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Basking Western Pond Turtle Response to Trail Use in Mountain View, California

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BASKING WESTERN POND TURTLE RESPONSE TO TRAIL USE IN
MOUNTAIN VIEW, CALIFORNIA

A Thesis

Presented to

The Faculty of the Department of Environmental Studies

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Paul E. Nyhof

May 2013

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The Designated Thesis Committee Approves the Thesis Titled

BASKING WESTERN POND TURTLE RESPONSE TO TRAIL USE IN
MOUNTAIN VIEW, CALIFORNIA

by

Paul E. Nyhof

APPROVED FOR THE DEPARTMENT OF ENVIRONMENTAL STUDIES

SAN JOSE STATE UNIVERSITY

May 2013

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ABSTRACT

BASKING WESTERN POND TURTLE RESPONSE TO TRAIL USE IN MOUNTAIN VIEW, CALIFORNIA

by Paul E. Nyhof

The western pond turtle (*Emys marmorata*) is the only native freshwater turtle in California, and it is listed as a California Species of Special Concern. One population near Moffett Naval Air Station in Northern California uses a highly altered water channel along a recently opened section of the Bay Trail, exposing western pond turtles (WPT) to high rates of human activity through recreational trail use. This research assessed whether human recreational trail use had a measurable effect on WPT basking behavior. WPTs were also trapped and marked to collect data on the structure and stability of the current population.

The lengths of basking periods of WPTs, when disturbed by human activity, were significantly shorter than background basking periods. Shorter basking periods can cause aquatic turtles to forfeit proper thermoregulation, leading to a decline in their ability to carry out necessary behaviors and physiological processes. The rate at which WPTs were disturbed by pedestrian recreational trail use was very low (<7% of pedestrian events led to disturbance), while motor vehicles caused a much higher rate of basking abandonment (45.5% of motor vehicle events led to disturbance).

Eleven WPTs were trapped in 2012, of which 61.5% were adults and 38.5% were juveniles. The sex ratio was 3:1 male to female. These findings are similar to data collected by another investigator in 2006 at this location.

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Introduction

Over the course of the last 100,000 years, human habitation has spread to nearly every corner of the globe. This widespread influence has led to a large number of effects on the natural world, many of which contribute to an increasing rate of species extinction. As the human population continues to grow, a staggering number of plant and animal species are disappearing forever.

The current rate of global extinction is estimated to be between 10 and 100 times the expected background extinction rate but may be even higher for particularly vulnerable species (Nott, Rogers, & Pimm, 1995). When discussing extinction events of this magnitude, it is impossible to exclude human activities from the list of definite causes. In many cases, harmful anthropogenic effects such as habitat loss, introduced species, overharvesting, and pollution are accelerating the loss of species. However, these damaging actions have greater effect on some species than others.

Chelonians, represented by turtles and tortoises, are one of the many taxa experiencing worldwide declines. This group consists of 317 species and has members on every continent, excluding Antarctica. Despite their global presence, the future of these creatures is in doubt as 42% of all turtle species are considered to have a threatened status (Buhlmann et al., 2009). Whereas some of the more widely recognized species have legal protections, others, particularly in the freshwater taxa, are often overlooked. This lack of proper protection has led to an alarming decrease in some freshwater turtle populations.

Freshwater turtles are often harmed by human activities due to their reliance on both aquatic and terrestrial habitat. Loss or degradation of either of these vital areas can lead to deleterious effects on turtle species. As populations continue to decline throughout their range, it becomes less likely that disturbed habitat will be recolonized.

The western pond turtle (*Emys marmorata*) is the only native freshwater turtle in California and is listed as a California Species of Special Concern. This status provides less protection than is awarded to species of threatened or endangered status, but it prevents taking of turtles or nests by projects under the California Environmental Quality Act (CEQA). Historically, this unique species ranged as far north as British Columbia and as far south as Baja California, with isolated populations present as far inland as the Mojave Desert (Lovich & Meyer, 2001). The common name given to *E. marmorata* can be misleading; even though the western pond turtle prefers slow moving waters, it has been known to thrive in streams, rivers, ditches, marshes, brackish water, and sloughs in addition to ponds (Reese & Hartwell, 1998). Despite their wide range of tolerable aquatic habitats, the number of WPTs in California is on the decline (Spinks, Pauly, Crayon, & Shaffer, 2003).

The rapid increase in California's human population over the past century has brought with it a massive conversion of aquatic and terrestrial environments to urban and agricultural uses (Germano, 2010). Damage inflicted to these natural areas harms the WPT due to the loss of aquatic and terrestrial habitats

needed for the turtle's life cycle and creates a much higher likelihood of human contact with WPTs. In addition to this widespread habitat alteration, harmful invasive species have been introduced through human activity, including the red-eared slider (*Trachemys scripta elegans*) and American bullfrog (*Rana catesbeiana*). The red-eared slider has been successful at outcompeting and displacing native WPT populations, whereas the bullfrog is a voracious predator of many aquatic amphibians and reptiles (Kiesecker & Blaustein, 1997; Pollock, Lopez, & Martin, 2007). These human influences have led to the extirpation of WPT populations across much of the species' historic range, including large sections of the San Francisco Bay Area.

WPTs spend much of the warmer months (April-September) in aquatic habitats throughout their range, which provide favorable environments for foraging, mating, basking, and predator avoidance (Vander Haegen, Clark, Perillo, Anderson, & Allen, 2009). However, due to the thermoregulatory needs of reptiles, it is the basking behavior that makes all other behaviors possible. Access to quality, disturbance-free basking sites can be crucial in determining the overall health of a WPT population because such sites allow the species to carry out activities necessary for survival and reproduction (Germano & Rathbun, 2008).

The WPT has been noted by a variety of researchers to be a particularly wary species, often abandoning basking behavior at the first hint of danger (Bury, 1972, personal observation). Regular occurrence of human activity near WPT

basking sites could pose a serious threat to the health of the turtle population. However, there have been no studies on the effects of human approach on WPT behavior.

As habitat loss, human contact, and invasive species continue to place pressure upon WPT populations in California, it is necessary to protect this native reptile wherever it remains. Extensive urban development in the Bay Area creates a high likelihood that any WPT populations in the region have been exposed to a range of additional threats, including roads, fractured habitat, and human recreational disturbances (McGowan & Simons, 2006; Moore & Seigel, 2006; Patrick & Gibbs, 2010). It is important that wildlife managers identify populations and then implement strategies and practices to encourage the growth and recovery of local WPT populations. Ensuring that populations are stable and exposed to minimal human disturbance can aid in the recovery and health of WPT populations.

This study will assist wildlife managers in protecting WPT populations by providing valuable behavioral and demographic data on how WPTs react to human recreational disturbances. Any WPT populations remaining near populated areas are likely to have frequent contact with human activity. This research will contribute important insight into whether human recreational activity causes disturbance and whether different types of human activity cause varying probabilities of disturbance. The additional demographic data collected on the specific population inhabiting this area of the Bay Trail near Moffett Federal

Airfield will be compared to previous data and serve as a case study that examines whether introduced human activity is likely to cause a shift in population structure.

Literature Review

Introduction

There are currently over 120 animal species listed as threatened or endangered in the state of California, with the number of candidate species growing every year (State of California Dept. of Fish and Wildlife, 2012). Threats to the survival of these species include habitat loss, competition, predation, pollution, and poaching. Although many factors contribute to species decline, the majority of them are directly linked to human activities. The population of California is projected to increase by 30% to over 50 million people by the year 2050, and with this increase will undoubtedly come additional human disturbance and pressure on the state's wildlife (State of California Dept. of Finance, 2013).

The San Francisco Bay area is a densely populated and largely urban environment. Due to the high levels of development, much of the natural environment has undergone alteration or elimination, leading to loss of habitat for many species. One of the most altered classes of ecosystems is aquatic habitat, including rivers, streams, ponds, lakes, estuaries, and wetlands. Urbanization often leads to a population decline for aquatic species, and it can be particularly

damaging to animals with low fecundity such as freshwater turtles (Garber & Burger, 1995; Rees, Roe, & Georges, 2009).

The western pond turtle is the only native freshwater turtle in California and is currently listed as a Species of Special Concern by the California Department of Fish and Wildlife (Jennings & Hayes, 1994; State of California Dept. of Fish and Wildlife, 2012). The petition to gain protected species status for the WPT on a national level was filed in 1992 but was deemed unwarranted in 1993 due to lack of convincing data (Dept. of the Interior Fish and Wildlife Service, 1993; Germano & Bury, 2001). Even though this petition is still technically listed as “under review” by the United States Fish and Wildlife Service, the animal’s status has remained unchanged since the initial rejection.

The historical range of the WPT once stretched from southern British Columbia through Washington, Oregon, California, and into the Baja peninsula of Mexico (Germano & Bury, 2001; Lovich & Meyer, 2001). Much of this range was along the coast, but it also extended east into the Central Valley of California, where a large population is thought to have resided. With the introduction of invasive species and increasing loss of habitat due to agriculture and urbanization, the modern range of the WPT has contracted drastically. Areas such as the Central Valley, San Francisco Bay Area, and southern regions of California have been left with severely diminished populations (Germano & Bury, 2001; Germano & Rathbun, 2008).

Taxonomy

The WPT was first classified by Baird and Girard in 1852 as *Emys marmorata*, and since then others have contested that its nomenclature should include several additional classifications. Seeliger (1945) identified the WPT as *Clemmys marmorata*, and first described two distinct subspecies: the Northwestern pond turtle *Clemmys marmorata marmorata* and the Southwestern pond turtle *Clemmys marmorata pallida*. Further debate has included evidence supporting the use of *Actinemys marmorata* as proper nomenclature. This paper will use *Emys marmorata* to describe the western pond turtle taxonomy.

Feldman and Parham (2002) recently argued that the WPT should be included in the *Emys* genus, and well known researchers including Meyer, Spinks, and Polo-Cavia classify it as such (Ashton, Lindt, & Schlick, u.d.; Feldman and Parham, 2002; Lovich & Meyer, 2002; Polo-Cavia et al., 2010; Seeliger, 1945; Spinks et al., 2003).

Ecology and Life History

Although WPT ecology has lacked significant study, the species is similar to other freshwater turtles, as it utilizes both terrestrial and aquatic habitat but spends the majority of the time in or near water. The WPT prefers both lentic and lotic aquatic habitats, including streams, rivers, ponds, lakes, estuaries, and wetlands (Bury, 1972; Germano & Bury, 2009; Reese & Welsh, 1998).

Favorable sites within these ecosystems often include deep, slow-moving water

with underwater refugia. Aquatic emergent basking structures such as rocks, logs, and tule mats are important for thermoregulation, especially in the absence of warm water. In addition, the animals are often found in moderate vegetative cover, suggesting that this cover has some value for predator avoidance (Reese & Welsh, 1998). Upland areas surrounding the aquatic sites typically contain preferred digging substrate such as loam or silty soil for overwintering and nesting. Suitable sites for these parts of the life cycle often include low, grassy vegetation (Bury, 1972; Rathbun, Seipel, & Holland, 1992).

The WPT is a generalist omnivore, feeding on a variety of plant and animal items depending on region and local ecology. The species frequently consumes aquatic insects, worms, crustaceans, fish, amphibians, and carrion when available. Turtles occasionally consume filamentous algae, tule roots, and other plant material, although females likely utilize these food sources more frequently than males (Bury, 1986; Rathbun et al., 1992). Various types of fish, squid, beef liver, and even cat food are all used as bait for trapping the WPT, suggesting that its diet may include many opportunistic food sources (Spinks et al., 2003; Bury, personal communication).

One of the behaviors most essential for freshwater turtle survival is thermoregulation through basking (Schwarzkopf & Brooks, 1985). Proper regulation of body temperature allows turtles to increase metabolism, ensure proper digestion, and be more effective in a range of behaviors including feeding, reproduction, growth, and predator avoidance (Bodie, 2001; Dubois, Blouin-

Demers, Shipley, & Thomas, 2009; Edwards & Blouin-Demers, 2007).

Freshwater turtles are known to spend a large proportion of daylight hours basking on emergent rocks, logs, and matted plants in order to achieve higher body temperatures (Miller, 1979). WPT basking is similar to that of other freshwater turtles and has been documented to possess ecological and behavioral importance (Bury, 1972; Reese & Welsh, 1998). This species has been observed basking on a variety of emergent aquatic basking structures, and will engage in submerged aquatic basking when water temperatures are high enough to allow desired levels of thermoregulation (Spinks et al., 2003; Bury, Nebeker, & Adams, 2000).

Aquatic environments with basking sites also allow WPTs the opportunity to avoid predation through quick access to deep water and underwater refugia (Reese & Welsh, 1998). This species has been observed to be exceedingly wary in the presence of potential predators and will often retreat to underwater bank refugia or deep water if a potential threat is sighted. Due to their poor swimming ability, this tactic is often more effective in water courses with lower velocity (Reese & Welsh, 1998). When limited quality basking sites are subjected to frequent human disturbance, the WPT may be less likely to engage in basking behavior, incurring metabolic costs.

The mating and courtship behaviors of the WPT are poorly understood, with infrequent verified observations. Mating is thought to occur underwater during the late spring to early summer, though no detailed studies have

confirmed this behavior in multiple populations (Goodman & Stewart, 2000; Rathbun et al., 1992). The timing of such behaviors is likely to vary depending on local climate and ecology.

Many populations, particularly in the northern range, appear to overwinter on land. However, depending on conditions, southern populations may overwinter in the aquatic habitat instead. Some turtles have been observed to travel up to 500 m from aquatic habitat to engage in overwintering behavior (Reese & Welsh, 1998). In addition, females require upland habitat for nesting behaviors, preferring loamy or silty, dry soil (Rathbun, Scott, & Murphey, 2002). Gravid females have been known to travel up to 1 km to find suitable nesting sites, though they may travel much shorter distances if suitable sites are available. The typical nesting periods stretch from mid June to late August, although this is largely dependent upon climate and local conditions. The hard-shelled eggs are deposited in a shallow hole and then covered and urinated upon for sealing purposes (Bury, 1972; Rathbun et al., 1992). WPTs exhibit temperature-dependent sex determination, a common occurrence in freshwater turtles (Spinks et al., 2003).

Hatchlings overwinter in the nest and emerge the following spring between March and April to make the over-land trek to aquatic habitat (Rathbun et al., 1992). Once there, the young turtles typically feed on larval insects and other small invertebrates. Growth rates and size classes are largely determined by climate, local productivity, and available resources (R. Bury, Germano, & G. Bury,

2010). Turtles are relatively vulnerable when they are hatchlings; their survivorship rises significantly once they reach a carapace length of at least 90 mm. On average, this size may take two to three years to achieve, although growth rate depends on local conditions and abundance of food (Vander Haegen et al., 2009).

Juvenile WPTs continue to predate on insect larvae, but they also begin to feed much more generally, in a manner similar to adults. Increased size now requires basking above the water, although less time is likely required for daily thermoregulation as compared to adults due to a greater surface-area-to-volume ratio (Bury et al., 2000). Even though juveniles are far less likely to fall prey to aquatic predators, they are still vulnerable to a host of terrestrial predators including skunks (*Spilogale spp.*, *Mephitis spp.*), coyotes (*Canis latrans*), raccoons (*Procyon lotor*), domestic dogs (*Canis familiaris*), and domestic cats (*Felis catus*) (Vander Haegen et al., 2009).

The adult WPT is often defined as an individual showing secondary sexual characteristics and having a carapace length of at least 120 mm (Germano & Bury, 1998). Reaching this size may take anywhere from three years in a warm, nutrient-rich ecosystem, to nine years or more in more northern areas (Germano, 2010). This age class spends a large portion of daylight engaged in basking behavior during the warmer months of May through September (Bury, 1972; Germano & Bury, 2001). Larger adults have been seen competing for basking

sites, but are somewhat less aggressive than other freshwater turtle species (Polo-Cavia, 2010).

Population Decline

Populations of WPTs have seen a steady decline throughout their range, particularly in California. The primary causes of this reduction include habitat loss through urbanization and agricultural expansion, as well as the introduction of invasive species (Germano & Bury, 2001; Goodman & Stewart, 2000; Rathbun et al., 1992; Reese & Welsh, 1998; Spinks et al., 2003). Much of the prime aquatic and terrestrial habitat necessary for WPT survival has undergone human development, and the presence of domestic and invasive species has led to increased predation and competition for resources such as food, nesting sites, and basking sites (Cadi & Joly, 2003; Germano & Bury, 2001; Rees et al., 2009; Reese & Welsh, 1998).

The Central Valley of California was once a vast, undisturbed region with a variety of aquatic habitats. As the area was developed for agricultural uses, thousands of acres of wetlands were drained to prepare the land for farming (Germano & Bury, 2001). Stream courses were altered and channelized, and much of the upland habitat was converted to farmland. Without natural habitat, the WPT population in the heavily agricultural Central Valley has plummeted. However, certain populations residing in altered habitat such as irrigation canals, stock ponds, and reservoirs within the Central Valley appear to have stabilized

(Germano & Bury, 2001). Large portions of this species' historical range, including the Central Valley, have been converted to agricultural purposes, leaving less habitable area for turtles.

Factors Affecting WPT Populations

The human population of California has increased rapidly over the past 50 years, and with this growth has come a need for larger urban areas (State of California Dept. of Finance, 2011). This transformation has led to habitat loss and a number of other threats linked to urbanization including predation by domestic pets, road mortalities, and disturbances due to human activity. Each of these consequences of urbanization has led to a decline in freshwater turtle populations, including the WPT.

Habitat Loss and Alteration

WPT populations in California face many threats to their survival, including habitat loss and alteration, invasive species competition and predation, and human disturbance. Highly urbanized locations, such as the San Francisco Bay area, have very few undisturbed natural sites suitable for freshwater turtles. Any surviving populations of *E. marmorata* are likely to inhabit sites that have in some way been altered by human activity. It is highly unlikely that valuable real estate will be converted to natural landscape, leaving altered habitat the only option for many regional populations.

Much of the riparian environment historically utilized by native turtles has been altered in a variety of ways including channelization, rerouting, and dam construction. The channelizing and rerouting of riparian zones has a detrimental effect on turtle survivorship because it decreases available food resources, reduces heterogeneity and amount of viable habitat, and dramatically alters species composition (Bodie, 2001; Segurado & Figueiredo, 2007). Straighter river channels also increase water velocity, making the habitat less suitable for the WPT.

It is often a policy of agencies managing waterways to remove any and all large woody debris (LWD) to assure maximum flow and prevent logjams. This action further degrades altered habitat because LWD serve as valuable basking structures that correlate with turtle density and are utilized by a number of prey species (Bodie, 2001; Lindeman, 1999). While it is widely accepted that emergent aquatic basking structures, such as LWD, are highly beneficial for WPT thermoregulation, no research has been published on specific implementation methods or WPT basking site selection in altered habitats.

River system alteration through dam installation has also been shown to alter WPT habitat enough to affect survivorship. Reese and Welsh (1998) found that dams in the Trinity River of California produced faster, cooler water that decreased the suitability of riparian habitat for *E. marmorata* downstream from dams. The high number of dams and reservoirs in California creates a

complicated matrix of effects that have the potential to alter many of the current WPT habitats.

In some instances, however, altered habitats have shown evidence that they may possess characteristics beneficial to turtle survival. A study by Germano (2010) suggests that a WPT population near a sewage treatment plant in the Central Valley of California benefited from the water nearby due to its increased temperature and high nutrient content. Germano (2010) determined that individuals within this population grew at a much faster rate than turtles in other locations and showed successful juvenile recruitment. While these may not be the only metrics used to ascertain whether a population is likely to survive or not, they do indicate some benefits with proximity to the sewage treatment plant. Regardless of these limited advantages, WPT numbers continue to decline in California, and more research on methods of improving altered habitat is required in order to increase the survivorship of remaining *E. marmorata* populations.

Other Factors Affecting WPT Populations

As urban areas expand and convert natural landscape into modern human uses, the construction of roads, buildings, and infrastructure have eliminated or drastically altered much of the original habitat used by the WPT. This loss of natural habitat is recognized as a major cause of population decline in this species (Germano, 2010; Rathbun et al., 1992; Spinks et al., 2003). While some altered areas such as drainage channels and canals have allowed the WPT to

achieve marginal success, these populations often require head-starting and other support to retain viable populations (Spinks et al., 2003). Another factor that may have a negative effect on freshwater turtle populations is predation by species commonly found near human development, such as raccoons (Marchand & Litvaitis, 2004).

As city and suburban growth stretches into natural areas, it leads to increased road density, which can cause elevated mortality among freshwater turtle populations (Marchand & Litvaitis, 2004; Rees et al., 2009). A study by Patrick and Gibbs (2010) determined road mortality to be a factor in the decline of a wood turtle (*Glyptemys insculpta*) population in Connecticut. Male freshwater turtles, including the WPT, rarely venture any great distance onto land for significant periods of time other than for possible overwintering. However, female WPT have been known to travel distances of over 1 km in search of proper nesting sites and often make repeated attempts (Rathbun et al., 1992). This terrestrial mobility places female turtles at a much higher risk of road mortality, which can lead to gender imbalance and instability within a population (Goodman, 2000; Spinks et al., 2003). A particular turtle population that has a high number of individuals can give the appearance of a healthy population. However, if there is a high male-to-female ratio, the population is likely to decline over time due to decreased juvenile recruitment (Germano & Rathbun, 2008; Spinks et al., 2003).

Data regarding the population structure of WPTs are vital, as they may point to the viability and fecundity of populations throughout the range. However, little published research addresses sex ratio and age structure for this species. One such study conducted by Bury (1979) revealed a male to female ratio of 1.17 : 1 in a relatively undisturbed population. Another investigation by Germano (2008), located in an altered habitat near Vandenberg Air Force Base, found a more heavily skewed 4.26 : 1 male to female ratio. Although each of these populations gave strong indications of juvenile recruitment, a high male-to-female ratio could cause considerable harm in the ability of a population to effectively reproduce and affect its overall efficacy.

The introduction of invasive species is another threat that can often result in a great deal of damage to native wildlife due to predation and competition. Two particular introduced species that continue to harm WPT populations throughout California include the American bullfrog (*Rana catesbeiana*) and the red-eared slider (*Trachemys scripta elegans*). Neither species is native to California, yet both are successful in many of the same habitat types in which *E. marmorata* is found. The establishment and rapid increase in the populations of these invasive species have led to a number of harmful consequences for the WPT.

The American bullfrog is native to the eastern United States, but has been widely distributed and largely successful in California. A voracious predator, this amphibian is known to feed on a wide range of prey including insects, larvae,

eggs, fish, other amphibians, and hatchling turtles (Kiesecker & Blaustein, 1998). While the juvenile and adult WPT are not potential prey to the bullfrog, hatchlings are particularly vulnerable due to their small size, less rigid carapace, and limited mobility (Spinks et al., 2003). Bullfrogs benefit from a high fecundity and broad diet, which has helped to make this species difficult to control or eradicate. The presence of American Bullfrogs throughout California signifies a dangerous threat to WPT survival.

The red-eared slider is a freshwater turtle native to the eastern United States that has been introduced largely due to the pet trade, as it is a commonly sold species (Cadi & Joly, 2003). Pet owners are often unprepared for turtles' typically long life spans, leading to their release or escape into the surrounding environment. These invasive turtles cause harm to the native WPT largely due to their aggressive competition for resources. The overlapping ecology of these two species causes friction and conflict in several respects.

Invasive red-eared sliders hold several advantages over the native WPT, including a lower age of maturity, higher fecundity, larger adult size, and more aggressive nature (Polo-Cavia et al., 2010). Cadi and Joly (2003) discovered that red-eared sliders outcompeted the native European Pond Turtle (*Emys orbicularis galloitalica*) for food, egg sites, and basking sites. The aggressive nature of this invasive turtle allowed it to forcibly take possession of prime basking sites, leaving only lower quality locations for the native turtle. This loss of thermoregulatory control would likely result in a lower survivorship. In addition,

red-eared sliders have been shown to have a higher tolerance for human presence, meaning they are less likely to forfeit basking sites when confronted with human recreational disturbances (Polo-Cavia et al., 2007).

Human Recreational Disturbance

Another important consequence of humans living near freshwater turtle habitat is the increased frequency of recreational activities. Recreation, including hiking, biking, fishing, and boating, may have significant negative effects on turtle populations. Moore and Seigel (2006) observed yellow-blotched map turtle (*Graptemys flavimaculata*) to determine the effects of fishing, boating, and jet ski activity on behavior. The study found these frequent human disturbances caused *G. flavimaculata* to abandon both nesting and basking activity, often for the duration of the day. This type of behavioral disruption can have harmful effects on both turtle survivorship and effective reproduction because it robs the turtles of valuable thermoregulation and may prevent successful oviposition.

Another study, conducted by Wolf and Croft (2010), examined the dynamics of human recreational disturbance on the Red Kangaroo (*Macropus rufus*) and Euro (*Macropus robustus erubescens*). Research found that the Flight Initiation Distance (FID) of these species varied greatly depending on factors including species, sex, human noise level, angle of human approach, and human mode of travel. This suggests that the distance at which recreational activity disturbs wildlife can vary depending on the factors involved. The study

also recommends that particular behaviors and practices could be employed by recreationalists to limit the level of disruption to wildlife.

Problem Statement

Research Objectives

The objectives of this study were 1) to determine whether, and to what extent, WPT basking behavior is influenced by human recreational activity along the section of the San Francisco Bay Trail that runs south from the eastern edge of Moffett Field to the Sunnyvale Water Pollution Control Plant, and 2) to assess basic demographic characteristics of the current population as compared to population demographics recorded by Alderete in 2006.

Research Questions:

- 1) What is the rate and composition of human recreational activity along the recently opened section of the Bay Trail?
- 2) Will WPTs routinely allow human presence within 30 meters in a heavily trafficked area?
- 3) Have demographic characteristics of the Bay Trail population of WPTs shifted measurably since 2006?
- 4) Do WPT individuals demonstrate high site fidelity?

Hypotheses:

H₀1: There is no significant difference in the likelihood of each type of human activity in causing WPTs to abandon basking behavior.

H₀2: There is no significant difference in length of basking period between WPTs submerging due to disturbance and those submerging on their own accord.

Method**Study System**

This study was conducted near the southern tip of California's San Francisco Bay, between the cities of Sunnyvale and Mountain View in Santa Clara County, California. The area is characterized by a Mediterranean climate where the majority of rainfall occurs during the winter months (December to February), while the summer months are relatively dry. The average annual temperature is 14.8° C (58.6° F), and the average annual precipitation is 39.1 cm (15.4 in.) (Worldclimate.com, 2011).

The specific area involved in the study includes a section of Moffett Federal Airfield, which is part of the NASA Ames Research Center (ARC), as well as portions of the San Francisco Bay Trail and Sunnyvale Water Pollution Control Plant (SWPCP). The site is 60 km (37 mi.) southeast of San Francisco and 20 km (12 mi.) northwest of San Jose (Figure 1).

The land in and around the study area is between 0 and 12 m above sea level, with the lower elevations comprising most of the study area. The geology of the soil is similar to much of the San Francisco Bay as it is composed primarily of fine alluvial sediment and bay mud (Brabb, 1993; Phillip Williams and Associates et al., 2004).

Figure 1. Study site near Moffett Federal Airfield. Image adapted from USGS Landsat Imagery (Sfbayquakes.org, 2013)

Moffett Federal Airfield has a military and aeronautic history dating back to 1933 that has resulted in the presence of hazardous materials, Superfund cleanup efforts, and non-native species (Alderete, 2003; *Ames History*, 2011). The area within Moffett Field and NASA Ames Research Center (ARC) has had a

range of purposes, including military facilities, aeronautics research, nanotechnology research, and flight tests (*Ames History*, 2011). This area is also adjacent to Lockheed Martin, another site with military and aeronautics history. These land uses have left the site greatly altered from ideal undisturbed WPT habitat.

Turtles within the study area use the expanse of channels running from the western edge of the Northern Channel to its termination near the Sunnyvale WPCP (Figure 2). The Northern Channel is used to shed surface runoff and underground water and is pumped toward the Sunnyvale WPCP. Throughout the area, WPTs have been seen basking on a variety of sites, including muddy banks, tule clumps, algae mats, and a wooden beam (personal observation). While the population is surviving, the recently opened section of the Bay Trail running beside the channel will bring a greatly increased human presence.

The Bay Trail is a largely completed 805-kilometer long (500 mile) system of trails ringing much of the San Francisco Bay. On September 20, 2010, a 3.9-kilometer (2.4 mile) section of the Bay Trail was opened along the Northern Channel on the northern border of Moffett Field (NASA.gov, 2010). This portion of the trail is built on top of the levee that separates the Northern Channel from the system of salt ponds to the north, and is owned by the USFWS (Figure 2). It is part of the South Bay Salt Pond Restoration Project, a 15,000-acre wetland restoration project in the South Bay. The Bay Trail is frequented seven days a week with a range of activities, including walking, running, and bicycling. Dogs

are not permitted on this portion of the Bay Trail, although this rule is often ignored.

Figure 2. Study system with Bay Trail segment selected. Image courtesy of Baytrail.org

The salt ponds near the study site are located on the north side of the Bay Trail segment and consist of ponds A3W, as well as several ponds owned and operated by the Sunnyvale Water Pollution Control Plant (SWPCP) (Figure 2). Pond A3W is a former salt manufacturing pond, but is now owned by the US Fish and Wildlife Service for the purposes of eventual restoration through the South

Bay Salt Pond Restoration Project. The Sunnyvale WPCP uses the WPCP ponds for various water purification and discharge processes.

The Sunnyvale WPCP is located to the east of the study site, near the end of the Northern Channel. The parking lot near the plant serves as an entry point for recreational use of the Bay Trail segment, resulting in a highly used public area. The channels to the north of the plant serve as effluent discharge areas that lead to the Guadalupe Slough and eventually carry the water out to the San Francisco Bay.

The specific sites observed and trapped within the study system include areas within Moffett Field, as well as along the Bay Trail. Both the Marriage Road Ditch (MRD) and Northern Channel were the primary WPT research habitat. The MRD vegetation consists of short turf grasses upland of the ditch and is dominated by both tule (*Schoenoplectus acutus*) and cattail (*Typha spp.*) within the ditch and along the banks with seasonal filamentous algae mats. Common animal species in the area include American coot, mallard, muskrat, ground squirrel, burrowing owl, WPT, carp, as well as a variety of invertebrates (Alderete & McGowen, 2002; personal observation) (Table 1).

Table 1
Common vertebrate species near the MRD

Common Name	Scientific Name
American Coot	<i>Fulica americana</i>
Mallard	<i>Anas platyrhynchos</i>
Burrowing Owl	<i>Athene cunicularia</i>
California Ground Squirrel	<i>Otospermophilus beecheyi</i>
Muskrat	<i>Ondatra zibethicus</i>
Western Pond Turtle	<i>Emys marmorata</i>
Carp	Family <i>Cyprinidae</i>

The Northern Channel has a slightly different species composition, with a more diverse plant and animal community. Plants along the channel include brome grass, wild mustard, plants of the family Geraniaceae, coyote brush, California thistle, mallow, tule, cattail, and pickleweed (Alderete & McGowen, 2002; personal observation) (Table 2). The common animal species include WPT, mallard, American coot, double-crested cormorant, snowy egret, great blue heron, green heron, Canada goose, prickly sculpin, carp, striped skunk, feral cat, raccoon and various invertebrates (Alderete & McGowen, 2002; personal observation) (Table 3).

Table 2

Common plant species near the Northern Channel

Common Name	Scientific Name
Brome grass	<i>Bromus spp.</i>
Wild mustard	<i>Sinapis arvensis</i>
Geraniaceae	Family <i>Geraniaceae</i>
Coyote brush	<i>Baccharis pilularis</i>
California thistle	<i>Cirsium arvense</i>
Mallow	Family <i>Malvaceae</i>
Tule	<i>Schoenoplectus acutus</i>
Cattail	<i>Typha spp.</i>
Pickleweed	<i>Salicornia virginica</i>

Table 3

Common vertebrate species near the Northern Channel

Common Name	Scientific Name
Western pond turtle	<i>Emys marmorata</i>
Red-eared slider	<i>Trachemys scripta elegans</i>
American coot	<i>Fulica americana</i>
Mallard	<i>Anas platyrhynchos</i>
Double-breasted cormorant	<i>Phalacrocorax auritus</i>
Snowy egret	<i>Egretta thula</i>
Great blue heron	<i>Ardea herodias</i>
Green heron	<i>Butorides virescens</i>
Canada goose	<i>Branta canadensis</i>
Prickly sculpin	<i>Cottus asper</i>
Carp	Family <i>Cyprindae</i>
Striped skunk	<i>Mephitis mephitis</i>
Feral cat	<i>Felis catus</i>
Raccoon	<i>Procyon lotor</i>

Note: *T. scripta elegans* was observed basking on two occasions, but was never successfully trapped during this study.

Human interaction with these habitats occurs as a result of activity on the newly opened section of the Bay Trail, as well as the use and maintenance of the golf course. The Bay Trail sees daily use by walkers, runners, and bicyclists; the trail is adjacent to the Northern Channel and is separated by a fence from the MRD. The golf course is heavily used by base personnel and requires a myriad of maintenance activities, including irrigation, herbicide, pesticide, fertilizer application, and the trimming of vegetation (Alderete, 2003). These added chemicals, along with any legacy pollution still in the system, are likely to drain into the Northern Channel.

The primary source of water for the Northern Channel is from surface runoff and groundwater infiltration (Alderete & McGowan, 2002). Water from the golf course and surrounding fields drains into the MRD, which is then pumped north to the Northern Channel. In addition, a significant amount of water is pumped from surrounding ditches into the Northern Channel. Groundwater infiltrates the entire channel system from the western portion of the study area and is an annual source of water flow (Alderete, 2003).

Study Design

To collect data on WPT response to trail use, I collected observational data along the Bay Trail from June through August 2011 and in June 2012. Observer locations were chosen based upon preliminary observation of turtle behavior, and focused on three sites of known frequent turtle basking behavior.

There were unequal numbers of observation days for each site due to security restrictions on site 3 and intermittent presence of basking turtles at site 2. Eleven observation days for site 1, seven observation days for site 2, and four observation days for site 3, resulted in a total of 22 observations days.

To collect data on basic population characteristics, I captured animals using baited hoop net traps placed in the Northern Channel and the Marriage Road Ditch. Each trap location was chosen based on areas previously observed to have WPTs present. Twelve traps were deployed May through August of 2012, and were checked for captured turtles every two days. There were intermittent periods where only two traps were deployed at one time. The term “trap-days” is defined as the number of days that traps were deployed, multiplied by the number of traps. The total number of trap days for this study was 648.

The Navy conducted a Superfund cleanup effort in the northern channel in 2006. Part of this activity included temporary removal of protected species from the area. Chris Alderete, a biologist at Moffett Field, headed the effort to trap and temporarily detain WPTs until the channel work was completed. During this trapping, he determined size, age, and sex of each individual and provided detailed sketches with notation for identification. Animals were not marked because permission to mark was not supplied by the California Department of Fish and Wildlife. All WPTs were released back into the habitat upon completion of the cleanup effort.

Data Collection

To collect data on turtle response to trail activity, an observer was posted at each of three different locations known to be popular WPT basking sites based on personal observations and confirmed by Chris Alderete (Sites 1, 2, 3). Due to the security restrictions involving access to Site 3, Sites 1 and 2 were observed more frequently (Figure 3). Each observer was concealed behind surrounding vegetation and natural barriers while observing both human activity and WPT behavior using binoculars and spotting scopes (Moore & Seigel, 2006). The distance from the observer to the basking turtles was greater than 25 m for each observation site.

During each observation period, detailed information on both human and WPT behavior were recorded. Information regarding human behavior included a time stamp, number of people, type of recreational activity, estimated noise level, and presence of dogs. The types of recreational activity included walkers (W), runners (R), bicyclers (B), and other (O), which were qualified most often as a motor vehicle. Noise levels were estimated based on the expected noise level of the passersby and were listed as quiet (Q), talking (T), and loud (L). The presence or absence of dogs with each type of activity was also noted, but dogs were rare due to posted signs.

Information regarding WPT behavior included time stamps, number of turtles, initial and exit behaviors, location, and whether their submergence was due to a human disturbance (Appendix A). Each turtle was numbered in the

order it was first observed, and both the initial and exit behaviors were recorded. Initial behaviors were recorded as either basking (B) or emerging (E), and exit behaviors were recorded as submerged with no disturbance (S), submerged due to disturbance (SD), or basking (B). While each observer was expected to observe every turtle until all turtles had exited from basking behavior, in some instances observers left prior to an individual exiting basking behavior. There were a total of 22 observations between the three sites, with a total of 68.5 h of observation. This total included 38.1 h at Site 1, 24.3 h at Site 2, and 6.1 h at Site 3.

Figure 3. Diagram showing observer locations for Sites 1, 2, and 3 along the Bay Trail.

Observations began between 0700 and 0800 hr and usually extended until basking activity became less frequent in the late morning or early afternoon, due to many of the resident turtles reaching desirable body temperature. These hours coincided not only with prime WPT basking time, but also a relative peak in

human recreational activity, as many employees and community members engaged in morning and lunch hour exercise.

The distances from each trail to WPT basking locations were measured to determine the minimum distance human recreational activity occurred in relation to WPT basking activity. Based on anecdotal observations, WPTs will often abandon basking behavior in the wild if human activity is present within roughly 40 m (pers. obs.). "Flight Initiation Distance" (FID) is defined as the distance at which a turtle abandons basking behavior. This distance is often used as a metric for measuring human disturbance of animals (Smith-Castro & Rodewald, 2010). The FID was not directly examined in this study, but regular human activity occurred within 25 m at Site 1, 30 m at Site 2, and 3 m at Site 3.

To collect data on population characteristics, turtles were captured using Memphis Net and Twine Co. baited hoop net traps with 1" netting and 24" diameter (Figure 4). Each trap was secured to the bank using stakes and twine, which caused one end of the trap to remain above water, providing any captured turtles access to air (Figure 5). A total of 12 traps were placed in the study system, with 11 placed in the northern channel, and one placed in the Marriage Road Ditch (MRD) (Figure 6). The twelve traps were deployed a total of 50 days between May 25th, 2012 and August 20th, 2012. Fewer traps (two) were deployed for the 24 days between June 15th and July 10th, 2012, compared to the other days. Trap deployment produced a total of 648 total trap-days.

Figure 4. Hoop net trap prior to deployment in the northern channel.

Figure 5. Hoop net trap deployed in the northern channel.

Figure 6. Diagram indicating trap locations along Bay Trail. A total of 12 traps were deployed.

Each trap was baited weekly with canned sardines, chopped squid, or fish heads. Traps were checked for captures every two days, and all species were immediately removed from the traps. Species captured included WPT (*Emys marmorata*), carp (Family *Cyprindae*), and prickly sculpin (*Cottus asper*). In each event involving the capture of *Cyprindae* or *C. asper*, individuals were immediately released into the channel, which resulted in no known injuries or fatalities.

All captured WPTs were measured, marked, photographed, and promptly released back into the habitat. Each released individual was observed to safely return to the Northern Channel with no observed injuries or fatalities. All handling and care of WPTs followed guidelines set by San Jose State University's Institutional Animal Care and Use Committee (IACUC) and best practices, as determined by previous WPT studies.

Measurements of WPTs included curved carapace length, straight carapace length, sex, scute rubbings, age estimation, and remarkable features. The curved carapace length was taken by stretching measuring tape along the center of the carapace from the anterior to posterior terminals. Straight carapace length was measured using a ruler running from the anterior to posterior terminal on the center of the carapace. For this study, only the straight carapace length was compared, and will be referred to as simply “carapace length” (CL). WPT sex was determined based upon secondary sexual characteristics using guidelines proposed by both Holland (1994) and Bury (1972). Rubbings were made of the plastron scutes using scotch tape and pencil for identification purposes. This approach was proposed and practiced by Dr. Jerry Smith, professor at San Jose State University (personal communication). Age was estimated based upon the number of scute rings on the ventral surface of the plastron (Bury & Germano, 1998). In some cases the scutes were too worn or damaged to accurately count, so estimates were made for every individual based upon the number of visible growth rings. Any remarkable features, such as missing limbs, deep cuts, or unusual markings, were noted and sketched on the data form (Appendix B).

Captured WPTs were marked using a triangular file to create a notch with a depth of 3-6mm in the marginal scute of individual turtles. A numbering system was adapted from Dr. Bury (1998) in which each individual had one or two notches corresponding to a unique identification number (Figure 7). To avoid

filing into any nerve tissue and causing the animal harm, the notches given to smaller juvenile turtles were shallower than for adults.

After marking, the turtle was placed on a white marker board with the identification number listed. A photograph was taken of the dorsal and ventral surface for identification purposes. The notches in the marginal scutes were clearly visible, as well as any unusual markings and colorations (Figure 8).

Figure 7. Numbered notching system for identification. Adapted from a design used by Dr. Bruce Bury (1998).

Figure 8. Photographs showing notching of marginal scutes. Distinctive markings and individual characteristics from both the ventral and dorsal perspective were visible.

Upon completion of the measurements, notching, and photographs, all WPTs were immediately released back into the habitat. Any turtles previously captured were recorded with the date, time, and location, and then checked for any changes in overall condition or health. After this evaluation, each individual was immediately released back into the habitat.

The IACUC of San Jose State University approved all methods and activities used in this study. Permission to access the levees and gates along the Bay Trail was obtained from the United States Fish and Wildlife Service. A permit was obtained from the California Department of Fish and Wildlife to trap and mark the WPTs, as it is listed as a California Species of Special Concern.

Permission for deployment of traps in the Northern Channel was obtained from the Santa Clara Valley Water District and Moffett Federal Airfield.

Data Analysis

Data analysis was executed using SYSTAT 13[®]. The total rate of recreational activity along the Bay Trail and rates for each category of activity were calculated by dividing the number of human activity events by the total observation time. These rates were also calculated separately for each of the observation sites.

A Pearson Chi-Square test for association was used to compare the disturbance rates for each category of recreational activity, including bicyclists, runners, walkers, and motor vehicles. This analysis was run for each of the three sites separately, as well as the total recreational activity along the Bay Trail. Chi-Square was also used to compare the percentage of basking turtles that abandoned basking behavior during each disturbance event.

Duration of basking periods (in minutes) of turtles before submerging due to human disturbance or control basking periods with no human presence were tested for normality and equality of variances. Since they did not meet both assumptions, the Mann-Whitney U test was used to compare the basking period length in response to human disturbance to the background basking periods (control).

Population structure data from 2012 were compared to data collected in 2006 by categorizing individuals into three major groups: juvenile, male, and female. Juveniles were defined as individuals too young to display secondary sexual characteristics (usually under 120 mm carapace length), and thus impossible to categorize as either male or female. Carapace length and population composition for each group was compared between trapping data sets. Individuals were also divided into two overall subgroups for comparison by carapace length: individuals <10 years old, and individuals ≥ 10 years. This was done in lieu of overall average age due to the fact that individuals exhibiting ten or more years of growth rings typically had very worn plastrons that were impossible to age any more accurately.

Recaptures of turtles previously captured in this study were also described to determine whether individual turtles showed site fidelity along the Northern Channel. Nineteen recaptures during the trapping period were examined for individual WPT capture locations and distance traveled between capture events. The “sphere of influence”, the territory in which the individual has been confirmed to be active, was also examined to determine each recaptured WPT’s movements.

Results

During 22 observation days, there were 1,238 human activity events. Bicyclists were the most common recreational activity, with 550 individuals.

There were 311 runners, 301 walkers, and 76 motor vehicles (Figure 9). Human activity rate along the Bay Trail overall was 18.07 individual human activity events per hour ($n=1,238$, $SE = 1.61$) (Figure 10). There were 8.09 cyclists per hour ($n=550$, $SE=0.77$), 4.54 runners per hour ($n=311$, $SE=0.79$), 4.40 walkers per hour ($n=301$, $SE=0.58$), and 1.11 motor vehicles per hour ($n=76$, $SE=0.30$).

Human recreational activity rates near Site 1 closely mirrored the overall activity rates for the study area. Site 2 exhibited a bicyclist rate similar to Site 1, but the runner, walker, and motor vehicle rates were lower than both Site 1 and the overall rate. Site 3 had a runner rate similar to Site 1 and the overall rate, however, the bicyclist, walker, and motor vehicle rates were all lower than Sites 1 and 2 (Figure 11).

Figure 9. Number of human activity events along the Bay Trail ($n=1238$).

Figure 10. Average human activity rate along the Bay Trail. Bicyclist ($SE=0.77$), runner ($SE=0.79$), walker ($SE=0.58$), and motor vehicle ($SE=0.30$).

Figure 11. Average human activity rate along the Bay Trail passing Sites 1, 2, and 3. Site 1: bicyclists ($n=349$, $SE=1.13$), runners ($n=230$, $SE=1.39$), walkers ($n=230$, $SE=0.62$), and motor vehicles ($n=69$, $SE=0.50$). Site 2: bicyclists ($n=181$, $SE=1.10$), runners ($n=46$, $SE=0.51$), walkers ($n=64$, $SE=1.15$), and motor vehicles ($n=6$, $SE=0.14$). Site 3: bicyclists ($n=20$, $SE=0.49$), runners ($n=25$, $SE=1.64$), and walkers ($n=5$, $SE=0.65$).

There were a total of 52 occurrences when WPTs submerged after basking; 30 of these events were due to disturbance from human activity, while 22 were due to turtles abandoning basking behavior of their own accord. The Mann-Whitney U test showed there to be a difference between basking duration when WPTs submerged due to human activity and when the submergence was unrelated to human activity (MWU=542.5; $df=1$; $p=0.00$; $n=52$). The average turtle basking period when human activity did not cause submergence was 42.8 ± 4.98 minutes ($n=22$), while the average turtle basking period when human activity caused submergence was 16.5 ± 2.75 minutes ($n=30$) (Figure 12).

Figure 12. Mean (SE) WPT background basking period and basking period due to human disturbance.

WPT basking was rarely disturbed by human activity, as only 25 out of 346 possible events ended with submergence due to disturbance ($\chi^2=52.88$; $df=3$; $p=0.00$; $n=346$). All recreational human activity displayed low (<7%) disturbance rates, but motor vehicles exhibited a much higher (45.5%) disturbance rate than any pedestrian recreational activity (Table 4). When basking WPTs were passed by bicyclists, turtles submerged 6.4% of the time ($n=141$). Runners caused turtles to submerge 2.0% of the time ($n=99$), walkers caused turtles to submerge 4.8% of the time ($n=84$), and motor vehicles caused turtles to submerge 45.5% of the time ($n=22$). The collective rate of disturbance was 7.2% ($n=346$) (Table 4).

Analysis by site showed 24 out of a possible 248 events at Site 1 ended in WPT submergence due to disturbance ($n=248$, $p=0.00$). Within these events, 7.3% of bicyclists caused disturbance ($n=109$), 3.2% of runners caused disturbance ($n=63$), 7.4% of walkers caused disturbance ($n=54$), 45.5% of motor vehicles caused disturbance ($n=22$), and a total of 9.7% of human events at Site 1 caused disturbance to basking WPT.

Out of a possible 52 events at Site 2, only one ended in WPT submergence due to disturbance ($n=52$, $p=0.00$). Within these events, 8.3% of bicyclists caused disturbance ($n=12$), no runners caused disturbance ($n=13$), no walkers caused disturbance ($n=27$), and a total of 1.9% of human activity events caused disturbance ($n=52$). No motor vehicles were observed using the trail while WPTs were engaged in basking behavior.

Out of 46 possible occurrences, no submergence was due to human disturbance at Site 3. There were total of 19 bicyclists, 24 runners, and three walkers near Site 3, none of whom caused WPT to submerge.

WPTs were disturbed a total of 25 times, with bicyclists responsible for 36% of total disturbances ($n=9$), runners responsible for 8% ($n=2$), walkers responsible for 16% ($n=4$), and motor vehicles responsible for 40% ($n=10$).

Table 4
*Number of events in which each disturbance type caused submergence.
Frequencies of turtle disturbance by type of human activity*

	Bicyclist	Runner	Walker	Motor Vehicle	Total
Disturbance	9	2	4	10	25
No Disturbance	132	97	80	12	321
Total	141	99	84	22	346
Disturbance Frequency Percentage	6.4%	2.0%	4.8%	45.5%	7.2%

At all sites, humans and motor vehicles always passed within 30m of basking turtles (Table 5). Of 346 total observed human activity events near basking WPTs, submergence and abandonment of basking behavior was triggered in a total of 25 instances. Thus, over 92% of human activity events within 30 meters of basking WPTs did not trigger basking abandonment. Table 5 shows WPT response by site and overall.

Table 5

Basking abandonment in the presence of human activity. Data was collected among 3 observation sites along the Bay Trail, indicating WPTs frequently allow human activity within 30 meters ('Aban.' = % Abandonment)

	Distance from humans (m)	No Response	33% Aban.	50% Aban.	66% Aban.	100% Aban.	Total	Response %
Site 1	25	224	1	3	3	17	248	9.7
Site 2	30	51	0	0	0	1	52	1.9
Site 3	3	46	0	0	0	0	46	0
Total		321	1	3	3	18	346	7.2

Trapping data collected during the 2006 calendar year by Chris Alderete, NASA AMES contracted biologist, included a total of 51 individual WPTs, comprised of 41 males, 3 females, and 7 juveniles. In 2012, I trapped a total of 13 individual WPTs, comprised of 6 males, 2 females, and 5 juveniles (Table 6, Figure 13). The WPTs captured in 2012 were less skewed toward males than in 2006.

Table 6

Number and gender composition percentage of 2006 and 2012 WPTs captured

	WPT Captures 2006		WPT Captures 2012	
	Number	%	Number	%
Male	41	80.4	6	46.2
Female	3	5.9	2	15.4
Juvenile	7	13.7	5	38.5
Total	51		13

Figure 13. Gender composition of two WPT population data sets.

The average size of individuals in each sex category in 2012 was compared to those from 2006. In 2006, the average carapace length of males was 168.3 mm ($n=41$, $SE=2.27$), females measured 163.3 mm ($n=3$, $SE=5.44$), and juveniles measured 98.3 mm ($n=7$, $SE=6.58$). Data from 2012 shows males to have an average carapace length of 156.8 mm ($n=6$, $SE=13.25$), females measured 146.0 mm ($n=2$, $SE=6.36$), and juveniles measured 83.8 mm ($n=5$, $SE=5.29$) (Figure 14).

Figure 14. Average (SE) carapace size (mm) for each sex category.

The average estimated carapace length of individuals aged less than 10 years in 2006 was 142.9 mm ($n=26$, $SE=6.03$), and was 110.6 mm ($n=9$, $SE=12.71$) in 2012. For individuals greater than 10 years, carapace length in 2006 average 174.8 mm ($n=26$, $SE=1.75$), and 164.3 mm ($n=4$, $SE=9.74$) in 2012 (Figure 15).

Figure 15. Average (SE) carapace length of WPT age classes.

A single individual captured in 2012 was positively identified with an individual captured and marked in 2006. This individual was identified by clear white splotches on both sides of the carapace and a distinct circular mark on a portion of the plastron based on detailed sketches and notes from 2006 and photographs from 2012. The specimen is a male with a very worn plastron, thought to be more than 10 years old in 2006, based on the readable growth rings. Comparison of the carapace length measurements taken in 2006 (converted from inches) and 2012 indicates that the turtle grew from 177.8 mm in 2006 to 184 mm in 2012.

A total of 13 WPTs were captured in 2012, and five of these individuals were recaptured during the season. The turtle identified as WPT 1 was recaptured a total of 11 times after the original capture, WPT 3 was recaptured three times, WPT 5 was recaptured 3 times, WPT 7 was recaptured once, and WPT 8 was recaptured once.

The trap locations for the recapture of each individual show WPT 1 captured a total of 12 times, each at trap 11. WPT 8 was captured twice at trap 2. WPT 3 was captured 3 times at trap 11 and once at trap 6, a distance of 825m from the original trap location. WPT 5 was captured once at trap 11, twice at trap 7, and once at trap 8. The furthest trap was 520m from the original trap location. WPT 7 was captured once at trap 10, and once at trap 11, 282m from trap 10 (Figure 16).

Figure 16. Distance of WPT recaptures from the original trap location.

The five recaptured WPTs allowed an analysis of each individual's movements and sphere of influence (SOI). For WPTs 1 and 8, the confirmed SOI was restricted to a relatively small area due to repeat captures at the original trap locations 11 and 2, respectively (Figure 17). WPT 3 had a confirmed SOI ranging from trap location 11 to trap 6, stretching 825 m (Figure 18). WPT 5 had a confirmed SOI ranging from trap 11 to trap 6, a total of 570 m (Figure 19). WPT 7 had a confirmed SOI ranging from trap 11 to trap 10, a total of 282 m (Figure 20).

Figure 17. SOI range for WPTs 1 and 8. Note: Shaded areas denote SOI range.

Figure 18. SOI range for WPT 3. Distance between trap locations is 825 m.

Figure 19. SOI range for WPT 5. Distance between trap locations is 570 m.

Figure 20. SOI range for WPT 7. Distance between trap locations is 282 m.

Discussion

The section of the Bay Trail examined in this study was first opened to recreational traffic in September of 2010, nine months before observational data were collected. The start of the observations coincided with the first basking season, during which this population of WPT was exposed to recreational human activity. While vehicular traffic is likely to have been similar to past seasons, recreational human activity has almost certainly increased since the opening of the trail to recreational use.

The majority of human activity observed along the trail was pedestrian traffic, consisting of bicyclists, runners, and walkers. The low frequency vehicular traffic was largely due to work trucks traveling along the levee system, which merges with the Bay Trail in several areas. The overall rate of human activity recorded in this study (18 events/hour) was much lower than observed in other

recreational studies involving San Francisco Bay Area Trails, one of which reported 68 human recreational events per hour while observing shorebirds (Trulio & Sokale, 2008). As the newer section of the Bay Trail observed in this WPT study becomes more widely recognized, it is possible that human activity levels could rise.

Site 1 had by the far the greatest exposure to human activity, measured by the overall number of human events and an average of 23 events/hour. The higher rate of activity was likely due to the proximity of site 1 to the parking lot near the Sunnyvale water pollution control plant (SWPCP), as well as the site being adjacent to the confluence of several trails. These factors not only led to heavy recreational traffic, but also contributed to vehicular traffic, as most motor vehicles using the levees were associated with the nearby SWPCP. Much like the average rates for all three sites, Site 1 was exposed to mostly recreational traffic, led by bicyclists, and followed by runners and walkers. The rate of vehicular traffic was much lower than any of the pedestrian categories.

The ability of ectotherms, including freshwater turtles, to regulate body temperature is an integral part of their physiological processes, behavior, and ecology. The body temperature of freshwater turtles determines the rate of all physiological processes and governs much of the behavior. Properly regulated body temperature positively affects turtles' foraging success, digestion efficiency, reproductive success, predator avoidance, and growth rate (Bulte & Blouin-Demers, 2009; Dubois et al., 2009). Emergent basking is a common

thermoregulative technique used by WPTs, so it is important to determine whether human activity is likely to disturb this essential behavior.

Observations made of basking WPTs in this study site showed that basking periods interrupted by human disturbance are significantly shorter than the background basking period. While WPT basking periods ending in submergence due to human disturbance averaged 16.5 minutes, the background rate was much longer, with an average of 42.8 minutes. Disturbances of this nature lead to interrupted thermoregulation and loss of heat energy, which could have profound effects on WPTs ability to survive and reproduce.

The overall rates of disturbance at all three observation sites were very low, with only 7% of human activities causing disturbance. This suggests that human traffic along the trail may only have a limited impact on WPT basking behavior. However, analysis of disturbance types showed WPTs were much more likely to respond to motor vehicles than any other type of disturbance. In fact, WPTs submerged 45% of the time when a motor vehicle passed by. A high rate of vehicular disturbance was also found in other studies examining human recreational use on wildlife. McGowan and Simons (2006) found that ATVs were much more likely to disturb shore birds than pedestrians were, and Moore and Seigel (2006) observed freshwater turtles frequently abandoning basking behavior due to boat traffic.

Pedestrian behaviors, divided into bicyclists, runners, and walkers, each showed a disturbance rate of <7%. But bicyclists had a slightly higher

disturbance rate than either runners or walkers. This was likely due to the higher average speed of bicyclists, as well as other observed factors, such as squeaky brakes, loud communication with other pedestrians, and abrupt stops. The noise and speed of bicyclists may be similar enough to vehicular traffic to cause an increase in disturbance, and other studies have noted disturbance to wildlife due to vehicular traffic (McGowan & Simons, 2006; Moore & Seigel, 2006; Rodgers & Schwikert, 2003).

The rate of disturbance caused by motor vehicles makes them a major cause of WPT disturbance. Fortunately, the frequency of motor vehicle events was low, and confined to areas near Site 1. These factors lessen the detrimental effect such traffic has on this WPT population's thermoregulatory ability and overall survivorship.

WPTs have been observed to have a particularly wary nature and are easily startled by nearby activity while basking (Bury, 1972; personal observation). "Flight Initiation Distance" (FID) is defined as the distance at which a turtle abandons basking behavior. This distance is often used as a metric for measuring human disturbance of animals (Smith-Castro & Rodewald, 2010). The published literature contains no studies of the FIDs of WPTs in undisturbed habitats, however this author has observed WPTs abandoning basking behavior along secluded portions of the Napa River and Coyote Creek when human presence was detected at a distance of 40 or more meters (personal observation).

Despite the highly sensitive nature of WPT basking behavior, this study suggests there may be a level of habituation developing among the population present along the Bay Trail. The FID was not directly examined in this study, however, human activity was frequently allowed within 25 meters near Site 1, within 30 meters near Site 2, and within three meters near Site 3. Habituation has been observed in other species, such as a study finding black ducks developing habituation to aircraft noise over time (Conomy, Dubovsky, Collazo, & Fleming, 1998).

Basking near Sites 1 and 2 were characterized by emergent basking on mud clumps, tule mats, and a wooden beam. Turtles were also observed occasionally surface basking on top of algae mats and reeds. Basking behavior at Site 3 was much different, as basking structures are not sufficient to allow a turtle to haul completely out of the water. Instead, turtles near Site 3 often basked half-submerged or hauled onto the steep slope of the north bank of the northern channel. This basking habitat may have been less ideal from a thermoregulatory standpoint, but the slope shielded WPTs from the trail and may have contributed to WPTs tolerating human activity to within three meters.

Both the data collected by Alderete in 2006 and the data from this study in 2012 show a male-skewed sex ratio. This is common in freshwater turtle populations due to females being exposed to increased predation and road mortality as they travel overland for nesting (Aresco, 2004; Germano & Rathbun, 2008; Patrick & Gibbs, 2010). This study site is highly impacted and fragmented

with high road density and heavy traffic in nearby roadways. Resident terrestrial predators such as skunks (*Mephitis mephitis*), feral cats (*Felis catus*), and raccoons (*Procyon lotor*) are also potentially detrimental to WPT survival (Alderete, 2003; personal observation). These factors all work to increase the likelihood that female WPTs will succumb to predation or road mortality while engaged in nesting behavior, contributing to a skewed sex ratio. Even given these factors, the low percentage of females, in the 2006 data especially, could be cause for concern.

The sex ratio of chelonians has been studied in other species, including a population of desert tortoises (*Gopherus agassizii*) in the western Mojave Desert. Doaks, Kareiva, & Klepetka (1994) found that even with low numbers of individuals, it is possible to determine the efficacy of a population. This study determined that any stochasticity in a population's habitat may have effects, but the most influential indication of population growth rate is the survival of large adult females. The recommendation from this research was to make any threats to female survival a top priority when developing a management plan. This course of action would likely apply to the population of WPTs along the San Francisco Bay Trail, as data suggests the proportion of females is low.

Juvenile recruitment is a key indicator of population stability, as it is a result of successful reproduction and hatchling survival. While the 2006 data set had a lower percentage of juveniles than this study's data, it may not necessarily point to lower juvenile recruitment. The nature of hatchlings and smaller

juveniles is often secretive, cautious, and centered around avoidance. Young turtles roam shorter distances, are small enough to fit between netting, and are less likely to engage in exploration of more open waters, making it more probable that they may avoid the type of hoop net traps deployed in both studies to capture WPTs (Bury, 1972; Germano & Rathbun, 2008). Given the number of juveniles younger than 6 years old captured in 2012, it appears that the population is successfully reproducing in this highly altered habitat.

Few conclusions can be drawn from comparison between the 2006 and 2012 trapping data sets, as the population size is low and methods differed between the studies. While 51 individuals were captured in 2006, the 2012 sample size of 13 presents low power due to limited representative sampling. No statistically significant comparison could be conducted between these two sets of population data due to the low *n* value. Additionally the methods used in 2006 for the capture and measurement of WPTs were slightly different than what was followed for this study. The investigator in 2006 also lacked permission to practice any sort of marking on the captured individuals, preventing a more extensive comparison of individuals between the 2006 and 2012 data sets.

One comparison that could be made was with the positive identification of WPT 11 in 2012 with “# 27” in 2006. This data point is significant because it shows that at least one past member of the population may be surviving and remaining in this altered habitat. It also hints at possible growth rates of WPTs in this habitat, although some accuracy may be lost from the conversion of the 2006

data from inches to millimeters. According to the two studies, this adult male grew roughly six millimeters in six years. While it is common for growth rates to slow upon reaching adulthood, this rate is lower than that observed by Germano and Rathbun (2008) in a similarly altered habitat. Other studies have pointed to increased growth rates near sewage treatment plants due to increased temperature of water and high nutrient loads, so the data from this one individual turtle is counter to what might be expected with a close proximity to SWPCP (Germano, 2010; Spinks et al. 2003).

During the summer of 2012, five individual WPTs were recaptured throughout the northern channel. Four of the turtles were recaptured fewer than four times, but a young juvenile identified as “WPT 1” was recaptured a total of 11 times in the same trap location. This sort of “trap happy” behavior was likely due to the fact that the small juvenile was based in an area near the trap, and the bait provided easy forage. Young WPTs are often thought to remain within close proximity of where they entered the water as a hatchling, and only begin to explore farther as they age (Bury, 1972; Germano, 2010), thus making it likely that the trap placement happened to be located within the juvenile’s sphere of influence (SOI).

The widest SOI observed was with WPT 3, which traveled 825 meters in 12 days or fewer. This type of range may be expected from an adult, but WPT 3 was a three-year-old juvenile with a CL of 69 millimeters. This travel distance from a small juvenile was contrary to what other studies have suggested is

common behavior for WPT juveniles. The water in the northern channel flows at very low velocity, so it is unlikely that the turtle was swept away with the current, and it lacked the sexual maturity to be searching for a mate. This type of behavior from a juvenile WPT may suggest a need to travel great distances for proper forage or other ecological needs.

Over the course of three days, WPT 5 traveled 570 meters from one trap to another. This rate of travel (190 meters per day) was the highest recorded travel rate of any recaptured WPTs. This individual was a seven-year-old undersized male (CL=105 millimeters) that displayed secondary sexual characteristics despite its small size. This individual may have been searching for a mate or traveled downstream for foraging purposes, but it does indicate an accelerated rate of travel for some members of the WPT population near the Bay Trail.

The western pond turtle is a California species of special concern due to population decline throughout the state. The WPTs currently residing along the Bay Trail are exposed to frequent human recreational activity and occasional vehicular traffic near the basking sites in their habitat. Pedestrian traffic rarely causes basking abandonment; however, motor vehicles making use of the levees cause a considerably high rate of basking abandonment. While motor vehicle traffic is infrequent, the thermoregulatory costs to disturbed WPTs could be high. In addition, heavier traffic could cause turtles to be injured or killed while crossing levees, given the long travel distances of some individuals.

There is some indication that WPTs within this study site have become habituated to human activity along the trail. Previously observed “Flight Initiation Distances” of 40 meters or more in remote areas appear much shorter in this habitat, allowing human activity within three meters in some cases. This is partly due to proper cover, but could also be a result of habituation to frequent human recreational activity.

Despite the appearance of a turtle population that has adapted to frequent human activity, there could be less obvious physiological impacts. Species exposed to repeated, regular stresses from human activity can build up stress hormones that lead to reduced reproductive success. Ellenberg, Setiawan, Cree, Houston, & Seddon (2007) found that stress-induced corticosterone concentrations of endangered Yellow-eyed penguins (*Megadyptes antipodes*) were due to increased tourist activity near the nesting and breeding sites. These higher levels of stress hormones were correlated with lower breeding success and fledgling weights, indicating severe reproductive costs. These same stress hormone increases also occur in turtles, as corticosterone levels have been shown to increase in hawksbill turtles (*Eretmochelys imbricate*) when subjected to stress as a result of human interaction (Jessop, Sumner, Limpus, & Whittier, 2004). If WPTs along this habitat are in a constant state of stress due to human activity, it may be harming reproductive success.

Population data from 2012 suggests that significant levels of WPT juvenile recruitment are occurring along the Bay Trail. The presence of both male and

female adults also indicates the population is surviving and some successful reproduction is occurring. A slightly skewed male-female sex ratio among adults is not uncommon for freshwater turtle populations, but it is a cause for concern if too few females are present in the system, as it indicated by the very high male-to-female ratio of the Bay Trail WPT population. High road density is linked to increased female mortality and a male biased sex ratio, which can lead to decreased reproduction and fecundity (Gibbs & Steen, 2005; Steen & Gibbs, 2004). Additionally, the seemingly slow growth rate noted in several individuals may indicate a lack of proper basking opportunities, thus stunting the growth of this population.

Recommendations

Recommendations for continued support and management of this population of western pond turtles include:

- 1) Continue to monitor the WPT population along the Bay Trail. With this study's population data as a baseline, additional trapping studies should be encouraged for academic and management purposes.
- 2) Study effects of trail traffic on turtle movement and fatality throughout the system by tracking female turtles as they travel over land and engage in nesting behavior.

- 3) Increase quality and availability of basking sites throughout the channel through installation of woody debris and replanting of tules and cattails along the channel.
- 4) Encourage public understanding and support of WPTs by adding information regarding their status and ecology to existing informational panels along the Bay Trail.
- 5) Investigate the efficacy of a possible radio telemetry study for this population. The limitations of nearby off-limits sites may be a hindrance, but the knowledge gained from this research would contribute greatly to current understanding of WPT behavior in disturbed habitat.
- 6) Consider supporting this population through a head-start program. While this population does exhibit juvenile recruitment, the mortality of hatchlings is likely high due to the disturbed habitat and abundance of predators.
- 7) Limit vehicular traffic near important WPT basking and nesting sites along the Bay Trail.
- 8) Educate motor vehicle drivers about the population of WPTs along the trail and the effects vehicular traffic can have on their survival. This includes SWPCP workers, construction contractors, Santa Clara County Water District employees, and members of the public engaged in volunteer or duck hunting activities along the levee system.

- 9) Study the FID of WPTs in response to various human activities. This could then be compared with responses from populations of WPTs in more remote areas lacking frequent human activity.

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Appendix A

Turtle Behavior Data Form

This field form was used for recording both the behavior of turtles and human activity along the Bay Trail (Figure A1). Time stamps were given for turtle 'Start' and 'Exit' behavior, as well as for any human activity. Each turtle was numbered under the 'turtle' column and had the basking location listed under 'location' to keep track of each individual's basking behavior. The type of human activity being observed was noted under 'human behavior', along with how many turtles were basking before and after the event in the columns '# of turtles before' and '# of turtles after', respectively. Any additional comments were included in the 'comments' column.

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Appendix B

WPT Data and Recapture Forms

WPT Data Form

This field form was used to record the data from each captured WPT (Figure B1). The researcher, location, date, time, and trap number were recorded for the original capture. The sex, carapace length straight, carapace length curved, and annuli count were all determined and recorded on the form. The rectangular box was used to place the scotch tape rubbing of the plastron for comparison and to aid in determining the annuli count. Below, any comments or observations made about the general condition or trapping of the individual were made. The images of the carapace or plastron were used to make sketches or comments about any distinguishing features, as well as note the notching locations. Photos of both the carapace and plastron were attached in the empty space below the comments section.

A recapture form was used to note any recaptures of turtles, as well as any changes in their condition (Figure B2). The date, time, and weather were recorded for each recapture, as well as the trap number and the turtle identification number. Any additional comments were listed in the 'comments' section.

WPT Data Form

Researcher: _____ Location: _____

Date: _____ Time: _____ Trap #: _____

Turtle # (Shell notch): _____ Sex: M F U Carapace length straight: _____

Carapace length curved: _____

Annuli Count: _____

Comments:

Figure B1. Field form used to measure and notch WPTs.

Turtle Recapture Form

Date	Time	Weather	Trap #	Turtle #	Comments

Figure B2. Turtle Recapture Form