no hatchling and juveniles (Figures 17, 19). Overtime this can lead to low recruitment and extirpation of the species in an area. A stable population will have a more symmetrical population demographic relative to size (Figure 18). Head-start programs introduce juveniles to the population, and they will eventually reach reproductive maturity and participate in recruitment to increase population numbers.

Head-started turtles are also very important at sites with extant western pond turtle population with low numbers as can be observed in Washington at sites of the Columbia Gorge in Klickitat and Skamania counties (Table 3). The introduction of head-start turtles has become one of the top management practices in Washington (Table 4). At places of introduction head-started turtles have also taken well to the environment in both Washington and California (Table, 5, Figure 13). Many western pond turtle populations are now predominantly made up of head-started turtles.

Western pond turtle juveniles are usually released between 10 months -1 year (Heppell et al. 1996, Spinks et al. 2003, Brown et al. 2015). At the time of release the head-started turtles are much larger than they would be in nature, approximately the size of a two year old turtle (Geist 2019). They are released in the summer in order for them to acclimate for the winter (Hays et al. 1999). The release of western pond turtles has been further studied and suggests that there are differences between soft and hard releases (Dana 2018). Soft release of head-started turtles implies that the head-started turtles are protected in an enclosed area at the release site for several days and provisioned with food before their release. A hard release is conducted by placing head-started turtles in the body of water with no acclimation time. According to Dana (2018), head-started turtles released through the hard method grew a lot faster that with the soft release.

The head-start program at Boggs Lake in Lake County, California, holds great promise for the increase in population numbers. Head-started turtles were first introduced in 2008 thus the first cohort of head started turtles should now be about 10 years old, and starting to become reproductively mature (San Francisco Zoo 2017). Dr. Geist has commented that he would like to resume surveys to see how the head-start program will affect the western pond turtle population number (N. R. Geist, Sonoma State University, pers. comm. 2019). This practice is ideal for this

site as non-native species are not present and there are no drainages that connect to the Lake or other bodies of water. The Lake County Land Trust maintains the site and the habitat is pristine and does to get many visitors. This allows for western pond turtles to use the site according to their phenology. There seems to be natural recruitment at the site as observations of gravid females seemed to increase (Figure 21). Future studies will be conducted on the status of western pond turtle populations at Boggs Lake.

The western pond turtle population at the University of California Davis Arboretum Waterway has also had success with the head-started turtle released (Figure 22). The turtles benefited from the removal of red-eared sliders and found that western pond turtles were getting larger with a 5-15 % increase in body weight and dispersed out through its habitat (Lambert et al. 2019). The population has had a positive growth trend with 115 western pond turtles present in 2019. For future research the identification of head-started turtles would be interesting to assess. The thought also arises of urban areas serving as suitable habitat for the conservation of western pond turtles needs to be further explored (Germano 2010, Hayes et al. 2018).

There are however some setbacks to head-start programs, the notion that the original problems leading to western pond turtle population declines are not being addressed (Heppell et al. 1996, Spinks et al. 2003, Lambert et al. 2019). Low recruitment does indeed lead to lower population numbers over time. But the reason for low recruitment has to be identified and resolved (Rosenberg et al. 2009). The reasons for high mortality rates in hatchlings and juveniles have been non-native competition and predation. Managers must first make sure that non-native species are removed from recovery sites before financial resources are invested into head-start programs. The reason being that although large head-started juveniles are being introduced into sites to increase recruitment, offspring of these head started turtles will not survive in nature in the presence of non-native predators. Thus the need for head-started programs will continue and western pond turtle populations will not be sustainable. Also not much is known of the genetic variation between populations and the effects of introduced head-started turtles. Another possible setback of head-start programs is the elimination of natural section due to the incubation of all eggs. The effects of these practices are not well understood yet.

Management Recommendations

Surveying and Monitoring

Following through with surveys and monitoring is essential to determine the stability and health of western pond turtle populations (Nichols and Williams 2006). Surveys on population numbers, demographic structure and habitat assessment are important to show the progress or next steps of management. Surveying should be conducted from March to July while emergent basking is more prominent (Hays et al.1999).

Data surveys should be conducted every year at management sites. If the financial investment in head-starting programs and restoration is taking place as management practices for western pond turtles then surveys must be conducted to evaluate the progress and identify obstacles at these sites. Surveys and radio-transmitter monitoring of head-started turtles that are released at sites is crucial to better understanding their behavior, life stages, land use and the

level of intervention needed at each site, in order to promote sustainably viable populations of western pond turtles.

Collaboration

Collaborations must be organized between government, non-government, non-profit, industry, agriculture and private landowners for western pond turtle populations to recovery at managed sites. A collaboration to standardize protocols for surveying across Washington, Oregon and California would be beneficial to increase data reliability. Human error is part of every experiment but protocols can be standardized between agencies. Once that is done the data will reflect accurate correlations and the science behind the management plans will be sounder. Also the more accurate the data is, the better funds can be allocated to the proper research, conservation practices and equipment.

Another benefit would entail good relationships with the public and stakeholders. In order for the management plans to have a significant impact, management agencies must implement the best management practices (Decker et al.1996). Not owning the land of a site that is being managed or if private landowners are involved requires open communication and collaboration in order for the site to serve as adequate western pond turtle habitat (Riley et al. 2002).

Collaborations among management agencies and organizations to provide education outreach regarding wetlands and the importance of the ecosystem for many endemic species including the western pond turtle is needed. School based education outreach programs should be established as a goal, as children are the future generations (Jacobson et al.2015). It is important to teach responsibility for the environment to preserve habitats and find more sustainable ways of life (Dettmann-Easler and Peace 1999). The information must be conveyed to the public regarding the status of endangered, critical and special species of concern. The public will have knowledge on the obstacles that face these species and would possibly be more inclined to participate in their recovery and conservation

Habitat Restoration/ Enhancement

Habitat restoration and enhancement must be conducted based on the results of surveys and monitoring conducted. Restoring wetland and riparian zones not only benefits western pond turtles, but also other organisms especially with the effects of climate change (Seavy et al. 2009). Western pond turtles have been determined to do best in habitats with a large amount of emergent basking sites, native plants and shrubs, access to upland, and lower disturbances (grazing, agriculture, industrial and recreational). Next, the question arises of what is the habitat being restored to? It is essential to determine the level of management intervention a habitat restoration plan requires, for example novel ecosystems require minimal intervention as they are restored to be sustainable while designed ecosystems require much more intervention (Higgs 2017). Providing adequate nesting sites will be important to increase hatching success (Holland 1994, Reese and Welsh 1997, Holte 1998). The habitat should serve as adequate habitat for the western pond turtle but also be resilient to climate change.

Non-Native Species Removal

The introduction of non-native species can alter an ecosystem and cause trophic cascades (Waller et al. 2018). The removal of non-native species, is essential to achieve sustainable western pond turtle populations, this could be conducted through either a management plan or done opportunistically (Hays et al.1999). The perceived results of taking this action is that fewer predators in the environment will allow for a greater probability of hatchling and juvenile western pond turtles surviving to reproductive maturity (Hays et al.1999).

Head-Start Programs

There is some controversy to using head-start programs, whether it be for the exclusion of natural selection, introducing genetically different turtles to sites or the thought of introducing diseases to sites by releasing head-started turtles (Heppell et al. 1999, Rosenberg et al. 2009, Vander Haegen et al. 2009). Head-start programs should be used as needed. Before head-started turtles are introduced some level of habitat restoration/enhancement and non-native removal management protocols should be established. Further definition and guidelines need to be established if head-start programs are to be adopted as a best management practice (Burke 2015).

Land Acquisition

The purchase of land would provide permanent protection as well as facilitation with management practice implementation. There are many government agencies that already own western pond turtle sites. This could allow access to land as well as follow through with surveys and research in collaboration with other organizations on western pond turtles that can give more information on life history and the development of new surveying protocols and strategies.

Conclusion

There are challenges in the conservation of western pond turtle population in Washington, Oregon and California. There is still much that we do not know about western pond turtle land use and life history. It has been a difficult species to survey and monitor as it is timid and wary of people. A delayed reproductive age has complicated recruitment as hatchling and juveniles are being predated and out competed for natural resources by non-native species. Human encroachment with urbanization and agriculture degrade wetlands, contaminate and fragment suitable habitat. With human populations in the vicinity of western pond turtle habitat emergent basking may be reduced which is a vital necessity for turtle health and helps females develop viable eggs. Turtle eggs are sensitive to cold and wet weather, which can result in hatchling failure. Climate change can affect phenology and life history of western pond turtles. Illnesses and their illusive causes can further decrease turtle populations as treatments are not yet available. Collaborations and further research in needed in order to determine best management practices.

Limitations of this Study

The analysis presented in this paper should not be cited as literal western pond turtle numbers present at these sites. This analysis used peer-review, unpublished literature and agency reports that utilized different methods of surveying. Error bars were not included in some analysis thus cannot yield accurate correlations. The data presented here are estimates based on limited data. Western pond turtle description and phenology differ from region to region depending on biotic and abiotic factors. Due to the large range of western pond turtles the information in this paper is general.

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