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Western Pond Turtle Summer Habitat Use in a Coastal Watershed

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WESTERN POND TURTLE SUMMER HABITAT USE
IN A COASTAL WATERSHED

A Thesis

Presented to

The Faculty of the Department of Biology

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Jae Abel

May 2010

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The Designated Thesis Committee Approves the Thesis Titled

WESTERN POND TURTLE SUMMER HABITAT USE IN A COASTAL
WATERSHED

By

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APPROVED FOR THE DEPARTMENT OF BIOLOGY

SAN JOSE STATE UNIVERSITY

May 2010

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ABSTRACT

WESTERN POND TURTLE SUMMER HABITAT USE IN A COASTAL WATERSHED

by Jae Abel

Western pond turtle (*Actinemys marmorata*) habitat use was studied in a coastal pond, lagoon, and stream system during the summer of 1995 and 1996 at Waddell Creek, Santa Cruz County, California. Location and habitat association data were recorded for locations and sightings of radio-tagged and un-tagged turtles during the normal active season. Summary comparison of habitat associations and habitat availability provided inference of habitat preference at several habitat scales. For most of the active season the turtles were in relatively sunny aquatic habitat, in deeper, slower velocity water. In addition, the turtles were most commonly associated with exposed and sub-surface woody debris, rooted bank, and branches positioned near the water surface. In the lagoon and stream this was usually associated with the thalweg and along positions just off the bank, where large wood and pool scour was most abundant. Newly placed and relocated floating wood was utilized for basking within days by radio-tagged and untagged turtles. Subsequent data on the basking behavior of a sub-set of radio-tagged turtles was developed with externally attached temperature sensors to chronicle periods when the turtle shell was exposed to sun. A regular pattern of extensive daily basking was identified in all thermistor-fitted turtles. The combination of sunny aquatic habitat with natural structural elements, particularly woody debris, which provided escape cover and basking opportunities, appeared to be the preferred habitat for this species.

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I would like to dedicate this work to my family, especially my mother Kaleen and my late father, Frank. Even after innumerable delays and interruptions for personal and career responsibilities, they never lost faith that I would eventually complete this effort.

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Introduction

Background

The western pond turtle (hereafter WPT) or Pacific pond turtle, (*Actinemys marmorata*) is a Pacific states species and at one time was a rather widespread and common semi-aquatic reptile. Although recognized as a distinct species, the taxonomic relationships of this species to other related species remain unsettled. Baird and Girard (1852) first described this species as *Emys marmorata*, and Girard (1858) referred to it as *Actinemys marmorata*. Seeliger (1945) described this species as *Clemmys marmorata* with two subspecies: the northern Pacific pond turtle (*C. m. marmorata*) and the southern Pacific pond turtle (*C. m. pallida*), and it was grouped with three congeners in North America (Ernst and Barbour 1989; Ernst et al. 1994). More recent taxonomic investigation and review have questioned this grouping (Bickham et al. 1996; Feldman and Parham 2001; Holman and Fritz 2001). Feldman and Parham (2002) and Parham and Feldman (2002) developed a case for the assignment back to *Emys*, grouped with the European pond turtle (*Emys orbicularis*) and Blanding's turtle (*Emys blandingii*) as a holarctic lineage grouping. Spinks et al. (2003) and Spinks and Shaffer (2005) adopted this taxonomy, and the latter work identified four clades with substantial genetic fragmentation within the *E. marmorata* species lineage. Holman and Fritz (2001) and Stephens and Wiens (2003) had redeveloped the evidence for *Actinemys marmorata*. This may be subject to additional review and revision, as taxonomists have not fully established an unequivocal lineage defense within and between the species, and additional data are probably needed (Bury and Germano 2008).

Originally, this species ranged generally west of the Sierra/Cascade ranges from southern British Columbia to Baja California and from sea level to nearly 2000 m elevation (Bury 1972; Ernst et al. 1994; Stebbins 2003). Storer (1930) described some of the basic life history of WPTs in the Central Valley of California and remarked on their ongoing use as a food resource. Burke et al. (2000) also noted the use of WPTs as a food source extending to the World War II era. WPTs were found in large numbers in a variety of aquatic habitats, including streams, lakes, ponds, sloughs and agricultural drainage ditches. The development of the Central Valley of California for agriculture largely eliminated much of this habitat (Buskirk 1990). The turtle is an omnivorous, opportunistic scavenger feeding on a variety of invertebrates, vertebrate carrion and aquatic plants (Bury 1986; Holland 1991; Stebbins 2003)

Bury and Holland (1993) chronicled much of the known information from the few studies conducted to date, but remarked that details of the ecology of the WPT throughout its range remained relatively unstudied. This may be due to two factors. The WPT is a wary and secretive species of turtle (Bury 1972; Bury and Holland 1993), thus making it relatively difficult to observe. Further, there are fewer species of freshwater aquatic turtles west of the Continental Divide (Ernst and Barbour 1989). The hydrology in western states does not support the abundance and variety of aquatic habitats that would foster turtle species diversity. In California, the WPT is the only native freshwater turtle found (Ernst and Barbour 1989; Ernst et al. 1994; Stebbins 2003). Thus, less general attention may have been devoted to turtle study in the West.

In a detailed study of WPT ecology, Bury (1972) examined aspects of their home range and basking behavior over four years in a northern California stream system. From 507 locations (3-10 locations per turtle for 131 turtles out of 578 in the study area) he concluded that home ranges and movements of males were much larger than females or the much more sedentary juveniles. Territoriality was weak, with large overlap in the habitat use by individual turtles. Bury's sampling efforts were largely confined to the stream channel. Observation of thermal ecology found that turtles used morning hours for basking and employed a number of behaviors, from position adjustments and partial shading to dunking, presumably to fine tune body temperature while basking (Bury and Wolfheim 1973). Suitable basking sites were limited, and aggressive behavior was observed at sites where turtles congregated along the stream to bask. Germano and Rathbun (2008) noted that in addition to aerial basking, turtles in their study areas exhibited "cryptic" basking, by settling in to localized microclimate habitats with elevated temperature (such as warm sand or algal mats) that provided the benefit of elevated body temperatures, but presumably with minimal exposure to predators.

There are few studies of reproductive activity for WPT. Holland (1988) described an observation of courtship behavior in WPTs that were submerged in water to a depth of 2 m. Feldman (1982) provided some notes on the relationship of egg hatching and habitat in WPTs from *in vivo* attempts to hatch eggs on differently saturated media. The eggs were observed to absorb moisture and rupture on saturated media. In addition, the hatchlings did not emerge when temperatures exceeded 27°C. From this he extrapolated

that WPT eggs are well suited for deposition in the hot, dry climate and soil conditions found far from water, much as generally described in Storer (1930).

Rathbun et al. (1992) investigated the nesting behavior and habitat use of WPTs in a riparian corridor flanked by coastal sagebrush and steppe habitat. They outfitted four gravid females with radio transmitters for tracking their movements. They found that the females moved considerably up and down the stream zone and also overland in upland habitats, on multiple days, prior to oviposition. Several widely scattered false nests had been constructed. They postulated that the nest site selection may have one or more determinants including appropriate thermal microclimate for incubation, avoidance of the flood plain to protect eggs and over-wintering hatchlings, and predator avoidance, by wider spacing of nests and egg-laying away from areas frequented by potential predators.

Rathbun et al. (1993) examined habitat use in two populations of turtles in south-central California. They found that turtles in stream areas primarily tended to use upland areas for overwintering activity, whereas the pond turtles tended to remain in the ponds for dormant periods. Davis (1998) found the same thing at Waddell Creek in central California. In addition, in both studies the majority of turtles were found in the lower reaches of the watershed, primarily the lagoon and slough reaches of these coastal streams. As Bury (1972) found, these turtles also seemed to prefer deeper pools with cover, rather than shallower more open sites. The turtles would congregate at basking sites, which were a limiting factor in distribution. The turtles also moved widely within the systems.

A marked decline in numbers of WPTs has been suspected (Brattstrom 1988; Buskirk 1990; Bury and Holland 1993; Holland 1994), so that the WPT was petitioned and reviewed as a potential Threatened or Endangered Species by the U.S. Fish and Wildlife Service (USFWS 1992). This petition was denied on the grounds of insufficient evidence on status and viability of populations within the historic range of the species (USFWS 1993). However, the recognition that range-wide, this species may be under some substantial pressures has renewed interest in field investigations on the natural history and status of WPTs.

Holland (1991, 1994), Germano and Bury (2001) and Spinks et al. (2003) highlighted many of the impacts that populations of WPTs currently face, including water development and diversion, agricultural conversion of upland habitat, urbanization, clearing and artificial confinement of stream channels, mining, collection for the pet trade and as a food resource, roads and railroads. Bodie (2001) reviewed the worldwide patterns of river management and the implications for freshwater turtles. A variety of riparian land use and water management practices have led to substantial loss of biodiversity and have negatively affected riverine turtles in both aquatic and adjacent upland habitats. Studies have been conducted in Northern California on WPT habitat requirements in larger regulated rivers, including comparisons of dammed and undammed reaches (Reese and Welsh 1997; Reese and Welsh 1998). Landscape level effects of the modification of the riverine environment may affect this species at the watershed population level, where the modified flow and thermal regime in the regulated reaches may be depressing the number of turtles. Elsewhere, WPTs have been recorded

in seemingly improbable habitats including as small, isolated populations occupying desert aquatic sites (Lovich and Meyer 2002). Although WPT is extirpated from much of its native habitat in the Central Valley of California, Germano (2010) found a population of WPT in heavily modified settling ponds at a municipal sewage treatment plant; WPTs were successfully reproducing and consisted of individuals with relatively high growth rate.

The introduction of exotic species as competitors and/or predators remains a more difficult problem to solve (Bury and Luckenbach, 1976). Stahl (1994) included a list of 16 potential competitor turtle species that have been introduced in the western states. Stahl (1993, 1994) demonstrated the impact of the red-eared slider (*Trachemys scripta*). The WPT seemed to show a shift in time and type of habitat use in an artificial enclosure and a reduction in fecundity in the presence of red-eared sliders. This is not surprising considering that sliders can be two to three times the size of the WPT. Gibbons (1990) described red-eared sliders as a generalist/opportunist species. Although systematic observations of interactions were not documented by Stahl (1994) to determine the competitive mechanisms, the implication was that WPTs are apparently out-competed for basking sites and feeding resources in the presence of another turtle species with similarly broadly defined niche characteristics. Red-eared sliders may also act as a parasite vector to depress WPTs. Spinks et al (2003) and Patterson (2006) found similar evidence for the effects of this exotic species. The competitive advantage red-eared sliders have over the native WPT in disturbed environments, may include some life-

history traits that are more tolerant of anthropogenic disturbance. Other exotic turtles are also suspected of having negative impacts on the WPT, but studies are lacking.

Bullfrogs (*Lithobates catesbeianus*, previously *Rana catesbeiana*) are a widespread exotic in California (Bury and Luckenbach 1976; Stebbins 2003), having been introduced more than once in the early part of the previous century (Storer 1925). Bullfrogs have been implicated in the loss or reduction of native frog populations in California (Moyle 1973; Stebbins 2003). They were described as a major problem for WPTs (Holland 1994; Bury and Holland 1993), since they prey upon a wide variety of invertebrate and vertebrate organisms including young turtles. Holland (1994) included a particularly dramatic photograph of an adult bullfrog holding a half-swallowed juvenile WPT in its mouth. The quarter- to half-dollar size hatchling WPTs are particularly vulnerable to this voracious predator. Other exotics known to prey upon WPTs include certain fish species such as largemouth bass (*Micropterus salmoides*) (Holland 1994).

Under pressures from habitat loss, habitat alteration and fragmentation, exotic species predation and competition, WPTs may be suffering substantial population loss, particularly at the southern and northern ends of the range. But in some individual circumstances, populations may be persistent and viable (Bury and Germano 2008). That is similar to the conditions faced by many of the world's turtle species (Klemens 2000). The suite of these problematic factors needs to be partially mitigated by better land-use practices, and even by direct management intervention where needed, for conservation to be successful (Siegel and Dodd 2000).

Study Objectives

The WPT is considered a Species of Special Concern by the California Department of Fish and Game, because of impacts to habitat and population numbers throughout its current range. Bury and Holland (1993) emphasized the need for studies targeted at the life-history and ecology of WPTs throughout their range, and Holland (1994) called for longer studies on the ecological dynamics of WPTs, because most studies up to that time were of less than three years in duration.

At Waddell Creek on the central California coast a large WPT population has been consistently present for decades, with turtles abundant in a stream mouth lagoon and an adjacent perennial pond named “Turtle Pond”. A California Department of Parks and Recreation management plan for the stream mouth required studies of sensitive aquatic species, and most of the effort was directed to WPT because they were the least understood species at the site (Smith et al. 1997). Studies were conducted of habitat use during the inactive season (Davis 1998) and of nesting habitat (Crump 2001). The present study looked at habitat use in the lagoon, stream and permanent pond during the active season. The site is particularly useful for WPT studies, as much of the habitat is protected within a state park, introduced predator or competitor species are absent and long-term studies are possible.

Study Area

The study area comprised the lower 3.8 km of the Waddell Creek watershed drainage located at the northwest boundary of Santa Cruz County, California (Figures 1-3). Waddell Creek is a perennial, fourth order (Strahler 1952) stream that flows generally

north to south more than 16 km from headwaters and tributaries to empty across a sand beach into the Pacific Ocean. The east and west (main) forks of the stream join approximately 5.5 km upstream of the mouth. A few springs and small, seasonal or perennial tributaries throughout the watershed also contribute flow and provide additional aquatic habitat. Highway 1 crosses the stream near the mouth. Private access roads extend up from the highway into the watershed along the stream.

Upstream of the lagoon, Waddell Creek flows through a coastal redwood and mixed evergreen forested canyon bottom, where the upslope vegetation is dominated by redwood (*Sequoia sempervirens*), California bay laurel (*Umbellularia californica*), Douglas fir (*Pseudotsuga menziesii*), Monterey pine (*Pinus radiata*), and tanbark oak (*Lithocarpus densiflorus*). The riparian edge is dominated by white alder (*Alnus rhombifolia*) and includes willows (*Salix spp.*), black cottonwood (*Populus trichocarpa*), box elder (*Acer negundo*), and redwoods. The canyon opens up approximately 2 km from the mouth of the stream, and the still-continuous riparian canopy is flanked along the outer edge by more gradual side slopes, ruderal grassland and agricultural fields growing annual row-crops. A few rural residences are set back from the stream edge. The agriculture has been practiced on and off since the limited settlement of the watershed but has been persistent for the past 2-3 decades.

At approximately 1.2 km from the mouth of the stream, the stream channel begins to meander and widen. This position is approximately the maximum upstream extent of the lagoon inundation within the present channel. Highway 1 crosses the mouth of the stream about 150 m upstream of the low-tide ocean-stream interface. The highway berm

was built across the original lagoon mouth, constricting the opening and confining the stream to a course through the relatively narrow bridge opening. Sand deposition from lower energy beach wave action, coupled with lower summer stream flows, result in a sandbar forming seasonally downstream of the bridge. This impounds stream flow as a ponded lagoon, inundating as much as 1000 m of the low-gradient meandering channel upstream of the Highway 1 Bridge. With the sandbar fully formed, the stream flow is drained by seepage through the sandbar. However, the sandbar may break and reform during the course of the summer driven by the interplay of wave energy depositing sand and by overtopping of the bar by stream flow. The sandbar remained at least partially open throughout nearly all of the 1995-6 study years. Anthropogenic breaching of the sandbar is also an agent in this seasonal dynamic. With formation and breaching, lagoon water depths may change by as much as 1.5 m between the “open” and “closed” condition. In the fully or partially closed condition, the lagoon reach resembles a shallow lake with the inundation submerging more stream bank, channel bar and laterally deposited woody debris. Emergent vegetation is also then partially submerged. In the fully open condition, the habitat through the lagoon reach resembles a typical stream configuration with lateral scour pools, exposed sand and gravel bars along the wetted edge and much reduced water depth through the open channel.

With the formation of the lagoon, salt water is typically trapped within the impounded area and may form a sharply stratified condition with the denser saline layer along the bottom. The salt wedge may extend upstream and occur as isolated pockets of salt water at depth in the pools. When the sandbar and lagoon have formed for

substantial lengths of time, this salt water layer may be eventually largely evacuated by gradual seepage through the sandbar due to the head pressure of the overlying fresh water.

The lagoon channel itself is much wider at the mouth and tapers upstream past the meanders to a wetted width similar to that of the stream by approximately 650 m upstream of the Highway 1 bridge. The lagoon is lined with vegetation beginning 200 m upstream of the Highway 1 bridge. Over-story of willow, box elder, and white alder line the edge, eventually forming a nearly complete canopy cover along the upper 300 m of the lagoon reach with the narrowing of the wetted width. Along some sections, the riparian overstory plants may extend substantially into the lagoon by low branches or trunks suspended just above or submerged by the high lagoon waterline. Understory of this riparian edge includes California blackberry (*Rubus vitifolius*), poison oak (*Toxicodendron diversilobum*), and young willows. The 200 m immediately upstream of Highway 1 are relatively open, with banks of emergent bulrush (*Scirpus spp.*) The emergent vegetation may be left out of water, or nearly so, during the drained lagoon condition. Downstream of Highway 1, the sandy beach border is unvegetated.

A lowland valley bench and seasonal marsh flank the lower reach of the stream and lagoon along the west side extending out for 300 m to the toe of the hill slope. An ephemeral pond (“Frog Pond”) and an old, shallow and overgrown channel provide seasonally ponded wetland conditions following local or winter runoff, extreme storms, wave events, or through groundwater movement when the summer lagoon has formed with a high enough sandbar that the channel is inundated to near the top of bank (Smith et

al. 1997). The marsh and bench are vegetated by a mix of wetland plants such as sedges (*Carex spp.*), rushes (*Juncus spp.*), cattails (*Typha spp.*), smartweed (*Polygonum spp.*), cinquefoil (*Potentilla anserina*), and marsh jaumea (*Jaumea carnosa*). On slightly higher elevation of drier microhabitat, coyote bush (*Baccharis pilularis*) and grasses are found. Upslope from the marsh bench, the hill slope is covered with coastal sage scrub habitat. An access road traverses the perimeter of the marsh bench along the hill slope toe. A dense riparian willow thicket with an understory of blackberry covers the upper one-third to one half of the west marsh/lagoon bench extending up to the meander of the stream/lagoon.

A similar but smaller floodplain bench exists along the east side of the upper lagoon area, extending to approximately 600 m upstream of the Highway 1 bridge. A floodplain riparian forest extends down along the lagoon on the easterly side and landward of the riparian border of the middle lagoon area (250-600 m upstream of Highway 1). Cattails, rushes, sedges, and tules predominate but are interspersed with coyote bush, blackberry, and poison oak along the slightly elevated areas. In the lower lagoon, the floodplain bench east of the lagoon is constrained by an access road set back from 15 m at the Highway 1 bridge to 60 m further upstream.

A permanent pond, "Turtle Pond," which was created by the access road serving as a dam, is situated along the east side of the marsh and lagoon area, immediately upstream of the mouth of the stream. The pond is up to 1.5 m deep when full. Depth is regulated by an overflow culvert that drains to the lagoon under the access roadway. The Highway 1 road berm flanks the pond on the south edge. A small grassland patch used

by nesting turtles (Crump 2001) extends up from the east boundary of the pond past its riparian border until it meets the toe of the slopes. A nearly continuous line of willow and Monterey pine trees borders the pond and produces a canopy overhang along the wetted perimeter extending up to 2.5 m over the water. The pond is filled in with bulrush (*Scirpus spp.*) with emergent plants near the shore along the shallowest perimeter areas. However, the majority of the pond surface is covered with bulrush growing from a floating mat of intertwined corms and roots largely detached from bottom rooting. Two open water pockets, 4 m and 8 m across were present toward the southeast portion of the pond. These open water pockets appear persistent as they are visible in aerial photographs that date back to the 1970s. Upland around the pond Monterey pines predominate in the overstory with occasional Douglas firs set back further. The upland understory was filled in with coyote brush, California sage (*Artemisia californica*), and poison oak as a mix of coastal scrub and Monterey pine forest habitat types in the vicinity of Turtle Pond.

In the watershed, road development is relatively sparse, but there is a long-standing road that extended upstream to the headwater forks and beyond that included three bridges and one ford. Portions of the original road were destroyed in storm flows during the 1997-98 winter and were replaced by a foot trail. In the wider lower valley, the roadway is set back from the stream, but upstream in the narrower canyon reaches the road may flank the stream directly with the road cut and fill placed low along the canyon toe. Public access for recreation such as hiking, camping and on-road mountain biking is allowed by the roadway and trail that ultimately extend to the headwaters at Big Basin

State Park. No public vehicle traffic is permitted past the park visitor center or ranger station, but private vehicles for residential access, farming, logging, and research regularly traverse the roadway. Although a public trail crosses the lagoon on a seasonal bridge toward the upstream end, the public is not permitted in the lagoon, marsh, or pond areas. The beach downstream of Highway 1 receives heavy recreational use. The park visitation and organic farming are presently the most intensive uses of the watershed.

Historically, water withdrawal for agricultural supply occurred at a diversion immediately upstream of the lagoon until 5 years prior to the initiation of this study. Limited water withdrawal now occurs for agriculture and domestic water supply. Additional limited water development toward the headwaters in Big Basin State Park occurs. The stream receives some effluent from a wastewater treatment plant near campgrounds at Big Basin.

Methods

Capture Census

Turtles were captured using baited hoop traps placed at a total of 33 stations throughout the lagoon, Turtle Pond, and intermittently at positions up to 2.5 km from the mouth of Waddell Creek. Traps were baited with canned sardines or raw fish and checked regularly. Opportunistic hand-capture of new turtles was also employed during snorkel surveys to retrieve telemetered turtles or during trap line service or telemetry transects. Trapping efforts were conducted nearly continuously from July to November in 1995 and April through July in 1996 to produce estimates of minimum population size

and demographics for the population. At the time of capture, carapace measurements were made with a customized measuring board. Weight was recorded, but weight depended upon whether or not the turtle urinated in response to handling. Female turtles were checked for reproductive condition (gravid or not and size of eggs). Turtles were aged by producing a count and trace on transparent sticky-tape of plastral scute annuli. Turtles were tagged for long-term, positive identification of individuals with a Passive Integrated Transponder (PIT, AVID: Advanced Veterinary Identification Device, NORCO California) inserted into the body cavity (Camper and Dixon 1988). Individual animals were also externally marked with a filed notch pattern in the marginal scutes (Cagle 1939), using a modified numbering system adapted from other studies of this species (Holland 1991).

Telemetry

A sub-set of 31 adult turtles (≥ 121 mm carapace length) were outfitted with external radio-telemetry tags affixed to the shell using techniques developed in similar investigations (Rathbun et al. 1993). Internal-antenna transmitters (Advanced Telemetry Systems, Isanti MN) weighing 20 g were glued to the carapace with small dabs of quick-cure epoxy cement (Devcon 5-minute epoxy, ITW-Devcon, Danvers MA) and a smoothed coating of dental acrylic catalyzed polymer (Jet-Brand Denture Repair Acrylic Powder, Lang Dental Manufacturing Co. Inc., Wheeling, Ill) to encase the package and temporarily bond to the shell. Prior to application, the dental acrylic was tinted with black copier toner to mute the color. After the first few turtles showed signs of some shell rot under the glue dots, only the acrylic polymer was used as a sufficient anchor,

and the epoxy was discontinued. Subsequently, the shell rot cleared in those affected individuals. The telemetry package was less than 5% of the total body weight. Male turtles had the radio packages attached centered on a longitudinal axis and on the rear of the carapace to minimize hydrodynamic drag. Female turtles had the radio packages mounted centered transversely and forward to minimize potential interference with mating.

We outfitted 15 male turtles and 16 female turtles with radio tags (Table 1), which had a unique broadcast frequency with at least 10 Hz bandwidth separation between transmitters, allowing remote identification of individual turtles. Additionally, the transmitters had a temperature-sensitive signal pulse modulator which caused the broadcast pulse rate to increase in proportion to temperature. Thus, from a remote location it was possible to detect whether an animal was submerged, exposed and in the air and/or basking in (partial or full) sun. This assisted with localization and approach of animals obscured by dense cover or other habitat conditions and improved accuracy of the position description. Transmitters also had a feature that turned transmission off for 12-15 h per day to extend battery life. A subset of the transmitters included a “mortality sensor,” so if the animal had not moved sufficiently to trigger a gravity-sensitive switch in a 24 h time period the pulse mode would change to the “inactive” pattern. This provided remote indication and additional corroboration on whether a turtle was active or not. Turtles were captured by hand near the projected end of useful battery life of the transmitter, typically, 10-12 months after deployment. At that time a replacement

transmitter was attached and the turtle released at the point of capture for continuing telemetry study.

A transect along the lagoon-stream center line was laid out in the field using a hip-chain from the Highway 1 bridge in a continuous upstream direction and marked at 25 m intervals using stakes and flagging to ensure visibility and more consistent and accurate location descriptions. The lagoon/stream transect extended approximately 5 km upstream to the confluence of the East and West forks of Waddell Creek. A second transect line was established around the perimeter of Turtle Pond. Turtle positions were described in relation to distance along the established transects and position relative to the wetted edge of the aquatic habitat. Other local landscape features were also used to consistently describe telemetered positions.

All radio-tagged turtles were located 1-5 times per field day by moving through the pond or lagoon/stream system on foot, or by boat when the lagoon was fully formed, while scanning for deployed tag-frequencies using a portable telemetry receiver and hand-held directional antenna (Model TRX-1000S receiver, Yagi 3-element antenna; Wildlife Materials, Murphysboro, Illinois). Upstream positions were accessed to the general area by vehicle and then on foot. The receiver/antenna had an effective range of up to 1 km or more with local land and water features variously affecting signal quality and range. Telemetry location efforts extended to the upstream range of telemetered turtles in the watershed. The telemetry traverses were generally performed beginning at the bottom of the watershed along the pond area, extending to the lagoon and then moving to the upstream activity centers. However, no specific traverse pattern or time

schedule was prescribed; a fixed schedule was purposely avoided to preclude potential bias in detection of behavior patterns (White and Garrott 1990; Reese and Welsh 1997).

Signal orientation from multiple position angles relative to the transmitter allowed triangulation to locate telemetered turtles. Locations were fixed using a combination of medium range and short range triangulation, pass-over scanning, and simultaneous directional telemetry and observation of exposed turtles. Medium-range triangulation from several vantages, at 10-40 m, was employed to localize turtles when access to the habitat was so difficult that close approach would have disturbed turtles and prevented judging original position of microhabitat. Short-range triangulation at 2-10 m distance was used, often in combination with pass-over scanning, where the original turtle position could be fixed without the approach affecting the original judged position; i.e., the turtle was positioned, unmoving in a refugium or was observed, and may have entered an adjacent refugium position on approach. Pass-over scanning was employed to fix locations of un-observed turtles that were stable in position in refugia. A notation of the estimated accuracy of the position location per the telemetry technique was also made: typically less than or equal to 1 m for observations and pass-over scan; 1-5 m for local triangulation; or >5 m for signal detection only, when only a general area position was achieved and no microhabitat association was possible to estimate. A location was described as a distance along the base transect line, lateral position as left, middle or right, and an estimate of distance from the bank wetted edge. The distance along the transect line was interpolated to approximately 1 m resolution using the marker flags/stakes along the transect line. For Turtle Pond, positions out into the interior of the

pond from the perimeter transect line were estimated. Secondary landscape features were also used to assist in describing locations efficiently, particularly for positions where substantial numbers of recurring locations were developed. Habitat descriptions were made using a tiered system of codes reflecting an increasingly localized habitat association on a pre-developed code system, modified from Scott and Rathbun (2001). General habitat, sub-type habitat and up to four micro-habitat composition associates were assigned for each observation made (Table 2). Habitat associations were assigned based on a combination of location and a field judgment of relative proximity of the tracked or observed turtle to predominate features at the location. Microhabitat composition assignments were composed of features associated within 1-2 m of the turtle location.

In addition to telemetered turtles, visual records of non-telemetered turtles were made during the telemetry efforts. The observed turtles were generally a subset of the population that was visible during basking. Observations of these turtles received the same location descriptions and habitat associations as telemetered turtles.

Determination of habitat association for telemetered turtles was limited in this study to the active season before entering a winter inactive period and after emerging from inactivity during the spring. To determine active season habitat use, telemetered locations were selected by examining seasonal movement patterns from the individual turtle records and eliminating locations where turtles were judged to be seasonally inactive, either hibernating upland or, in the case of turtles localized in Turtle Pond, inactive and immobile in the floating tule mat. Position records of <1m resolution were

used to develop active season assignments. Location and habitat association records were not included for two days following capture and installation of a transmitter on a turtle because of possible disturbance effects. Further selection of relevant telemetry records for habitat analysis was made by selecting records for individual turtles at least 2 hours apart.

Habitat Availability

Comparing available habitat to the habitat features recorded in close proximity to turtle locations provides inference on habitat preference. Available habitat was determined by estimating relative area of coverage of all coded habitat types using a combination of field notes of habitat features along the transect line, field-drawn maps of areas of concentrated turtle activity, and estimates of coverage from aerial photography overlain with a grid. These allowed me to estimate within 1 m² the relative area of individual general, meso- and microhabitat elements. The habitat increment of 1 m² was chosen to approximate the resolution achieved with localizing turtle encounters in the telemetry effort. Since turtles can move freely overland and in aquatic habitats, the boundary of “available” habitat could be very large. However, most of the active season habitat use proved to be aquatic. Therefore, mapping of available habitat in analyses was limited to aquatic habitat plus a 2 m wide perimeter of upland habitat. Further, the aquatic habitat analyzed was limited to four specific areas occupied by telemetered and observed turtles within the lagoon, pond and stream.

To investigate the depth preference of turtles, the position of turtles along the lagoon and stream transect line was compared to the thalweg of the stream channel.

Rather than a fixed depth measurement, this method allowed comparison to the thalweg, which was the deepest part of the channel at that position along the transect. In the lagoon, absolute depths would also lose their meaning with tidal changes and with inundation changes due to sandbar development.

Mapping of available habitat was limited to field maps and notes from 1995-1996 when habitat features were constant. Over the winter of 1996-1997 a large storm produced substantial scour throughout the stream channel and lagoon. Similar and progressive effects occurred during the El Niño storm years of 1998-1999. These high runoff events substantially reorganized habitat features in the stream and in the lagoon. Although movement telemetry was continued after 1996 to develop the basking temperature data, the habitat association analysis was limited to 1995-1996.

Manipulated Habitat Experiments

Response experiments to created basking habitat were conducted by fashioning floating basking perches of logs and weathered boards, and then anchoring these in positions near areas known to be used by turtles. Anchored basking sites were further manipulated at three positions by moving and reorienting the materials. Eleven floating basking positions were established: three in the lagoon and eight in Turtle Pond (Table 3).

Basking Temperature

Following the telemetry and habitat assessments, 14 g temperature recorders (TidbiT Temperature Logger, Onset Computer Corp., Bourne MA) were mounted on 5 turtles similar to the methods employed to mount radio telemetry tags (Table 4). The

temperature recorders were programmed to store a reading on either a 15-minute or 30-minute interval. The recorders allowed continuous monitoring of temperature of the mount package, which would then show a temperature spike during basking. Recorders were operated for 1-3 years from 1997 to 2000 with periodic exchanges to check the status of the turtle, replace the recorder and download data. Graphed data were used to check for diurnal timing and duration of basking.

Results

General Activity Patterns

WPT was the only species of turtle captured or observed. A total of 198 individual turtles were captured during the study period July 1995-April 1997, and 90 of 133 (68 %) turtles that were mature enough by size and morphology to be sexed were males. Minimum ages of 137 of the turtles were determined by scute annuli (Figure 4). Comparing rings of readable scutes from turtles recaptured over multiple years demonstrated that rings were annually formed. Age distribution of these turtles was between 1 and 20 years, but the majority of captured turtles were at least 10 years old. Turtles greater than approximately 14 years were less competently assigned an age because of crowding of the annular ridges from progressively slowed growth after maturity and general wear of the scute surface. Turtles from the soft-bottomed Turtle Pond had as many as 20 distinct annuli. Turtles from the rocky-bottomed stream and lagoon showed substantial wear, and visible annuli probably underestimated turtle age.

Radio-telemetered turtles were tracked from August 1995 through December 1996 for the “active season” habitat study. Not all turtles were tracked for the same

amount of time, but a total of 4,713 telemetry locations of 31 telemetered turtles were made during this time. Five of the 31 transmitted turtles (3 males and 2 females) remained in and near Turtle Pond. Two female turtles moved between Turtle Pond (winter) and the creek and lagoon (active season) and 24 turtles remained in the creek or lagoon in the active season. Of these, 2 males and 3 females moved between the lagoon and upstream activity areas. Telemetered turtles continued to be monitored during the winter habitat study in 1995-6 and 1996-7 (Davis 1998), the nesting study in 1997 and 1998 (Crump 2001), and the temperature/basking study in 1997-2000.

Turtles appeared to have two seasonal activity phases. During the warmer, drier months, turtles moved freely throughout the sub-systems traversing aquatic habitat and making short distance sojourns across land between aquatic habitats. During colder months, and especially with the first large storm runoff, turtles tended to leave the stream/lagoon habitat and move to the permanent pond or to upland refugia, partially buried under various substrates. Turtles occupying the permanent Turtle Pond adjacent to the lagoon mouth would generally stop substantive movements during cold months and seek relatively stationary refuge in the floating mat of tules. During the study period, the active season extended from the onset of the telemetry into November or December and then generally resumed in late March, depending on the individual turtle. Typical examples of turtle movement patterns are shown in Figures 5-11. After identifying the active season periods, and eliminating data on relatively inactive turtles, the final count of telemetered active season position records with habitat detail was 3,105.

A total of 2,551 observations of non-telemetered turtles were made during the study period, and 2,544 (99.2%) of these observation records were of basking turtles (lagoon=99.2%, n=821; upland=100%, n=7; Turtle Pond=99.2%, n=1644; stream=100%, n=36). Turtles with and without transmitters occurred together at basking positions, and the proportion of large basking turtles with transmitters observed in the second year was similar to the proportion of transmittered turtles versus the total population of large turtles captured.

Beyond direct observation of localized turtles, the telemetry signal via either strength, tone, rapid variation in the localized position, or drop-out allowed for confident assignment of general behavior occurring at a telemetry location at time of localization. If it appeared that the telemetered turtle had been disturbed before final localization, the estimated behavior just prior to the disturbance was assigned. The majority of coded behaviors recorded during the active season were of either basking or resting turtles.

Only two observations of turtles in courtship or mating were made. Both interactions were between an untelemetered male turtle and a female turtle wearing a transmitter. One observation of turtle courtship behavior was made in Turtle Pond with a male displaying to a female that was situated on emergent tules 8 m from the bank. The other observation was of a male turtle mating with a telemetered female in shallow water in the stream at the upper end of the lagoon.

Habitat Associations

Among general habitat types observed by telemetry positions, most were in water >0.5 m from the bank, amounting to 93.7% of stream observations, 90.2% of lagoon

observations, and 98.7% of pond observations (Figure 12). Individual turtles moved between the pond, lagoon and stream, but primarily occupied only one aquatic habitat during the active season. However, there was some limited use of the marshy area and the ephemeral pond on the west side of the lagoon early in the spring and movement to the stream/lagoon as those habitats dried. One additional turtle exited Turtle Pond in mid-summer and remained in upland scrublands in an inactive state for 17 days before returning to active behavior in the pond. Otherwise, upland habitat use during the active season appeared to be restricted to moving between the pond and the stream and to upland nesting forays by female turtles.

I found that individual turtles were localized in 1 of 4 activity areas: Turtle Pond, the lagoon, the Snag-Meander Pool section of stream and the Tramway Springs Pool Series reach of stream (Figure 13). Turtle Pond near the mouth of the lagoon area contained more than 70 turtles, based on basking observations and trapping. Turtle use of the stream was confined primarily to the lagoon, but also two relatively unshaded sections of upstream habitat. The lagoon reach included the stream reach from approximately 75 m downstream of the Highway 1 bridge to approximately 1,000 m upstream of the Highway 1 bridge along the stream transect line (Figures 1 and 13). This included the stream reach that would be seasonally inundated with the highest sandbar formation. The Snag-Meander Pool area included a reach of stream approximately 1,460-2,010 m upstream from the Highway 1 bridge on the stream transect line (Figures 2 and 13). The Tramway Springs Pool Series included a reach of several pools separated by riffles approximately 3,700-3,940 m upstream of the Hwy 1 Bridge (Figures 3 and

13). Although traps were set in the stream up to 3,800 m upstream of Highway 1, only one trap capture of turtles occurred upstream of the lagoon. Turtles located upstream by opportunistic hand capture moved there from the pond or lagoon areas, based on prior capture data. Untelemetered turtles were observed upstream at these same activity areas. No un-telemetered turtles were observed or hand-captured on the stream in areas other than the two upstream activity centers, but telemetered pond or lagoon turtles were tracked moving to, and localized to, positions between the activity centers. In addition, female turtles from the lagoon moved upstream to access nesting areas in agricultural fields. One female and one male turtle each traveled upstream continuously to the tributary forks of Waddell Creek, approximately 5,000 m from the mouth but returned immediately back downstream. The female turtle nested in an agricultural field before returning to the lagoon area. The male turtle finally settled at the Tramway Springs Pool Series.

Habitat associations were broken down by activity area, with the Snag-Meander Pool and the Tramway Springs Pool Series combined as the stream activity area. For the turtles moving through the upstream reaches, habitat data were incidentally recorded but not used in this analysis since the association was transitory and considered less reflective of preference. Three levels of resolution were used. General habitat positions were recorded as < 50 cm or > 50 cm from shore and in or out of the water (Figure 12). For more precision, actual distances from shoreline were recorded. For habitat type, the percentage of the total assignments based on the number of observations in pond, lagoon, pool, and glide, riffle, upland types, etc., was compared to available habitat. Habitat

composition assignments recorded the relationship to specific structural features, such as exposed large wood. Up to four composition features were assigned for recorded locations.

In the Turtle Pond, from 7 telemetered turtles, 126 positions were developed within 1 m of resolution confidence and 928 positions at 1-5 m of resolution. Turtle Pond locations were much more difficult to identify precisely without disturbing the turtle due to the difficulty of access on the floating tule mat. However, the relative uniformity of the habitat components in the vicinity of the telemetry positions made confident assignments more likely. The dominant positions, based on telemetry, were out away from the shaded banks and localized around the two open water pockets the pond (Figure 14). Although the open water pockets made up less than 1.5 % of available habitat, 64.3 % of locations within 1 m and 36.5 % of locations 1-5 m were within open water areas (Figure 15). Other microhabitat component assignments for Turtle Pond telemetered turtles, with disproportionate use compared to available habitat at < 1 m resolution, were exposed large woody debris (11.3 % available vs. 34% use) and submerged aquatic vegetation, (0.5 % available vs. 15% use). However, at 1-5 m resolution these small, discrete patches of habitat were not identified as preferred habitat. Use of submerged woody debris, overhanging branches and tules was extensive, but was generally similar to their availability in the pond.

Habitat use comparisons based upon 1,687 sightings of untelemetered turtles in the Turtle Pond were biased by the cryptic nature of much of the available habitat, and most turtles were basking or floating at the surface in open water; habitat assignments

reflect only a subset of actual turtle positions. However, observations showed disproportionate use compared to their availability of open water (92.2%), and exposed large woody debris (82.4%) and more limited use of live branches of trees (7.7%) and submerged woody debris (7.7%) (Figure 15).

Lagoon area habitat assignments from 17 telemetered turtles included 1442 positions localized to within 1 m and 214 positions localized to 1-5 m resolution. Most lagoon positions were relatively near the shore (Figure 16), but most (90.2%) telemetered observations were of turtles > 50 cm from shore (Figure 17). The wetted edge habitat categories, water <50 cm from shore and land <50 cm from shore, had a combined use of 7.8% of the telemetered observations (Figure 17). The land observations were an even smaller percentage (1.9%) of the telemetered turtle positions, and were largely of two turtles that temporarily occupied the ephemeral pond in the marsh swale, west of the lagoon or were of turtles moving between Turtle Pond and the lagoon.

Available habitat was assigned as lagoon for the lagoon area, because the entire reach would be inundated when the sandbar was closed. However, habitat types used were split between pool (52.6%) or lagoon (42.2%), depending on whether the observation was made with a fully/partially formed lagoon or in the stream-like habitat when the sandbar had not yet formed or the sandbar had over-topped and breached (Figure 18). When the lagoon was not formed, turtles were typically located in the deeper scour pools rather than shallow glide (3.1%) or other habitats. However, even when the lagoon was formed, turtles were typically located in these same inundated deeper scour pools.

Although most (83%) of habitat composition in the lagoon area was the open water of the channel, it received little use (1.9%) (Figure 19). The habitat composition assignments from the telemetered turtle localizations were dominated by surface exposed and submerged natural structure, especially where the thalweg was near shore (Figure 19). These assignments were consistent between the <1 m and 1-5 m resolution assignments, and included submerged woody debris (<1m=87.7%, 1-5 m=74.8%, combined telemetry assignments=86%) and exposed large woody debris (<1 m=64.4%, 1-5 m=51.9%, combined telemetry assignments=62.8%), overhanging tree branches (<1 m=58.1%, 1-5 m=30.8%, combined telemetry assignments=54.6%), and roots/undercut bank (<1 m=48.9%, 1-5 m=28.5%, combined telemetry assignments=46.3%) (Figure 19). There was some use of boulders (<1 m=16.5%, 1-5 m=30.4%, combined telemetry assignments=18.3%), cattails or other emergent vegetation (<1 m=9.3%, 1-5 m=16.4%, combined telemetry assignments=10.2%) and open bank or rock (<1 m=9.4%, 1-5 m=10.3%, combined telemetry assignments=9.5%). The observations of telemetered turtles associated with submerged rock/boulders and open bank or rock were primarily made of turtles at the Highway 1 bridge rip rap bank armoring where this habitat feature was concentrated. Very little upland habitat use occurred during the active season even though the lagoon channel is flanked by dense riparian vegetation and seasonal marsh.

Untelemetered turtles were sighted in the lagoon activity area, and habitat assignments from 821 observations mapped at 1 m resolution were developed similar to those of the telemetered turtles. As in the case of untelemetered turtles in Turtle Pond, lagoon observations were generally available only when turtles were basking or

otherwise exposed. The microhabitat component assignments for observed untelemetered turtles in the lagoon activity area were dominated by submerged woody debris (95.6%), exposed woody debris (94.6%), roots/undercut bank (78%) and live branches of trees (67.5%) (Figure 19).

The stream habitat observations of turtles were confined to the Snag-Meander Pool activity area and the Tramway Springs Pool Series activity area. From 8 telemetered turtles, 301 positions of <1m resolution and 97 positions of 1-5 m resolution were compiled. Most (93.7%) of these turtles were located in water more than 50 cm from the stream bank (Figure 20). However, most were also relatively close to shore (Figures 21 and 22). In the Snag-Meander Pool area, position records at < 50 cm from the bank were turtles occupying a pool with vertical banks abutted by a large root wad with good basking and escape cover against the bank. Habitat type assignments of the combined telemetry positions in the stream were almost exclusively pool (97.2%), although pools made up just under half (49.5%) of available habitat (Figure 23). Habitat composition assignments made of telemetered turtle positions were predominately of submerged woody debris (94.2%), exposed large woody debris (82.4%), roots/undercut banks (71.4%), and overhanging tree branches (54.3%) (Figure 24). Open water made up more than 80 % of available mapped habitat, but less than 1% of turtle positions were in open water.

Habitat assignments from 36 observations of untelemetered turtles sighted in the stream activity area and were developed similarly to the telemetered turtles. As with untelemetered turtles in Turtle Pond and the lagoon, stream observations were generally

available only when turtles were basking or otherwise near or at the surface, so the habitat assignments reflect only a subset of the occupied/associated components. However, as with the telemetered turtles, observations were almost exclusively in pools (Figure 23) and associated with submerged wood (95.6%), floating woody debris (94.6%), roots/undercut bank (78%) and live branches of trees (67.5%) (Figure 24).

In addition to recording habitat and habitat features, which showed turtles concentrated in pools and associated with floating and submerged wood, turtle positions in the stream channel and lagoon activity areas were recorded in relation to thalweg positions (Figures 25-27). The thalweg was the deepest part of the channel, so thalweg position elucidated the role of habitat depth. An assignment of left, middle or right was noted for each telemetered or observed-turtle position along the transect line. Turtle telemetry records of less precision than 1-5 m resolution and turtle locations associated with the trap stations were not included. In the lagoon activity area, 2477 turtle positions were recorded (Figure 25). Of these, 2,268 positions (92%) overlaid the thalweg line. At the Snag-Meander Pool area, a total of 265 turtle position records were plotted, with 172 (65 %) aligning on the thalweg position (Figure 26). At the Tramway Springs Pool Series activity area, 169 turtle positions were plotted, and 162 (96 %) of these were at thalweg positions (Figure 27). In both the lagoon and the upstream activity areas, the thalweg alignment was typically through the deepest part of lateral scour pools and usually associated with large woody debris that created the pool. Although the lagoon area had various degrees of inundation and tidal action over the active season, the deeper

water pockets were consistently used, even when inundation provided relatively deep water throughout the remainder of the lagoon.

Basking

Open water pockets in Turtle Pond had limited open basking positions. Two pieces of aged wood, a 30 cm x 3 m weathered board and a weathered log with a worn, flat face ~30 cm by 2 m long were anchored to float in the largest open-water pocket of Turtle Pond. In the lagoon, a large floating log, approximately 1 m tapering to 0.6 m diameter and >5 m long was maneuvered into position and anchored near the bank 150 m upstream of Highway 1, where it would float continuously over deeper water. A debris pile of wood was constructed using 3-8 cm diameter woody debris, supplemented by logs of ~0.25 m by 2 m long, and anchored by rope along the boulder rip rap 15 m upstream of the Highway 1 Bridge. A large log 0.75 m diameter and 4 m long was anchored to the tree branches overhanging the existing small woody debris 350 m upstream of Highway 1. Several of the sites for the placed wood were locations where a few turtles had been observed basking, but the basking positions were poor or limited by difficulty of accessing basking structures (steep rip rap, bank or side of log) or shaded by edge of tule mat or overhanging branches. Within days, turtles heavily began to utilize the placed wood as basking habitat. The placed wood in the open water pocket of Turtle Pond became a premium basking location, with up to 48 turtles stacking on each other for better exposure on the single 0.3 m wide by 3 m long plank. The half round log 0.3 m wide and 2 m long was also used, but was more difficult for smaller turtles to access. An additional open water pocket approximately 3 m long and 2 m wide was cut into the solid

tule mat, and a basking log was installed. This habitat feature was discovered and regularly occupied by turtles within weeks. Larger and smaller pieces of wood 0.25 m wide by 1-2 m long installed in the open water pockets along the pond perimeter were used only very lightly. These positions were typically much more shaded with nearly full canopy cover. In the lagoon, the placed wood was heavily used within weeks, and turtles continued to use the wood as it was moved and repositioned up to 10 m between anchor points, landed up onto or away from the emergent vegetation, or moved to the opposite bank of the lagoon. On a few occasions, turtles were observed perched on floating hoop traps, using these exposed positions for basking.

Of 5 turtles outfitted with temperature recorder devices, recapture, data recovery and redeployment were completely successful for 4 of the turtles. Nearly continuous data were recorded from 1-3 years on these turtles between 1997 and 2000. One of the turtles (WPT125) was injured in a flood and found on the beach without the temperature data logger-transmitter package. Temperature logger data in Pacific Standard Time are in Figures 30-59, as the 15 or 30 minute interval temperature records by date and time per year, as cumulative annual scattergram plot of the temperature by time of day, and as representative 5 day samples of expanded daily time-temperature sequences. Peaking of the temperature occurred at times when the turtles (and the attached temperature loggers) were in direct sun during basking or exposed upland travel. Data strings extended throughout the year from the active season and through the winter inactivity period. During the active season, this record of elevated temperatures suggests that the turtles were exposed for extended periods to direct heat throughout the daylight hours with little

discernable regular daily patterns. Elevated temperature measurements were observed from early in the morning to late in the afternoon with relatively rapid changes between time recordings. A substantial number of measurements for all turtles extended to the maximum reading that the recorder could measure (38 C). Expanding the scale of the time-temperature plots revealed daily elevation of temperature that totaled approximately 20-30% of the day and generally from the mid-late morning hours into the early-to-mid afternoon hours. Although individual daily records varied, there tended to be a concentration of elevated temperature readings toward the mid-day. This was especially true in fall months, due to reduced day length, but also occurred on foggier days. The general diurnal pattern was interspersed with days where temperature elevation was less or extended across a broader portion of the day; these also appeared to be associated with foggier days. Some elevated temperature recordings occurred even occurred in winter, when the turtles were generally inactive.

Some moderately elevated temperature measurements in the lagoon were recorded at night, as well as on foggy days. This unexpected result was apparently because the, saline bottom waters acted as a solar collector, reaching moderately high temperatures (30 C). During foggy periods, the signals from transmitted turtles were often intermittently received as the turtles dove to the warm, saline bottom waters to “bask,” resulting in signal attenuation.

Discussion

Study Needs and Study Effects

At Waddell Creek, low intensity land use, protection of much of the watershed in a state park, limited water development or diversion, and lack of exotic bullfrogs, turtles and fish result in a watershed presumably with relatively natural habitat functions. Based on the number of captured turtles, their size range, age distribution from annuli and observations of successful nesting (Crump 2001), the population of turtles in the lower Waddell Creek drainage appeared to be robust and sustainable. However, long-term follow-up studies with the permanently marked individuals would be necessary to fully understand longevity and recruitment rates since individuals of this species are known to live for 40 years or more (Bury 1972; Bury and Germano 2008). In fact, trapping surveys in 2007 (J. Smith, pers. com) extended maximum age of turtles at the site to 32 years, based upon recaptures of turtles aged in this study. In addition, 28% (13 of 46) of turtles were 20 years old or older. Unfortunately, in 2007 young turtles were rare throughout the Waddell Creek site, and only males were captured or seen in Turtle Pond. Additional study is apparently needed, especially of reproduction and population recruitment in this watershed.

The telemetered turtles were observed in similar, adjacent positions as untelemetered turtles. One telemetered turtle was recovered in a moribund condition exhibiting evidence of an attack by some unidentified predator. It did not successfully respond to veterinary care. No other telemetered turtles were ever found in a moribund condition. The remains of a tagged but untelemetered turtle were found crushed along

the Highway 1 edge adjacent to Turtle Pond. Otherwise, multiple recaptures of telemetered and non-telemetered turtles confirmed them to be in apparently healthy condition. The observation of an untelemetered male turtle mating with a telemetered female, and of courtship behavior by a telemetered turtle (rare under any circumstances), suggest that the telemetry technique and other handling did not appreciably affect the behavior and habitat use of the telemetered turtles.

Habitat Use

Although a wide mosaic of upland, semi-aquatic and aquatic habitat types were available and telemetered turtles could move freely throughout the system during the active season, the vast majority of active season time was spent almost exclusively in the aquatic habitat. This pattern of nearly exclusive aquatic habitat use has been observed in other studies and would be considered typical (Bury 1972; Holland 1991; Rathbun et al. 1993; Reese 1996; Bury and Germano 2008).

The habitat elements that WPT seemed to prefer during the active season include deeper water with ready access to submerged escape cover and to a (wood) basking area that can be accessed from nearby cover. WPT were not typically found in terrestrial habitats during the active season even where dense vegetative cover would afford substantial camouflage even along water's edge. Two of the telemetered turtles spent some time upland during the warmer summer months but that was in an inactive state. Otherwise, upland habitat use was largely confined to overwintering and to female turtles on nesting forays.

Basking is apparently a dominant requirement of turtles, and in this study individual turtles outfitted with thermal recorders were found to bask for more than 30% of the day. Observations of basking of telemetered and untelemetered turtles were quite common, especially in the more open habitat areas. At times, telemetered turtles in the lagoon would “disappear” because the radio signal from the transmitter would be completely attenuated by the conductivity of the warm salt water layer as the turtle dove to the bottom. The temperature recorder on one of the turtles also registered elevated temperatures in the middle of the night on a few occasions. Cryptic basking similar to what has been reported elsewhere (Holland 1991; Germano and Rathbun 2008), with turtles embedded in warm sand and algal mats, may be occurring at Waddell Creek and would be a likely explanation for turtles that spend substantial amounts of time in the warmer saline layer of a stratified lagoon.

The importance of both large wood and basking behavior was dramatically demonstrated changes in turtle habitat use in response to manipulation of floating wood. Large wood also provides escape cover when it is positioned over deeper water. Further, the wood in streams is associated with pool development and depth in the thalweg, another strong turtle habitat association. In coastal streams, pools and large woody debris are also major features of steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) habitat, and their increase is a goal of restoration efforts (Shirvell 1990; Bilby and Ward 1991; Bjornn and Reiser 1991; Cederholm et al. 1997; Dominguez and Cederholm 2000). Addition or recruitment of large woody debris is also positively linked to increased structure and habitat diversity for other vertebrates (Roni 2003) as well as productivity in

the macrobenthos trophic layers of a stream community (Keim et al. 2002; Harrison et al. 2004).

Turtle and steelhead/salmon requirements substantially differ in that turtles in this study were strongly associated with sunny habitats that allowed aerial basking. In Turtle Pond and the lagoon they avoided shaded edges, and the two heavily-used upstream sites had relatively open canopy compared to the little-used remainder of the stream. The restriction of most upstream turtles to two reaches may also have been associated with availability of extensive woody pools and the distance to suitable nest sites. A telemetered female at Tramway Springs regularly moved downstream 1800 m to use a tomato field for nesting, and another lagoon turtle moved upstream almost to the forks, but after numerous explorations she retreated downstream to nest near the lagoon (Crump 2001). These relatively open reaches of stream with good basking habitat in proximity to suitable nesting areas may be valuable as staging areas for females prior to initiating the upland nesting forays.

Management Implications

Habitat modifications from wood removal, by humans or floods and closure of riparian canopy in the absence of floods may lead to habitat changes that affect basking opportunities both by losing basking substrate in the form of large woody debris and progressively shading the stream channel. Encroachment by fast-growing deciduous trees such as alders and willows may change the microclimate of a narrow stream channel, reducing the effective basking opportunities at areas that were once suitable. Over time, these landscape-level changes are likely to have major effects on the

suitability of active season stream and lagoon habitat for turtles. Periodic large floods may assist in creating a mosaic of open areas and foster wood recruitment into the stream, maintaining suitable habitat for WPT.

Because of the importance of basking, turtles are also sensitive to disturbance. The WPT is wary by nature and may rapidly dive from basking sites when approached from as far away as 100 m (Siegel and Dodd 2000; Bury and Germano 2008; observations in this study). Campgrounds, streamside use by residents and recreational use of the lower lagoon (which is prohibited, but still occurs) can make sites unsuitable for turtles by disrupting basking for thermoregulation. In some systems, competition for basking sites with exotic turtle species that may not be as wary could put the native species at a disadvantage.

Careful selection of sites for sustained improvement of the thermal ecology of this species as well as refugia from predators, proximity to other key habitat areas (such as nesting sites), and potential for disturbance from other human incursions into the habitat should all be considered when applying active management in conservation actions for the WPT.

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Figures

Figure 1. Map of Turtle Pond, lagoon and stream at the mouth of Waddell Creek. The Turtle Pond transect encircled the pond along the wetted edge. The map includes the lagoon and stream transect baseline from -150 m to +1100 m (Highway 1 bridge= station 0).

Figure 2. Map of Snag-Meander Pool reach of Waddell Creek. The map includes the stream transect from approximately 1200 to 2550 m upstream of Highway 1.

Figure 3. Map of Tramway Springs Pool Series at Waddell Creek. The map includes the stream transect from 3150 m to 4450m upstream of Highway 1.

Figure 4. Age distribution of western pond turtles captured at Waddell Creek in 1995-1997. Ages are from annuli counts which are normalized to 1997. Those individuals with “1997 Age > Annuli Count” showed sufficient scute wear that the turtle was likely older than visible annuli.

Figure 5. Movement of female Turtle 16 in 1995-1997 at Waddell Creek.

Figure 6. Movement of male Turtle 22 in 1995-1997 at Waddell Creek.

Figure 7. Movement of female Turtle 61 in 1995-1997 at Waddell Creek.

Figure 8. Movement of female Turtle 71 in 1995-1997 at Waddell Creek.

Figure 9. Movement of male Turtle 110 in 1995-1997 at Waddell Creek.

Figure 10. Movement of male Turtle 139 in 1996-1997 at Waddell Creek.

Figure 11. Movement of female Turtle 169 in 1996-1997 at Waddell Creek.

Figure 12. Telemetered positions of active turtles in Turtle Pond, lagoon, and stream at Waddell Creek in 1995-1996.

Figure 13. Plot of all 1995-1996 active season WPT telemetered positions recorded along the lagoon-stream transects at Waddell Creek. (Note: superimposition of plotted telemetry locations occurs at this scale.)

Figure 14. Active season telemetry and sighting locations of turtles in 1995-1996 in Turtle Pond. Positions plotted on a baseline perimeter transect of the Turtle Pond along the wetted edge (x-axis) and a distance into the interior of the pond from that perimeter point (y-axis). The open water areas are overlain. Open water pockets #1 and #2 were pre-existing. Open Water Pocket J&J was cut through the floating tule mat.

Figure 15. Active season habitat feature use and availability in Turtle Pond in 1995-1996 from telemetry locations and sightings.

Figure 16. Plot of all 1995-1996 active season telemetered and observed turtle positions plotted along the lagoon-stream transect for Waddell Creek. There is superimposition of plotted points at this map scale.

Figure 17. Active season general habitat type use and availability in the lagoon at Waddell Creek in 1995-1996 from telemetry locations and sightings.

Figure 18. Active season habitat type use and availability in the lagoon at Waddell Creek in 1995-1996 from telemetry locations and sightings.

Figure 19. Active season habitat feature use and availability in the lagoon in 1995-1996 from telemetry locations and sightings.

Figure 20. Active season general habitat type use and availability in the stream at Waddell Creek in 1995-1996 from telemetry locations and sightings.

Figure 21. Plot of all 1995-1996 active season telemetered and observed turtle positions along the lagoon-stream transect at the Snag-Meander Pool Series at Waddell Creek.

Figure 22. Plot of all 1995-1996 active season telemetered and observed turtle positions along the lagoon-stream transect at the Tramway Springs Series on Waddell Creek.

Figure 23. Active season habitat type use and availability in the stream at Waddell Creek in 1995-1996 from telemetry locations and sightings.

Figure 24. Active season habitat feature use and availability in the lagoon in 1995-1996 from telemetry locations and sightings.

Figure 25. Relative thalweg position, Lagoon. Left, mid, right thalweg plotted against transect distance with positions of active season telemetered and observed turtles in the lagoon area of the stream at Waddell Creek in 1995-1996. There is extensive superimposition of positions at this scale.

Figure 26. Relative thalweg position, Snag-Meander Pool. Left, mid, right thalweg plotted against transect distance with positions of active season telemetered and observed turtles at the Snag-Meander Pool area of the stream at Waddell Creek in 1995-1996. There is extensive superimposition of positions at this scale.

Figure 27. Relative thalweg position, Tramway Springs Pool Series. Left, mid, right thalweg plotted against transect distance with positions of active season telemetered and observed turtles at the Tramway Springs Pool Series area of the stream at Waddell Creek in 1995-1996. There is extensive superimposition of positions at this scale.

Figure 28. Temperature recorder temperature at 15 minute intervals for turtle #9 at Waddell Creek in 1998.

Figure 29. Temperature recorder temperature at 15 minute intervals for turtle #9 at Waddell Creek in 1999.

Figure 30. Temperature recorder temperature at 15 minute intervals for turtle #9 at Waddell Creek in 2000.

Figure 31. Cumulative daily temperature versus time of day for turtle #9 temperature recorder at Waddell Creek in 1998-2000

Figure 32. Temperature recorder temperature at 15 minute intervals for turtle #9 at Waddell Creek for July 1-5, 1999

Figure 33. Temperature recorder temperature at 15 minute intervals for turtle #9 at Waddell Creek for October 1-5, 1999.

Figure 34. Temperature recorder temperature at 15 minute intervals for turtle #14 at Waddell Creek in 1997.

Figure 35. Temperature recorder temperature at 15 minute intervals for turtle #14 at Waddell Creek in 1998.

Figure 36. Temperature recorder temperature at 15 minute intervals for turtle #14 at Waddell Creek in 1999.

Figure 37. Cumulative daily temperature versus time of day for turtle #14 temperature recorder at Waddell Creek in 1997-2000.

Figure 38. Temperature recorder temperature at 15 minute intervals for turtle #14 at Waddell Creek for July 4-9, 1999.

Figure 39. Temperature recorder temperature at 15 minute intervals for turtle #14 at Waddell Creek for October 25-30, 1999.

Figure 40. Temperature recorder temperature at 15 minute intervals for turtle #125 at Waddell Creek in 1998.

Figure 41. Temperature recorder temperature at 15 minute intervals for turtle #125 at Waddell Creek in 1999.

Figure 42. Cumulative daily temperature versus time of day for turtle #125 temperature recorder at Waddell Creek in 1998-1999.

Figure 43. Cumulative daily temperature for turtle #125 temperature recorder at Waddell Creek in January-February-1999.

Figure 44. Temperature recorder temperature at 30 minute intervals for turtle #125 at Waddell Creek for July 15-20, 1998.

Figure 45. Temperature recorder temperature at 15 minute intervals for turtle #125 at Waddell Creek for October 20-25, 1998.

Figure 46. Temperature recorder temperature at 30 minute intervals for turtle #165 at Waddell Creek in 1998.

Figure 47. Temperature recorder temperature at 15 minute intervals for turtle #165 at Waddell Creek in 1999.

Figure 48. Temperature recorder temperature at 15 minute intervals for turtle #165 at Waddell Creek in 2000.

Figure 49. Cumulative daily temperature versus time of day for turtle #165 temperature recorder at Waddell Creek in 1998-2000.

Figure 50. Temperature recorder temperature at 15 minute intervals for turtle #165 at Waddell Creek for July 5-10, 2000.

Figure 51. Temperature recorder temperature at 15 minute intervals for turtle #165 at Waddell Creek for October 22-27, 2000.

Figure 52. Temperature recorder temperature at 30 minute intervals for turtle #202 at Waddell Creek in 2000.

Figure 53. Temperature recorder temperature at 30 and 15 minute intervals for turtle #202 at Waddell Creek in 1998.

Figure 54. Temperature recorder temperature at 15 minute intervals for turtle #202 at Waddell Creek in 1999.

Figure 55. Temperature recorder temperature at 15 minute intervals for turtle #202 at Waddell Creek in 2000.

Figure 56. Cumulative daily temperature versus time of day for turtle #202 temperature recorder at Waddell Creek in 1997-2000.

Figure 57. Temperature recorder temperature at 30 minute intervals for turtle #202 at Waddell Creek for July 1-6, 1997.

Figure 58. Temperature recorder temperature at 15 minute intervals for turtle #202 at Waddell Creek for July 1-6, 2000.

Tables

Table 1. Turtles with telemetry tags for habitat study at Waddell Creek in 1995-1996

Turtle ID	Gender	Carapace Length (mm)	Activity Area
WPT008	M	163	Turtle Pond
WPT009	M	153	Lagoon
WPT011	M	150	Stream: Snag-Meander Pool
WPT013	M	152	Lagoon
WPT014	M	171	Lagoon
WPT015	F	164	Lagoon
WPT016	F	168	Lagoon, Turtle Pond
WPT017	F	168	Lagoon
WPT018	F	149	Lagoon
WPT019	M	146	Stream: Tramway Springs Pool Series
WPT021	F	159	Lagoon, Stream: Snag-Meander Pool
WPT022	M	153	Lagoon
WPT023	M	151	Lagoon, Turtle Pond
WPT027	M	149	Lagoon
WPT061	F	138	Turtle Pond
WPT071	F	158	Lagoon
WPT082	M	155	Lagoon
WPT087	F	155	Lagoon
WPT088	M	148	Lagoon, Stream: Snag-Meander Pool
WPT093	F	142	Lagoon
WPT097	M	144	Turtle Pond
WPT110	M	139	Turtle Pond
WPT118	F	160	Lagoon, Upstream
WPT119	M	133	Lagoon
WPT139	M	160	Stream: Tramway Springs Pool Series
WPT169	F	138	Turtle Pond
WPT173	F	130	Lagoon, Stream: Snag-Meander Pool, Stream: Tramway Springs Pool Series
WPT177	F	164	Stream: Snag-Meander Pool, Stream: Tramway Springs Pool Series
WPT183	F	121	Stream: Snag-Meander Pool
WPT200	F	143	Lagoon
WPT202	M	163	Lagoon, Stream: Tramway Springs Pool Series

Table 2. Turtles with temperature recorders at Waddell Creek in 1995-1996

Turtle ID	Begin Date	End Date	Recording Interval	Record Count	Activity Area Begin	Activity Area End
WPT009	10-Jul-1998	22-Dec-2000	00:30 00:15	72436	Lagoon	Stream: Snag-Meander Pool
WPT014	10-Jan-1997	02-Dec-1999	00:30 00:15	78393	Lagoon	Lagoon
WPT125	14-Jul-1998	28-Feb-1999	00:15	21959	Turtle Pond	Lagoon
WPT165	04-Jul-1998	19-Dec-2000	00:30 00:15	70087	Turtle Pond	Turtle Pond
WPT202	31-Jan-1997	06-Aug-2000	00:30 00:15	68565	Stream: Tramway Springs Pool Series	Lagoon

Table 3. Recorded and Mapped Habitat Features

General Habitat	Habitat Type	Habitat Composition Elements
S= water, w/in 50cm of shore	P= Pond	b = overhanging branches, living
E= land, w/in 50cm of water	Sw=Marsh-Swale	c = cattails, rushes, tules
L= land, > 50 cm of water	Po= Pool	d = submerged rock/boulders
U= undetermined	G= Glide	f = exposed woody debris
	Ri= Riffle	o = open rock or bank
	Ru= Run	r = roots, undercut bank
	Rt=Riparian Thicket	s = submerged woody debris
	F=Open Field	w = open water
	H=Hillslope	g = grassland
		h = herbs
		l = leaf litter
		t= thicket understory
		u = undetermined

Table 4. Placed wood basking sites installed at positions in the lagoon and in Turtle Pond

Station	Location Description	Baseline Map	Baseline Distance	Baseline Position	Distance From Bank (m)	Estimated Depth (m)	Total Turtles observed
WLF01	Vic TP-8/9. Large log float in open water	TP	321	R	26.7	1.4	771
WLF02	Vic TP-8/9. Small log float in open water	TP	321	R	26.1	1.4	307
WLF03	Vic TP-5. Log float at outer edge of willow canopy	TP	266	R	4.5	1.2	0
WLF04	Vic. TP-6/7. Log float in open water	TP	268	R	15.2	1.2	132
WLF05	Vic. TP-3. Log float at edge of willow/tules	TP	127	R	4.5	0.8	2
WLF06	WDL-7, Log float at outer edge of willows anchored to submerged woody debris; moved downstream up to 8m	LAG	327	L	2.4	1.1	295
WLF07	0+98R, Downstream side of concrete slab in lagoon, moved upstream and downstream 15m	LAG	98	R	3.0	1.1	36
WLF08	0+5L, Log float anchored to rip rap a lagoon edge along bridge abutment, lateral scour pool.	LAG	5	L	1.2	0.9	51
WLF09	Vic. TP-2: log float along pond perimeter partially under willow and pine canopy	TP	96	R	3.0	0.6	14
WLF10	Vic TP-8/9. Plywood strip float ring open water	TP	321	R	27.0	1.4	18
WLF11	Weathered plank at J&J opening cut into cattail mat	TP	256	R	12.1	1.4	8

APPENDIX A: Data Tables of Turtle Habitat

APPENDIX TABLE A1. Telemetered Turtles: Turtle Pond Habitat Association Assignments

Habitat Association Assignments	Radio Track Locations <1m	Radio Track Locations >1- 5m	Total Radio Track Locations	% Of <1m Observations With Habitat Feature Assignment	% Of <1- >1-5m Observations With Habitat Feature Assignment	% Of all Observations With Habitat Feature Assignment
General Habitat						
W = Water >0.5m from shore	118	919	1037	93.7%	98.7%	98.7%
S = Water <0.5m from shore	1	1	2	0.8%	0.2%	0.2%
E = Land <0.5m from shore	6	5	11	4.8%	1.0%	1.0%
L = Land >0.5m from shore	1	0	1	0.8%	0.1%	0.1%
Totals	126	925	1051	100.0%	100.0%	100.0%
Habitat Type						
P = Pond	125	924	1049	99.2%	99.8%	99.8%
La = Lagoon	0	0	0	0.0%	0.0%	0.0%
Sw = Marsh-Swale	0	0	0	0.0%	0.0%	0.0%
Po = Pool	0	0	0	0.0%	0.0%	0.0%
G = Glide	0	0	0	0.0%	0.0%	0.0%
Ru = Run	0	0	0	0.0%	0.0%	0.0%
Ri = Riffle	0	0	0	0.0%	0.0%	0.0%
Rt = Riparian Thicket	0	1	1	0.0%	0.1%	0.1%
F = Open Field	0	0	0	0.0%	0.0%	0.0%
H = Hillslope	1	0	1	0.8%	0.1%	0.1%
Totals	126	925	1051	100.0%	100.0%	100.0%
Habitat Composition						
a = algae, aquatic plants	19	10	29	15.1%	2.8%	2.8%
b = branches-living	36	495	531	28.6%	50.5%	50.5%
c = cattails, tules, rushes	105	923	1028	83.3%	97.8%	97.8%
d = rock/dirt boulders	0	2	2	0.0%	0.2%	0.2%
f = exposed woody debris	43	31	74	34.1%	7.0%	7.0%
o = open bank	0	0	0	0.0%	0.0%	0.0%
r = roots, undercut bank	1	0	1	0.8%	0.1%	0.1%
s = submerged woody debris	37	491	528	29.4%	50.2%	50.2%
w = open water	81	338	419	64.3%	36.5%	39.9%
g = grassland	0	0	0	0.0%	0.0%	0.0%
h = herbaceous vegetation	3	0	3	2.4%	0.3%	0.3%
l = leaf litter	1	0	1	0.8%	0.1%	0.1%
t = thicket understory	1	0	1	0.8%	0.1%	0.1%
Totals	327	2290	2617			

APPENDIX TABLE A2. Telemetered Turtles: Lagoon Habitat Association Assignments

Habitat Association Assignments	Radio Track Locations <1m	Radio Track Locations >1- 5m	Total Radio Track Locations	% Of <1m Observations With Habitat Feature Assignment	% Of <1- >1-5m Observations With Habitat Feature Assignment	% Of all Observations With Habitat Feature Assignment
General Habitat						
W = Water >0.5m from shore	1299	194	1493	90.1%	91.1%	90.2%
S = Water <0.5m from shore	82	1	83	5.7%	0.5%	5.0%
E = Land <0.5m from shore	33	14	47	2.3%	6.5%	2.8%
L = Land >0.5m from shore	28	4	32	1.9%	1.9%	1.9%
Total	1442	213	1655	100.0%	100.0%	100.0%
Habitat Type						
P = Pond	0	0	0	0.0%	0.0%	0.0%
La = Lagoon	569	130	699	39.5%	60.7%	42.2%
Sw = Marsh-Swale	11	1	12	0.8%	0.5%	0.7%
Po = Pool	793	78	871	55.0%	36.4%	52.6%
G = Glide	50	2	52	3.5%	0.9%	3.1%
Ru = Run	1	0	1	0.1%	0.0%	0.1%
Ri = Riffle	5	0	5	0.3%	0.0%	0.3%
Rt = Riparian Thicket	13	3	16	0.9%	1.4%	1.0%
F = Open Field	0	0	0	0.0%	0.0%	0.0%
H = Hillslope	0	0	0	0.0%	0.0%	0.0%
Total	1442	214	1656	100.0%	100.0%	100.0%
Habitat Composition						
a = algae, aquatic plants	52	5	57	3.6%	2.3%	3.4%
b = branches-living	838	66	904	58.1%	30.8%	54.6%
c = cattails, tules, rushes	134	35	169	9.3%	16.4%	10.2%
d = rock/dirt boulders	238	65	303	16.5%	30.4%	18.3%
f = exposed woody debris	929	111	1040	64.4%	51.9%	62.8%
o = open bank	135	22	157	9.4%	10.3%	9.5%
r = roots, undercut bank	705	61	766	48.9%	28.5%	46.3%
s = submerged woody debris	1264	160	1424	87.7%	74.8%	86.0%
w = open water	30	2	32	2.1%	0.9%	1.9%
g = grassland	0	0	0	0.0%	0.0%	0.0%
h = herbaceous vegetation	10	0	10	0.7%	0.0%	0.6%
l = leaf litter	15	4	19	1.0%	1.9%	1.1%
t = thicket understory	11	3	14	0.8%	1.4%	0.8%
Total	4361	534	4895			

APPENDIX TABLE A3. Telemetered Turtles: Stream Habitat Association Assignments

Habitat Association Assignments	Radio Track Locations <1m	Radio Track Locations >1-5m	Total Radio Track Locations	% Of <1m Observations With Habitat Feature Assignment	% Of <1- >1-5m Observations With Habitat Feature Assignment	% Of all Observations With Habitat Feature Assignment
General Habitat						
W = Water >0.5m from shore	277	96	373	92.0%	99.0%	93.7%
S = Water <0.5m from shore	21	0	21	7.0%	0.0%	5.3%
E = Land <0.5m from shore	2	0	2	0.7%	0.0%	0.5%
L = Land >0.5m from shore	1	1	2	0.3%	1.0%	0.5%
Total	301	97	398	100.0%	100.0%	100.0%
Habitat Type						
P = Pond	0	0	0	0.0%	0.0%	0.0%
La = Lagoon	0	0	0	0.0%	0.0%	0.0%
Sw = Marsh-Swale	0	0	0	0.0%	0.0%	0.0%
Po = Pool	292	95	387	97.0%	97.9%	97.2%
G = Glide	3	1	4	1.0%	1.0%	1.0%
Ru = Run	2	0	2	0.7%	0.0%	0.5%
Ri = Riffle	3	0	3	1.0%	0.0%	0.8%
Rt = Riparian Thicket	0	0	0	0.0%	0.0%	0.0%
F = Open Field	1	0	1	0.3%	0.0%	0.25%
H = Hillslope	0	1	1	0.0%	1.0%	0.25%
Total	301	97	398	100.0%	100.0%	100.0%
Habitat Composition						
a = algae, aquatic plants	14	2	16	4.7%	2.1%	4.0%
b = branches-living	172	44	216	57.1%	45.4%	54.3%
c = cattails, tules, rushes	0	0	0	0.0%	0.0%	0.0%
d = rock/dirt boulders	3	0	3	1.0%	0.0%	0.8%
f = exposed woody debris	246	82	328	81.7%	84.5%	82.4%
o = open bank	1	0	1	0.3%	0.0%	0.3%
r = roots, undercut bank	231	53	284	76.7%	54.6%	71.4%
s = submerged woody debris	286	89	375	95.0%	91.8%	94.2%
w = open water	2	0	2	0.7%	0.0%	0.5%
g = grassland	1	0	1	0.3%	0.0%	0.3%
h = herbaceous vegetation	2	0	2	0.7%	0.0%	0.5%
l = leaf litter	3	0	3	1.0%	0.0%	0.8%
t = thicket understory	1	0	1	0.3%	0.0%	0.3%
Total	962	270	1232			

APPENDIX TABLE A4. Un-Telemetered Turtles: Observed Turtle Habitat Association Assignments

Habitat Association Assignments	Turtle pond		Lagoon		Stream	
	Sighted Turtle Location Feature Count	% of Sightings With habitat feature assignment	Sighted Turtle Location Feature Count	% of Sightings With habitat feature assignment	Sighted Turtle Location Feature Count	% of Sightings With habitat feature assignment
General Habitat						
W = Water >0.5m from shore	1681	99.6%	804	97.9%	34	94.4%
S = Water <0.5m from shore	0	0.0%	7	0.9%	1	2.8%
E = Land <0.5m from shore	3	0.2%	9	1.1%	1	2.8%
L = Land >0.5m from shore	3	0.2%	1	0.1%	0	0.0%
Total	1687	100.0%	821	100.0%	36	100.0%
Habitat Type						
P = Pond	1664	98.6%	0	0.0%	0	0.0%
La = Lagoon	0	0.0%	364	44.3%	0	0.0%
Sw = Marsh-Swale	1	0.1%	0	0.0%	0	0.0%
Po = Pool	20	1.2%	456	55.5%	35	97.2%
G = Glide	0	0.0%	0	0.0%	0	0.0%
Ru = Run	1	0.1%	0	0.0%	0	0.0%
Ri = Riffle	1	0.1%	0	0.0%	0	0.0%
Rt = Riparian Thicket	0	0.0%	1	0.1%	0	0.0%
F = Open Field	0	0.0%	0	0.0%	1	2.8%
H = Hillslope	1	0.1%	0	0.0%	0	0.0%
Total	1687	100.0%	821	100.0%	36	100.0%
Habitat Composition						
a = algae, aquatic plants	42	2.5%	0	0.0%	7	19.4%
b = branches-living	93	5.5%	554	67.5%	5	13.9%
c = cattails, tules, rushes	1670	99.0%	11	1.3%	0	0.0%
d = rock/dirt boulders	0	0.0%	160	19.5%	0	0.0%
f = exposed woody debris	1390	82.4%	777	94.6%	36	100.0%
o = open bank	26	1.5%	79	9.6%	1	2.8%
r = roots, undercut bank	2	0.1%	640	78.0%	33	91.7%
s = submerged woody debris	130	7.7%	785	95.6%	36	100.0%
w = open water	1556	92.2%	5	0.6%	0	0.0%
g = grassland	2	0.1%	0	0.0%	0	0.0%
h = herbaceous vegetation	0	0.0%	0	0.0%	0	0.0%
l = leaf litter	4	0.2%	2	0.2%	0	0.0%
t = thicket understory	3	0.2%	1	0.1%	0	0.0%
Total	4918		3014		118	

APPENDIX TABLE A5. Mapped Activity Area Coverage: Available Habitat

Habitat Coverage Assignments	% of Turtle Pond With Habitat Feature Assignment	% of Lagoon With Habitat Feature Assignment	% of Stream With Habitat Feature Assignment
General Habitat			
W = Water >0.5m from shore	91.3%	98.3%	95.1%
S = Water <0.5m from shore	3.2%	1.7%	4.9%
E = Land <0.5m from shore	2.7%	2.3%	5.5%
L = Land >0.5m from shore	2.8%	5.2%	0.0%
Habitat Type			
P = Pond	94.5%	0.0%	0.0%
La = Lagoon	0.0%	100.0%	0.0%
Sw = Marsh-Swale	0.0%	0.0%	0.0%
Po = Pool	0.0%	0.0%	49.5%
G = Glide	0.0%	0.0%	28.1%
Ru = Run	0.0%	0.0%	6.5%
Ri = Riffle	0.0%	0.0%	15.9%
Rt = Riparian Thicket	3.0%	0.0%	0.0%
F = Open Field	0.0%	0.0%	0.0%
H = Hillslope	0.2%	0.0%	0.0%
Habitat Composition			
a = algae, aquatic plants	1.3%	83.0%	81.8%
b = branches-living	0.4%	10.3%	0.3%
c = cattails, tules, rushes	0.4%	1.5%	3.1%
d = rock/dirt boulders	11.3%	7.1%	9.1%
f = exposed woody debris	28.0%	7.0%	9.0%
o = open bank	0.0%	0.7%	2.1%
r = roots, undercut bank	0.5%	1.0%	7.8%
s = submerged woody debris	28.0%	4.6%	5.9%
w = open water	81.9%	1.4%	0.5%
g = grassland	0.0%	0.0%	0.0%
h = herbaceous vegetation	2.7%	0.9%	0.9%
l = leaf litter	0.0%	0.0%	0.0%
t = thicket understory	0.0%	0.0%	0.0%