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Western Pond Turtle: Biology, Sampling Techniques, Inventory and Monitoring, Conservation, and Management

R Bruce Bury, Hartwell H Welsh, Jr., David J Germano, Donald T Ashton (Editors)

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Western Pond Turtle: Biology, Sampling Techniques, Inventory and Monitoring, Conservation, and Management

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Front Cover

Close-up of Western Pond Turtle from Trinity River, California. Photograph by Garth Hodgson.

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From the Editor

My earliest memories of Western Pond Turtles are the images from Eugene Kozloff's *Plants and Animals of the Pacific Northwest* that I borrowed from father's bookshelf. Those plates inspired expeditions to ponds and creeks in search of the real thing. Today, Western Pond Turtles remind me of some of the most ecologically interesting places I have visited, beaver ponds in the Pacific Northwest, clear water and conifer forest of the Trinity River, and oxbow lakes and cottonwood forests on the Sacramento and San Joaquin rivers.

Western Pond Turtles occur only along the Pacific Rim of North America, where it appears to be declining in numbers in some parts of its geographic range. As a result, its status is of concern to many government agencies and other parties. In this volume, the authors summarize available knowledge, interpret ecological patterns, describe sampling protocols, develop a conservation assessment, and discuss strategies for effective management of this species. In doing so, a diverse and talented group of authors has created a handbook that a field biologist or manager can use or adapt to local or regional needs. This volume will aid in improved protection and management of the Western Pond Turtle and, perhaps, be adapted for use with other freshwater turtle species that are in jeopardy.

Nathaniel E Seavy
Editor, Northwest Fauna
Bolinas, California

Acknowledgments

Our work represents the merger of several efforts. One team was the Western Pond Turtle Working Group, which is an interagency group of interested biologists and managers primarily focused on the Pacific Northwest (Oregon and Washington). Their information was merged into a report on this turtle produced by the ''herpetology'' group of the Redwoods Science Laboratory, US Forest Service, Arcata, California. Other contributors have added information across the range of the species.

Contributors of information and providers of assistance included John Applegarth, Teresa DeLorenzo, Terry Farrell, Marc Hayes, Dan C Holland, Rob Lovich, Jim Kauppila, Philip A Medica, and Greg Sieglitz. Reviewers of earlier drafts or sections were Grant Gunderson and Deanna Olson (US Forest Service), as well as Claire Puchy and Stephan Kohlmann (Oregon Department of Fish and Wildlife). The entire final manuscript was read by Hannah Lucas, Jeffrey Lovich, Peter Lindeman, and anonymous reviewers. We thank them all. We appreciate the attention and assistance of Nat Seavy in the preparation of this effort.

Many agencies, organizations, and individuals provided logistical support, time for biologists, and meeting facilities. For these amenities, we wish to thank the kind assistance of:

Federal agencies.—Bonneville Power Administration, Army Corps of Engineers, Bureau of Reclamation, US Forest Service, US Fish and Wildlife Service, US Geological Survey, and the Bureau of Land Management (BLM).

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Organizations and private entities.—Friends of Buford Park and Mt. Pisgah, Oregon; Northwest Ecological Research Institute; Oregon Coast Aquarium; Oregon Natural Heritage Program; The Nature Conservancy; Woodland Park Zoo, Washington; and several private citizens.

We are especially grateful to the BLM Oregon/Washington State Office, Forest and Rangeland Ecosystem Science Center (US Geological Survey), US Forest Service regions 5 and 6 and the Pacific Northwest and Southwest research stations, and the Partnership for Amphibian and Reptile Conservation for financial support to complete the final manuscript and to cover some of the publication costs.

Dedication

We dedicate this effort to Dr Robert C Stebbins, Professor Emeritus, University of California at Berkeley, for his commitment to science, conservation, and education. He served as a wise mentor to many students in herpetology.

REFLECTIONS ON TURTLES IN THE TRINITY RIVER BASIN

Sluggish, clear green water, deep cavernous pools
with rapids or wide shallow reaches between—
hiding the world of turtles, mink & otter, trout, crayfish & snail.

With snorkel, mask & sneakers, join that world—
submerged or nearly so, float, dive, swim, kick, paddle, root for
the elusive Clemmys until you begin to think & feel like a turtle
(& frogs begin to look good to you—tasty).

Have you seen a turtle today?
Yes, after a long day, about 30.
The dead lampreys stink & putrefy into inky spots among the rocks.
One yearling turtle was lying there chewed apart;
so little thought begun.
The garter snake gets the tadpole or little trout and chokes it down;
the hawk with one tight reach detaches the snake from earth.

In the water you watch arcs of cycles, hear the gears fitting together.
Deer mill about like pets, trout jump, a bear sloshes through the stream.
The Trinity River—Big blank spot on most maps,
missing from mental gazettes.
Leave it so.

Roger A. Luckenbach
along the South Fork of the Trinity River
August 1973

CHAPTER 1

OBJECTIVES, NOMENCLATURE AND TAXONOMY, DESCRIPTION, STATUS, AND NEEDS FOR SAMPLING

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OBJECTIVES

Our main goal in this book is to synthesize the known information about the biology, management, and conservation of the Western Pond Turtle (*Actinemys marmorata*). Our specific objectives are to 1) better determine the current status of its distribution and abundance based on proven sampling designs and techniques, 2) summarize and evaluate known biological information, 3) recommend techniques to detect significant changes in population and habitat condition, and 4) improve monitoring for long-term trends in turtle populations.

Development of sound sampling procedures and methods is based on a variety of sources: published research papers on the species (our first preference for information), judicious use of unpublished reports, and knowledge from several ongoing efforts by individuals interested in this species. We considered all of these sources but attempted to exclude or restrict use of those in the unpublished ''gray'' literature. Moreover, we do not attempt to provide a set protocol (for example, a standardized design or approach) because there are too many variables at play across the range of the Western Pond Turtle. Instead, we offer techniques that have worked for us and other biologists, yet we encourage further experimentation to improve these. Although this book may appear to be the ''final word'' or the largest synopsis of this species, we consider it more as a starting point to address so many unanswered questions about this endemic turtle in western North America.

NOMENCLATURE AND TAXONOMY

This species has until recently been called the Western or Pacific Pond Turtle (*Clemmys marmorata*), but its relationships (phylogeny), and name (taxonomy), are currently in flux. Early phylogenies were based primarily on morphologic, ecologic, and geographic evidence, but more recently molecular and genetic evidence have challenged classic views. Here, we outline the history of its name, some recent taxonomic arguments, and consider subspecific and other variation in the Western Pond Turtle.

The Western Pond Turtle is in the family Emydidae, which is the largest and most diverse family of turtles with 48 species across 3 continents, and 32 or more species are in the New World (Collins and Taggart 2009; Ernst and Lovich 2009). Recent investigations into relationships within the Emydidae have resulted in taxonomic revisions, but not all authors agree on the placement of the Western Pond Turtle within the family. A final naming decision is deferred pending additional evidence. Its nomenclature in key checklists and publications has varied widely in the last decade.

Scientific Name

The species was first collected in 1841 and later described as *Emys marmorata* by Baird and Girard (1852) based on specimens collected from Fort Steilacoom in the Puget Sound area, western Washington State. This wetland area is just west of the present-day Fort Lewis Military Reservation, just south of Tacoma, Washington.

The first use of *Clemmys marmorata* was by Strauch (1862). Supported by morphological evidence (McDowell 1964; Bramble 1974), this remained the name of favor by most authors for more than a century. Molecular and genetic analyses have indicated *Clemmys* is paraphyletic (a genus that did not include all the descendants of a common ancestor). This prompted a breakup of the genus, sparking the current naming controversy. Following the argument of Holman and Fritz (2001), Iverson and others (2003) recommended *Actinemys marmorata* (and Pacific Pond Turtle) as the standardized name, claiming *Actinemys* best serves to reflect the diversity of this monophyletic group. This placed the species in its own monotypic genus, *Actinemys*, as ascribed more than 150 y ago (Agassiz 1857), just a few years after the original description.

The original description (Baird and Girard 1852) and many recent papers (Cochran 1961; Feldman and Parham 2002; Spinks and others 2003, 2010; Fujita and others 2004; Krenz and others 2005; Spinks and Shaffer 2005) place the species in the genus *Emys*. Today, this arrangement would place the Western Pond Turtle in a genus with the European Pond Turtle (*Emys orbicularis*). This is a great geographical separation with 1 species each in western Europe and in western North America, although this pattern is not unknown for other taxa. For example, different species of limestone salamanders of the genus *Hydromantes* occur only in California, whereas their nearest relatives (recently reassigned to their own genus, *Speleomantes*) are found in Sardinia and Italy. The genus *Emys* may also include the Blanding's Turtle, otherwise known as *Emydoidea* [= *Emys*] *blandingii*.

Several authorities show both names for the genus. For example, Rhodin and others (2008) list this species as "*Actinemys* or *Emys*," but reverse the order in Rhodin and others (2010) as "*Emys* or *Actinemys*." Reynolds and others (2007) use *Emys* [= *Actinemys*].

Stephens and Wiens (2003) discuss conflict between morphological and molecular data, but in the interest of future taxonomic stability they recommend *Actinemys*, predicting description of new species within both *Actinemys* and *Emys*. Central in the debate is whether shell kinesis evolved twice (Feldman and Parham 2002) or was secondarily lost (Holman and Fritz 2001) within the subfamily Emydinae. The scientific name remains in flux and it may require some time for the generic name and relationship of other turtles to stabilize. Most authors agree that the traditional *Clemmys* is paraphyletic, and that the name *Clemmys* should be reserved only for the genus type specimen: the Spotted Turtle (*Clemmys guttata*). There remains debate over the name for the Western Pond Turtle. For this book, we choose the widely recognized name *Actinemys marmorata* (see Iverson and others 2003; Rhodin and others 2008; Ernst and Lovich 2009; Fritz and others 2011).

Common Name

A variety of common names have been used in the past. In the original description, Baird and Girard (1852) did not use a common name for the species. Other early publications referred to "Pacific" in the common name: Van Denburgh (1922) used "Pacific Terrapin," Storer (1930) used "Pacific Fresh-water Turtle," Seeliger (1945) used "Pacific Mud Turtle," and Banta (1963) had "Pacific Pond Terrapin," whereas Pope (1939), Carr (1952), Stebbins (1954), and 12 others since 1970 (Table 1) used "Pacific Pond Turtle." The name "Western Pond Turtle" appears to have been first used in the *Field Guide to Western Reptiles and Amphibians* (Stebbins 1966) and has been the most used name (n = 37) since (Table 1). We follow recent convention and use Western Pond Turtle as the common name.

Taxonomy

Even within the species there is taxonomic controversy. Two subspecies were recognized by Seeliger (1945): the Northwestern Pond

TABLE 1. Common names used to describe the Western or Pacific Pond Turtle in recent years.

Common name	Reference
Pacific Pond Turtle	Bury (1972a); Pritchard (1979); Ernst and Barbour (1989); Iverson and others (2001, 2003); Feldman and Parham (2002); Rathbun and others (2002); Spinks and Shaffer (2005); Fritz and Havas (2006); Scott and others (2008); Ernst and Lovich (2009)
Western Pond Turtle	Banks and others (1987); Bury (1970, 1975, 1995); Ernst and Barbour (1972); Collins and others (1978); Nussbaum and others (1983); Holland (1985, 1994); Rathbun and others (1992); Ernst and others (1994); Jennings and Hayes (1994); Gray (1995); Storm and Leonard (1995); Reese and Welsh (1997, 1998a, 1998b); Bury and Germano (1998, 2008); Hays and others (1999); Goodman and Stewart (2000); Germano and Bury (2001); Collins and Taggart (2002); Lovich and Meyer (2002); Spinks and others (2003, 2010); Stebbins (2003); Jennings (2004); Matsuda and others (2006); Bickham and others (2007); Lubcke and Wilson (2007); Germano and Rathbun (2008); Iverson and others (2008); Germano and Bury (2009); Germano (2010); Bury and others (2010); Polo-Cavia and others (2010a)

Turtle (*Clemmys marmorata marmorata*) from north of the American River in central California to Puget Sound, Washington, and the Southwestern Pond Turtle (*C. m. pallida*) from central California south to Baja California. A zone of intergradation was reported to occur in the San Joaquin Valley, California (Seeliger 1945; Stebbins 1985; Jennings and Hayes 1994). However, Seeliger (1945) based subspecific differences on minor changes in presence and shape of the inguinal (a small plastral scute) and coloration (a highly variable feature range wide). Further, presumed subspecific differences may arise from variation within populations rather than being immutable characters. The concept of subspecies has lost favor in recent years, and this is one case where most experts now do not recognize these minor shell and color differences.

Holland (1994) suggested that there are 3 morphologically distinct species in what was earlier recognized as *Clemmys marmorata*. These approximately correspond to the previously described 2 subspecies and a 3rd undescribed species from the Columbia River Gorge, Oregon. His analysis remains unpublished and, thus, is not followed here. We include it to point out that there may be geographic variation in several color and morphological characteristics of the species over its relatively large range.

Analyzing phylogeography and population genetic variation across the range of the species, Spinks and Shaffer (2005) found a distinct northern clade (group) with little genetic variation from the vicinity of San Francisco Bay and northward, but high variation in turtles from southern California and the Central Valley, California. The northern clade overlaps what has been previously described as Northwestern Pond Turtles (Seeliger 1945), but the intergrade zone and the southwestern ''subspecies'' appear to form several distinct clades. While there may be 4 clades within this species, Spinks and Shaffer (2005) await more evidence on the number and distribution of phylogenetic taxa before recommending taxonomic revision (for example, naming new species). Recent evidence suggests a strong divergence between the northern and southern groups, with the divide occurring where there earlier was a major marine embayment in central California (Spinks and others 2010).

Here, we do not recognize the subspecies described by Seeliger (1945). Biologists need to be alert to the recent description of 4 clades (groups) proposed by Spinks and Shaffer (2005), especially with 3 of them occurring south of the San Francisco Bay region. We define and discuss the ecology, sampling techniques, survey procedures, or specific conservation issues of populations over broad patterns (for example, northern versus southern groups), yet we do not match these to any described clades or subspecies.

DESCRIPTION

The coloration is very variable. In some specimens the carapace is olive or horn-color with few or no markings. In others a few broken and very irregular black lines are present. These lines frequently have become so numerous that, blending and crossing, they appear as the ground color, or form a very fine network through which the original ground color shows more or less *indistinctly. Sometimes the carapace is almost black.*

Van Denburgh (1922)

The Western Pond Turtle is a semiaquatic turtle that reaches a maximum length of 241 mm and maximum weight of approximately 1200 g. Most adults are 160 to 180 mm long and 500 to 700 g in weight. Color and markings vary by geography, ontogeny, and sex (Bury and Germano 2008). However, most are olive to dark brown dorsally, often with darker reticulations (dots, streaks). This color is cryptic as the dorsal color basically resembles a rock in a stream or pond (Bury 1995). Ventrally, they are yellowish, sometimes with dark blotches in centers of the plastral scutes (Bury and Germano 2008). Over most of the range, males have a yellowish to white chin and underside of the throat, whereas females are light brown with dark spots on the chin and throat (Plate 1). Animals in the San Joaquin Valley, California, may have more yellow or pale color on their shell and appendages (Plate 2). Also, color dimorphism is less pronounced or absent in south coastal California (see Bury and Germano 2008) but has not been well described.

Hatchlings are 25 to 31 mm long (carapace length) and weigh 3 to 7 g at the time of emergence from the nest. They tend to be a light brown, darkening with age (Holland 1994). The shell is soft and pliable and their tail is relatively long (Nussbaum and others 1983; Stebbins 1985, 2003; Bury 1995). The young grow rapidly, and the shell is usually fairly hard by 3 to 4 y of age.

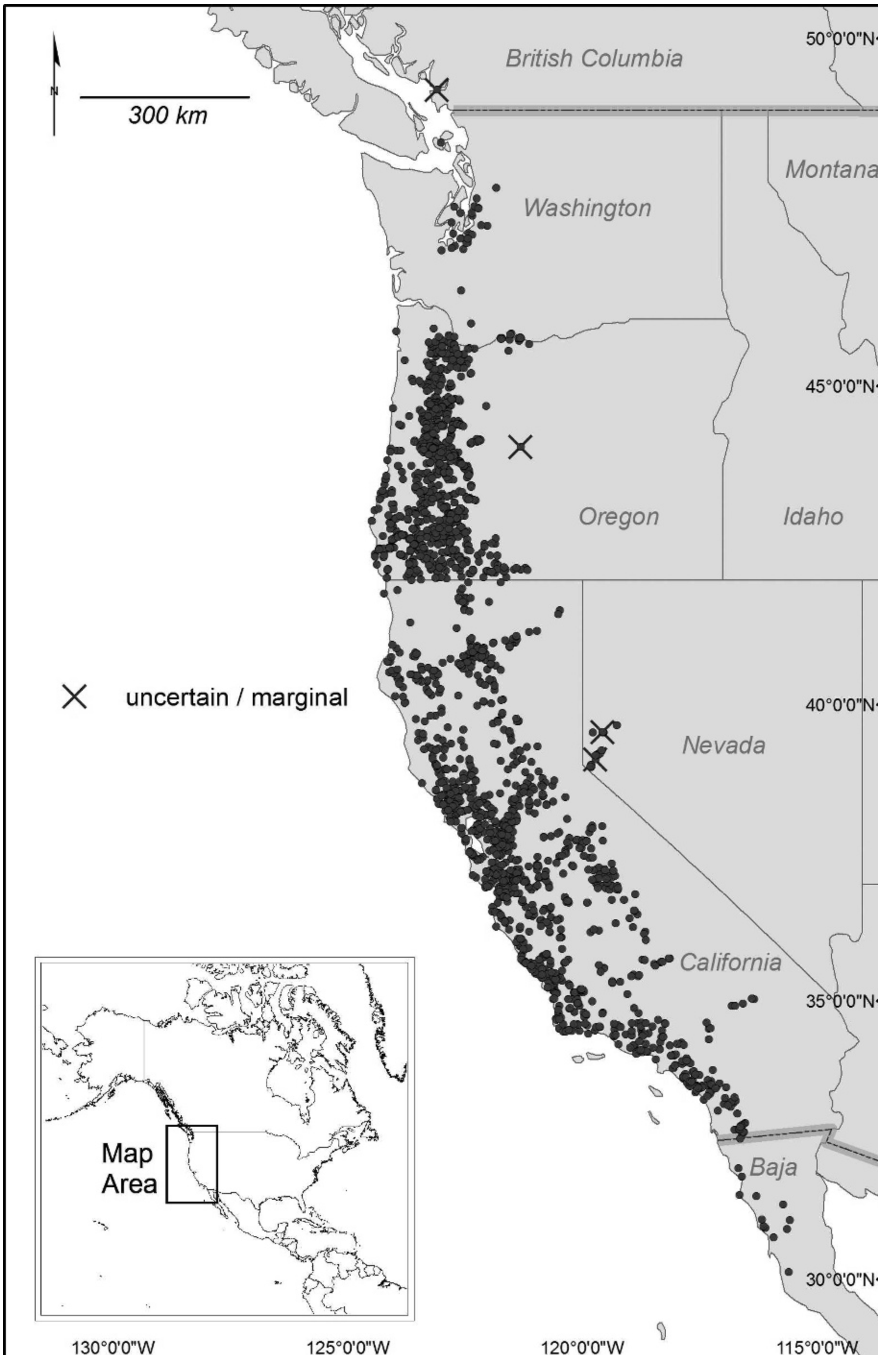
Western Pond Turtles display sexual dimorphism at maturity. In the Trinity River, secondary sexual characteristics were present by the time animals attained a carapace length (CL) of 125 mm (Reese 1996; D Holland, pers. comm.). Farther south, they reach maturity at a smaller size, 110- to 120-mm CL (Holland 1994; Germano and Bury 2001). The sex of adults usually can be distinguished reliably using just a few visible features (see Chapter 7). However, adults in southern California may lack the color dimorphism of turtles from farther north. No single characteristic is completely reliable, so it is best to look at several characters to determine sex. Juveniles (about <110- to 125-m CL) of both sexes tend to resemble females with a basic brown coloration with darker dots or reticulations on the head and neck.

DISTRIBUTION

The Western Pond Turtle occurs chiefly west of the Sierra-Cascade crest (Fig. 1) along the Pacific Coast of North America (Bury 1970; Stebbins 2003; Bury and Germano 2008). The first specimens and the type locality were from near Tacoma, in the Puget Sound area of western Washington (Slater 1939; Hays and others 1999). There are some old observations of the turtle in southwestern British Columbia (Gregory and Campbell 1984; Matsuda and others 2006; Saumure 2007), but no recent sightings. In contrast, Cook and others (2005) stated that historical and recent evidence strongly suggests that the Pacific (= Western) Pond Turtle was introduced into British Columbia and never did occur there naturally. The turtle ranges south through the Sierra San Pedro Martir and coastal rivers in Baja California (Smith and Smith 1979; Welsh 1988; Lovich and others 2005, 2007), but there are few records in the southern terminus of its range (Grismer 2002). Some isolated records occur in eastern Oregon (Holland 1994; Bury 1995) and in the Truckee and Carson rivers in western Nevada (La Rivers 1942; Banta 1963), but it is uncertain whether these sites contain native or introduced turtles (Spinks and Shaffer 2005; Bury and Germano 2008). Fossil evidence shows that *A. marmorata* or an ancestor has existed in the western United States since at least the late Pliocene (Hay 1908), and this species occurred in the western parts of the Great Basin in

→

FIGURE 1. Distribution of the Western Pond Turtle. Localities within 500 m were consolidated into a single site. X indicates sites with uncertain or marginal occurrences, including extinct sites and sites where (re)introductions have occurred or are suspected. Prepared by Kimberly L Barela (KLB) and Deanna H Olson, US Forest Service, Pacific Northwest Research Station, Corvallis, Oregon, from regional databases including California Natural



Diversity Database, Nevada Department of Wildlife, Oregon Biodiversity Information Center, and Washington Department of Fish and Wildlife. Records for Baja California are from the literature (see Chapter 1). This is part of the Turtle Mapping Project sponsored by Partners in Amphibian and Reptile Conservation and for the senior thesis of KLB, BioResource Research Interdisciplinary Science Program, Oregon State University, Corvallis, Oregon.

Nevada, Oregon, and Washington in the Pleistocene (Brattstrom and Sturn 1959).

STATUS

The Western Pond Turtle is listed as ''Endangered'' by Washington State, ''Sensitive-Critical'' by Oregon, ''Species of Special Concern'' by California, ''Sensitive'' by the US Forest Service in the Pacific states, and a ''Species of Special Concern'' by the Bureau of Land Management. In California, Jennings and Hayes (1994) recommended ''State Endangered'' status in southern California from the Salinas River (near Monterey) south along the coastal slopes and from the Mokelumne River (near Stockton) south in the San Joaquin hydrographic basin, and ''State Threatened'' level for the rest of California. The California Department of Fish and Game has reduced an earlier possession limit from 2 turtles to 0, and the species is now protected from take or harm in California.

This species was proposed for Federal listing in 1991 but found not warranted at that time by the US Fish and Wildlife Service (USDI 1992). Currently, it is not included on the Federal Threatened/Endangered Species List nor is it listed as a candidate species. It is estimated that population declines may be occurring in more than 80% of its range (Holland 1994), but many areas have not been surveyed and long-term monitoring is lacking. Losses appear to be most severe in northern populations in Washington State (see Hays and others 1999) and, if native, in British Columbia (Matsuda and others 2006) as well as southern California and Baja California, where many populations have been lost (Brattstrom 1988; Goodman and Stewart 2000; Lovich and Meyer 2002). Habitat loss and alteration, isolation of populations, introduction of nonindigenous species, and pollution negatively affect populations of Western Pond Turtles. However, much new habitat has been created in the form of stock ponds and other artificial water features that have benefited the species.

Western Pond Turtles are relatively long-lived and some reach an age of 50 y or more in the wild (RB Bury, unpubl. data). Hatchlings are small at approximately 25 mm long and grow to adults with shells 160 mm or more long. Females in northern populations do not achieve reproductive status until 7 to 12 y of age (Germano and Bury 2001), but can do so in 4 to 6 y in southern areas (Germano and Rathbun 2008; Germano 2010). These population differences are important to consider when designing monitoring plans and for achieving effective conservation strategies for the species.

NEED FOR SURVEY TECHNIQUES AND MONITORING STUDIES

Small, incremental changes in the composition of populations can result in declines or extirpation of species or local/regional genetic stocks. Adult turtles may persist many years after a population has collapsed below the threshold of viability (that is, with little or no recruitment). However, hatchlings and young turtles are difficult to observe in the wild, often are solitary, often use microhabitats that differ from other age classes, and thus are frequently undersampled. Also, some larger turtles may actually be quite young because they have a high rate of growth (Germano and Rathbun 2008; Germano and Bury 2009; Bury and others 2010; Germano 2010). Sampling of Western Pond Turtles requires innovative techniques and a long-term commitment of resources to ensure that all portions of the population are effectively sampled.

Reliable and effective sampling protocols are needed for effective conservation and management efforts of the Western Pond Turtle. Here, we attempt to provide a review of its habitat use, ecology, and conservation as well as examine effective sampling and field techniques based on the input of many experts from different regions and perspectives. Such an approach may assist management to maintain populations of this native turtle and recover those that are depleted. Removing or reducing threats to the species and its habitats may prevent the need to list the Pond Turtle as threatened or endangered. A substantial proportion of the habitat of this species does not occur on public lands; therefore, successful conservation may require state and federal agencies to join in efforts with interested citizens and landowners to monitor and protect this species throughout its range. Inventory and monitoring efforts should employ scientifically rigorous methods yet achieve the greatest possible efficiency to ensure the widest coverage of populations. Consistency in data collection is necessary to allow consolidation and analysis of information from different geographic areas (Anderson and others 1999).

Field surveys may be needed to 1) determine the presence of Western Pond Turtles in an area (or a reasonable determination that they were not found), 2) assess their relative abundance or status with a population estimate based on established criteria (for example, mark and recapture study), 3) provide baseline information on population features (for example, age and sex ratios), and 4) assess population response to habitat changes over time. Effective survey protocols are needed for agency management actions (for example, location of campgrounds along a river on public lands), impact assessments (for example, construction of a bridge over a stream or road construction), and habitat conservation planning (for example, a timber harvest plan around a pond).

The primary purpose of field monitoring is to detect significant changes in demographics and habitat use over time, and to determine whether management and protective efforts have been successful. Monitoring is needed to assess the effectiveness of conservation measures and identify factors affecting achievement of local or regional objectives. Monitoring designs must attempt to identify the primary causal factors of change in distribution, abundance, and population features of Western Pond Turtles. Ideally, monitoring would occur early enough to allow time for corrective actions to be undertaken that would prevent the need for listing of the species as threatened or endangered in all or parts of its range. The techniques and approaches described in this handbook should help users achieve consistency, efficiency, and reduced or no bias in surveying and monitoring across the range of the Western Pond Turtle, thereby strengthening management and conservation efforts.

CHAPTER 2

SYNOPSIS OF BIOLOGY

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OVERVIEW

Here, we summarize the biology and habits of the Western Pond Turtle (*Actinemys marmorata*) to provide a framework for studies of its biological features and a foundation to address sampling issues. It is vital to understand the biology of a species before attempting to conduct field surveys, undertake population studies, or manage populations for long-term viability. Our biological information is from our collective knowledge as well as scientific papers and some unpublished reports. We cite references only for specific statements.

THERMAL ECOLOGY

Turtles are most visible when they are exposed on logs, rocks, or shorelines during periods of aerial basking, one of their primary means to increase body temperature. Western Pond Turtles spend varying proportions of the day basking, depending on a combination of factors that may include ambient air temperature, water temperature, and body size (Bury 1972a; Reese 1996). In the spring-summer activity period, turtles may spend 2 to 4 h a day basking. Turtles may bask out of water less often, if at all, in southern parts of the range or warmer aquatic habitats. Here turtles may engage in aquatic basking (for example, resting in upper thermal layers found in algal mats), where they are not easily observed.

Aerial basking may occur less often in warm areas. In the Central Valley, California, the combination of hot air temperatures in the summer and many shallow-water habitats (for example, marshes, ponds) elevates water temperatures for relatively long periods each year. Turtles can reach suitable body temperatures by floating in the upper water column or sitting in algal mats only partially exposed. Sometimes turtles burrow under algal mats in shallows, where water temperatures are relatively high and there is an abundance of food (algae and many invertebrates). With binoculars, one can sometimes detect emergent nose tips or tops of shells in floating vegetation or open water.

In the Central Valley of California, Germano and Bury (2001) noted low frequency of observed turtles at several sites where they trapped high numbers of turtles. In one slough, they observed few turtles but trapped many in

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algal mats on the banks of a slow creek where the water surface temperature was high (maximum about 34°C at surface). Visual searches would probably yield more observations if conducted in the spring when air and water temperatures are much lower than in summer. Under cooler conditions, turtles may be forced to aerially bask to increase body temperature to required levels for the proper functioning of physiological processes. In a coastal California stream, Rathbun and others (2002) found some turtles with radio transmitters that buried themselves into warm sand and remained for hours.

In many areas, though, basking sites are important for Western Pond Turtles. Wood perches on the Trinity River in northern California were used disproportionately by turtles relative to their availability (Reese and Welsh 1998a). Reese (1996) found basking site characteristics were similar between juveniles and adults with respect to water depth and perch diameter, but differed in flow characteristics, with juveniles using basking sites in lower flow areas more than adults.

Social Behavior

Courtship and mating takes place underwater but has been observed only a few times (Holland 1988; Ashton 2007; Bettelheim 2009). The male moves in front of the female. Then the male scrapes with his toes at the anterior marginal shields of the female carapace usually in sets of 3, alternating between limbs and pausing briefly between bouts. He also waves his forelimbs side to side in front of the female. The female may turn away, with the male in pursuit. Sometimes the female raises her posterior end up off the substrate, a signal for mating. Holland (1988) observed copulation of turtles in the field in mid-June in southern California and in captive specimens in late August and early September. In northern California, courtship has been observed in spring and fall (Reese 1996; Ashton 2007).

Western Pond Turtles may be aggressive toward one another, especially when crowded on basking sites (Plate 3). Although rare in nature, turtles will bite each other, presumably to displace another turtle in its space or in competition for basking sites (Bury and Wolfheim 1973). More often, turtles present an open-mouth gesture that signals an aggressive stance. Turtles may yawn on occasion, but this behavior is not directed at other turtles. When a turtle directs the gesture (wide-open mouth) at another turtle, the recipient usually moves or turns away. Animals will also jostle each other on basking sites and sometimes push one another off into the water.

Daily and Seasonal Activities

Although considered primarily an aquatic turtle (Nussbaum and others 1983), the Western Pond Turtle may spend half the year or more on land in some environments. Overland journeys among multiple bodies of water, often round-trips, have been recorded (Reese 1996; Reese and Welsh 1997). Access to mates, food resources, basking sites, cover, or predator avoidance may prompt this behavior (Reese 1996), although additional studies are needed.

Seasonal cycles of activity are often influenced by reproductive behavior. For example, female turtles may spend a portion of their time nesting in terrestrial habitats in May through July (Reese 1996; Reese and Welsh 1997; Rathbun and others 2002). Aquatic sampling in these months may miss some females, so sampling should also include August and September if the goal is to sample most adult females. Pond turtles may be active all year in the southern part of their range, but are inactive where winters are cool or cold. Even in the northern part of their range, however, they may occasionally engage in emergent basking during sunny winter days.

Overwintering

Most Western Pond Turtles overwinter buried in substrates on land or underwater from beginning in September or October and ending between March and May (Reese 1996; Rathbun and others 2002). Adult pond turtles in Washington overwinter about equally on land and in the water, with the proportion of turtles in each habitat varying somewhat from year to year (F Slavens, pers. comm.). Adult turtles in central California moved out of a stream in fall and spent the winter (mean of 111 d) on land, whereas turtles living in a nearby human-created pond remained in the pond all winter (Rathbun and others 2002). In flowing waters (streams, rivers) and flood-control reservoirs, turtles move up to 500 m or more into upland habitats where they burrow into duff and soils and remain over the winter (Reese 1996; Goodman 1997a; Reese and Welsh 1997). Turtles may move out of stream channels to reduce mortality caused by winter/spring high flows (Rathbun and others 2002; H Welsh, pers. obs.), but this relationship is poorly documented.

In Oregon, turtles living on the floor of the southern Willamette Valley departed flood-control reservoirs as early as 23 August and as late as 20 November (K Beal, pers. obs.). Further, the average date of emergence from the aquatic habitat to occupy a terrestrial overwintering site was 15 October for 12 turtles tracked with radio transmitters. In southern Washington, turtles tracked with radio transmitters moved to overwintering sites as early as August and as late as December, then reappeared at ponds from February to April (F Slavens and K Slavens, pers. obs.).

Along the Trinity River in northern California, turtles dug into hillsides above the high-water mark for overwintering sites (Reese 1996). Habitat at overwintering sites includes conifer, hardwood, and mixed conifer-hardwood forest, with canopy closure generally greater than 50%. Turtles mostly dug into duff under shrubs in Oak (*Quercus* sp.) stands and avoided Pine (*Pinus* sp.) stands. Slopes of overwintering sites along the Trinity River varied from 0 to 30%, with no apparent preference for a particular aspect (Reese 1996). Turtles moved from the river to terrestrial sites from 17 August to 25 December, but mostly in September and October (Reese 1996; Reese and Welsh 1997). They began moving back to aquatic habitat (usually side pools next to the river) in February and March. This may allow them to take advantage of warmer, more productive waters, while cold, high-flow conditions still exist in the mainstem of the river. They returned to the main river from 15 April through 17 June (Reese 1996).

In the upper Mad River in northern California, Bondi (2009) found turtles moving to overwintering sites at different times related to the hydrologic characteristics of the river section. Turtles living in an upstream stretch that had intermittent flow and dry stretches in late summer left the sometimes widely separated pools in early August. Those in a downstream stretch with permanent water did not move to land until early October. Turtles using the upper intermittent reach migrated back to the river earlier than those at the lower permanent reach. Bondi (2009) also found that turtles inhabiting the intermittent portion of the river had significantly smaller body size than those residing in the perennial reach. Thus, the amount of time spent on land versus in water appeared to differentially influence important physiological processes in the 2 populations.

In the Willamette Valley, Oregon, turtles selected overwintering sites that had predominately southern aspects and slopes between 10 and 35 degrees (K Beal, unpubl. data). Near Lookout Point Reservoir in Lane County, Oregon, turtles selected sites with cover of low shrubs including Salal (*Gaultheria shallon*) and Oregon Grape (*Berberis nervosa*). They appeared to prefer duff layers 2.5 to 12.5 cm deep or surface debris, and sites typically lacked tree cover. Turtles often traveled for several days on land over steep and rocky slopes to reach overwintering sites (K Beal, unpubl. data).

Turtles tracked with radiotelemetry showed that individuals often return to the same terrestrial overwintering site each fall (Reese 1996; Goodman 1997a; Bondi 2009). In northern California, Reese (1996) determined an average distance of 167 m for overwintering sites from the Trinity River, whereas Bondi (2009) found that turtles had average distance from water of 101 to 119 m over 2 y along the nearby Mad River. During terrestrial overwintering, turtles may emerge to bask on sunny days and may even move to new overwintering sites (Holland and Goodman 1996; Reese 1996).

HOME RANGE

Most turtles remain in a relatively small home area (Bury 1979). In a northern California stream, male turtles had linear movements (mean = 367 m) that were twice those of females (149 m) and juveniles (145 m; Bury 1972a, 1979). Some adult turtles, however, moved over 1 km over a 3-y period and one marked individual covered a distance of 1.5 km in a 2-wk period. Reese (1996) found that during the summer months, juveniles in the Trinity River had a mean aquatic home range length covering 84 m of river channel. Their home ranges were smaller than those of adults but similarly included terrestrial components. Juvenile turtles may exhibit considerable mobility.

Reese (1996) reported that juveniles sometimes travel back and forth between low-flow portions of the river and adjacent ponds. These journeys may be motivated by thermal preferences, distribution of food resources, swimming abilities, or predator avoidance (Congdon and others 1992). Bondi (2009) found that males had larger home range sizes and greater average length of aquatic movements than did females at 2 sites (permanent and intermittent flow) of the Mad River in northern California.

Sporadic, long-distance movements may constitute dispersal and mate searching by males (Reese 1996), and if they span long distances may facilitate genetic dispersal. Goodman and Stewart (2000) found that total aquatic home range area of female turtles in 2 southern California streams lacked differences (1342 ± 1235 m^2 and 3059 ± 2249 m^2, respectively). There were differences, however, for linear movements (1273 ± 1138 m and 335 ± 276 m, respectively) perhaps because one stream was much wider (mean = 9.5 m compared to 1.0 m).

DIET

Western Pond Turtles are dietary generalists, locating food by sight or smell (Evenden 1948; Bury 1986). The majority of their diet consists of small aquatic invertebrates, while carrion and small vertebrates (fish, frogs, tadpoles) are occasionally eaten but appear to be a minor component (Bury 1986). Food items include aquatic insect larvae, crustaceans (cladocerans and crayfish), and annelids. Plant material is consumed in variable amounts and includes Pond Lily (*Nuphar polysepalum*) inflorescences, Willow (*Salix* sp.) and Alder (*Alnus* sp.) catkins, Ditch Grass (*Ruppia* sp.) inflorescences, and green filamentous algae. Juvenile turtles are principally insectivorous, whereas adults may consume more plant material (Bury 1986).

Small vertebrates, including tadpoles and egg masses of Foothill Yellow-legged Frogs (*Rana boylii*), have been found in the stomachs of Western Pond Turtles, but it is unclear whether these were ingested as prey or carrion (Holland 1985; Bury 1986). A variety of small animals occurs in filamentous algae and may supplement the diet when algae are consumed by turtles (Bury 1986). Pond turtles may also feed on *Daphnia* sp. and other small invertebrates in the water column using neustophagia, which is a modified form of gape-and-suck feeding allowing turtles to siphon food from the water surface (Belkin and Gans 1968; Holland 1994).

HABITAT ASSOCIATIONS

Western Pond Turtles are habitat generalists and can be found in a variety of waters from sea level up to 1370 m (4500 ft), and even up to 2000 m (6600 ft) in the southern part of their range. However, they seldom occur in large numbers over 1500 m (4900 ft). Turtles occur in rivers, streams, lakes, ponds, reservoirs, stock ponds, settling ponds of wastewater treatment plants, and permanent and ephemeral wetland habitats (Plates 4–6). In general, aquatic habitats for this species are relatively rare across much of the western landscape. For example, a pond or stream may have turtles present but then there can be 5 to 25 km (or more) of open, dry terrain before another waterway is present. There are some large marsh areas (for example, Klamath Lake basin, Oregon and California border), but many other shallow lakes and marshes have been converted to agricultural fields (for example, San Joaquin Valley, California). Standing water is often limited across the range of the turtle (for example, only 1–5% of the land surface area is water).

Turtle populations appear to occur in a disjunct distribution pattern. Germano and Bury (2001) found presence (that is, at least 1 turtle observed or caught) at 10 of 28 (35.7%) sites in the San Joaquin Valley, California, and only 5 of 20 sites (25%) in the Sacramento Valley, California. They observed turtles at 37.0% of the pond and lake sites, 14.3% of the canal/slough/stream habitats, 33.3% of the river sites, and 50.0% of the marsh habitats in the Central Valley. However, their surveys suggested that visual searches may not have been a reliable predictor of turtle presence or population size in Central Valley habitats. Turtles in this region apparently do not bask out of water regularly (DJ Germano, pers. obs.). The most ever observed were 20 turtles basking at 1 large water body, yet more than 700 have been trapped and marked in 12 y at this same site. It appears that pond turtles in the San Joaquin Valley bask less as water temperatures increase. Additionally, fewer than a dozen Western Pond Turtles are ever seen basking at a 1.3-ha pond at high elevation near the town of Gorman, California, but more than 250 turtles have been marked there (DJ Germano, pers. obs.). Thus, reliable determination of presence of these turtles, especially in the southern portion of the range, should employ both visual searches and trapping or snorkeling surveys.

Use of thermal regimes may differ among size classes. There were thermal differences in aquatic microhabitats used by turtles in the Trinity River, California. Juveniles were found in areas with water temperatures of 12 to 33°C and adults used areas with temperatures from 10 to 17°C (Reese 1996). Hatchling turtles are relatively poor swimmers and seek areas with slow, shallow, warmer water with emergent aquatic vegetation (Holland 1994; Reese 1996).

Reese and Welsh (1998a) examined differences in habitat use between a dammed and a natural fork of the Trinity River in northern California. The dammed fork had more sedimentation, lower water temperatures, increased canopy cover, and higher water velocities compared with the natural fork, all of which are potentially relevant to pond turtles. While turtles selected for deep water, low velocities, and the presence of underwater refugia on both forks, on the dammed tributary they were more associated with basking structures, which may be especially important due to the lower water temperatures. On the natural tributary, pond turtles tended to be in slower-flowing portions of the river with warmer water (Reese and Welsh 1998a).

AGGREGATIONS IN AQUATIC HABITATS

Pond turtles tend to aggregate where favorable conditions exist: quiet waters with cover and basking sites. For example, a suitable site along a small river or stream is a deep pool (for example, 1–2 m deep) with boulders, fallen trees, or brush piles. Intervening riffles and shallows are likely used only for movement between pools or foraging opportunities. Turtles also congregate in waters with dense thickets along the shore or where there are undercut banks. Some turtles occur in marshes or ponds with surrounding open terrain. Most abundant populations occur in areas lacking dense human population or development (Bury and Germano 2008), although small populations do occur in urban settings.

Western Pond Turtles often show a clumped distribution within flowing water. Along 3.5 km of stream in northern California, Bury (1972a) found most turtles in 37 pools and few in connecting, long shallow riffles (Fig. 2). Moreover, about a third (36%) of all captures were consistently made in just 5 pools (13.8% of the number of pools) and most turtles (59%) were in just 10 pools (27.0% of the pools). Several pools (n = 8) had a low catch with means of 0 to 2 turtles present on repeated visits. These were usually shallow (<1 m) with few or no basking sites. The distributions of turtles were significantly correlated to size of pools (more turtles in larger, deeper pools) with abundant cover such as logs or boulders (used for basking and underwater retreats). This pattern was for subadult and adult turtles because few turtles less than 3 y old were found in this stream. Reese (1996) also found clumped distributions on the 2 forks she studied on the Trinity River in northern California.

In the Umpqua River basin of southern Oregon, basking turtles were concentrated in relatively few pools (Fig. 3). The pools with large numbers usually had haul-out sites such as logs or boulders. Sites were revisited 3 times. There were 111 turtles observed at 4 sites (94.9%), whereas 4 other sites had only 1 turtle each and 1 site had 2 turtles. Those 9 pools represented 30% of the sites visited; no turtles were seen in the remaining pools.

POPULATION DENSITIES

Densities vary between aquatic systems based on factors such as amount of suitable habitat, hydroperiod, and level of disturbance. For example, Bury (1972a) estimated a density of approximately 250 Western Pond Turtles per hectare in a tributary of the Trinity River, California. This site was searched for 3 summers, yet some animals may have moved in and out of the defined study area. Reese and Welsh (1998b) determined population densities of 19 turtles per hectare on 2 reaches of the mainstem Trinity River, and 13 turtles per hectare on 3 comparable reaches of the South Fork Trinity River. These are relatively wide rivers (for example, more than 15 m wide in many places). In southern Oregon, 114 turtles were observed in a 0.5-ha pond (S Wray, pers. obs.). Pond turtles may congregate in a few remaining portions of streams or ponds as waters dry up in late summer and early fall. If

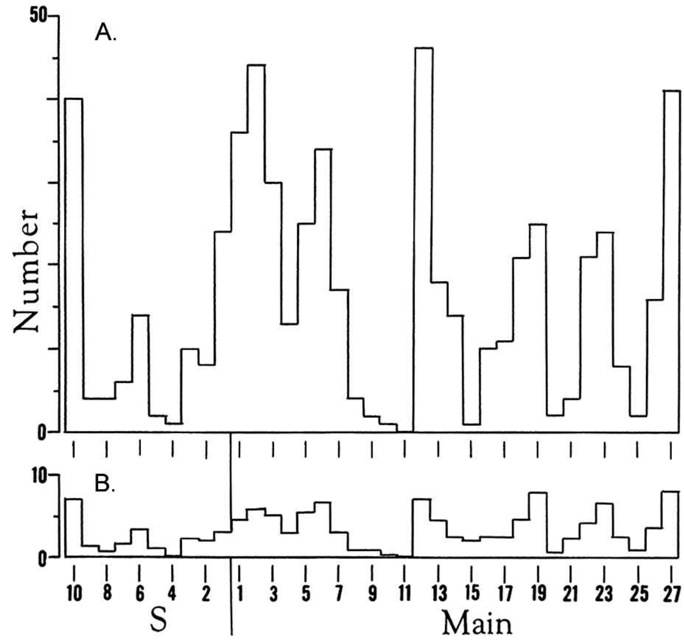

FIGURE 2. Turtle distribution in 37 pools spaced along 3.5 km of a tributary stream of the Trinity River, Trinity County, California, 1969 to 1971. Top: Total catch by pool and only for 1st capture. Bottom: Mean number of turtles captured at each pool (number of visits varied slightly), includes new and marked turtles. From Bury (1972a).

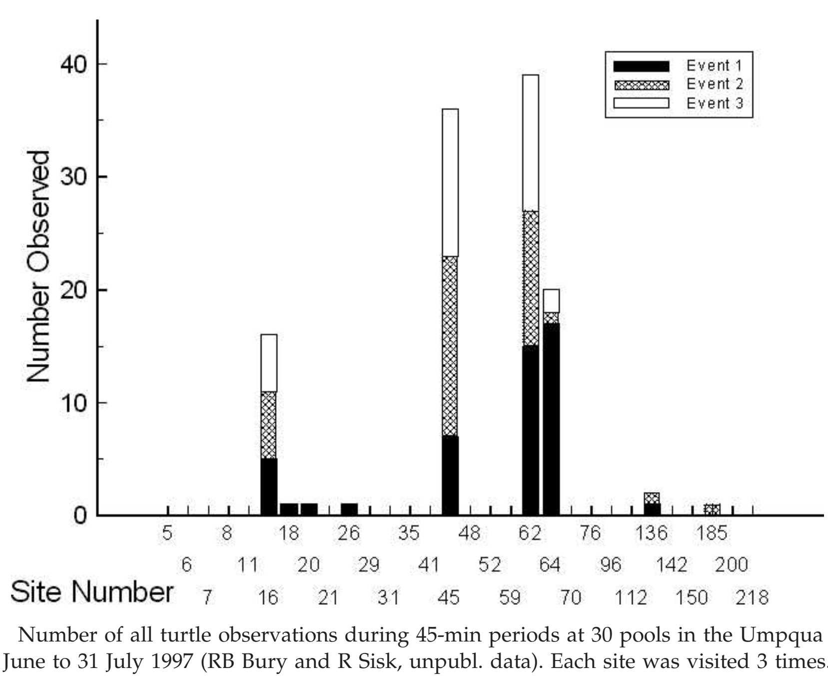

FIGURE 3. Number of all turtle observations during 45-min periods at 30 pools in the Umpqua River basin, Oregon, 12 June to 31 July 1997 (RB Bury and R Sisk, unpubl. data). Each site was visited 3 times.

sampled at these times, a high density is found but represents only a snapshot of the turtle's activities. Turtles could forage and live in temporary waters and then move to permanent water holes or streams with increased drying of the landscape. Conversely, turtles may move to sites on land (D Pilliod, pers. obs.). The type of survey, time of year, and experience of surveyors can bias estimates of density. All of these factors need to be taken into account when comparing densities of turtles between systems.

REPRODUCTION AND SEX RATIOS

Age at sexual maturity of Western Pond Turtles is poorly known. The youngest females to carry eggs were 4 y of age in coastal central California (Germano and Rathbun 2008), an average of 4.4 y at a site in the southern San Joaquin Valley (DJ Germano, unpubl. data), and 4.4 and 5.4 y of age at settling ponds of 2 sewage treatment facilities in the San Joaquin Valley of California (Germano 2010). Most females found with eggs are older than 6 y of age.

Sexual maturity is usually estimated based on size. Females appear to start carrying eggs at 130- to 135-mm carapace length (CL) (Holland 1994; Germano and Rathbun 2008; Germano 2010; DJ Germano, unpubl. data). We do not know when males become sexually mature, but external signs of sexual dimorphism appear at 110- to 120-mm CL (Plate 7, Plate 8). Age at maturity influences adult sex ratio (Gibbons 1990a; Lovich and Gibbons 1991). Sex ratios in most populations of Western Pond Turtles appear to be equal, but there can be local variation (Bury and Germano 2008). We advise caution when interpreting data with deviations from a sex ratio of 1 male: 1 female unless sample sizes are large (for example, more than 300 individuals; see Bury 1979).

Females usually deposit eggs from May through July with the more northern populations depositing eggs later in the season than those in the south. In southern Washington State, nesting occurs as early as 27 May and as late as 15 July (F Slavens, pers. obs.). In a nesting area searched daily at Fern Ridge Reservoir in the southern Willamette Valley, Oregon, turtles began nesting between 2 June and 15 June every year from 1993 to 2000 and the duration of the nesting period ranged from 32 to 42 d (K Beal, unpubl. data). In the Trinity River of northern California, nesting occurs in June and July (Reese 1996).

When nesting, gravid female turtles generally leave the water in the evening and move into upland habitats to excavate a nest. Females may be out of the water for a few hours to several days. In the Willamette Valley, Oregon, radio tracking of female turtles and daily search of nesting areas in late spring suggested annual nesting by females and repeated use of the same nesting area by some individuals (K Beal, pers. obs.). One female was found to nest in the same area for 5 consecutive years, 1993 to 1997. Most nest sites were 5 to 80 m from the edge of water bodies, whereas some were 100 to 150 m and a few about 500 m away (Storer 1930; Holland 1994; Holte 1998).

Nests are typically excavated in compact, dry soil with high clay or silt fractions, in areas with short grasses or forbs that allow exposure to direct sunlight (Rathbun and others 1992, 2002). Nests have been found on constructed dike slopes, road-cuts, and roadsides (K Beal, pers. obs.). Aspect is usually south or west facing and on a slope of 25 degrees or less. Nesting areas may have many false scrapes.

Female turtles may void their bladders to soften the soil and then excavate a flask-shaped nest chamber with their hind limbs. Once eggs are deposited, females pack moist soil and surrounding vegetation into a dirt plug that closes the neck of the nest chamber (Bettelheim and others 2006). This plug dries into a hard seal within a few days.

Eggs are off-white in color, elliptical-oval in shape, and range from 32- to 42-mm long and from 18- to 25-mm diameter. Mass of eggs ranges from 7 to 11 g. The egg shell is hard with a ''bone-china'' texture. The time from ovulation of eggs to deposition in a nest is unknown. Incubation time is 73 to 132 d under artificial conditions (Lardie 1975; Feldman 1982) and 94 to 122+ d in the wild (Holland 1994; Goodman 1997a). Hatchlings appear to overwinter in the nest in northern California (Reese and Welsh 1997) and western Oregon (K Beal, unpubl. data). In southern and central California, some hatchlings may emerge from the nest chamber in the fall, whereas others overwinter in the nest chamber and emerge in spring (Holland 1994). Hill (2006) reported finding 20 hatchlings (excluding recaptures) in the San Joaquin Valley, California, with most in April (65%), some in May (20%), and fewer in June (15%). It

FIGURE 4. Radiograph of adult female Western Pond Turtle showing shelled eggs. Photograph by David J Germano.

was not clear if these were from eggs deposited in the prior or current year. The pattern of overwintering of eggs and hatchlings is widespread in freshwater turtles (Gibbons and Nelson 1978; Ultsch 2006) but needs further study to elucidate possible differences across the range of the Western Pond Turtle.

Most counts of clutch sizes in Western Pond Turtles are from radiographs of gravid females (Fig. 4). Mean clutch size varies from 4.5 to 8.5 eggs (range 1–13): Feldman (1982); Rathbun and others (1992); Goodman (1997a); Pires (2001); Lovich and Meyer (2002); Germano and Rathbun (2008); Scott and others (2008); Germano (2010); DJ Germano, unpubl. data. Larger females have more eggs per clutch.

The number of annual clutches a Western Pond Turtle has appears to vary geographically. Females in western Oregon may deposit 1 clutch per year (Holte 1998). Females can produce 2 clutches per year in southern California (Goodman 1997b; Goodman and Stewart 2000; DJ Germano, unpubl. data), coastal Central California (Germano and Rathbun 2008; Scott and others 2008), and Oregon's Willamette Valley (K Beal, unpubl. data). A few females had 3 clutches in 1 y in the San Joaquin Valley, California (DJ Germano, unpubl. data). Recently, Scott and others (2008) reported that the estimated range of intervals between the laying of 2 clutches in the same season was 27 to 43 d. They tracked 39 turtles through 66 individual turtle nesting seasons, during which time they deposited an average of 1.3 (SD = 0.7) clutches per year. Individual turtles had no eggs in 10 seasons, a single clutch in 27 seasons, and double clutches in 29 seasons. Clutch frequency did not vary significantly with turtle size. For turtles with 2 clutches in a single year, the average 1st clutch (mean = 6.0, SD = 0.9) had significantly more eggs than their 2nd clutch (mean = 5.3, SD = 1.3).

GROWTH

Ontogeny, environmental conditions, geography, and individual variation all contribute to the variable growth rates seen in this species. Most hatchlings are 25- to 32-mm CL upon emergence from the nest (Plate 9). Growth rates are proportionally greatest in hatchlings, which can almost double in size by the end of the 1st growing season (Bury and Germano 1998; Germano and Rathbun 2008; Germano 2010). Generally, growth rate is high for the first several years, then decreases each successive year, and, depending on the part of the range, growth slows rapidly by the end of the 8th year in the southern part of the range and by the 14th to 16th year in the northern part of the range (Germano and Rathbun 2008; Germano and Bury 2009; Bury and others 2010; Germano 2010). Estimated growth rates for hatchlings from the Trinity River, California, during their first 4 growing seasons ranged from 6.1 mm/mo in the 1st season to 1.3 mm/mo in the 4th season (Reese 1996).

Growth rates vary geographically (Table 2), tempered by local conditions. Turtles in coastal central California take about 4 y to reach 120 mm (Germano and Rathbun 2008) and slightly less than 2 y in the San Joaquin Valley of California to reach 120 mm (Germano 2010), but in northern California and southern Oregon turtles require from 5 to 10 y to reach the same size (Germano and Bury 2009; Bury and others 2010). In general, growth rates of turtles in central California are much faster than those

TABLE 2. Comparison of approximate carapace lengths (in mm) of young turtles at different ages based on Richards growth modeling of carapace lengths.

Age (y)	Central California coast (Germano and Rathbun 2008)	Hayfork, northern California (Bury and others 2010)	Southern San Joaquin Valley (Germano 2010)
0	27	35	26
1	69	46	88
2	96	58	125
3	114	69	146
4	126	80	158
5	136	90	165
6	143	100	169
7	147	108	172

from the mountains of northern California (Fig. 5). Surprisingly, turtles in the Klamath Lake basin of southern Oregon (relatively high elevation of 1200 m) had fast growth rates; this pattern is likely related to abundant food in eutrophic waters in the basin (Bury and others 2010). Growth rates may vary widely within regions, particularly with faster rates occurring in some standing waters compared to flowing conditions (Germano and Bury 2009; Bury and others 2010).

Survivorship of Life Stages

High mortality of many turtles is known to occur in nests, which are subject to predation by a variety of predators (Bury and Germano 2008; Wilcox 2010). Also, hatchlings must crawl from the nesting area to aquatic sites, which can be a challenge for an animal about the size of an American quarter (Plate 9). Nests can also dry out or be invaded by ants (Lovich and Meyer 2002). In areas where hatchlings emerge in the spring, eggs or hatchlings may drown during winter rains or flooding. Although the maximum life span is unknown, some turtles live to be over 55 y old in the wild (Plate 10). This is based on turtles first captured and marked as adults (estimated age of 15+ y) and recaptured 39 to 42 y later (Bury 1972a; RB Bury, unpubl. data). Mature females may nest over several

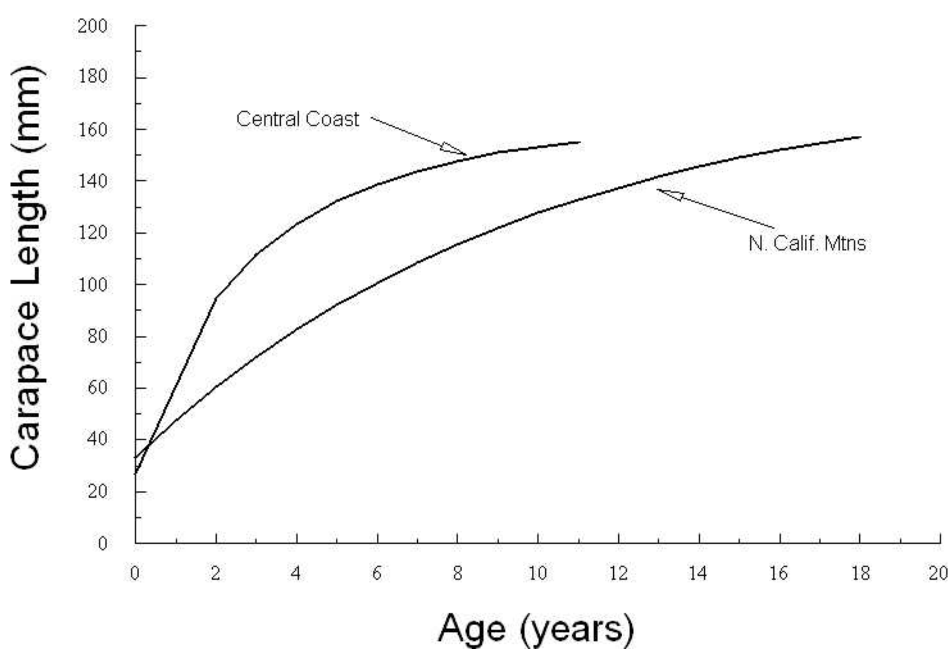

FIGURE 5. Comparison of representative growth rates of Western Pond Turtle populations from northern and southern (central coast) California sites.

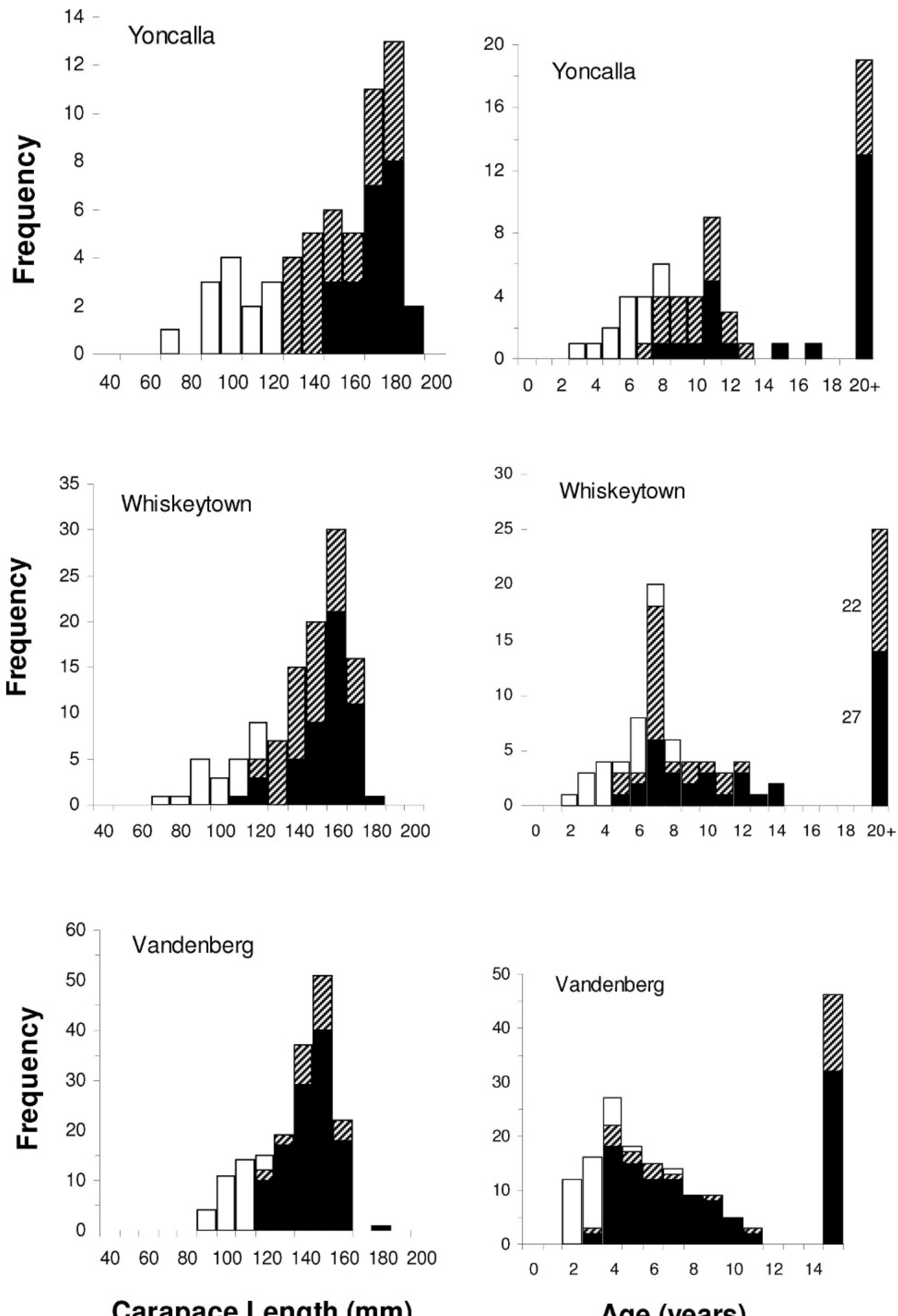

FIGURE 6. Comparisons of size structure (left) to age structure (right) for 3 populations across the range of the Western Pond Turtle: northern (Yoncalla, Oregon), midrange (Whiskeytown, northern California), and southern (Vandenberg, southern California). In each case, the size structure has few small turtles, a situation that is often interpreted as failed reproduction. Those age-structure profiles that show many young turtles are indicative of recent successful reproduction. Open symbols = juveniles; hatched = females; solid = males.

decades, which increases chances for successful nesting events. However, we do not know if females of this species continue to produce eggs over their entire life span.

Currently, there is no estimate of survivorship in this species. Thus, we caution against speculation of population status and trends until such data are reported. Survival is likely low for early age classes (1–3 y of age) because these are small-sized animals that are vulnerable to many predators. However, young turtles are seldom found in populations because they are small, cryptic, and sedentary. Thus, their numbers may be underestimated unless one makes a concerted effort to carefully search shallows, small backwaters, and feeder tributaries where the young tend to occur.

POPULATION STRUCTURE: SIZE AND AGE

The demographic structure of populations is important to understanding the status and conservation needs of turtles (Ricklefs 1990; Charlesworth 1994). Turtle populations often consist of many adults and few young (Dunham and Gibbons 1990; Gibbs and Amato 2000). In most populations large turtles are by far the most often sighted or captured, which often is interpreted to indicate little to no reproduction in populations. For example, concern has been raised for the long-term persistence of the Western Pond Turtle based on analyses of size to define its demographic structure (Reese and Welsh 1998b; Lovich and Meyer 2002; Spinks and others 2003; Lubcke and Wilson 2007). However, size structure does not correspond to age structure in many populations (Germano and Bury 2009; Bury and others 2010; Germano 2010).

It is important to determine the proportion of young turtles based on their actual ages. Even though size structures indicated little recent reproduction, many young turtles have been found across the range of the species (for example, Germano and Bury 2009; Bury and others 2010). Age determination is accurate in Western Pond Turtles up to 10 to 15 y depending on latitude and elevation (Germano and Bury 1998). In most habitats in the southern part of its range, turtles grow relatively quickly and discernable annuli form for up to 8 to 10 y (Germano and Bury 2001; Germano and Rathbun 2008; Germano 2010), whereas in northern latitudes and some high-elevation habitats in the central part of the range, annulus formation can be discerned for 15 to 16 y (Germano and Bury 2009; Bury and others 2010). Ages as determined from scute annuli properly reveal the proportion of young in turtle populations (Fig. 6). Size alone has been shown not to be useful as an indication of population trends or for conservation assessments of turtle populations (Bury and others 2010). The lack of hatchlings and 1- to 2-y-old turtles can just as likely be due to the inability of biologists to capture these secretive individuals as to their actual absence from the population. Thus, at a minimum, a scute annuli–based age structure of a population is needed to best evaluate demographic structure in the Western Pond Turtle.

CHAPTER 3

SAMPLING DESIGN CONSIDERATIONS

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STATEMENT OF THE QUESTION OR HYPOTHESIS

Logically, the first step of any project or study is to define a research problem or question with a set of clear objectives for its resolution. Sampling design sets the level of intensity: degree of independence and minimum sample size required to provide useful and statistically reliable results. The question should be grounded in information on the characteristic(s) of the species in the community where it will be studied. Consider the spatial (that is, local, regional, or range-wide comparisons) and temporal (that is, short- versus long-term) scales of activity patterns (both annual and daily), reproductive ecology and life-history stages, geographic range (including elevation limits), and habitat associations of the species. Moreover, Fellers (1997) summed it as:

> *In defining the goals of a study, it is imperative to evaluate critically the level of detail that is needed . . . The collection of more detailed information involves a trade-off in terms of increased cost, fewer sites visited, or fewer repeat visits. The three levels of information (species presence, relative abundance, population size), represent points along a continuum of increasingly detailed information.*

It can be misleading or myopic to determine life-history aspects or conservation needs of Western Pond Turtles (*Actinemys marmorata*) on only one or a few populations. It can be far more informative to study and compare populations of the species over a wide geographic range and wide variety of habitat types. Further, sampling several populations in an area may be needed to encompass the range of even local variation (for example, populations in a warm stream, coldwater stream, small pond, or large reservoir).

Heyer and others (1994) posed study questions as inventory (a study of specific area to determine presence of a species) or monitoring (to determine species composition and abundance at one or more sites through time). We would add a 3rd level: research (specific, focused questions). Further, environmental heterogeneity or variation can effectively be addressed by 1) recognizing the variation, subsampling within different habitat types, and then comparing the estimates among the habitat types (a study design called blocking or stratified sampling); or 2) ignoring the heterogeneity without regard to habitat type (not recommended). For both cases, sampling bias is minimized by randomly distributing samples in the study area. Replication is important in studies to provide confidence in the estimates obtained and to minimize the effects of localized factors and the wide range of variables that often occurs when only one or few study sites are used (Heyer and others 1994). Fellers (1997) compared the advantages of selection of study sites: representative site selection is flexible and focused, but potentially biased; whereas random site selection has stronger statistical rigor, with results that may be extrapolated to the entire study area (range of inference), but such criteria are sometimes difficult to meet in the wild.

Visual surveys are a relatively inexpensive option for determining presence of turtles in an area. Their value to approximate estimates of abundance is unclear and requires further evaluation. Capture-mark-recapture studies area more reliable way to determine actual population size, age structure, and other population features. They are also the most reliable approach to monitor long-term population trends. However, mark-recapture studies are labor intensive because they require hand capture (snorkeling) or trapping many turtles over time.

AVAILABLE KNOWLEDGE TO FRAME THE QUESTION

A review of the literature is an essential prelude for any study. The literature on freshwater turtles has increased exponentially in recent years and is now rich with study designs and new approaches. Most of this pertinent literature exists in the major herpetological journals (for example, *Copeia*, *Herpetologica*, *Journal of Herpetology*, *Herpetological Conservation and Biology*, *Amphibia-Reptilia*), specialty ones (for example, *Chelonian Conservation and Biology*), and topical or ecological outlets (for example, *Ecology*, *Ecological Applications*, *Oecologia*, *Conservation Biology*). Many insightful questions on what to study in a wild population of reptiles were posed by Cagle (1953) and they remain germane to this day (see Trauth 2006). A new study on the Western Pond Turtle can profit from approaches and designs used with other species of freshwater turtles (for example, see Bury 1979; Gibbons 1990a; Congdon and Gibbons 1996; Klemens 2000a; Bodie and Semlitsch 2001).

Besides these classic and recent advances by other investigators on a variety of freshwater turtles, we provide a review of key papers on Western Pond Turtles by topic (see Chapter 2). We are aware of 3 dissertations and 14 theses that addressed aspects of the biology of the Western Pond Turtle (Fig. 7). At least 2 other master's theses are in progress. A recent species account summarizes key information on this turtle (Bury and Germano 2008). There are several bibliographies available on the Western Pond Turtle, including these 2 large efforts:

Slavens F, Slavens K. (20 November 2006.) Pond turtle bibliography. http://www.pondturtle.com/ptm2.html

Bettelheim M. (25 November 2007.) Western Pond Turtle (*Clemmys marmorata*) library. *Atlantis Magazine*. http://www.atlantismagazine.com/bettelheim/marmorata.html

Although these bibliographies have large numbers of entities, many are gray literature sources that may have unreliable information (see Chapter 9). Similarly, Internet searches can be useful for the rapidity, but they can turn up many questionable statements or dogma. There is no substitute for a solid grounding in the peer-reviewed scientific literature. These resources help frame the study objectives in ecological theory and tenets of conservation as well as provide the latest methodologies and techniques to undertake field research on turtles. The number of theses and dissertations, bibliographies, and publications of the Western Pond Turtle is relatively high. It is among one of the better studied reptiles in Western North America, yet much remains unknown of its ecology and status.

DOCUMENTATION AND LEVEL OF RIGOR NEEDED

Successful research or monitoring projects require clear documentation of study design, careful management of field data, rigorous analysis, and critical interpretation of results. To be useful for future researchers and land managers, data should be collected and stored in a standardized and accessible manner and should include consistent meta-information such as geographic location, date, time, and environmental conditions (for example, weather, stream flow level, local land use, and local and regional disturbances), along with the sampling method used and a quantification of the effort.

Statistical rigor (for example, adequate sample size, appropriate analyses) has been lacking in some earlier field studies. The most effective approach is to develop hypotheses and determine the statistical tests before fieldwork commences. It is important to determine how many samples or number of observations will be required to answer the question at hand with sufficient power and reliability. These and other

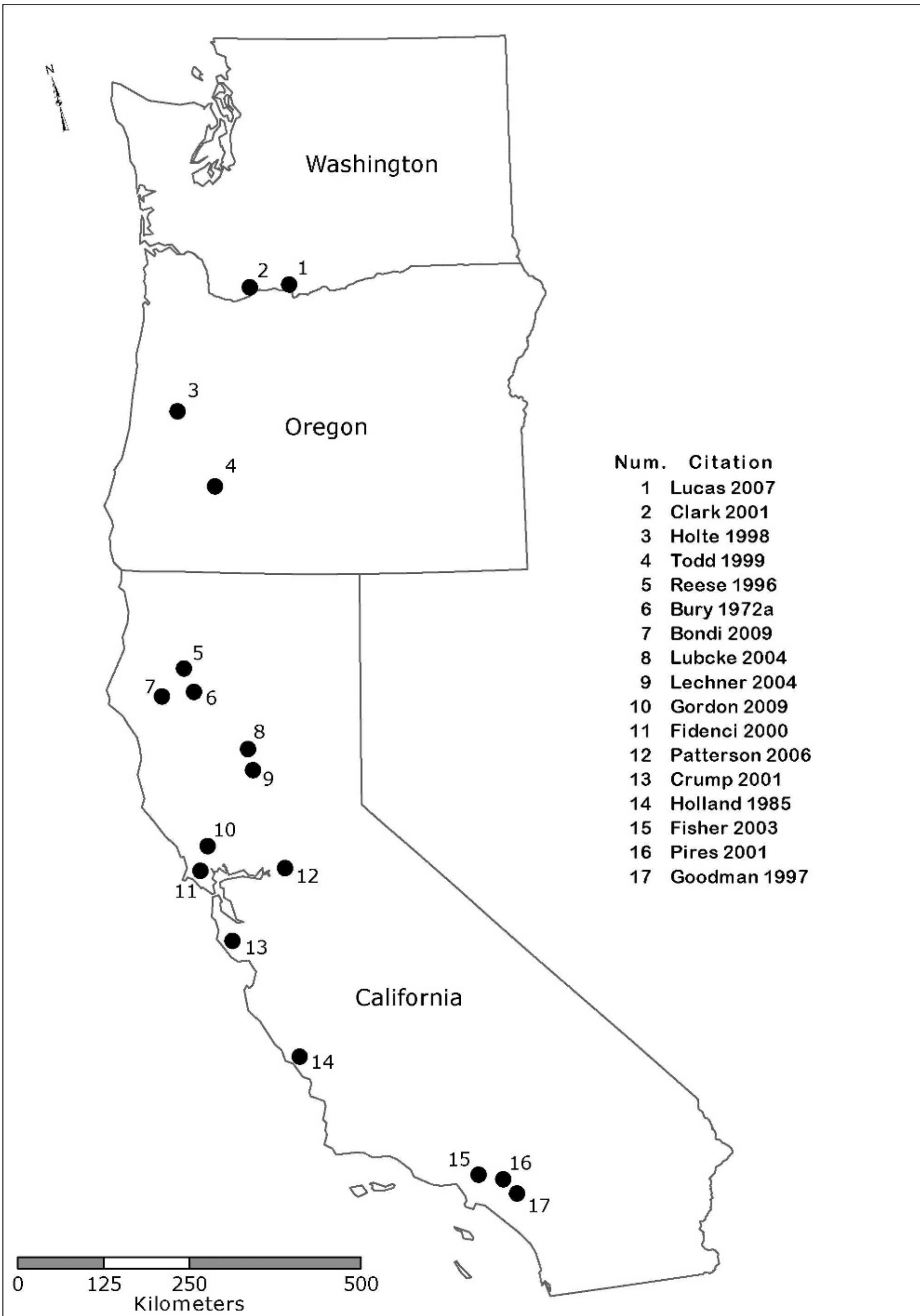

FIGURE 7. Geographic locations of representative MSc theses (open circles) and PhD dissertations (solid circles) on the ecology of the Western Pond Turtle.

key statistical components of a field study are provided elsewhere (see Hayek 1994 or current books on study designs for sampling vertebrates). It is also advisable to consult a statistician prior to fieldwork rather than afterwards.

New studies will benefit greatly from being designed to be a potential future scientific manuscript (even if it fails to merit publication later). This is the most demanding approach because the design, data collection, and interpretations are subject to peer review by external scientists with the option of rejection. It is critical to document all aspects of a project essential for future replication. This is especially important when monitoring is the primary goal because repeated sampling will ultimately provide information on trends in populations or changes in distributions. The success of a research or monitoring project depends on the extent to which all the potentially confounding factors are considered and addressed.

Studying Different-Sized Turtles

An important consideration is the apparent association of juveniles and adult turtles with different environmental features in aquatic and terrestrial habitats. For example, in the mainstem Trinity River, California, juvenile turtles were found in higher proportions in off-channel ponds compared to adults (Reese 1996). Small-sized turtles often live in shallows and not in deep-water areas where adults are more common (RB Bury, pers. obs.; see Chapter 5). When designing a sampling scheme, it is important to sample the full range of aquatic habitats to increase the probability of encountering all life stages in proportion to their abundance. These may include streams, rivers, ponds, wetlands, vernal pools, and reservoirs. One also needs to sample both shallow and deep portions of waterways.

Selection of Study Area

Sample area eligibility should be determined by a set of criteria that eliminate from the sampling pool those portions of the basin or study area where monitoring efforts would be inefficient for finding turtles or inappropriate for addressing particular questions (Appendix 1). Several guidelines for the aquatic portion of the turtle's life might include

1. *Accessibility:* Sections or areas that are inaccessible (for example, private ownership where access is not granted or the owners cannot be contacted) are removed from the sampling pool.
2. *Elevation:* Areas above 1300 m (4500 ft) sea level should be excluded unless turtles are known to occur there.
3. *Stream order:* First- and 2nd-order streams (usually <1 m across) and with a closed canopy overhead should be removed from the sampling pool. This criterion should be applied primarily to projects in the northern latitudes of the range. In more southern areas or Oak woodland areas, such as the foothills to the Central Valley, California, Western Pond Turtles may be found in great abundance in low-order streams if there are deep pools of water or concentrations of cover (for example, boulders, Willow [*Salix* sp.] thickets). Some streams that are intermediate or dry up in late summer may have turtles persisting in widely separated pools with water (for example, deep plunge pools below waterfalls) (Bondi 2009). Turtles can move overland from these more temporary waters to other sites with permanent water.
4. *Pond size:* Small, deep ponds (for example, >1 m deep in the middle) may hold many turtles. However, we suggest excluding shallow waters (<1 m deep) that are 0.1 ha (about ¼ acre) or smaller. These types of waters are likely temporary and may be dry by the end of summer. Turtles may move between small and larger waters, using these seasonally available resources. All waters may be included for better representation and to quantify which conditions are most suitable for pond turtles, if funding and time allow.
5. *Human-modified waters:* Reservoirs that are seasonally drawn down (for example, flood-control reservoirs) appear to have few turtles (Holland 1994). Still, there may be sampling questions that involve these regulated waterways. Further, we need to better understand and document turtle populations in human-modified waterways. Some reservoirs or modified waterways have high turtle numbers (Germano and Bury 2009; Germano 2010; Bury and others 2010).

SELECTION OF SAMPLES

Well-designed projects randomly select samples (sites, points, or belts) from an eligible pool of potential sampling sites (for example, a river basin). In theory, samples should have the same probability of yielding observations (for example, there is no bias due to complexity of site or distance from access points). Depending upon the question, the range of available sample sites should encompass a whole watershed or a large number of samples from a particular habitat type in a catchment. The number of samples to be selected should be determined after carefully considering the total size of the eligible area, time and resource constraints, and the sample size that is required to answer the question(s) posed.

Because river/stream and pond sites have somewhat different eligibility criteria, they should be separated before individual sites are considered. After sorting by site eligibility criteria, there is a smaller pool of potential sampling areas. A map can then be created that displays regions or specific sites within the basin that have been classified as eligible. Lists of randomly selected sample areas may include inaccessible sites. Attempt to select more sample units than can be surveyed. Then, when a site cannot be safely reached, it can be replaced by another site in the sampling pool.

Pond and Standing Water

If all sites cannot be sampled, we recommend random selection of a subset. Alternatively, choose the most suitable sites (based on stated criteria) that are a reasonable proportion of the known ponds, lakes, or other waters (hereafter referred to as sites) within the study area. Although this type of selection occurs often, it limits inference to the one study area. Where the sample area is less than 1 ha (2.5 acres), attempt to sample the entire body of water. In sites $\geq$1 ha (2.5 acres), establish more than 1 study portion to increase coverage and account for habitat heterogeneity over larger areas. Most sites less than 1 ha can be observed from 1 point. Open, deep water lacking vegetation is seldom inhabited by turtles, so these areas are usually excluded from observations.

Flowing Water

To more evenly distribute sample units while retaining randomness in the selection process, select a predetermined number of sample units per linear distance of eligible streams in the basin area. For example, if there are 2 eligible streams within the study area (stream *A* with 10 km of habitat and stream *B* with 14 km) there is 24 km of eligible stream distance. A sample unit for every 2 km of stream distance would result in a total of 12 samples selected: 5 in stream *A* and 7 in stream *B*. A further consideration would be to stratify stream habitat units based on flow type (turbulent or nonturbulent) and depth (pool, run, glide; Hawkins and others 1993) to ensure sampling in each possible habitat type.

CLASSIFICATION OF SAMPLE SITES

Understanding how human actions and differences in natural habitats affect turtle distribution may inform management actions for minimizing or preventing negative effects from perturbations. Thus, we need data on the effects of these habitat variables to allow stratification for comparison of different types of ponds and rivers. We recommend collecting data on 3 aspects to characterize lake, pond, and riverine sites: 1) presence of nonindigenous species, 2) human-influence criteria, and 3) habitat features.

PRESENCE OF INTRODUCED SPECIES

Although evidence is fairly recent, introduced species may be detrimental to the Western Pond Turtle (Spinks and others 2003; Bury 2008a). Thus, field biologists and managers might wish to determine the presence and abundance of introduced species. Fieldworkers need to make positive identification of these nonnative species. Location or capture may require extensive sampling (visual, seining, and trapping) because some of these invasive species can be cryptic, nocturnal, and elusive. The following species are common introductions in the Pacific states:

1. Fishes: Bass (*Micropterus* spp.), Sunfish (*Lepomis* spp.), and Catfish (*Ictalurus* spp.).
2. American Bullfrog (*Lithobates catesbeiana*).
3. Freshwater turtles: Sliders (*Trachemys scripta*) and Cooters (*Pseudemys* spp.); these species can be observed easily because they bask often. Other introduced turtle species, such as the Common Snapper (*Chelydra*

serpentina) and Softshell Turtles (*Trionyx* and *Apalone* spp.), are mostly aquatic and are seldom observed.

Presence of an introduced species does not automatically imply that they are detrimental to Western Pond Turtles, but there are many examples of losses or reductions in other native species due to invasive species (Boersma and others 2006; Bury 2008b). Yet, such statements require rigorous testing to establish cause-and-effect relationships.

Human Influences

This type of classification is used to determine the level of human use within an area, which can range from natural or pristine conditions to heavily developed areas. Finding a body of water that is in a truly ''natural condition'' is difficult because humans are drawn to water bodies for recreation, individual water uses, and industrial uses. Thus, classifying a body of water into ''natural condition'' should be done in a relative sense and could be made based on the following criteria:

- The water lies outside the corporate limits or major influence of any city or town.
- There are no temporary (for example, campgrounds) or permanent human habitations within 0.5 and 1 km of the body of water, respectively.
- There are no major roads within 100 m of the body of water.
- Substrate of the body of water is unaltered (that is, no recent history of digging or dredging).
- There are no agricultural activities nearby or above the body of water that would allow runoff (that is, pesticides) to flow into the body of water.
- Little or no livestock grazing occurs at the edge of the body of water.

There may be some overlap in classification using these criteria. Use the classification based on the influence that is the most prevalent at the site. These water bodies may be subclassified or sorted as:

- *Natural, Forested:* All the items above are satisfied and the immediate area surrounding the body of water is forested.
- *Natural, Not Forested:* All the items above are satisfied and the immediate area surrounding the body of water is not forested.
- *Light Human Development:* Only 1 of the first 4 items above is not satisfied.
- *Heavy Human Development:* Two or more of the first 4 items above are not satisfied.
- *Agricultural:* Where this activity predominates (>50% of land around a turtle site).
- *Grazing:* If the activity has obviously altered the water body or surrounding habitat.

Habitat Features

Bodies of water can be classified based on the suitability of aquatic habitat for Western Pond Turtles. Habitat quality classifications may range from unsuitable to favorable for turtles, but they can vary considerably depending on location and water body type. Currently, it is difficult to formulate an objective set of criteria for classifying habitat into categories that are universally acceptable by field biologists. Still, there are known habitat features that can serve as guidelines for making such classifications (Reese 1996; Reese and Welsh 1998a; Todd 1999). The objective way to measure habitat quality is based on the actual use by turtles and on the status of resident populations (that is, is the population reproducing and are there representative individuals of multiple age classes present). Three major habitat features to consider are

1. *Size of water:* Large bodies of water tend to have low mean temperatures and lack basking or cover away from shore. Thus, they generally provide less suitable habitat for pond turtles than smaller bodies of water. A body of water that is relatively warm year-round or most of the year would provide more favorable habitat quality for turtles.
2. *Depth of water:* Bodies of water where most of the system has a depth greater than 2 m are less suitable as turtle habitat than systems that are shallower. Productivity also decreases with water depth due to reduced solar insolation. Depths less than 2 m that also provide accessible underwater refugia for turtles appear to be preferred. Large ponds and large rivers that have a considerable amount of open water in the

center are generally unsuitable for pond turtles in the deeper areas, but turtles could be abundant near shore.

3. *Structures:* An abundance of basking or cover sites is often a key indicator of suitable habitat for Western Pond Turtles, at least in stream and river systems (Bury 1972a; Lindeman 1999a). Emergent logs and rocks/boulders separated from shore are preferred basking sites, followed by such cover types next to shore (especially over deep water). Fallen trees, brush piles, or Willow thickets may provide cover for many turtles. Emergent vegetation (for example, Cattails [*Typha* sp.], Blackberry [*Rubus armeniacus*] thickets) also provides concealment. Turtles seldom use open areas of shorelines unless there is deep water nearby or cover such as undercut banks. There are exceptions (for example, an open pond that is the last remaining water in an area or sewage treatment ponds).

Combining these 3 habitat features can provide an index of overall habitat quality. While this index is somewhat subjective, it can provide a means for site comparisons in the future. For each habitat feature, if it meets the criteria assign a 1 and, if it does not meet the criteria, assign 0 (see Appendix 2). Total the numbers for the 3 habitat features to determine the classification of the overall habitat.

Using these 3 levels of classification (presence of introduced species, human influence, and habitat quality) can result in a large number of unique groupings. This may result in small sample sizes for each habitat type, which would make meaningful comparisons difficult. Grouping classifications before analysis may help alleviate this sampling problem.

EPILOGUE

The investigator interested in reptilian populations . . . finds an assortment of fragmentary facts that are difficult if not impossible to integrate, and often immediately require the test of repetition. . . . repetition of field observations in a critical spirit may be fully the equivalent of experimental test.

Cagle (1953)

CHAPTER 4

VISUAL ENCOUNTER SURVEYS

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Overview

Visual encounter surveys (VES) are designed to ascertain quickly the occurrence and relative number of individuals at study areas. They may also determine the relative distribution and general population status of turtles within and between river basins. The VES is based on a standardized timed period to observe turtles.

Western Pond Turtles (*Actinemys marmorata*) can be observed and counted during bouts of atmospheric basking (Bury 1972a; Bury and Wolfheim 1973). Use of binoculars or spotting scopes is effective for locating and observing turtles in the wild (see Lindeman 1997, 1999a, 1999b). Basking counts have served as indices of relative abundance for the European Pond Turtle (*Emys orbicularis*; Lebboroni and Cecchini 2005), and Map Turtles (*Graptemys* spp.; Jones and Hartfield 1995; Selman and Qualls 2008, 2009). For these species, there were comparisons to turtles captured in traps or other methods. However, if only using basking counts, results should be used with caution.

Observations of Western Pond Turtles are often the preferred field technique for general assessment of occurrence (presence/not found). The VES survey is useful over large areas (for example, a river basin) or when there are limited budgets. Yet, this technique has limitations because of a lack of critical information on the times of basking by turtles under different temperature regimes. Also, the number of replicates and the duration of surveys that are used to relate visual counts to number of turtles occurring in an area or study site can vary among locations and make comparisons inaccurate at best. Thus, visual surveys for determining the relative abundance of turtles must be used with caution. In part, methods used for VES in the past have been inconsistent because of different survey duration, time of year, and number of replicates (Holland 1994; Germano and Bury 2001). Here, we attempt to provide better standardization and rigor of techniques and approaches used in VES.

Western Pond Turtles are ectotherms that rely on external energy sources to elevate and maintain body temperature during parts of their active season. They may engage in periods of atmospheric basking on logs or rocks out of water (Plate 5, Plate 6). During these periods, they are often visible. However, some turtles may avoid detection while basking. Small turtles are hard to observe in the wild and they may bask out of water only for short periods of time as they heat up rapidly. Turtles of all sizes may crawl out of water into thickets (for example, Willow [*Salix* sp.], Blackberry), where they are difficult to observe. Western Pond Turtles have keen eyesight above water and are especially sensitive to movement. They also have acute hearing and respond quickly to sounds. Because of these traits, the species is usually wary to approach and the number of turtles basking at a site may be underestimated in the wild. Lastly, turtles may engage in aquatic basking where

TABLE 3. Number of Western Pond Turtles observed and later captured by hand (snorkeling) in 3 pools in a tributary of the Trinity River, Trinity County, California (RB Bury, unpubl. data).

Pool	*n* observed	*n* captured (by hand)	Capture difference
A	21	25	+4
B	26	22	−4
C	11	8	−3

they remain submerged in warmwater areas such as hidden under algal mats.

PLANNING SURVEYS

It is best to plan field surveys to encounter turtles during times of atmospheric basking during their active season. Although the active season of Western Pond Turtles depends upon location (altitude and latitude), most turtles bask out of water from approximately April to September. Still, field surveys for turtles should be based on a determination of peak basking periods. Surveys should be conducted on sunny days between the hours of 08:00 and 12:00, sometimes to 17:00, but adjusted to local conditions. In areas with cooler temperatures, the hottest part of the day may be the peak time for basking. In locales with extended hot weather, such as the Central Valley of California, turtles may show a crepuscular pattern with minimal or no atmospheric basking during the hottest part of the day. Atmospheric basking may not occur in summer in hot climates such as the San Joaquin Valley, California.

The number of turtles observed during atmospheric basking may indicate the size of the population, but this relationship has not been well established. Earlier, Bury (1972a; RB Bury, unpubl. data) found that the number of turtles observed in pools in a stream approximated the number of turtles captured in the same pools by hand while snorkeling (Table 3). In the highest count (Pool A), a peak number of 18 turtles were observed one morning and 21 on the next day. Both observation periods were 3–5 h long and conducted from a nearby cliff (about 10 m high) over the basking site. An intensive hand search of the pool on the 2nd day after the basking period yielded 17 turtles (all removed to be measured and marked). Before release, the pool was checked again 2 h later and 8 more turtles were found (total = 25 turtles). At 2 other sites, slightly more turtles were observed than captured by hand (Table 3). At this study area, the microhabitats or hiding places used by the turtles were fairly well known as searches were repeated and intensive over several summers.

Cursory or single scans of a pool will likely underestimate the number of turtles present. Sometimes only a few turtles are observed in complex habitats such as a pool with many boulders and woody debris. Turtles may congregate in root wads or tangles of brush or Willow thickets along shorelines; yet few turtles may be spotted (RB Bury, pers. obs.). Often one will only hear turtles entering the water (splashing) and no counts are feasible. In such situations, the numbers basking are underestimated. This species is unusually wary of people and often departs from a basking site before an observer can get close enough for viewing.

In California's Central Valley, Germano and Bury (2001) found that the number of turtles seen during visual surveys was significantly correlated with the number of turtles captured in traps (Pearson's correlation, $r = 0.689$, $P = 0.0045$), but the relationship was not particularly strong (Fig. 8). No turtles were captured at 4 sites, which also lacked turtle sightings. Conversely, no turtles were observed at 2 sites but 2 and 10 turtles were caught. Six turtles were seen at another site but only 2 were trapped, whereas 10 turtles were seen but only 1 turtle was trapped at a 4th site. Low numbers of turtles were trapped ($n = 6$) at one creek compared to the relatively high numbers seen during visual surveys ($n = 17$); however, 40 were hand captured at this same site later in the summer.

Prior to establishing a VES in a new area, it is important to determine the basking peak times and microhabitats (for example, logs, brush thickets) available for basking. If mats of algae or other aquatic vegetation are present, turtles may surface on the top or in upper layers while remaining hidden. Look for heads just at the surface. This will increase the likelihood of relating numbers observed to the actual size of the population (for example, found by trapping or hand capture).

Surveys at sites in the Umpqua River basin, Oregon (RB Bury and R Sisk, unpubl. data), suggested a steady decline in the numbers of turtles basking as summer progressed, with a

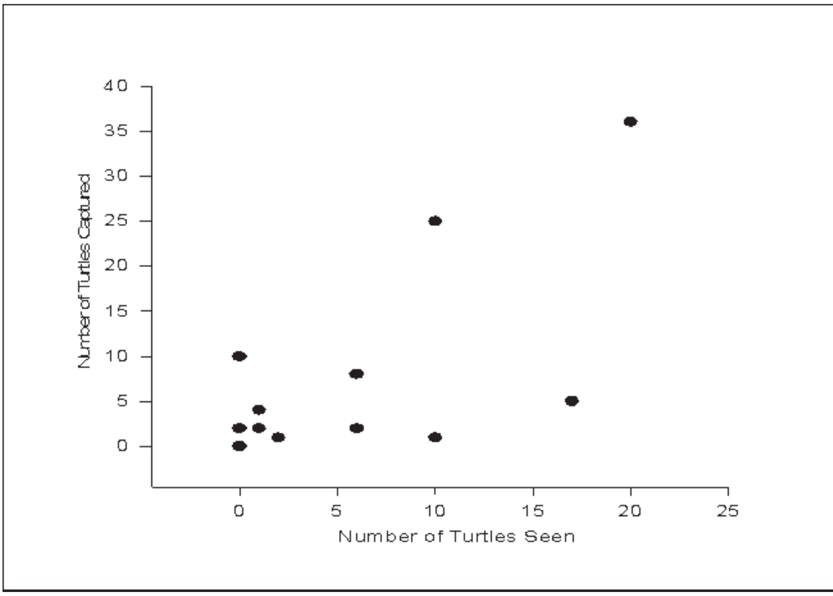

FIGURE 8. Number of Western Pond Turtles captured in traps compared to number previously observed at the same site. From Germano and Bury (2001).

slight increase as fall approaches (Fig. 9). In northern latitudes, it appears that the optimal season for observing turtles occurs earlier in the year at pond sites compared to river and stream sites (R Horn, unpubl. data). The observation period in areas such as the Sacramento Valley of California should emphasize early spring before the onset of high temperatures when turtles cease aerial basking. The best observation period will vary between drainages and between years. Time spent in atmospheric basking often decreases as summer progresses (for example, time to reach elevated body temperatures is less in higher ambient temperatures and warmer water lessens the need for aerial basking time).

Additional information from the Umpqua River basin in southern Oregon (RB Bury and N Sisk, pers. obs.; R Horn, unpubl. data) indicated that repeat visits during suitable survey times (that is, peak hours of basking in the late morning) and seasons can improve the accuracy of surveys. Data collected over 2 summers showed that 3 visits (2 wk apart) per activity season provide reasonably accurate and consistent estimates of the number of turtles basking at sites in rivers. The maximum numbers of turtles detected visually at 3 pond sites in the Umpqua Basin (R Horn, unpubl. data) was a consistent percentage of the population estimate from captures, ranging from 40.3% to 53.5%. Fewer replicates of VES underestimated the number of turtles present.

In southern Oregon, 35-min observation periods detected many turtles at pools along the Umpqua River (R Sisk, R Horn, and RB Bury, unpubl. data). Longer periods of observation at a site yielded few or no new turtles (Fig. 10). Less time tended to underestimate the numbers present, especially of juvenile turtles. We recommend that tests be conducted to determine optimal basking times (for example, 30 min or longer) at each area or set of sites. Further, it is important to spend 1 d each month observing turtles at 1 or more known sites to calibrate seasonal activity. It may be possible to use remote cameras (for example, time lapse) to record turtles basking, but we know of no one using such automated systems at this time. The visual survey data are best used to determine the presence of turtles. Attempts to correlate visual counts to population demographics such as density and age structure is not recommended as such features are only reliably determined by mark-capture studies.

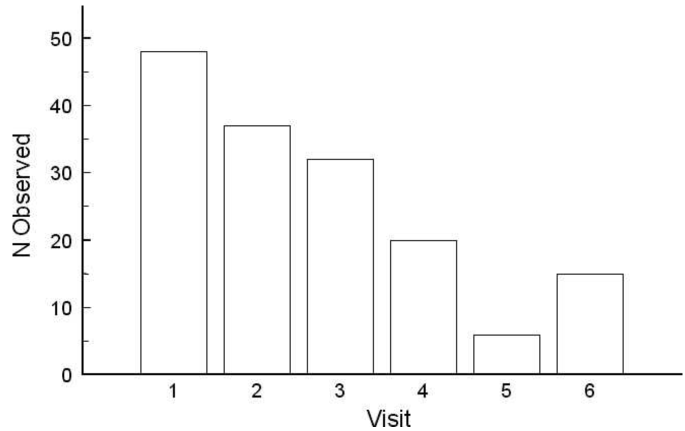

FIGURE 9. Total number of turtles observed at 60 randomly selected sites over 6 visits spaced at approximately 2-wk intervals between 12 June and 29 August 1997. Umpqua River basin, Oregon. From RB Bury and R Sisk (unpubl. data).

METHODS AND PROCEDURES

Personnel and Training

At least 1 member of the crew should have a background in wildlife biology or a related field and be a skilled wildlife technician with an understanding and appreciation of experimental design, survey protocols, and accurate data recording. All crew members need training with the survey protocol and in accurate data recording.

For consistency during surveys, the same person(s) should make observations. One person can conduct the surveys while the second records data. If multiple sites are to be surveyed, fatigue in observation can be alleviated if members of the crew trade off assignments between survey sites. If there is no 2nd person, data can be spoken into a handheld voice-activated recorder. As a safety precaution, if there is only 1 person conducting observations, that person should carry a 2-way radio or cell phone in case of an emergency.

Establishing Observation Points

Observations made at streams should be done after winter rains and spring runoff has decreased to allow for more stable water conditions. If possible, establish sites the previous summer or early fall and then sample the following year. If this is impractical, establish sites a day or more before surveys are to begin so turtles frightened off basking sites have time to recover from the 1st disturbance. Sample areas should be visited and marked to identify observation points for relocation. Record the exact coordinates of observation points by using a quality map or Global Positioning System and document how to relocate the point and how to minimize any disturbance when returning.

Procedures to establish observation points are designed to provide the surveyor with flexibility in selecting suitable locations (Appendices 1–3). This is necessary because strictly random selection of observation points is unlikely to result in the selection of appropriate sites for observation because turtles usually occur in clumps or aggregations related to basking, cover sites, and water depth (Bury 1972a, 1979). Once criteria for sampling areas are identified, then randomly or systematically select a number of observation points from a subset of those areas. In streams and rivers, select the first accessible location with suitable habitat quality that is at or downstream from the beginning point. The protocol for ponds is similar, with the sample area likely being the entire shoreline. Observation points should be selected from locations within the sample area that provides a wide view of the body of water. A small amount of movement around this point (10–20 m) may be needed to avoid obstructions and to fully view the sample area.

Observation points need to include physical features that will maximize turtle viewing opportunities. The availability of basking sites (for example, emergent rocks, logs) is probably the most important feature. In streams and rivers,

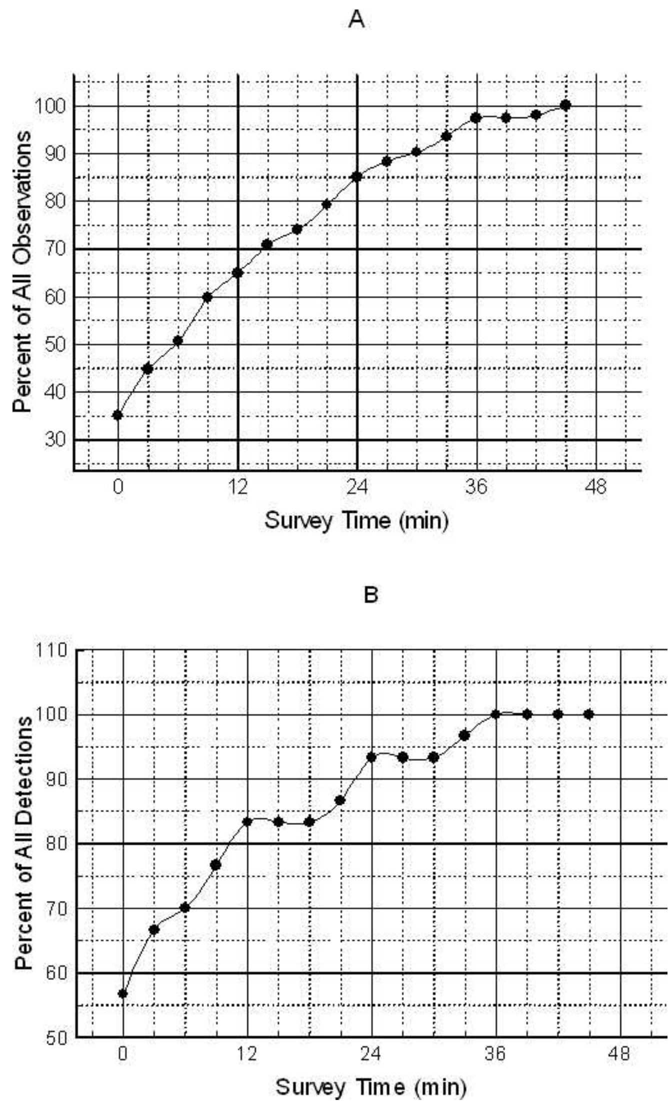

FIGURE 10. Proportion of turtles basking over 45-min visual surveys (n = 30 events), 12 June to 29 August 1997 (RB Bury and R Horn, unpubl. data). South Umpqua River basin, Douglas County, Oregon. A. Percentage of all turtle observations versus time. B. Percentage of turtle detections by site versus time.

observers should try to select observation points that overlook pool habitats. Although these turtles move through all types of stream habitats, most time is spent in deep pools or areas with heavy cover (Bury 1972a, Reese and Welsh 1998a).

Approach

A relatively short observation period of 15 min or less at each point may suffice to denote presence of turtles. This allows a greater number of points (shorter time period) per hour of field work. A large number of points could be recorded in special circumstances such as conducting surveys from a boat or raft while drifting down a river or stopping along roads at pullouts overlooking a stream or river (it is best to first check when inside the vehicle). The point counts and floating surveys can help establish presence of turtles and assist in determining basin-wide distribution patterns. The visual point surveys are relatively easy to establish and are broadly comparable between geographic areas.

One person using binoculars will observe for 15 min per site. Record the maximum number of turtles that is observed at any time, and record separately the adult and nonadult sizes. Record all information on appropriate data forms (Appendix 2). Each site selected for a survey will be visited until turtles are observed or for a maximum of 3 visits. Repeat visits to a site should occur at least 3 d apart and preferably a week apart. No trapping should occur within 1 wk prior to survey visits.

Once observation locations have been established, a subset of the sample areas may be randomly selected for more intensive surveys or studies. A more comprehensive visual survey (for example, 30 min per observation period) will provide more detailed population information: the number of individuals as well as estimates of sex and size classes, where feasible. However, visual surveys are most reliable to establish presence of turtles. In warm environs, visual surveys may underestimate or miss turtles because turtles seldom bask out of water. Record the maximum number of turtles observed at any time, and separate by adult and juvenile (<120-mm carapace length) sizes. To maintain consistency, one may survey each selected site 3 times per year (for example, in late spring, early summer, and late summer) for 2 y.

HABITATS

Lentic (Still Water) Habitats

Visual surveys of lentic (still water) habitats often require sitting hidden behind shrubs, trees, or other cover on or near pond and lake banks. Use binoculars to scan the water for basking or floating turtles. Suitable locations for conducting counts should be determined prior to the start of surveys. Find locations that afford the best view of potential basking sites, including protruding or floating woody debris, rocks or boulders, emergent vegetation, and overhanging vegetation that touches the water surface. Turtles will also use pond banks, especially where basking sites are not available.

Approach the location quietly. Listen for the sound of turtles plopping into the water. Look for turtle heads extending out of the water. Because water is relatively calm in ponds, it is often possible to sight turtles floating at the surface with their noses or heads protruding or upper carapace exposed. A turtle's nose and head look like a triangular, dark object emerging about one-half inch above the surface, and it takes practice to distinguish a head from the leaf of an emergent plant or small branch tip. Where turtles have received frequent disturbance, they often become wary and may not bask readily. On the other hand, Western Pond Turtles can become habituated to people in some situations (for example, in city duck ponds; RB Bury, pers. obs.).

Survey duration depends on the size of the water body. Sit for at least 0.5 h with as many potential basking sites in view as possible. Turtles that have been frightened into the water will show their noses or heads at the surface within about 15 min and will eventually crawl back onto basking sites if the observer is well hidden. If the entire water body is not visible from one vantage point, then survey from several stations, moving slowly from station to station. Visit each vantage point at least twice during the active season. Different basking sites are used at different times of day depending on sun angle, so make sure to survey from vantage points at the times of day when the associated basking sites are most sun exposed.

Lotic (Flowing) Habitats

Creeks are difficult habitat to survey for Western Pond Turtles. They must be surveyed on foot, which often causes turtles to hide. Creeks often are overhung with vegetation, making it difficult to find good shoreline vantage points. Visual surveys are not recommended in this type of habitat unless there are deep pools present. Still, field crews should work along creeks to check deep pools, still water, and sunny banks where turtles congregate in pools.

Visual surveys of rivers can be labor intensive because watercourses can be long, and a thorough survey requires visiting many pools or stations spaced along the watercourse. If there is a significant amount of river to survey, the most effective method is by kayak, canoe, or raft floating slowly downstream with binoculars raised, scanning the water margins and basking sites, and recording observed turtles.

A floating river survey is probably the most efficient survey possible per unit effort, because both banks are covered and there are virtually no gaps in river coverage. For streams with limited access from the bank, this method allows complete coverage. Randomly chosen beginning points may be established that can be repeated in subsequent years. However, the beginning and ending point will be dependent on river access locations. We recommend a minimum distance of 8 km (5 mi) for each reach floated to include a variety of conditions. Record all major areas with turtles, collecting the same data as in the 15-min surveys. The floating survey can also be used to survey lakes. River surveys may employ 2 methods: a motorized boat (electric is preferred) or human-propelled boat (for example, an inflatable kayak). The motorized boat may work best on lakes and large rivers and the inflatable kayak (or similar craft) may be more practical on smaller rivers. The floating survey and boat operation requires additional training, skill, and attention to safety compared to the point surveys that are conducted while on land.

Turtles are capable of learning and will see the kayaks coming and dive earlier each time, especially if they have been captured previously by crews working from boats. It may be worth camouflaging the boats or using boats that are not brightly colored. Turtles will jump off basking sites from as far as 75 m away, so observers should look far ahead. Turtles tend to be near shorelines simply because there are few midstream basking objects. It helps to have one person scan the right side of the river, while another scans the left side. Observers should float approximately 10 m from the shoreline.

Be sure to check side channels and backwater areas of rivers where turtles often concentrate in slack water. Adult turtles are often found aggregated around deep water near cover. Hatchlings and small young are usually found in the shallower water around gravel bars, but are difficult to observe from any distance because they are small, cryptic, and usually bask alone. However, they do engage in basking and can be spotted in shallows (RB Bury, pers. obs.).

SAFETY

Conducting research near or on the water has inherent dangers that may require the use of lifejackets, water safety training, boat handling training, and emergency communication planning. Prior to any activity near or on the water, it is essential to develop a safety plan specific to the conditions. For government employees, all personnel need lifejackets, water safety training, boat handling training, and an approved itinerary prior to conducting field activities near or on the water. It is the responsibility of the investigator to know the safety requirement of the agency they are working for and to develop a safety plan.

Any survey, capture, or trapping of turtles around or in water should take into account adequate safety procedures. General safety procedures, common to any work around water, include working in teams of at least 2 people and carrying radios or cell phones for voice communication, sound signaling devices such as whistles, first aid kit, lifejackets, and diver's knife. Workers should dress appropriately for the conditions including inadvertent submerging. Pre–field procedures should include first aid, water safety, and boat handling training, emergency communication planning, and site-specific hazard analysis to increase preparedness. If working on foot, footgear with good traction should be worn. Care should be taken when crossing streams. Select wide, shallow crossing points. If working in manually propelled watercraft such as canoes or kayaks, a US Coast Guard–approved personal flotation device must be worn at all times. Workers should be trained in preventing capsizing and what to do in the event of one. A dry bag to hold extra clothing and gear that cannot be submerged should be onboard, as well as a throw bag for buddy rescue and a bailer. Special care should be taken when using canoes or kayaks in rivers. Scout rapids ahead on land as much as possible. Fast currents, particularly in combination with rocks, logs, debris jams, root wads, or falls, should be avoided. Time periods of high river flow should also be avoided.

Additional safety procedures are required for working in motorized watercraft (*Department of the Interior Motorboat Operator Certification Course Student Reference Manual* [http://training.fws.gov/EC/resources/motorboat/pdf/Doimocc.pdf]). Snorkeling or diving also warrant additional safety concerns (see Chapter 5). Detailed safety procedures for working on foot in streams and rivers, including snorkeling, are given in Brenkman and Connolly (2008).

CHAPTER 5

SAMPLING OF TURTLES: TRAPPING AND SNORKELING

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INTRODUCTION

Capturing turtles allows for the assessment of many population parameters, including demographic structure, sex ratio, fecundity, morphometric variation, and individual parameters (age, growth, health, injury, diet, movement). Many of these important features are not feasible or are less reliable when derived from visual surveys (Holland 1994; Germano and Bury 2001), but are possible with animals in hand for accurate measurements (for example, exact shell length, identification of sex, age determination). Further, capture of turtles allows animals to be marked for future recapture, which allows for estimates of population size, individual movement, growth rate, survival, and longevity. Capture of turtles can also be used to validate or calibrate results from visual surveys. Turtle capture is usually accomplished by trapping or by hand, but it is only recommended when visual surveys do not accomplish the goals of the study.

Trapping is often the best technique to capture Western Pond Turtles (*Actinemys marmorata*) in ponds and other standing water, especially if abundant aquatic vegetation, poor water clarity or quality, or muddy substrates make other capture methods difficult or risky. In our experience, trapping is less effective in flowing portions of streams and rivers. Capture in flowing waters is generally best done by hand: walking along the creek and feeling under cover objects or snorkeling in larger waters. However, hand capture methods may

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introduce bias if search effort is not consistent between observers and habitats, and snorkeling can pose safety concerns for the surveyors. Even though trapping in rivers or streams (flowing parts) is generally ineffective, it may be the only option in situations where there is a lack of qualified divers or other safety concerns exist (for example, swift or murky water, obvious or hidden hazards, water quality).

Reliance on a single method may produce a biased sample from the target population (Plummer 1979). For example, Ream and Ream (1966) found different results in sex and size of turtles for 5 techniques of capture (also see Frazer and others 1990). This problem may be corrected by using a variety of sampling techniques to obtain turtles (see Bider and Hoek 1971; Plummer 1979; Vogt 1980; Congdon and Gibbons 1996). Timing of surveys can also introduce bias. For example, a proportion of the females in a given population may not be available for sampling by aquatic methods for some portion of the nesting season (when females are on land). Some researchers report variability in capture rate by life stage, sex, and species (Lagler 1943; Cagle and Chaney 1950; Ream and Ream 1966; Frazer and others 1990). It is time well spent to explore a variety of sampling methods prior to selecting one technique and to minimize any bias in the results. Lastly, investigators need to be cautious about reporting differences in sex ratios and sex classes unless they have obtained large sample sizes of turtles (see Bury 1979). Thus, we review several techniques and methods to capture turtles for studies and monitoring to improve the quality and value of one's efforts.

REQUIRED PERMITS

State scientific collecting permits are required to capture Western Pond Turtles in all states where they occur naturally. Traps must be clearly and durably labeled with the name of the responsible organization, contact name, phone number, and permit number. Investigators and workers must possess a State scientific collecting or study permit. Other permissions may be needed from federal agencies (for example, at units of the National Park Service or refuges operated by US Fish and Wildlife Service), state agencies (for example, state parks, state game management units) or from the landowner or manager.

TRAPPING

Trapping is best suited for still waters (lentic) such as lakes, reservoirs, ponds, or vernal pools, but is sometimes useful in backwaters or other slow-water portions of rivers and streams (Reese 1996; Germano and Bury 2001; Bury and others 2010). If used in flowing waters (lotic), baited traps should be placed with the opening facing down current so the drifting scent of the bait will guide turtles toward the opening. Traps can also be modified by the addition of drift fences to guide turtles towards and into the trap opening. Baited traps are effective at capturing all but the youngest age classes. Less used but effective under certain conditions are ''basking'' traps, which are constructed of floating wood or plastic tubes that trap turtles in a net basket when they dive off a basking platform. These basking traps can be hand-built or obtained through several commercial sources.

TRAP DESIGNS

There are many types and designs of turtle traps (Figs. 11–15), and most catch turtles (Plummer 1979; Bury 2011). The size of traps should reflect waters to be sampled and available financial resources of the investigator. A variety of turtle traps can be purchased from commercial fisheries suppliers (mostly in the eastern United States) and most cost US$40 to $100 each, with larger traps costing more. Alternately, traps can be constructed out of hardware cloth or chicken wire (Iverson 1979). Most work well, but we suggest having a combination available to adapt to local conditions. Although there are other trapping methods that have been used on turtles elsewhere (for example, eastern North America), here we describe types of traps that have been successful at capturing Western Pond Turtles (baited funnel traps, drift fence with funnel trap), each with various designs. All traps should be constructed with nonstretch fine-mesh netting (2.5-cm size), such that turtle appendages do not become entangled. Traps need to be constructed so that there are no loose areas or sharp edges (for example, traps made out of chicken wire) that could entangle and drown turtles or cause injuries. Special care is needed to ensure the top of the traps remain above water to allow captured turtles to surface for air (Bury 2011).

FIGURE 11. Two types of traps used to catch Western Pond Turtles. Top: Smaller version of collapsible trap with addition of bicycle inner tube zip-tied to outside rim to serve as a float. Bottom: Large hoop trap with wood spreaders and Styrofoam floats attached around spreaders.

Traps can be secured on top of a shoal or outfitted with reliable floats to keep a portion of the trap chamber on the surface to reduce the drowning hazard. Some turtles may become wary of traps after their initial capture (Tinkle 1958), but this may be rectified by changing type of bait. We advise a period of experimentation and field testing of type and number of traps, location, and other variables prior to establishing a survey effort. Trap types, materials, and costs are individual decisions. Experiment with types and settings to adapt to local conditions.

Funnel Traps

Most investigators trapping Western Pond Turtles use baited funnel traps (Germano and Bury 2001; Lovich and Meyer 2002; Rathbun and others 2002; Spinks and others 2003; Germano and Rathbun 2008). Collapsible traps can be home built, but most investigators purchase them. One of the most effective baited traps is a lightweight, small trap (about 0.6 m long) with funnels at one or both ends to allow easy turtle entry (Iverson 1979). These can be made by rolling a sheet of chicken wire or hardware cloth to form a 0.6-m long tube and wiring 2 pieces of mesh into funnels to attach to each end. The materials are cheap, but construction is time consuming and is hard on the hands, so wear gloves when building them. The round design can be flattened and easily pulled open in the field. Traps can also be formed into more of a rectangular shape, but these do not collapse as well. Rarely, turtles will get entangled in the mesh so traps need to be checked at least every 12 h. Also, semiaquatic mammals cannot chew out of these wire-mesh traps and may drown inside.

A similar design can be followed using nylon netting with a frame for support. These can be constructed of nylon mesh stretched between 2 to 4 hoops about 0.3 m in diameter. Materials can be purchased from net companies. An adaptation has been developed that uses polyvinyl chloride (PVC) pipes (sealed on each end with caps) tied along the outside of the trap. Hooks on the PVC pipes spread the hoops (resulting in taut netting) and the PVC tubes serve as flotation devices. Attach a dark- or drab-colored cord to the trap and tether to shore near basking objects.

An adaptation to the funnels could include use of a 1-way door because there is some evidence that turtles escape traps (Frazer and others 1990). One-way doors are used on commercial crab traps, but these have not been tested rigorously for use in trapping Western Pond Turtles. Frazer and others (1990) briefly mentioned that 1-way Plexiglas doors did not make any difference in escape rates of turtles in the eastern United States, and the use of 1-way doors on several traps at 2 sites seemed to hinder the capture of Western Pond Turtles (DJ

FIGURE 12. Commercial collapsible traps. Top Left: View of a moderate sized trap that is lightweight and portable. Top Right: Side view of large version. Bottom: Side-by-side comparison of mouth and funnel of traps. Bicycle inner tubes tied around outside of traps serve as floats (air added when in field). White twine on large trap shows areas where we mended traps in field.

Germano, pers. obs.). For the Red-eared Slider (*Trachemys scripta*), baited hoop traps appear to catch more males than females (Thomas and others 1999). If a female enters a trap, it may attract males. We have found no consistent difference in catch of sexes of Western Pond Turtles in baited traps (Germano and Bury 2001; Germano and Rathbun 2008; Germano 2010).

Commercial collapsible traps have been our favorite choice in recent years as they catch turtles well, are portable, and are reasonably low cost. Contact fishing supply companies that

FIGURE 13. Large commercial traps (see Fig. 12) without floats set in a pond where there is no concern for the trap moving.

specialize in nets. These traps are of various sizes and primarily used for crayfish and fish (Fig. 12). We have found that the moderate-sized traps (smaller one; Fig. 12) are highly effective for Western Pond Turtles. This design (model FT-D in some catalogs) is 70 cm long with a flat bottom (will not roll in water), and the dome-shaped ''roof'' (33 cm tall) allows turtles access to air. These traps are lightweight (approximately 1.5 kg), and relatively inexpensive (half the price of the larger size). Still, it is a small size overall and, if many turtles enter the trap, it may sink or be moved to deeper water. If you are concerned that the trap could move into deeper water, add a cord to the trap and tie it to something on shore. There may also be a benefit to having the trap set further into a pond (for example, to thwart predators or vandals). Add floats to the trap (Fig. 12), tie the cord to a solid object on shore (for example, tree trunk, vegetation, or a stake driven into the ground), and cast the entire trap out into a pond (for example, into an area with aquatic vegetation or next to branches).

A larger trap (95 cm long) with a higher dome (60 cm tall) and thicker rings is useful in deeper waters, such as lakes. Again, floats can be added but are not necessary in waters with shallow, sloping bottoms (Fig. 13). Additional floats can be made from 1-L empty soda bottles and put inside the trap as an added measure to ensure turtles can access air. These traps (model FT-FA) are moderately heavy (3.4 kg) and tend not to move once in place, such as on a shoal. Still, we always use parachute cord (doubled) or rope to tie the trap to the shore or to an upright stake in the water. In our experience (RB Bury, DJ Germano, pers. obs.), these traps may also catch semiaquatic mammals that can easily chew through the nylon mesh and some turtles that had been caught may escape.

Most commercial turtle traps are large sized (for example, 1–2 m long) and constructed of metal hoops 1 m in circular diameter. They are sturdy and durable (Fig. 11, bottom), but heavy: 2.2 kg without spreaders and 4.5 kg with spreaders. These hoop traps are best for large waters, and where invasive species may occur (as they capture Snapping [*Chelydra serpentina*] and Softshell [*Apalone* sp.] Turtles effectively because they have large mouth openings). Traps can be placed alone in shallow water (Fig. 13).

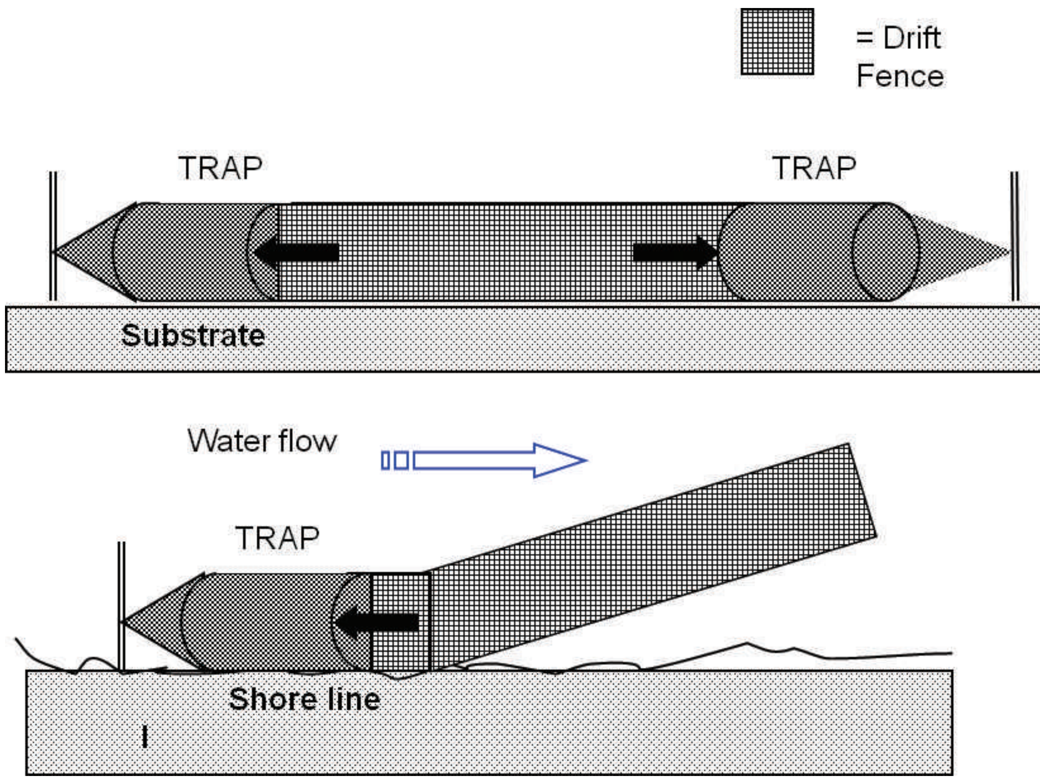

FIGURE 14. Two designs of drift fences and wings used to guide turtles into fyke traps. Top: Side view of drift fence stretched between two traps. Bottom: Slanted view of a trap with one arm serving as a drift fence. Black arrows indicate entrance into traps.

In standing water with a mud bottom, the turtle hoop trap is pulled taut by driving a stake in front through the front hoop or using cord to tie it to a stake in front. Then, a rope is tied to the back ''V'' area of the trap (which itself is tied in a big knot and used to access the trap) to another stake or to objects on shore, and pulled taut. We modified this system because traps sometimes need to be set in rocky substrate. We added wooden spreaders (2.5 × 3.5 cm; 1.5 m long). The netting must be taut for the mouth funnel to work properly. We attach the spreaders up the sides so the trap mouth will be underwater when the trap is floating. Large hoop traps from commercial sources are moderately expensive and can be cumbersome in the field because of their large size, long spreaders, and extra setup times. Further, they simply may be too large for many areas where Western Pond Turtles live.

Turtles can be attracted to traps by the scent of bait. The bait can be suspended in the middle of the trap either in a bait bag or tying string around the key of a sardine or tuna can. However, there appears to be no increase in catch over just placing the bait inside and on the trap floor (see Nall and Thomas 2009; DJ Germano, pers. obs.). For canned bait, perforate the can with small holes or open along one edge with a can opener to release the juices, but do not open cans all the way, as turtles or fish will eat the bait. To reduce expense in large studies, bulk baits (for example, fresh fish, raw meats) can be placed in bait boxes (for example, 35-mm film canisters, plastic bottles, or aluminum beverage cans with punched holes) or in wire mesh bags inside the trap. When emptying bait containers, pour off excess liquid in cans and then place them in a large plastic bag for disposal off-site.

Plummer (1979) stated that it is important to be open-minded and opportunistic in any collecting endeavor and suggested investigators experiment with several different kinds of bait on each population to determine the most

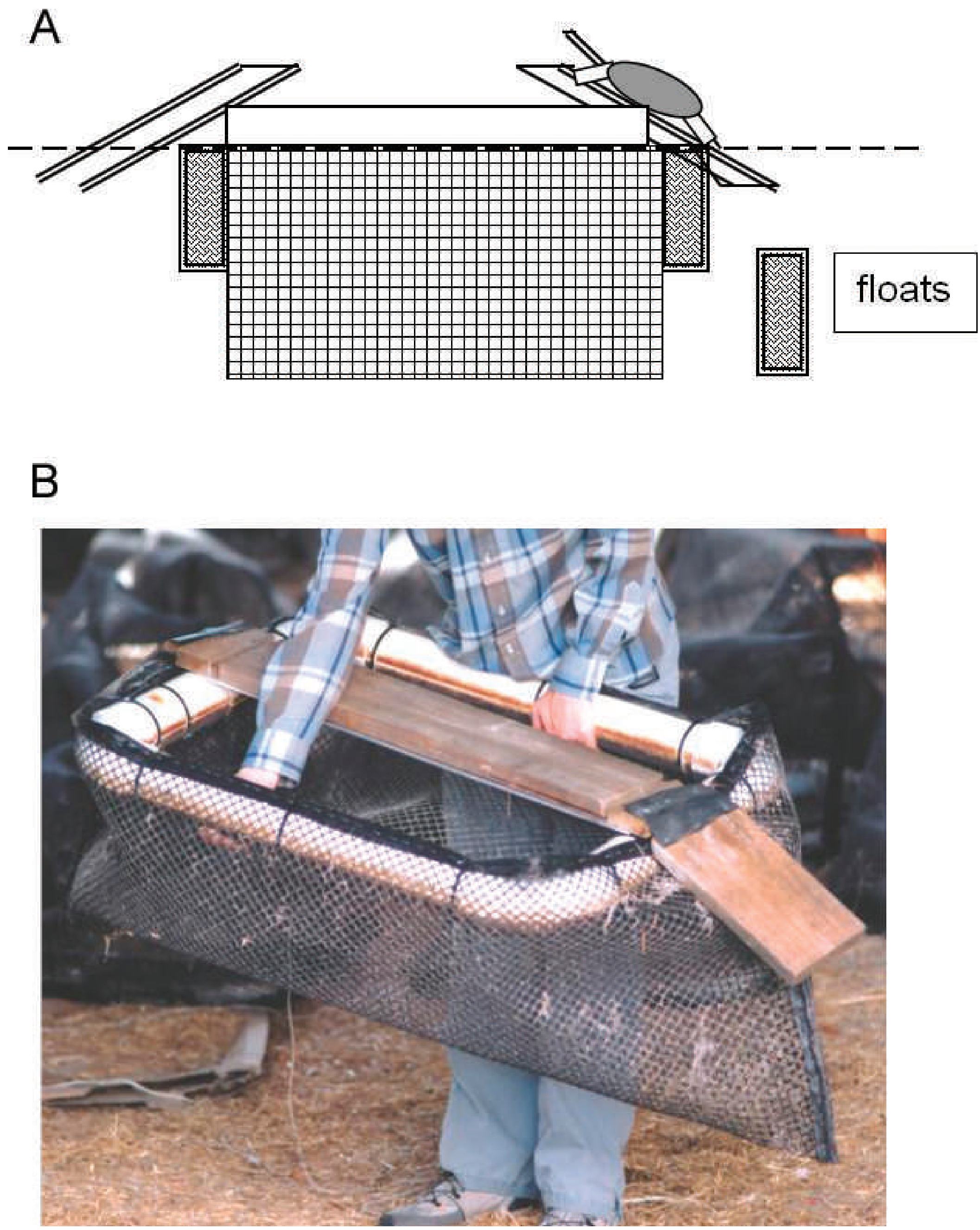

FIGURE 15. Top: Schematic side view of a basking trap that catches turtles when they slide or dive off end of ramps into the mesh trap. Smooth railing at top of trap prevents turtles from crawling out. Bottom: Picture of a basking trap. Photograph by Hannah Lucas.

attractive bait. Of 17 different types of bait used on aquatic turtles in Kansas, Voorhees and others (1991) had most success with bait with a jelly-like fluid: fresh mussels (freshwater) and canned creamed corn. Plummer (1977) found equal yield in catch of Smooth Softshell Turtles (*Apalone mutica*) in traps baited with fresh chopped fish or commercial dog food (sauce cubes), but turtles did not enter unbaited traps or those with bait more than 1 to 2 d old. Jensen (1998) caught most Alligator Snapping Turtles (*Macrocheelys temminckii*) with fish and most Red-eared Sliders with chicken entrails. Thomas and others (2008) reported that they caught significantly more Sliders (and Painted Turtles [*Chrysemys picta*]) in traps baited with frozen fish or canned mackerel than using creamed corn. Other baits used include fresh chicken, pieces of beef, or beef liver (Rose and Manning 1996; Spinks and others 2003; Thomas and others 2008). Although it is widely held that putrid baits are best to attract turtles, fresh baits are by far the most productive in traps (Lagler 1943; Tinkle 1958; Legler 1960; Plummer 1977, 1979).

Canned sardines in oil (no flavorings) work well as bait to catch many species of freshwater turtles (Legler 1960) and have been used to capture Western Pond Turtles (Germano and Bury 2001; Lovich and Meyer 2002; Rathbun and others 2002; Germano and Rathbun 2008; Germano 2010). We have also caught many turtles using cat food (salmon, tuna) or canned tuna fish in oil (RB Bury, pers. obs.). Fresh fish such as mackerel has been used successfully to attract Western Pond Turtles (D Holland, pers. comm.). Fidenci (2000, 2005) found that pieces of raw beef were superior to fish as bait in ponds he sampled in central California, but this appears to have been a special case. He pushed a wire through the bait and placed it in shallows, and then waited for turtles to bite the bait. He then grabbed turtles by hand. We have considered using earthworms (crushing a few to increase the smell) or small crayfish, which occur in many of the habitats of Western Pond Turtles. They readily eat these food items in captivity, but we have not used them for bait in the wild. While a number of baits have been successful in luring Western Pond Turtles into traps, there has only been limited testing to identify the preferred baits for Western Pond Turtles in different habitat types and seasons.

Drift Fence Traps (''Fyke'' Traps)

Drift fences may be used to increase captures in baited traps or can be used for trapping without bait. Two designs (Fig. 14) are effective under different field conditions. A mesh drift fence (for example, 1 m tall × 10 to 20 m long) with floats on top and sinkers on the bottom can be stretched tight across a pond or bay. Attach the ends of the drift fence to openings of turtle traps at each end of the fence. Pull the fence tight by driving in wood stakes at the rear of each trap. Turtles that encounter the drift fence are guided into the traps. This design was effective for turtles in Nebraska ponds (J Lynch, pers. comm.) and in the upper Midwest (Vogt 1980; Congdon and Gibbons 1996). A variation is a trap with one wing set at an angle from a trap at the edge of stream, river, or pond (Sexton 1959a). Turtles are intercepted as they move along the edgewater and the wing guides them into the trap. This design has been employed successfully for Western Pond Turtles in tributaries of the Sacramento River (G Lubcke, pers. comm.). Lastly, traps with wings can be set in rivers or deep waters. These traps may be 1.0+ m tall and 2+ m wide with long wings or drift fences (Vogt 1980). These have been used effectively to trap turtles in large rivers in the eastern United States (RC Vogt, pers. comm.) but, to our knowledge, have not been tested in western North America. These are likely not the best choice in most situations in western North America because they are expensive, bulky to haul, and require a relatively long time to set up and operate.

Basking Traps

Basking traps have been used with Western Pond Turtles with various degrees of success in California (Reese 1996; Fidenci 2000; Spinks and others 2003). Basking traps can be constructed with a floating frame of wood or PVC pipe and commercial fishnet or hardware cloth (metal) that hangs suspended from the frame (Fig. 15). They require no bait, but turtles need to crawl up ramps. The ramp can be designed as a treadle that can flip inward when a turtle moves over the trap but then drops back to its original position. Others have boards across the center of the trap and turtles fall into the trap when exiting. Often turtles require time to become accustomed to basking traps unless the researcher is able to work the trap around an existing basking site. If the trap relies on creating a new basking site, it may be more effective when the bottom portion is left open or no mesh trap is attached for some time. This allows turtles to become habituated to the presence of the structure. Attach the mesh portion of the trap when ready to catch turtles. Basking traps tend to be fairly large (for example, 1–1.5 m^2), and can be awkward to move.

Several designs of basking traps have been used to catch turtles in other regions (see Carr 1952; MacCulloch and Gordon 1978; Plummer 1979; Browne and Hecnar 2005). One is simply a wire mesh basket attached to the side of a basking station (for example, a log) used by basking turtles. Because the top of the basket is at water level, turtles can leave at will when the trap is unattended. When ready to catch turtles, a person startles or runs towards the basking turtles, which causes turtles to dive off into the mesh trap. Then one boats or wades out to the trap to remove turtles from the basket before they escape.

TRAPPING TECHNIQUES

Sample Methods

Selection of sites to trap may include random subsamples of the area that was used for visual encounter surveys, or areas where site-specific presence or demographic data are required. A subsample method is useful in areas where visual surveys indicate concentrations of turtles or where one wants to correlate the number observed with the number captured. It is also useful for the systematic gathering of data where Western Pond Turtles or other species of invasive turtles (for example, Red-eared Sliders, Snapping Turtles) are suspected to occur. The 2nd or site-specific method may be more useful to gauge abundance and trends in Western Pond Turtles. Trapping is also useful to monitor the efficacy of mitigation in project areas (for example, measures of turtles prior to and after a construction project). The trapping protocol here is offered as a consistent and repeatable method that may allow reliable comparisons between sites. We suggest relatively short bursts of trapping (1 or 2 nights minimum) with as many traps as are available. However, investigators need to experiment with methods that work locally or regionally. Instructions and advice provided here are only recommendations. Circumstances can dictate other densities, placements, and duration of time between to trap checks.

Trap Density and Placement

In general, we set traps about 10 m apart along shorelines. Trap spacing may be reduced to 5 m apart in areas of dense cover (for example, root tangles). We set a trap on each side of large objects such as a log or tree in the water, or several large boulders. In lakes or reservoirs, try to trap in 2 to 3 bays. If the number of traps is limited, apply a trap set in each bay in successive time periods and consider the entire effort to be 1 trapping replication (but account for recaptures if turtles move between bays).

Place the traps in or near cover and near basking sites (for example, floating logs, brush piles, vegetated shoals, rocky points) where turtles congregate. We set traps on each side of logs, keeping the trap length parallel to the object in the water. Set or toss traps into vegetated shoals (for example, Cattails, aquatic vegetation). In slow streams or rivers, place the traps upstream from basking sites within pools or in side channels or oxbows. Attempt to locate the trap in slow water near bank overhangs or in cover that creates backwaters. Traps should be securely anchored (as described previously). We make a field map of location of each trap, so that all traps can be relocated rapidly on the return visit and no traps are left behind.

We routinely set 6 traps (4 moderate-sized and 2 large-sized collapsible traps) in a small pond (Germano and Bury 2001; RB Bury and DJ Germano, pers. obs.), but we have not tested what proportion of each type achieves better results. On occasion, we also set out 1 large hoop trap, especially in urban areas where there may be introduced turtles (many are larger sized than Western Pond Turtles). Usually, there is insufficient time to cover large waters or many sites.

Replication

We recommend a minimum trapping effort of at least 1 night with 4 turtle traps (a trap set event) to increase the probability of captures. An additional trapping session is recommended 2 to 4 wk later. In some waters, most of the yield is on the 1st night of trapping. However, turtles may continue to be trapped over 3 d, perhaps longer. In general, we have found reduced yield the longer traps are set in small ponds, but we have seen no pattern in larger waters. Experiment with length of trapping sessions. Some turtles avoid traps once caught or, possibly, may temporarily emigrate from their site of capture. Recapture of these individuals may require a new bait type or different techniques (for example, traps with wings or snorkeling). There is no set protocol at this time for the number of traps or how many nights to set them.

Set and Check Times

Traps should be checked at least every 12 h (overnight set) and more frequently in the day to reduce the chances of turtle escape or mortality. Frazer and others (1990) found that during an experiment turtles escaped from traps much more frequently than anticipated. Over a 24-h period, 16 of 24 Painted Turtles and 2 of 8 Snapping Turtles (*Chelydra serpentina*) placed into traps escaped. Smith and Iverson (2004) reported daily activities based on traps checked every 3 h. Painted Turtles and 2 other species had peaks in midmorning (09:00–12:00) and most had high catch at dawn (06:00–09:00).

We found it best to set traps in late afternoon and evening (for example, between 16:00 and 19:00). We try to check traps 06:00 to 08:00 and this is consistently when most turtles are in traps (RB Bury, pers. obs.). We rarely find turtles after the morning check. In late afternoon or early evening, we check traps again and add a small amount of new bait or rebait traps, if bait is missing. Trapping is also successful with checks just in mornings (DJ Germano, pers. obs.).

To determine the catch per unit effort, record the time when traps are set and pulled. As an example, employment of 6 traps for 2 nights equals 12 trap-nights. Although checking of traps in less than 12 h may disturb turtles and lower the yield (Lagler 1943), traps checked and rebaited at 1- to 2-h intervals had a higher capture rate than did traps left for much longer periods (Legler 1960). However, checking traps this often can be impractical.

Disturbance

Disturbance by observers at sites could affect the capture success of turtle traps. Limit the amount of time spent in the water when setting and checking traps. Avoid having more than 2 people at the site and leave the area promptly once the traps have been set. Areas where recreational use is high should be avoided because traps may be stolen or vandalized. Sometimes recreational use is concentrated on weekends; therefore, trapping during midweek may be desirable at these sites. Attempt to camouflage traps and place them where they will be inconspicuous to humans yet accessible to turtles.

Theft of traps or contents is possible in areas where human activity is high. In these areas, it may be necessary to set traps and have 1 person watch them continually. Basically, run a trap line and stay in sight of all set traps. Traps occasionally yield turtles in relatively short periods (for example, 1–2 h in the evening or early morning). Sometimes, turtles will be attracted to bait set in shallow water and in relatively short time (Fidenci 2005). There is a trade-off between leaving traps unchecked and having turtles escape (Frazer and others 1990) or of disturbing turtles at the trap and immediate area by frequent checking of traps. Turtles vary in response to presence to people (for example, some turtles in city parks are habituated to our presence). Experiment with times of checking to maximize yield of turtles.

MORTALITY AND BYCATCH IN TRAPS

If a turtle found in a trap appears dead, remove it to a dry bucket and place in the shade. We have found 3 turtles (out of >3000 trapped) that had no movement or responses when removed from traps set overnight. We held the turtle with its head down, and pushed gently on its plastron to force any water out of the lungs. Gently push and pull on the legs to pump air into the lungs. Then, we placed the turtle in a safe area (where no predator can attack it). All of the ''dead'' turtles recovered in 6–10 h, but one took 20 h. The longest record was an adult female that started to move a little after 8 h but then fell limp again. We kept her overnight, and she was fully recovered when checked the next morning.

Turtles have remarkable ability to recover from anoxia (lack of oxygen). Turtles can remain underwater for extended periods (Ultsch and others 1984). Some species overwinter in ponds, but these areas are cold in winter and turtles slowly adjust to the change. During trapping surveys, however, water and air temperatures are relatively high. Survival of anoxic turtles rapidly decreases with elevated temperature. Still, our preliminary observations suggest high potential of turtles to recover from apparent drowning. If turtles do not recover, they should be kept for later disposition (for example, museum specimens, dissection). Preserve in the field (a task that takes 15 min or longer) or freeze the carcass.

Bycatch may result in mortality of species other than turtles. Although rare, turtle traps will on occasion catch fish. Checking twice a day reduces loss of fish. Few fish die in traps if checked frequently. Crayfish and bullfrog tadpoles may be taken in large numbers in certain situations. Mortality is rare. A caution is catch of belostomatid water bugs (flat body with large front claws) that may reach 90 mm long. These insects attack prey and kill them with a piercing (beak) mouthpart. They can inflict a ''bite'' that is more painful than that of a hornet or several at once (RB Bury, pers. obs.). They can usually be shaken out of traps.

In some water, a problem is bycatch of semiaquatic mammals (for example, Muskrat [*Ondatra zibethicus*], Nutria [*Ondatra zibethicus*], Mink [*Mustela vison*], River Otter [*Lontra canadensis*], Beaver [*Castor canadensis*]) that could enter a trap and drown. Otter and Beaver likely would destroy the trap while escaping. We have never trapped any of them. The other mammals appear able to chew through the nylon netting and escape, and we have not discovered drowned or hypothermic mammals in any nylon-mesh traps. Sometimes, Nutria and Muskrat drown or die of hypothermia in chicken-wire traps. Although Nutria is an invasive species and considered a pest, as is Muskrat in parts of California, the use of chicken-wire mesh traps was changed to mesh netting and no more were found dead because they chewed out of the mesh. Several traps had large holes that later had to be patched.

Investigators must operate traps in accordance with local, regional, or state fishing regulations (sometimes separate from scientific permits). Be alert to special rules for threatened or endangered species of fish or other aquatic biota in the trapping area. For example, trapping with long drift wings is not allowed in areas with migrating stocks of salmonid fishes. Some waters may be closed to trapping (for example, during runs of spring Chinook Salmon, *Oncorhynchus tshawytscha*).

HAND CAPTURE: ''MUDDLING'' AND SNORKELING SURVEYS

The purpose of hand capturing turtles is the same as for trapping: to determine population parameters and individual characteristics not measurable with visual surveys. Hand capture is usually employed in flowing waters where trapping would be inefficient or impossible. It can also be useful in standing waters.

To reemphasize, conducting research near, in, or on the water has inherent dangers that may require the use of lifejackets, water safety training, boat handling training, scuba and snorkeling safety, and emergency communication planning. Prior to any activity near, in, or on the water, it is essential to develop a safety plan specific to the conditions. Most federal and state agencies have established safety requirements for conducting field activities near water. It is the responsibility of the investigator to know the safety requirements of the agency they are working for and to develop an approved safety plan before sampling is initiated. Advanced planning is the key to keeping everyone safe during field activities.

''Muddling''

Turtles can be captured by wading through shallow water and feeling with your hands through algal mats, vegetation, undercut banks, under boulders, or other cover objects with your hands (Cagle and Chaney 1950; Bayliss 1975; Vogt 1981). This is termed ''muddling'' in the eastern United States (Cagle 1950), and it is usually done in ponds, lakes, or slow rivers. During muddling, your head and upper body are usually above water. Besides an agency-approved safety plan for working near or in water, there are special considerations that should be recognized for those working in eastern North America because of the presence of aggressive turtle species (Snapping Turtles [*Chelydra* spp.], Softshell Turtles [*Apalone* spp.]) and poisonous snakes in the water. This was not of concern in western North America until recent evidence of invasive species of turtles

(Bury 2008a). Besides biting turtles, there is also danger in cutting oneself on trash and debris in waters. Procedures to address hazards associated with muddling must be addressed in the safety plan before sampling is initiated.

Some researchers report this technique may result in a larger proportion of capture of juveniles than mature turtles (Cagle and Chaney 1950; Gibbons 1968; Moll and Legler 1971). Muddling may be useful to locate juveniles of Western Pond Turtles. In northern California, more juveniles were captured by hand searches of shallow areas than by setting traps or diving in deeper pools (Bury 1972a; RB Bury, unpubl. data).

Snorkeling

Free diving using a mask and snorkel is a specialized technique that appears to be the most effective technique to sample Western Pond Turtles in streams and rivers. The technique has been widely used to sample many populations (Bury 1972a; Holland 1994; Reese 1996; Reese and Welsh 1998a, 1998b; Todd 1999). Snorkel surveys depend on experience and skill, which can vary between divers and, thus, introduce bias. Therefore, comparisons between areas should be viewed with caution.

Emphasis on safety is extremely important when using snorkeling as a capture method. Prior to any sampling effort, the surveyors must be aware of the safety requirement of the agency they are working for and must develop an approved safety plan before sampling is initiated. Scuba and snorkeling are inherently dangerous, and most agencies require specialized training before these techniques can be used. Nobody should attempt to use these techniques who has not been properly trained and not met the requirements of the agency they are working for. In developing a safety plan we recommend that in addition to addressing the standard hazards associated with scuba and snorkeling, you also consider some of the potential hazards we discuss below that can be associated with conducting surveys to collect pond turtles. While we will discuss a number of potential hazards, this is not a comprehensive list. It is the responsibility of the investigator to conduct a thorough assessment of potential hazards and include the appropriate safety precautions in the safety plan.

All waters can hide hazards beneath the surface, but streams and rivers have the added danger of moving water. In a strong current, logs, branches, and boulders can form natural strainers able to trap and hold a diver. Many human-produced hazards may also be present, especially near bridges. Beware of barbed wire, broken glass, old cars, and other metal wreckage. Fishhooks and fishing line may be plentiful in some areas. Touch lightly under objects to avoid injury. Rope, wire, or fishing line, or even vegetation in the water can entangle a diver. The type of fins a diver uses can pose additional safety concerns when searching for turtles. Fins with vents or holes in them can hook on branches, trapping the diver by the fin. In even a moderate current, divers trapped by the foot may not be able to reach back and free themselves.

Constituents of the water can also present hazards. Microorganisms can cause ear infections, especially later in the season during algal blooms. Chemical contamination may present a serious hazard in some areas. Just because turtles are present does not mean the water is safe for humans.

There is danger of being bitten while feeling underwater for turtles. Although mammals (for example, River Otter, Beaver) occur in bank undercuts and other refugia. Be extra cautious if there are scat piles on shore (indicates presence of River Otter) or Beaver holes and cut trees and shrubs along waterways. We skip actively used entrance tunnels (for example, Beaver), often marked by fresh cut leaves and twigs.

Be particularly attentive when searching near or under large woody debris or boulders, which could roll or fall, trapping the diver. Before reaching under any object, push firmly against the object to ensure it is secure and will not move. If there is any doubt to the stability of an object or other safety concerns at a site, skip the site. Again, snorkeling should be employed only by skilled personnel and under the strictest of safety guidelines outlined and addressed in an approved safety plan.

Search Techniques

Developing search techniques should go hand in hand with developing the safety plan. The specific methods used to search for turtles may pose additional safety concerns that need to be addressed in the safety plan. In this section we describe some of the techniques we have developed to increase the probability of finding turtles during a survey. It is the responsibility of the investigator to include the safety procedures for implementing these techniques in the safety plan. The search method depends on the depth of the water and whether pools or riffles are being searched. In smaller streams and creeks we generally start at the lower reach of suitable habitat (for example, a pool in a stream) and systematically work upstream. Any stirred-up mud or debris will float downstream and out of your view forward (upstream). In larger rivers with stronger current, it is difficult for surveyors to swim upstream against the current and they may need to search in a downstream direction. Conducting searches in a downstream direction poses additional safety concerns that must be addressed in the safety plan.

Regardless of the direction of the search, divers search for turtles using both visual and manual techniques. First, check visually under objects and then do a tactile search with your hands in crevices. For deep pools, search basking sites and the surface of the water for the heads of turtles; if they are observed, dive where the turtle was last seen and feel for the turtle. Search bank undercuts or under large boulders or rocks. You will need to use your hands to search in many places because stirring up sediment will reduce visibility. Use a slow ''windshield wiper'' arm motion to feel for turtles in vegetation or mud.

Divers can walk shallow riffles and search under hummocks with their hands and visually search into the water. If deep enough, it is usually more effective to float or crawl through riffles and probe with your hands rather than walking upright and bending to reach under objects (RB Bury, pers. obs.). This allows for a longer reach under objects and into crevices. Slowly push your hands into root tangles (for example, Willow [*Salix* sp.] roots) because many turtles hide in these thickets; sometimes the water will be shallow (for example, <0.5 m). Be sure to check side channels, oxbows, and backwater pools because juvenile turtles will often be found in these areas. In rivers or large waters, divers need to scan ahead when underwater looking for turtles in open water; then search crevices, under rocks and logs, in woody debris piles, and through root wads and aquatic vegetation. Turtles congregate in large numbers in some sites, and a population can be underestimated without rigorous search of habitat for these ''hideouts.'' We have found several such hideouts by following radio-tagged turtles.

Surveyors need to use extreme caution when reaching into and searching around debris and undercuts due to the potential of becoming entangled or trapped. The safety plan should address methods to prevent these types of emergencies, as well as procedures that can be implemented if an emergency situation arises. Only properly certified and trained personnel should be involved in these types of surveys.

Above water, turtles appear to have keen senses of hearing and vision. Basking turtles may jump in the water when they spot a person as far as 100 m away (D Reese, pers. obs.). Divers can sneak up on basking turtles by approaching from underwater and then reach up and grab the basking turtle or watch from underwater while creating some disturbance on the surface, causing the turtle to dive off the basking site into the view of the diver. This technique can also be used to help train new divers. By watching underwater while turtles are seeking cover, the diver becomes more aware of the types of places where turtles may hide.

Underwater, turtles appear to be less wary than when basking (D Ashton, RB Bury, pers. obs.). A diver can often approach within a few meters of a turtle without being noticed. When a turtle does notice the diver, it may freeze in place, flee by swimming, or cover itself with sand and silt. When a turtle is first observed, the diver should notice its position and general behavior (such as basking, active, stationary in underwater refugia) before capture. Capture the turtle and hold onto it for a minute, scanning the immediate area for other turtles before taking animals to measure. Often there will be more than 1 turtle in the immediate vicinity, usually within a few meters.

Reese and Welsh (1998b) developed a standardized sampling protocol to compare Western Pond Turtle populations from 2 forks of the Trinity River in northern California. Their method involved divers searching each side of the river and used hand signals to communicate. The teams started upstream of the survey area to avoid disturbing the area prior to diving. Divers moved downstream with the flow, keeping aware of the other team on the opposite shore while searching the underwater area from the bank to about 4 m out (the feasible search area for a diver floating downstream). To avoid biasing the search effort, both dive teams moved at a similar pace, applying a consistent search effort across all habitat types, including backwater pools, islands, side channels, and marshy banks. Once divers captured a turtle, it was given to a team member who recorded the location of capture, time of capture, specific data about the turtle, and other factors that could affect turtle activity, such as weather, water conditions, human disturbance, and evidence of predator activity. The turtles were released at the point of capture after being measured and marked. Several different habitat types may be present in an area, and backtracking may be necessary. For example, when side channels are long, divers may want to return to survey them after surveying the main channel. Reese and Welsh (1998b) also described methods to survey vernal pools, ponds, oxbows, large backwater pools, and wetland habitats for turtles. The number of divers needed depends upon the size of the habitat being surveyed and the number of divers and support personnel to safely conduct the work.

Regardless of capture method (trapping or hand capture), handling of turtles should be limited to that needed for assessment, measurement, photographs, and marking. Minimize time turtles are held and be sure to not crowd them in buckets or totes. All work should be part of a designed and permitted survey or study. Prior to attempting capture, become familiar with the field procedures for proper handling of turtles and standardized measurement techniques (see Chapter 7).

CHAPTER 6

SPECIALIZED SURVEYS: NESTS, HATCHLINGS, AND YOUNG

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INTRODUCTION

Nesting surveys are useful for determining where female turtles are depositing eggs as an indication of potential areas for recruitment of hatchlings into turtle populations. Surveys can also assist managers in making informed decisions on land use or human activities in areas with turtles. This information is important when managing for the viability of a relatively long-lived, late-reproducing species like the Western Pond Turtle (*Actinemys marmorata*), especially as human development expands. Even when physical habitat remains intact, predation on turtle nests can be high, so the presence of nests alone does not necessarily imply successful recruitment. Other threats to nests and hatchlings include flooding of sites and a loss of connectivity between nesting and aquatic habitat (Holland 1994; Hays and others 1999). A synopsis of reproductive biology and nesting behavior was presented in Chapter 2. Here, we present information for conducting nesting surveys.

IDENTIFICATION OF POTENTIAL NESTING HABITAT

Nesting habitat may be the most specialized habitat requirement of Western Pond Turtles, but the location of potential habitat areas can be difficult to delineate as nests are well camouflaged and difficult to detect visually. Nesting areas may be limited due to natural scarcity of suitable habitat features in the vicinity of aquatic habitat, as well as habitat loss. Suitable nesting habitat is characterized by open areas with southern exposure and substrates soft enough for nest excavation.

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TABLE 4. A general suitability index for nesting sites of the Western Pond Turtle (after Holland 1994; Holte 1998).

Habitat feature	Nest potential		
	High	Medium	Low
Aspect/exposure	S, W, SE, SW	NW, E	NE, N
Size of clearing	>10 m^2		<10 m^2
Vegetative cover	Short grass/herb	Long grass/herb/shrub	Shrub/tree
Soil	Clay/hard/silt		Sand or rock
Slope (%)	0–30	30–60	60–100

Although Western Pond Turtles are noted for nesting 1 km or more from water (Storer 1930), most nests occur within 50 m of water's edge (Rathbun and others 1992; Holland 1994). To identify nest sites in an area, begin at the landscape scale with aerial photos or Internet maps (for example, satellite views) and work your way down to site surveys that are conducted on foot (or on hands and knees). Using aerial photos at a scale of 1:12,000 or larger, identify and map all nonforest or open habitats ($\leq$10% tree canopy closure; with a significant open, grass, forb, or shrub vegetative component) within 100 m of an inhabited water body. Smaller-scale photos such as 1:24,000 may not provide sufficient detail for identification of potential habitat. Images from landscape maps and Geographic Information System (GIS) sources available over the Internet may be helpful tools for locating potential nesting areas in some areas.

Assign a reference number to all potential nesting areas that require field surveys and then enter the location parameters into a GIS. This will assist in providing a permanent record of sites surveyed or those that need surveys. Complete site numbers are most informative if they include Universal Transverse Mercator coordinates and a unique site identifier.

Prior to nesting season, visit sites to determine potential for turtle nesting based on key characteristics (Table 4). If time is limited, eliminate sites with low nest potential (for example, high canopy) from the field surveys. Attempt to concentrate efforts in areas near suitable aquatic habitat (for example, pools with basking sites) or known high concentrations of turtles. Document your findings on a Nest Search Form (for example, Appendix 2) and photograph the area.

Nest searches need to be conducted during the nesting season. Cues of intact nests fade quickly. Intact nests are well camouflaged and can be difficult to find, although recent nests can have a distinctive appearance for a few hours, up to a few days. The herbaceous vegetation at the nest is typically flattened in the approximate size and shape of a turtle (10–15 $\times$ 15–20 cm). If it is a recent nest, it may still be moist. The soil within or immediately adjacent to this area is disturbed and a clod of mud or dried soil (30–80 mm in diameter), often containing vegetative fragments, plugs the neck of the nest chamber (Fig. 16). Beneath the nest plug, the cavity opening is circular or ovoid (35–45 mm in diameter) and the nest chamber is 80 to 110 mm deep and shaped like an inverted lightbulb or pear (Bettelheim and others 2006). There may be false scrapes (shallow holes or depressions with no eggs deposited) or evidence of predation (excavations with shell fragments) in the vicinity.

SITE VISITS AND MONITORING PERIOD

Knowledge of local nesting times of turtles is needed prior to conducting nest surveys. Presence of eggs in females can be determined through radiographs (Gibbons and Greene 1979; Hinton and others 1997) or palpation in the inguinal cavity, which is done by inserting a finger into the space in front of hind legs on both sides at the same time (see Chapter 7). Recently, Scott and others (2008) palpated a set of turtles 5 or 6 times during a season, and even turtles that laid 2 clutches would lack noticeable eggs on 2 or 3 of these occasions. Eggs are generally detectable for a few weeks, so nest surveys targeted too early or too late could miss the nesting season.

Considerable variation in timing of nesting among individuals, sites, and years is common. In the northern portion of its range (for example, Oregon), nesting is usually from late May through July with peak activity occurring

FIGURE 16. Nests of the Western Pond Turtle. View of nest chamber and removed eggs of Western Pond Turtle that were dug up by a predator. Ahjumawi Lava State Park, Shasta County, in northern California, June 2006. Photograph by California State Parks.

in June (K Beal, pers. obs.). This is consistent with timing of nesting in Trinity County, northern California (Reese 1996). On California's central coast nesting movements have been documented from late May to early August. At Goose Lake in the San Joaquin Valley of California, females start producing clutches of eggs in late April (DJ Germano, unpubl. data), so nesting may start as early as early May. Double clutching has been documented in California (Goodman and Stewart 1998; Lovich and Meyer 2002; Germano and Rathbun 2008; Scott and others 2008) and Oregon (Holland 1994; K Beal, unpubl. data).

Three or more visits to potential sites are often needed to find evidence of nests. The 1st search period may be between 15 May and 1 July in northern latitudes or starting 1 May in southern parts of the range. Nest searches should be conducted during morning or early afternoon hours (08:00–15:00) to avoid possible disturbance to nesting turtles, which mostly start moving overland in the late afternoon and evening hours (Holland 1994; Holte 1998). Early morning searches increase the chance of finding nests where the plug is still moist, providing a useful visual cue. Early morning searches also increase the chance of finding spent females returning to the water.

On some substrates, tracks may be followed back to the fresh nest site. If you encounter a turtle at a nest site, place a marker near the turtle and walk away making some noise (F Slavens, pers. comm.). Gravid females on their way to nest will have a full bladder and eggs. The bladder contents are used to soften the soil prior to nest excavation. Females that have recently completed the nesting process often have mud caked on their anal shields, hind feet, and legs (Holland 1994). Nesting often occurs in the evening, with females usually moving to the nesting site in the late afternoon or early evening and returning to the water by early morning. Some female turtles make several nesting forays over days or weeks before depositing eggs (Rathbun and others 1992; Reese 1996). When conducting nest surveys, it is wise not to carry anything that may attract predators (for example, food or substances that might leave an odor).

Locating nesting areas depends on finding recent or hatched nests, or most likely, evidence of nest predation. Most nests that we find are those that were dug up by predators. These are uncovered (plug missing, hole dug out), often with eggshell fragments present. They may also appear as shallow depressions. Turtle eggs can be distinguished by soil caked on shell fragments, unlike those of ground-nesting birds, which are cleaner. Preyed-upon turtle eggs often have irregular fragment sizes with holes and broken edges pointing inward, and soil disturbance at the nest. Eggs that hatch naturally appear to be cut across their circumference from within, and there is minimal ground surface disturbance around a nest where hatchlings have emerged naturally.

Surveyors should search potential nesting sites for nest-like depressions in the ground.

Nests usually occur in clusters due to nest-site fidelity by females or limited availability of nesting habitat, so surveyors should carefully inspect the area for other nests after one has been found. All nest locations should be marked temporarily with surveyor flags while an area is being searched, so that active nests are not disturbed and information is not destroyed. Eggshell fragments should be excavated from inactive nests and attempts made to determine approximate clutch sizes from each nest.

A 2nd visit to nesting areas should occur between 15 June and 15 July. These visits are needed because recently excavated nests are more readily located compared to older nests. Also, additional visits assure that nesting is not continuing into the summer. Whether nesting is detected or not, complete a Nest Search Form (for example, Appendix 2) and describe the number and characteristics of any nests detected.

SEARCH GRID

A nest surveyor can cover a large area quickly by walking a 3-m-wide grid and visually searching for nests. Clearings and open areas can be more intensively surveyed using an Enhanced Nest Survey, where one walks a grid block (1-m^2 grid size) and carefully searches for nests. These often are done in areas (for example, a flat bench above flood zone of a river) where some nests have been dug up by predators. Still, efforts are best conducted by experienced surveyors who have developed a search image for intact nests.

INTACT NEST SEARCH

To locate a nest, gently poke and prod the ground at potential nest sites with your fingers, a small knife, or a stick. If you are able to uplift or dislodge a ''clump'' of soil somewhat circular in shape, it may be the nest plug. Do not remove the plug and be careful to keep it intact and replace it exactly as found. Do not excavate or further disturb the soil. Evidence of previous years' nests or depredated nests (Fig. 16) is also a good indication that there may be intact nests present in an area. However, one needs to be cautious in thinking that all the nests are located by predators. Those nests that escaped predators are also the same ones that are seldom located by surveyors. Thus, counts of nests dug up by predators are an unknown fraction of the total nesting effort in an area.

MAP AND MARK NESTS

For comparisons of annual nest locations, nests should be accurately mapped and marked on the ground. Field flagging should be offset and discrete to prevent predators (for example, Coyotes [*Canis latrans*], Raccoons [*Procyon lotor*]) or humans from learning the location of nests. One scheme places marker flags at 1 m northwest of the nest (C Haws, pers. comm.). Previous research showed no change in mammalian predator attraction to turtle nests with flag markers (Tuberville and Burke 1994), but some predators learn routes of investigators. For the Enhanced Nest Survey, overlay a 10-cm grid on the block grid (each 1 m^2) and map the location. Establish a reference point by using a compass and meter tape to mark the nest on the ground. Document any necessary deviation from the reference point distance or azimuth.

LOCATING HATCHLINGS AND YOUNG

Juvenile and hatchling turtles are rarely found during most surveys because they are small sized (25–70 mm long), sedentary, and cryptic. Both newly hatched turtles and young turtles in the water are usually not captured during trapping and snorkeling procedures (see Chapter 5). To locate hatchlings or young turtles, intensive search with a separate set of techniques is required in microhabitats other than those used by adults.

On occasion, hatchling turtles may be found on land using the same techniques as described for nest searches, as they are often found in the nesting area directly after emergence. Timing is essential in finding these newly emerged turtles. Hatchlings often overwinter in the nest in northern populations, and usually emerge in late winter or early spring (Holte 1998; Buskirk 2002). Emergence dates from nests in the Willamette Valley, Oregon, range from 25 January to 24 March (Holte 1998; K Beal, pers. obs.). Emergence in the fall has also been documented (Storer 1930) but does not appear to be common (Buskirk 2002). We know little about times of emergence from nests across the range of the Western Pond Turtle.

Searching for hatchlings can be time consuming, and may be dangerous to them. Hatchlings are small and cryptic in color so searching itself might jeopardize hidden hatchlings (for example, by being stepped on). For example, hatchlings have been found buried in the grass or duff inside the wire cages used for predator exclusion (K Beal, pers. obs.). Hours to weeks after emergence from the nest, hatchlings leave the nesting area and, presumably, move to suitable aquatic habitats. Young turtles tend to seek warm, calm, shallow waters. Hatchlings show up in shallows of rivers, streams, and other waters in late spring (Hill 2006). On occasion, they can be spotted basking at the edges of quiet waters. Some have been found by walking slowly along the edges of waterways; they may be sitting in the shallowest pools or hidden under small pieces of cover (RB Bury, pers. obs.).

Like hatchlings, other young turtles also tend to occur in habitats off the main channel of rivers such as tributaries, ponds, puddles, and marshes as well as other small water bodies with slow or still, shallow water, and emergent vegetation. These sites must be searched to increase detections of younger turtles. Small turtles often occur alone, which is different from the aggregations of adult turtles that occur in some situations (see Chapter 2). Small turtles often seek the cover of mud, vegetation, leaves, debris, or rocks along the shoreline, in or at the edge of the water.

There are several approaches to catching young turtles in the water. One technique is to establish a transect (for example, 1 m wide and 20 m long) along the shallows of a stream, and then attempt to turn over every cover object. A potato rake or other small rake, used gently, can greatly aid the number of cover items one searcher is able to turn. Albeit preliminary, we find approximately 1 small turtle per 35 m^2 of area or 1 h of search effort (GW Bury, RB Bury, pers. obs.). Still, we do not know the effectiveness of these intensive searches in shallow habitats (that is, detectability) and that can be improved using mark-recapture techniques. Other strategies to determine presence include using minnow traps in shallow water, floating near juvenile turtle basking sites in a boat, and hand collecting by searching under larger rocks (basking sites) protruding out of water in shallows.

Thus, we seldom know if few young turtles in populations represent a lack of recruitment or our failure to adequately locate and count them. More research on early life stages of turtles is critically needed. Considering the difficulty of finding hatchling turtles, it is not surprising that little has been published on their ecology and habits. Future studies must be done with care to avoid harm to turtles or habitats. Further, we need to realize that an accurate survey of juvenile turtles will require intensive effort and a separate set of methods from those used for adults. They merit special methods of mark-recapture and attachment of radio transmitters. Without these efforts, little can be concluded about the life history and relative abundance of younger turtles.

CHAPTER 7

FIELD PROCEDURES

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PERMITS

Western Pond Turtles (*Actinemys marmorata*) are protected in every state where they occur naturally, and in Baja California, Mexico. A scientific research permit from each state or appropriate Mexican government agency is required prior to capture or study of Western Pond Turtles. In California, an additional memorandum of understanding is required to work with Western Pond Turtles and a notice to conduct a study (with permit numbers) needs to be sent to the closest regional office of the California Department of Fish and Game prior to initiation of any work. All states require a

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detailed study plan. Anyone applying for a permit must ensure proper training is provided to all persons who will assist in field efforts. Further, special permits are required on certain federal lands (for example, national parks) and other areas (for example, state parks, private timber lands). Always check first with the landowner before initiating a study or survey.

PROCEDURES AND PRECAUTIONS FOR HANDLING OF TURTLES

Field Guidelines

Handle turtles as little as possible. Investigators may wear disposable nonlatex or rubber gloves when handling turtles to prevent the transmission of disease. It is useful to have 2 people present during handling because it allows one person to hold turtles and take measurements while the other records data. Hold the turtle firmly by the shell and use both hands whenever possible. Western Pond Turtles rarely bite, but they have sharp claws and often struggle to free themselves. Turtles often urinate or defecate when handled, and they emit a musky odor (easily removed later with soap and water). They may scratch or cause abrasions, but handlers must hold turtles firmly and not drop them. Complete any measuring, marking, and release of turtles in an expeditious manner. Usually, turtles should be released within a few hours of capture. Do not retain turtles beyond the day of capture unless necessary for a permitted study.

Turtles should be kept in containers with high sides, such as 5-gal plastic buckets or 10-gal storage tubs. Place a lid or piece of cloth over the top to darken the container. Put only about 2 to 5 cm of water in the bottom so all turtles can reach air to breathe. Keep captured turtles out of direct sunlight because overheating is possible in a short time. Separate large and small turtles to avoid injury to smaller individuals and ensure smaller turtles can reach air. Some investigators place only 1 turtle in each container (K Beal, pers. obs.). Return and release all turtles at the point of capture after measuring and marking are complete.

Equipment Sanitation

Care should be taken to avoid the introduction of disease or spread of introduced species while conducting surveys and handling Western Pond Turtles. Thus, equipment must be thoroughly cleaned and sanitized when moving between basins or study areas. Clean equipment daily at end of sessions. If there is a suspected die-off or disease at a site, you should be even more cautious, including use of disposable plastic gloves and thoroughly cleaning equipment before moving to another site or a later revisit to the same site. Several solutions are available for sanitizing equipment to help reduce the risk of spreading organisms and diseases; and some can also be used on turtles to treat wounds:

- 2% Chlorohexadine solution is useful for sanitizing equipment and hands (T DeLorenzo, pers. comm.). It is commercially available under the name Nolvasan® from veterinary supply houses. Dilute at a ratio of 1 oz. per gallon of water for soaking wetsuits, traps, and other equipment. Nolvasan can be used directly on turtles to clean wounds or fresh carapace notches, but care should be taken to avoid mucous membranes.
- Betadine® (10% povidone iodine) also works well for sanitizing marking equipment, wounds, and hands (D Holland, pers. comm.) but is not recommended for use on wetsuits.
- Quat-128 is a veterinary disinfectant that works well for all equipment, but we do not recommend it for use directly on turtles. Quat-128 is available from janitorial supply houses (''WAXIE'') in 1-gal jugs. Dilute to 1:60 with water to produce a ''double-strength'' solution (the label calls for a 1:128 dilution for regular strength). It can be mixed on-site, but fill containers with water first then add the Quat-128 to avoid excessive foaming.
- Bleach is often used to clean equipment. Closely follow instructions to properly dilute bleach; many people use too strong of a solution. Metallic and plastic equipment can be soaked in a 5% bleach solution for 10 to 20 min, but bleach will deteriorate textile equipment (wetsuits, waders), and should not be used on hands or turtles.

A large plastic tote is useful for dipping equipment. Sanitized equipment should be rinsed with clean water prior to being used on turtles. Clearly labeled spray bottles of different sanitizing fluids can be useful in the field, but used fluids should be considered chemical waste and disposed of properly (that is, in a drain that leads to a wastewater treatment plant). For some projects, especially where disease outbreaks are suspected, it may be prudent to buy separate sets of field gear to be dedicated to those specific sites. Even these should be cleaned between visits or daily to reduce reinfection of sites.

While in the field, turtle traps need to be cleaned of all animal and vegetative material. One can usually shake off most vegetation. Then, set in the sun (ultraviolet-B exposure) or clean with disinfecting solution. We have found it efficient to take traps to a commercial carwash to use power nozzles to knock off dirt and debris. Then, wash with soap and hot water, and spray well with clean water. Wash traps near the field site and not when back at your home facility. Thoroughly dry traps before their next use. Such cleaning is increasingly important due to the potential to spread Zebra Mussels (*Dreissena polymorpha*), Quagga Mussels (*D. bugensis*), and other invasive species in western North America.

Sick or Injured Individuals

Surveyors may come across sick or injured turtles in the field. When people know you are working with turtles, they may bring you sick, injured, or orphaned turtles or call for advice about them. Parasites and bacterial infections are relatively common and contagious in turtles, so it is imperative that infected turtles never be housed with other turtles. Ethically and biologically sound procedures to treat sick or injured turtles are not always available, and these individuals may need to be taken to a rehabilitation center or a veterinarian. A veterinarian should euthanize severely injured animals.

State laws make it illegal to keep Western Pond Turtles as pets in California, Oregon, and Washington. Unfortunately, some Western Pond Turtles are still collected as pets or for food consumption. Captive turtles may escape and can be found in residential neighborhoods or may enter new watersheds. These ''orphan'' turtles may appear healthy and it might be tempting to release them in an area with other turtles. However, these translocated turtles may introduce disease into other populations. Orphan turtles should be reported to the state fish and wildlife agency. You may be required to surrender the animal if release is not a viable option, or they may provide an appropriate release site location. However, Western Pond Turtles are a protected species, and the state fish and wildlife agencies have the responsibility and authority to determine if and where orphan turtles should be released. Stress of captivity, unsanitary domestic conditions, starvation, and most importantly, contact with other turtle species, greatly increase the risk of transmitting disease. ''Good intentions'' to save one animal could have a negative effect on an entire population of wild turtles where the orphan is released.

An experienced veterinarian should care for an obviously sick or injured turtle. These animals are difficult to feed in captivity and are prone to starvation if their dietary needs are not met. Such an animal should be placed in a box, preferably with a closed lid, kept in a quiet place, and taken to a person who can treat the animal. Always note the location at which you found the turtle, so that it may be released at or near the same place. Relocating turtles to new sites is strongly discouraged and should only be done with the approval of the state fish and wildlife agency. Spread of disease, disruption of gene flow within a population, and stress endured by the turtle are primary reasons for avoiding relocation (Dodd and Seigel 1991; Seigel and Dodd 2000). This species likely has a high level of site philopatry (that is, has a learned and likely restricted home area or range), which hinders relocation efforts because turtles are likely to attempt to return to their familiar home areas.

Outside of permitted scientific studies, we strongly discourage picking up any turtles in the wild, but there may be instances where it is important to help an animal. A turtle crossing a road in obvious danger of being crushed by a vehicle should be carried quickly to the side of the road and released in the same direction it was first going and on the side of the road to which it was traveling. Avoid drawing attention to what you are doing, so that additional people do not disturb the turtle, and remember to ensure your own safety on the roadway.

DATA COLLECTION AND MANAGEMENT

Field data forms and incidental observation forms (Appendix 1, Appendix 2) can be modified for specific work and copied onto waterproof paper. We recommend lamination of the data code sheets and explanations and taping them into a clipboard for quick reference in the field. Field research can be intensive and subject to the challenges of measuring live animals in the field under varied environmental conditions. Develop equipment checklists (for example, Appendix 3) that are reviewed before going into the field. Thus, equipment should be carefully organized prior to departure for the field. We use a tackle or hard plastic box to hold key materials.

A pencil or permanent ink pen can be used for recording data on waterproof forms. Pencils and pens are easy to break or lose in the field, so it is a good idea to include extras in your field supplies. Every entry box should be filled in or a slash should be entered when data are not available. If entry boxes are left empty it may be assumed that the data were overlooked. Original data should be proofed each day to locate and correct errors soon after completion of field surveys. Make photocopies of all data forms or enter information into computer databases. The original is kept in the office or safe location while the copy is placed in a field binder. This binder remains with the field equipment and can be used when questions arise about previous surveys, locations, or the identification of individual turtles.

Measurements

Data collected on each captured turtle should include sex, weight, length, and other size measurements. Other useful data include age (estimated by annuli counts), sex, reproductive condition, and health (Appendix 1). Photos and tissue samples may be collected for some studies.

Weight.—Weights are taken on each turtle captured. Field spring scales work well for weighing turtles. Purchase a range of calibrations (for example, 25, 100, 300, and 1000 g) to record weights to the nearest gram. Use the smallest scale possible for each turtle to improve the accuracy of the measurement. Smaller turtles can be directly weighed by attaching the ''alligator'' clamp of the scale hook to the posterior edge of the carapace. Keep a hand beneath the turtle to catch it if the clip does not hold. For larger turtles, place a large rubber band around the turtle like a belt and attach the scale clip to the rubber band (for a more reliable hold, replace the scale clip with a modified paper clip to hook the rubber band). Clip to the rubber band on the ventral surface so the turtle hangs belly-up to minimize struggling in the first few seconds, allowing for a more accurate measurement. Alternatively, turtles can be weighed in a mesh or plastic bag that can be sanitized after each use (remember to deduct the weight of the bag). Sanitize bags between uses and remember to deduct the weight of the bag to get the turtle's weight.

We now routinely use a portable electronic scale (battery operated) with convenient ranges (for example, 0–50 g, 0–1000 g). These are fairly durable for field use and more accurate (for example, to 0.1-g level) than spring scales and are about equal in cost (when several spring scales are needed). A closed-cell foam ''donut'' on the weighing tray can be used to keep the turtle in position on its back during weighing. Set the foam donut on the scale and record the tare; place the turtle on the donut on its back, and record the weight. When the turtle is placed on its back, you usually have a few seconds to work before the turtle struggles.

Shell measurements.—Due to the difficulty of fully extending a live turtle, length measurements are of the shell rather than head to vent or tail. Standard lengths include maximum measures of carapace length (CL), carapace width (CW), and shell height (Ht) as straight-line measurements over the top of the carapace and plastron length (PL). Girdle width and other measurements can be taken, depending on research needs. Most shell features are highly correlated to one another so that little information is gained once an adequate sample is measured (for example, 30 adults of each sex). Once a sample of data is obtained (and compared graphically), it is a better use of time and less stress on turtles to take the fewest measurements (for example, only carapace length and weight).

Standard lengths are measured using calipers to record the straight-line distance. For adult turtles use large sliding ''tree'' calipers (50-cm length; aluminum), which are available at most logging supply stores. They fit well across the top and bottom of the carapace and plastron so that the longest points of the carapace are easily measured to the nearest millimeter. Be sure to order calipers with metric marks and to 1 mm. The ends of the tree calipers are too bulky for precise measurements in some instances such as tight spots or on small turtles. We use a hacksaw to reduce prong lengths by one-third and to set a sharper angle (for example, >45%). Blunt the points if they are too sharp. Accuracy is to 1 mm. Some prefer to use finer-scale dial calipers and record to the 0.1 mm. Dial calipers are readily available in 150-mm length, but the more ideal 200-mm-length calipers are scarce. Dial calipers often come with sharp tips that should be filed blunt before use on turtles.

There are 3 commonly used methods for measuring carapace length, and they can vary by several millimeters. A common dimension used is the maximum carapace length (CL). This is measured from the outer edge of the 1st or 2nd marginal to the last marginal on one side or another of the midline. This dimension is prone to some wear and damage; thus, this measurement may skew growth or fitness models. Another measure is the minimum carapace length (cl) recorded along the midline of the carapace, from the cleft between the last marginal at the tail to the cleft between the nuchal and the 1st marginal anteriorly. These areas are less prone to wear and can provide a more consistent measure. A 3rd dimension for measuring the carapace is midline carapace length (mcl). This is similar to minimum carapace length except the measurement is made from the tip of the nuchal rather than the cleft to the sides of the nuchal. Midline carapace length is often 0.25 to 1 mm longer than minimum carapace length. Some individuals lack the nuchal and others may have a split nuchal, so midline and minimum carapace length are the same.

Plastron measurements may provide a more stable metric for growth and demographic studies because they are less prone to damage that could affect measurements. Maximum plastron length (PL) is measured with the calipers flat with the plastron. Minimum plastron length (pl) is the midline (insert prongs into cleft at each end of the plastron). Be gentle with the calipers while taking this measurement as the tissue in the midline cleft is sensitive. The bulky ends of calipers limit access for a close measure of minimum plastron length. Again, if possible, use dial calipers for minimum plastron length.

For shell height, measure the tallest straight-line distance using tree calipers. For carapace width, the tree calipers are lined up with the suture between the 2nd and 3rd vertebral shield. Maximum carapace width can also be included, measured at the widest point of the shell, usually around the 4th vertebral shield. Whatever set of measurements you decide to take, be clear, consistent, and precise in what is being measured and how and include this information (that is, metadata) in an archived data set.

Size Class

Carapace length may be used to assign turtles to a size class category. In general, hatchlings are 20 to 34 mm long and then juveniles are turtles up to approximately 120-mm CL, which is the approximate size they reach sexual maturity (Bury and Germano 2008). Adults are usually more than 120 mm and show signs of sexual maturity in secondary characteristics, although turtles vary in the rate of growth and the size at which they reach sexual maturity (Bury and Germano 2008; Germano and Bury 2009). Thus, size classes are only categories for approximate definition of population structure. It may be better not to employ such arbitrary classes but, instead, show collected data.

Sexing

The Western Pond Turtle begins exhibiting sexual dimorphism in morphology and color when turtles are about 110- to 120-mm CL. These features may be obscure in some turtles and it may be difficult to determine sex, but generally a suite of characters can be used to make a determination on sex. Females tend to have a more dome-shaped carapace than males (Plate 7). Males have a concave or indented plastron allowing them closer access to the female during copulation, whereas the plastron of females is flat or slightly convex, providing more body space for eggs. The cloaca in females is usually located close to the edge of the carapace or anterior to the edge, while the male's cloaca is located at or posterior to the edge of the carapace. The base of the tail of males is generally thicker in diameter; this is where the penis withdraws. Eversion of the penis is conclusive evidence of a male (Plate 8). Males may have a light-colored maxilla (side of the head below the eye; both sides of the mouth), and light yellow or cream-colored chin and throat, which is usually subtle in young adult males but becomes more pronounced with time. Females usually have darker maxillae that are often striped and have the appearance of a mustache. The chin and throat of females are typically darker than those of males and are often vermiculated. In south coastal California, there may be little color differences between the sexes. Males have a more angular snout, whereas the female's is blunt. Even from a distance, a mature adult male can be identified by the angular snout, light-colored face and chin, and often by its flatter shell.

Reproductive Condition

The reproductive state of females can be assessed determined by palpation. Eggs are detectable in the inguinal cavity for only a few weeks, so absence of eggs does not imply that the female has not or will not reproduce during a given breeding season. It is best to use 2 people where one person holds the turtle firmly and also gently pushes the head and forelimbs into the shell. With practice, one person can perform this technique alone. The other person grabs the back legs of the turtle and firmly yet slowly pulls the legs out of the shell; then, insert your forefingers (or pinkie fingers) of each hand into the inguinal cavity (just in front of the hind leg). Gently feel towards the anterior for eggs. If calcified eggs are present, they will be detected as hard lumps. Sometimes you can touch the tips of your fingers inside the body cavity; if so, there are no eggs. With practice, one person can perform this technique alone. Palpation is relatively easy to perform on an active animal that allows its back legs to be restrained, and thus provides access to the inguinal cavities, but some turtles keep all extremities tightly pulled into their shells during capture. If the turtle refuses to extend her back legs, however, an animal can be encouraged into activity by placing her in shallow water. She will extend her legs and start to move toward deeper water once an opportunity to escape presents itself. Or, an adult turtle held by its hind foot will eventually tire of holding its body weight and allow the leg to be extended (P Lindeman, pers. comm.). At this point, the back legs can be grabbed and restrained.

Eggs can also be counted by taking radiographs of females (see Chapter 6). Portable x-ray machines are available but they may cost US$5000 or more to purchase. The film needs to be taken back to a facility for processing. Turtles can be taken to a veterinarian with an x-ray machine, but this generally entails transport of the turtle to town and back to the field for release. Digital x-ray machines are now available, which eliminate the need for film and developing; but these are fairly expensive.

Age Estimates

Determining the ages of turtles is used widely and similar to counting the rings on the cross section of a tree (for example, Cagle 1946; Sexton 1959b; Graham 1979; Germano 1988). Although Wilson and others (2003) raised doubts about the use of scute rings to indicate yearly increments in turtles, when properly employed the method is highly accurate for many species of freshwater turtles (Germano and Bury 1998). In particular, there was a statistically significant correlation between the number of rings and age in years for the Western Pond Turtle (Bury and Germano 1998). This evidence included recapture of many individuals where 1 ring was deposited annually, but scute annuli can be used to determine ages of turtles only to certain years.

Growth lines identified on the external scales (scutes) of turtles reflect growth due to deposition of beta keratin (a protein) seasonally. Annuli are most easily seen on the ventral (or plastral) scales of Western Pond Turtles into young adulthood. In older individuals, the rings wear to a smooth surface and are no longer useful for aging purposes. Further, the most recent annuli are nearly identical in size and become too compressed to effectively distinguish among them. Rings are useful only to about age 8 to 10 in southern populations due to their rapid growth rates. Annuli remain an excellent tool for determining age of most turtles less than 12 y old and can be used on some individuals up to around 16 y old (for example, in the northern part of their range). Scute annuli can be used to determine ages of turtles only to certain ages.

Turtles grow the most during their first 10 to 12 y, so when rings are correctly read, counting annuli may be the most useful technique for determining age. Turtles for which age can be determined can comprise up to about 60% of a population. Age determination using annuli is probably most useful in generating age-size plots, which have a number of practical applications, such as estimating growth rates.

To age a turtle, count the complete rings on the abdominal scute on the plastron or the 3rd costal on the carapace (see Appendix 4). These are among the largest, flattest scutes on Western Pond Turtles. For studies of growth, measure the width of each annulus with calipers or prepare a plaster cast for later examination in the lab (Plate 11). Castings are useful for determining growth rates in this species (Bury and Germano 1998; Germano and Rathbun 2008) and can be used as a permanent reference when recaptures are made in the future (for example, to demonstrate that 1 ring is deposited annually).

Photographs

Photographs of the carapace and plastron are useful to confirm identity of recaptured individuals and can be used to observe changes over time (growth, injury, healing). The advent of digital cameras aids photography of individual turtles and provides permanent record of marked turtles. Once the shell is dry, we routinely write this code number on the CL and PL with a waterproof marker (black). This aids identification of recaptured individuals later. We record the photograph number on a field data sheet to aid in matching capture records with photographs.

If marking is done using a visible notch (see below for marking techniques), take the photos after marking. Habitat photos are also recommended for documenting change over time at a site. Ecological studies often include photo documentation, but even a site visit should include a few general shots of the site to be archived in a project database.

Collecting Tissue Samples

Tissue samples may be collected for a wide range of uses, but should only be taken as part of a permitted scientific study. Blood samples are used for genetic analyses, studies of physiology, disease, and more. In most cases, blood can be withdrawn from a vein by needle (venipuncture), but there is a risk of injuring the turtle if done improperly, so it should only be done by a veterinarian or other trained individual. Blood samples need to be properly stored after collection.

Many disease and physiological studies call for blood to be collected using a heparinized syringe and chilled on ice (not frozen). However, blood collection for DNA analyses should not be collected with heparinized syringes as heparin interferes with DNA extractions (P Spinks, pers. comm.). Blood collected for DNA analyses can be stored in ethanol (95%) or in a blood-preservation buffer at ambient temperature for a short amount of time (for example, while in the field) but should be refrigerated or frozen for more long-term storage.

Blood and tissue also can be collected by tail clipping as the clip site will bleed; however, it can be difficult to get a sufficient sample and contamination of the sample is possible. Tail tips are useful for genetic analyses, but are not as versatile as blood samples for DNA, physiology, and disease work. To collect the tail tip, clip off about the size of a pea with sharp, clean scissors and place the sample into a vial with 95% ethanol. Make sure to clean the scissors thoroughly between samples to avoid cross contamination of samples. A convenient way to clean scissors and forceps is with hydrogen peroxide; it is inexpensive, widely available, and destroys both tissue and DNA. A small volume can be reused several times before it is discarded and replaced. Only clip the fleshy tip of the tail, do not cut into the tailbone, which contains the spinal cord. Do not attempt to collect tail tips from turtles with missing or injured tails due to the risk of damaging the spinal cord or vascular system. For cut tissue, be sure to cauterize (using aluminum sulfate or shaving ''styptic'' stick) and apply disinfectant to any wound. Let air-dry before returning turtles to water.

Finally, clearly label each sample with a number and record on the data sheet: locality where the turtle was captured (include latitude/longitude or Universal Transverse Mercator, if possible), date of collection, name of collector including collector's field number (if applicable), size and sex of animal, and any other pertinent remarks. And remember, if you are storing tissues in ethanol, many kinds of ink (including ''permanent'' ink tubes) are soluble in alcohol. The safest way to mark vials is to use pencil, since it is completely insoluble. If you like to use a pen, make sure to test it first.

MARKING SYSTEMS

The ability to identify individual turtles aids in a wide range of studies including home range determinations, movements, growth, and population estimates. Large sample sizes are usually required to make valid inferences in these studies. We do not recommend marking an occasional individual or at scattered sites because this will add little to the biological understanding of the species. It is better to focus marking efforts on specific questions or larger populations in defined areas where long-term studies are likely to continue.

The carapace provides an easy surface for marking of turtles and several methods have been employed over the years. Painting bright numbers or affixing stickers have been used in the past, especially in behavior studies, because individuals can be identified from a distance. We generally discourage use of bright, obvious marks, though, because they can cue predators or influence turtle behavior. Paints wear off relatively fast. Notching the marginal scutes of the carapace provides a durable mark which is unobtrusive. The carapace can also be used as a surface to epoxy telemetry radios or other equipment onto turtles.

Carapace Notching—Adults and Subadults >70 mm

We use a small, sanitized file, either triangular or half-round bastard type, to cut a 3- to 4-mm-deep V-shaped notch into the center of the marginal scutes that correspond to the assigned number (Appendix 1). Double notching of a single scute is feasible if done with care, but we do not recommend it because of the possibility of pieces of the carapace chipping out and, thus, rendering the mark unreadable or difficult to decipher in the field.

Carapace Notching—Hatchlings and Young <70 mm

Marking hatchlings poses some mortality risk due to their soft shells and fragility. The decision to mark hatchlings or 1-y old turtles should take this risk into account. Hatchlings should only be marked where there is a specific need (for example, a study of movement patterns or ecology of young turtles). Further, recapture of 1- to 2-y-olds is rare in the wild. Because of these factors, we do not recommended marking turtles until they are 2 y old in southern populations and 3 y old in northern populations, or once the shell is hardened.

If young turtles are to be marked, a relatively safe procedure is to use small cuticle or iridectomy scissors to snip a small triangular notch 1.0 to 1.5 mm deep (deeper can cause injury) from the center edge of the marginal scute. Roughen the edges of the cut very slightly with a small triangular file or emery board. Special numbers need to be reserved for hatchling marking. Mark only the 1st and 2nd, 10th, 11th, and 12th left and right marginals. These scutes have more flare than those near midbody. Do not mark the marginals on the bridge (where the carapace and plastron meet) because this may result in injury to small turtles (Appendix 1).

When marked hatchlings are recaptured, it may be necessary to enlarge the original notches (proportionate to the size of the turtle), which aids in future recognition of the mark. Use silver nitrate (styptic pencil) to cauterize any wounds (for example, sites that bleed) during marking, especially with young turtles. It is recommended to clean the notches and any wounds with a disinfectant.

Numbering Codes and Assignments

There are several code systems available to permanently mark turtles (Bury 1972a; Ferner 1979; Graham 1979). Earlier, an additive system (Appendix 1) using numbers was developed marking only scutes with flaring and none along the bridge (Cagle 1939). Gibbons (1988, 1990b) suggested a similar system but with an alphabetical coding system (for example, Left Marginal 1 [LM1] = A; LM2 = B, etc.). To our knowledge, these systems have not been employed on Western Pond Turtles.

Many turtles marked in the 1980s to 1990s by Holland (1994) employed all the scutes, even along the bridge (Appendix 1). This is an additive system for the hundred and thousand series. For example, LM1 = 400 and LM2 = 800.

If both are marked, then the turtle is in the 1200 series. Holland used a set of consecutive numbers across the entire range of the Western Pond Turtle. However, the numbering series grew large with up to 2 marks on single scutes such that LM1 has 2 marks (^ ^) = 800 to LM 4 with 2 (^ ^) = 6400. This system had numbers between 1 and 11,000 (but not all codes were used). Today, it is difficult at times to figure out the codes as there is no master list available.

A simpler system (Appendix 1) has single marks used consecutively along the marginals (Bury 1972a): Right Marginal (RM) 1 to 9 = 10 to 90; LM 1 to 9 = 1 to 9. Thus, the system is intuitive where RM 2 = 20 plus LM 1 = 1, or Code #21. The hundred series are denoted by different sequences of marks on the 4 posterior marginals RM 11 to 12 and LM 11 to 12. This system appears to be limited to a maximum of approximately 1200 different codes. It is workable for sites that cannot be reached by turtles in different populations.

Although there is potential for investigators to use the same numbers (for example, 1–500), field biologists should make themselves aware of other studies occurring in the same geographic area. Thus, investigators are now free to use their own system but should coordinate studies with state authorities on which system to employ. Marking turtles is allowed only for permitted research projects.

Coordination and use of numerical marking numbers within and between states or study areas should occur, but has been difficult to accomplish. Investigators should also alert local or regional offices of wildlife agencies about studies employing marking of turtles. In turn, the biologists might learn of either prior or current studies in the same area and develop better working relationships with local/regional people. Mark-recapture data are to be reported annually to the state coordinator as a condition of the permit. A statewide database for codes was established in Oregon but was discontinued in the early 1990s. To our knowledge, there is no single depository for code numbers at this time, but a new system is under development in California.

Passive Integrated Transponders

Passive integrated transponders (PIT tags) have been used in wildlife studies for decades and may prove to be a better way to mark turtles range-wide than traditional notching systems (see Elbin and Burger 1994; Rathbun and others 2002; Gibbons and Andrews 2004). The PIT tags can be inserted into the body cavity or epoxied to the inner surface of the carapace. The PIT tags can be quickly and accurately read with a scanner and are not exposed to the wear and tear a carapace endures over time. Investigators usually file a single notch in the plastron to indicate a tag has been inserted. When recaptured, turtles with a plastron notch are scanned with a PIT tag reader and identified. However, a reader is required and PIT tags are moderately expensive if individually coded (approximately US$5.00/tag) and, for most studies, can be a high cost when hundreds of turtles are marked.

RADIOTELEMETRY STUDIES

Use in Field Studies

Radiotelemetry is useful to generate valuable information on both spatial and temporal patterns of activity, microhabitat use, reproduction, and behavior. This is a powerful tool for identifying site-specific patterns that provide a framework for monitoring or managing populations. However, equipment and materials can be costly and most studies require large investments of time to locate individual animals. Telemetry must be conducted in an area that is accessible by foot or boat. If coupled with a survey effort, it can provide information that helps explain high or low capture rates, such as seasonal terrestrial migrations that reduce aquatic capture success.

Radio transmitters of various sizes can be manufactured or purchased to accommodate tracking of different age classes (Bury 1972a; Holland 1994; Reese and Welsh 1997; Bondi 2009). Radiotelemetry of juvenile turtles could be particularly useful as we know almost nothing about their ecology because they are cryptic and difficult to locate. For radiotelemetry studies, the radio and epoxy weight combined should be no more than 10% (<5% is preferable) of the turtle's weight, placing a limit on battery life.

Transmitter Installation

Attach the telemetry transmitter to a single, anterior costal scute on the turtle's carapace with the antenna wrapped around the carapace just above the marginal scutes. For long-term studies, PC-7© epoxy can be used to bind the radio to the carapace (Reese 1996) because this material is a slow-setting epoxy that produces little heat during curing. Other epoxies can produce significant heat during curing, which risks burning the underlying tissue (Renaud and others 1993). Radios attached using silicone aquarium sealant are easily dislodged in the field and clear epoxy deteriorates in the 1st season and is, therefore, only suitable for short-term uses. A new epoxy attachment for quick field use is now available (see Appendix 5).

Radios should ideally be installed in the evening, allowing the epoxy to set overnight while the turtle is less active. The turtle can be placed in a plastic storage box with a lid and left in a dark, quiet, and cool place until it is released the next morning. Attach the radio transmitters following a set procedure (modified from Belzer and Reese 1995):

1. Clean the radio and antenna attachment sites thoroughly using ethanol and a toothbrush (phenolic impurities are highly toxic to turtles; Quesenberry and Hillyer 1993).
2. Cover all scute junctions in the radio attachment area with thin strips of masking tape. Growth occurs at these junctions, and junctions should not be spanned by PC-7 (or other rigid adhesives).
3. Apply a ring of reusable winter window caulk on the scute to which the radio will be attached. This creates a barrier to prevent the PC-7 from extruding onto adjacent scutes when the radio is pressed into place.
4. Mix PC-7 as directed on the package and apply within the caulk ring.
5. Gently press the radio into the PC-7, but do not apply pressure to the red coil area of the radio. This can detune the radio. Position the radio with the antenna pointing posteriorly. Try to set the radio in as streamlined a position as possible, then mold the PC-7 to fill any depressions that could snag aquatic vegetation.
6. Epoxy the antenna in a wide arc around the carapace using PC-7 on the costal scutes just above the marginal scutes. Do not apply PC-7 to the scute junctions, but fill these junction areas with a flexible adhesive such as 5-min epoxy or aquarium sealant so the antenna does not snag on underwater vegetation. The arc of the antenna should not exceed 75% enclosure around the carapace. If the antenna tip gets too close to the antenna base, the signal will be muted. Alternatively, leave antenna trailing free (see Appendix 5)
7. Allow PC-7 to cure overnight before returning the turtle to water. PC-7 securely attaches the transmitter to the carapace for long-term studies, but removal may be difficult and requires use of a fine saw and electric miniature sander. For short-term studies, a softer epoxy is preferable (Appendix 5).

Depending on the study objectives, radio-tagged turtles should be relocated from every 2 h (when tracking gravid females) to once a week (when tracking active season movements) to once a month (when tracking winter movements). Locations can either be marked by hand onto aerial photographs or recorded with a Global Positioning System unit and downloaded to a computer mapping program. When turtles are detected in an area but are not visible, locations can sometimes be obtained by triangulation. Namely, the observer should try to detect a signal from several different vantage points, such that imaginary lines drawn from each point towards the audible radio transmission would cross at the turtle location. When unable to obtain a signal, the tracker should return to the location where the turtle was last found and search in increasingly larger concentric circles. The breadth of the search area will depend on the frequency of signal monitoring. Keep in mind that within a period of several days, turtles can move as much as a kilometer overland (Reese 1996).

Field Tips for Radio-Tracking Turtles

In rocky terrain and deep river gorges, the transmitter signal can bounce off rock faces and give a false directional signal. Keep this in mind while attempting to determine a location. If the signal sends you back and forth, try moving further away to get to a different vantage point. If you detach the antenna from the telemetry receiver, a received signal confirms that you are near a turtle (within approximately 30 m); however, you have no directionality from the signal. Careful planning ahead of time will improve safety for the turtle, the equipment, and the researcher, and in turn increase the integrity of the data obtained. It is important that the study methods and equipment are appropriate and feasible for use with turtles, in the terrain of the study area, and for the duration of study period.

Habitat Measurements

Prior to starting habitat work in a riverine environment, review safety standards for working in and around water on foot (Chapter 4) and for diving (Chapter 5). A minimum of 2 people are needed for any work in water. Reese and Welsh (1998a) measured habitat characteristics using a quadrat: a floating, rectangular frame made of polyvinyl chloride tubing and measuring 3 × 6 m. Marks are made on the quadrat with permanent ink, dividing it into 9 subquads (1 × 2 m each). The 9 subquads are aligned in a 3 × 3 grid. The 3 subquads closest to the bank are designated with a ''B,'' the 3 in the middle with an ''M,'' and the 3 on the river side (closest to thalweg) with an ''R.'' Besides a letter code, the upstream subquad is labeled number 1, the center is number 2, and the downstream subquad is number 3. For example, water temperature taken in the subquad upstream and closest to the bank would be in ''B1.''

In the field, the quadrat is laid on the water surface or partly on land and partly on water, long side parallel to the shoreline, with the center over the location where the turtle was first observed. For each quadrat, measure the following variables: distance to bank, shoreline vegetation type, transect flow types, water flow velocity, water depth, presence of basking sites, underwater cover objects, depth of bank undercut, water temperature, percent canopy closure, maximum water depth, mean water depth, minimum flow, maximum undercut bank, and mean undercut bank. Further, site variables associated with the quadrat, including bank slope and aspect, shoreline vegetation type, channel type, and aquatic mesohabitat percentages are measured at turtle capture locations. The quadrat can be centered over turtle capture locations or random points for comparison. Guidelines and example sheets for habitat assessment are provided in Appendix 1 and Appendix 2.

CHAPTER 8

CONSERVATION AND RESTORATION STRATEGIES

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INTRODUCTION

The enemies of reptiles, in addition to thoughtless man, are numerous.

Pickwell (1947)

To ensure survival of the Western Pond Turtle (*Actinemys marmorata*), strategies are needed to protect and restore its populations and habitat across its range. Ecosystem management works with present conditions and uses an understanding of natural ecosystem processes and disturbance regimes to direct ecosystems to a potentially different future (FEMAT 1993). The use of an ecosystem approach requires knowledge of both processes and functions. Several conservation principles are central to an ecosystem approach to protect and enhance survival of all wild populations (Doak and Mills 1994; Robinson and Wilcove 1994; Wilcove 1994):

1. Species that are well distributed across their range are less prone to extinction than species that are restricted to small portions of their range.
2. Large, intact blocks of habitat with many individuals present are more likely to persist than small fragmented blocks of habitat with few individuals.
3. Habitat patches that are in close proximity are preferable to more widely dispersed habitat.

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4. Habitat between protected areas that more closely resembles suitable habitat for the species is more easily and successfully traversed by dispersing individuals.
5. Connected populations are better than disjointed ones.

While this handbook emphasizes the needs of Western Pond Turtles, here we review the concepts of ecosystem processes and management that are critical for the long-term recovery and persistence of its habitat. Further, this approach should enhance the protection of not just Western Pond Turtles, but the needs of all other species in the ecosystem, such as native fishes and amphibians. Where Western Pond Turtles have experienced declines, these conditions are potentially reversible where management actions are integrated with long-term efforts to protect and restore the functional stability of these ecosystems.

PROCESSES TO PRESERVE OR RESTORE ECOSYSTEM FUNCTIONS

Preservation

The primary management needs for the Western Pond Turtle are the effective protection of its aquatic and terrestrial habitats. Measures to protect intact, functioning habitat have the greatest likelihood of successfully maintaining viable populations, are often easier to implement, are less expensive, and have greater long-term sustainability than restoration or other efforts (Kauffman and others 1997).

Management strategies that protect and restore the functioning of entire watersheds are needed to provide adequate protection for the Western Pond Turtle (Reese and Welsh 1998a). Protection of the aquatic and terrestrial habitat could require complete exclusion of some activities. This may be necessary to ensure the proper functioning of biological and physical processes, as described in the Northwest Forest Plan's Aquatic Conservation Strategy (USDA, USDI 1994; see also FEMAT 1993). Still, preservation or total protection of waterways is a challenge in western North America where most waters are managed or altered for human use, and demands for water increase yearly. Water bodies in the west are magnets for human recreational activities, including fishing, rafting, boating, and swimming. Further, campgrounds are often located adjacent to streams, rivers, lakes, and reservoirs, which bring larger numbers of people into turtle habitats each year.

Restoration

Ecological restoration is the reestablishment of functions and processes to predisturbance conditions (Kauffman and others 1997). The goal is to ensure that the dynamics of natural ecosystem processes in degraded habitats are again operating normally. The 1st step should be passive restoration, which is cessation of negative activities that are causing degradation. If passive restoration is not successful, then a more active approach is needed. The Northwest Forest Plan (USDA, USDI 1994) is an ecosystem-based approach to forest management in the Pacific Northwest. The Aquatic Conservation Strategy of the Forest Plan has the goal of maintaining healthy stream and riparian conditions, in part by allowing for natural disturbance regimes, such as cyclic fires that modify stands. The distribution of land-use activities needs to minimize peak stream flows, protect headwater areas, and maintain riparian areas along larger channels. This should limit sediment production, restore the condition of riparian vegetation, and restore in-stream habitat complexity. These actions will improve Western Pond Turtle habitat.

A critical component to the survival of Western Pond Turtles is the connection of habitats in lowland valleys. The northernmost populations of Western Pond Turtles occur in the Puget Trough in Washington State. They occur in the Willamette Valley, Oregon, but status is unclear. Turtles frequent the Umpqua and Rogue river basins, in southern Oregon, and southward through the Coast Ranges of California. They were once abundant in the Central Valley of California. Many of the valley populations now appear to be isolated due to the spread of agriculture and urban development in these lowland, relatively flat landscapes (Bury and Germano 2008). Within these areas, the identification and restoration of habitat on government-owned land (for example, national wildlife refuges) for the benefit of the Western Pond Turtle could serve to secure healthy populations in a surrounding ''sea'' of less suitable habitat. Most lowland acreage is in private ownership and its management for pond turtles will necessitate some creative measures dealing with landowners of many types. However, there are state and federal funds available for wildlife habitat restoration and suitable habitat for pond turtles (that is, ponds) can benefit many other species as well as enhance private property.

The restoration of habitat for the Western Pond Turtle involves: 1) restoration of aquatic habitat complexity; 2) restoration of terrestrial nesting and overwintering habitats; and 3) the reconnection of these 3 habitat types. Many salmonid fish projects have been designed to restore stream complexity through restoring natural flows and by adding in-stream structures (for example, large pieces of coarse woody debris). Projects that may restore the more open grassy areas required for turtle nesting have been limited and experimental. Most of these projects involve returning a site to early stages of plant succession. It is difficult to maintain this stage because of encroachment of shrubs and trees over time. However, the restoration of natural hydrological flows and floodplain connectivity may help by allowing periodic overbank flows, resulting in a return to earlier succession stages.

Restoring the connectivity between in-stream and upland habitat can be difficult in areas with moderate to high human disturbance as well as high proportions of private landownership. Private landowners are often concerned that restoring natural river processes will result in loss of land from erosion or a reduction in acreage available for farming, development, or other uses. Many roads and railroads sever the link between terrestrial and aquatic habitats used by these turtles. One way to restore the link is through relocation or removal of barriers, but this is impractical in most cases due to the high costs. Underpasses can be developed by the creative use of existing culverts, but their success usually requires some directional barriers to direct turtles to culverts and fencing to keep them off roads or tracks.

Rehabilitation

In situations where habitats are so severely altered that effective restoration of the habitat is infeasible, rehabilitation of the area may be the last option available. These are efforts to make the land useful again after natural or anthropogenic disturbances (Kauffman and others 1997). There is no implication that it is restored to a predisturbance condition. It may include replacement of in-stream and pond/lake habitat features. An example is the proper timing of water release from reservoirs to approximate natural flows. Another example is the improvement of in-stream habitat complexity by the addition of logs and boulders to streams, and re-creating side channels important for hatchling habitat. In some areas, returning a site to an earlier stage of vegetative succession (grass-forb) for the benefit of turtle nesting may be possible, but retaining this stage may require frequent active intervention, including burning, mowing, or scraping. It may be possible to partially reconnect the land and water habitat types via installation of roadside drift barriers, underpasses for roads and railroad tracks, or periodic road closures.

Mitigation

Actions or modifications that attempt to alleviate the detrimental effects from anthropogenic actions compensate for habitat losses, but many do not display the structural or functional attributes of the original system. Declining populations, such as those in western Washington or around the Los Angeles basin, California, have all or portions of their habitat so severely altered that mitigation (for example, habitat replacement) may be the only remaining option. Agricultural and development pressures have resulted in a significant reduction of emergent wetlands within the range of the Western Pond Turtle and mitigation of impacted wetland habitats has occurred frequently in response to environmental mandates. For example, a marsh near a city may be developed if land of equal or greater value is purchased elsewhere (Kentula and others 1992). However, few mitigation sites have specifically targeted the needs of wildlife (Pearl and others 2005). The design of habitats should include open water with refugia and basking sites. In larger wetlands, the construction of offshore islands (hummocks) or coarse woody debris may provide basking sites and cover and be relatively free from predators of Western Pond Turtles. However, this type of management needs further scrutiny and study because wetland mitigation is not the only type of habitat mitigation required to provide for the life-history needs of Western Pond Turtles. The maintenance of early succession in adjacent uplands, such as grasslands or grassy areas with widely spaced shrubs, is important to ensure availability of nesting habitat. Terrestrial mitigations could include nesting areas, overwintering habitat, and safe connectivity between aquatic habitats.

Translocations

Relocating turtles that would be eliminated from a site due to development is a controversial practice. There are several risks associated with translocation, including disease transmission between animals from the source site and the release site and the risk that the source population may be reduced when turtles are moved (for example, removed from immediate harm until the project is completed). It seems logical to collect turtles and move them to a nearby waterway. However, freshwater turtles have strong homing abilities (Williams 1952; Emlen 1969; Ernst 1970; Carroll and Ehrenfield 1978; Bury 1979). Thus, released turtles will tend to home back to their site of collection and many may die in the process (for example, crossing roads or unfamiliar terrain). On the other hand, there is a possibility that turtles moved considerable distances may not home back. Ernst (1970) found in the Painted Turtle (*Chrysemys picta*) half of the animals ($n = 50$) returned after being moved 1 km upstream, and 21 of 50 turtles returned when moved l km downstream. However, only 12 of 60 turtles returned home when they were moved 2 km downstream of a home area. Possibly, turtles lose their environmental cues when moved farther than 1 km from a familiar home area. The fate of those turtles that do not home back needs to be followed to assure their survival.

There have been very few projects where turtle relocations were documented and there is no published information on translocation of the Western Pond Turtle. One unpublished study reports relocation of turtles in Douglas County, Oregon, in 1992 (Holland 1994). Adults were taken from a city ''duck'' pond and moved to a seminatural pond about 30 km away. Two years later most individuals had remained at the new site. Long-term monitoring at translocation sites is needed to determine success before the process is considered anything but experimental or a stopgap measure (Dodd and Seigel 1991; Holland 1994; Germano and Bishop 2008).

Head-Starting Programs

Head-starting is the captive rearing of hatchling turtles to a body size that will likely result in an increased probability of their survival in the wild. Head-starting begins with collection of eggs or capture of recently hatched or emerged turtles (for example, ones that emerge from a nest). The hatchlings are reared in a predator-free environment, usually under favorable conditions of light, heat, and food to enhance growth and development at higher rates than occur in the wild. These turtles are then released after several months in captivity when they have reached a carapace size (for example, 60–90 mm) that makes them less vulnerable to predation.

Head-starting of turtles is not a universally supported conservation measure because it does not address the underlying problems of habitat loss, high levels of predation, or any other factors that may limit a population in the wild. There are severe drawbacks to most of these programs (see Dodd and Seigel 1991). For example, Heppell and others (1996) determined that even a small decrease in adult survival of Yellow Mud Turtles (*Kinosternon flavescens*) could quickly overcome any potential benefits of head-starting. What head-starting may do is provide a last-ditch tool for rebuilding populations that are at dangerously low levels and where it is clear they cannot recover on their own. This measure will have only temporary benefits to critically threatened populations if the underlying causes for declines are not corrected. From this standpoint, head-starting is a tool that may provide time while developing solutions to underlying problems.

Genetic distinctiveness and variation in populations also needs to be considered when attempting to head-start turtles. Local populations are adapted to particular environmental conditions (for example, optimal growth rates and maximum size). Moving different genetic stock into a population (probably at a low density) could alter the genetic composition of these turtles. There are also risks such as transmission of disease between populations with addition of captive-reared individuals. These risks and concerns need to be considered prior to initiating head-starting.

Head-starting has been used for years in Washington State, where many native populations have been lost due to habitat impacts and disease (Hays and others 1999; F Slavens, http://www.pondturtle.com/ptmain.html; accessed 1 December 2010). Some turtles were moved over a distance of 250 km from the source population (from north of the Columbia River to the Puget Sound area near Olympia). Survival of releases has been high and led to presence of adults in the population (Vander Haegan and others 2009). Earlier, the Oregon Department of Fish and Wildlife and US Army Corps of Engineers started an experimental project near Eugene in the Willamette Valley (http://el.erdc.usace.army.mil/emrrp/turtles/species/wpond.html; accessed 1 December 2010). Captive-reared turtles were released near the nest sites, as well as up to 70 km away in the Willamette Valley. Young turtles are surviving years after release (K Beal, pers. obs.). Recently, several head-starting projects have been started in zoos in Oakland/San Francisco and San Diego, California.

MULTIPLE-SPECIES CONSERVATION EFFORTS

The successful preservation or restoration of secure aquatic habitat linked by safe dispersal corridors should enhance the survival of turtles along with other ''at-risk'' species such as native fish and amphibians. Likewise, preservation or restoration efforts for these other species will benefit Western Pond Turtles.

The range of the Western Pond Turtle in the Pacific Northwest overlaps many areas with salmonid fishes. There has been much stream restoration work accomplished in the past decade, and many more projects are planned to assist in the recovery of threatened and endangered salmonid stocks. The vast majority of in-stream restoration efforts focus exclusively on the needs of salmon. Although most improvements for salmonid fish are beneficial for the Western Pond Turtle, some projects may have detrimental effects.

Habitat enhancements for salmonid fishes include planting streamside vegetation, especially along narrow streams. Loss of direct sunlight may reduce basking sites for the pond turtle and limit open areas for nesting. It may help pond turtles if the amount of streamside planting is reduced on the northern shore of streams or ponds. These more open areas could be relatively small if located next to pools in streams and rivers that have basking sites or cover, where turtles congregate. Further, Western Pond Turtles need open nesting habitat just outside of riparian buffers. Leaving occasional open areas on south-facing slopes, especially if gradual ($<25°$), may provide nesting habitat for pond turtles.

Some streams have small dams, which reduce velocity and increase water temperatures. Eliminating these structures will benefit salmonid fishes by decreasing downstream water temperatures and removing migration barriers. Maintaining small ponds or side pools, after dam removal, could not only benefit turtles, but also provide off-channel pools for rearing habitat for juvenile salmonids and in-stream pools for summer holding habitat for adult fish waiting for high flows in the fall to migrate up to spawning reaches.

The creation of in-stream structures usually benefits both salmonid fish and Western Pond Turtles. Large pieces of coarse wood (for example, trees) added to streams increase basking and cover sites for turtles. The two most used types of structures are: 1) rock-boulder weirs; and 2) large pieces of coarse wood. These structures slow water velocity and create more pool habitat. When rock weirs are being placed, large flat or sloping rocks in the created pool could be used for basking structures or as escape cover. When coarse wood is being placed in streams, the best position for turtles is to place the root wads or logs at an angle to the stream and partially submerged, which allows turtles to haul out and bask as well as have underwater cover. For erosion control purposes, log placement is usually angled upstream. This keeps the flow and velocity away from the bank and toward the center of the river.

Several other species of animals may also benefit from measures that help Western Pond Turtles. For example, the Oregon Chub (*Oregonichthys crameri*) is an fish endemic to the Willamette Valley, Oregon. Its aquatic habitat consists of slack water such as Beaver (*Castor canadensis*) ponds, oxbows, side channels, and flooded marshes. It prefers shallow water (generally <2 m) and warm summer water temperatures greater than 16°C (USFWS 1998; Scheerer 2007). These same conditions are also preferred habitat by Western Pond Turtles. The addition of basking sites (for example, tree trunks) into these waters and the nearby

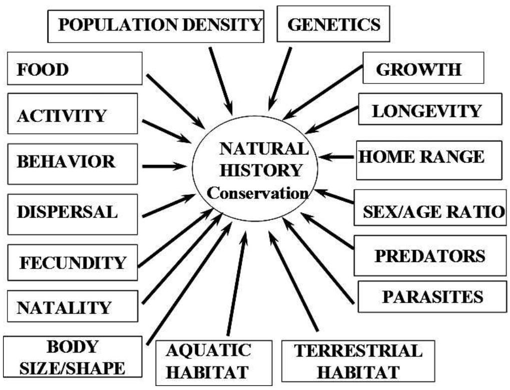

FIGURE 17. Selected key factors that influence the persistence and health of a turtle population.

presence of nesting habitat could make optimal habitat for the pond turtle.

Further, Red-legged Frogs (*Rana aurora*, *R. draytoni*) and the Foothill Yellow-legged Frog (*R. boylii*) have habitats similar to the pond turtle across large portions of their ranges. The Red-legged Frog tends to occupy ponds and slower moving water, whereas the Yellow-legged Frog frequents streams and rivers, especially in warmer climates (Corkran and Thoms 1996). Conserving or improving aquatic habitats for the Western Pond Turtle could benefit these 2 frog species.

Lastly, the needs of the Western Pond Turtle should be incorporated into efforts to restore waterfowl habitats. There are many national wildlife refuges throughout lowlands in the Pacific states. These public lands are regularly maintained and manipulated to benefit waterfowl. One practice that may benefit both Western Pond Turtles and waterfowl is the construction of islands away from shore. These may be free from terrestrial predators, although some predators are capable of swimming. Still, these islands could be kept fairly open (for example, by occasional burning). Inclusion of basking sites (for example, tree trunks, brush) in ponds and lakes will favor turtles as will mowing or burning adjacent to wetlands to create nesting areas.

Risks to the Species

Western Pond Turtles have several life-history traits that make them vulnerable to human impacts (Fig. 17). These include the need for both aquatic and terrestrial habitats as well as connectivity between these habitats. The turtle has relatively slow growth rates in many populations and displays late maturation (for example, sexual maturity reached at 5–10 y of age). The detection of declining populations may be difficult due to the long-term persistence of adult turtles at sites that may no longer have juvenile recruitment. The recovery of a long-lived, slow-growing species is difficult once a population is depleted. Management measures to prevent declines are crucial to the long-term viability of the pond turtle (Aresco 2005a). However, we need to recognize our current inability to locate most natural nests as well as hatchlings and small-sized turtles. Underestimates of these life stages can bias interpretation of recruitment in populations.

Conservation measures are intended to avoid or reduce risks to a species from human activities. Habitat destruction and degradation appear to be the most widespread and pervasive threat to biodiversity within the United States, followed by competition with or predation by nonindigenous species (Wilcove 1998). This is also true for the Western Pond Turtle. This turtle would benefit from humans maintaining and improving suitable habitat, controlling or eliminating the impacts of native and nonindigenous predators, and protecting remaining wild populations.

Here, we describe risk factors to Western Pond Turtles followed by suggestions or guidelines on how to reduce those risks. Many factors interact and their relative importance may vary by geographic area due to different limiting factors. We use available data, literature, and our collective experience to identify conservation measures. However, we have little or no published information available on Western Pond Turtles in many parts of its range. It is time to develop testable hypotheses on these issues. In particular, we have not yet applied and tested methods for the maintenance and enhancement of pond turtles in all their ecosystems, especially those with heavy human influences.

Aquatic Habitats

Habitat loss or degradation.—The loss or alteration of wetland habitats through conversion to other uses, such as development and agriculture, are extensive in North America (Dahl and Johnson 1991) and account for much of the direct loss of aquatic habitats throughout the range of the Western Pond Turtle (Hays and others 1999; Germano and Bury 2001; Bury and Germano 2008). Flood-control and hydropower dams alter the flow regimes and channel morphology of our streams and rivers. These dams narrow the active floodplain, which reduces and isolates habitat for wildlife. The mainstem (dammed tributary) of the Trinity River in northern California had more sand sediment, decreased water temperature, increased canopy cover, and higher water velocities than the South Fork of the Trinity River that lacks any impoundments (Reese 1996; Reese and Welsh 1998a). Dams have resulted in substantial loss (41–94%) in the frequency and depth of large, deep pools in some streams (FEMAT 1993). On the other hand, reservoirs create large impoundments of standing water with long shorelines, some of which may prove beneficial to the Western Pond Turtle.

Contaminant spills and pollution kill turtles directly as well as indirectly by removing the prey base or degrading habitat quality. Chemical spills pose a threat to Western Pond Turtle populations near highways and industrial areas. Holland (1994) reported several contaminant spills into aquatic habitats inhabited by turtles in southern Oregon during 1993. These included a diesel spill that negatively impacted 50 to 100 turtles, resulting in the death of some animals. However, most turtles were not harmed by this spill and no long-term consequences occurred (RB Bury, DJ Germano, unpubl. data). Bury (1972b) studied the effects of contaminants on the species following a diesel spill in a northern California creek. He found 1 dead turtle, and surviving turtles had swollen eyes, swollen necks, uncoordinated movements, and sloughing epidermis, up to a month after the spill. However, the population seemed to have about the same number of animals in later years (RB Bury, unpubl. data), so impacts may have been temporary with the fuel flushing out of the system. Turtles living in lakes and ponds may experience substantially greater and longer impacts as they lack the flushing ability of river systems. In recent years, northern California has experienced a number of contaminant spills into aquatic systems, such as the 1991 herbicide spill in the Upper Sacramento River at Cantara (see Luke and Sterner 2000) and a latex paint spill in the Smith River in 1994, but no studies of turtles occurred.

Mining activity can add toxic metals into streams and ponds that may have a direct impact on turtles (Henny and others 2003), or indirectly by reducing the food source, such as aquatic insects. Succession of riparian vegetation may increase canopy closure, which creates shady areas with cooler water temperatures thereby precluding turtle use of some habitats. Irrigation can dry streams and eliminate aquatic habitat. The conversion of complex riparian areas to more simple ecosystems due to residential encroachment negatively affects pond turtles. In urban areas, the amount of impervious cover dramatically increases surface runoff during storm events. This increases the input of pollutants, such as oil and gasoline, and the frequency of high flow events that create challenging in-stream conditions for aquatic organisms including turtles. The conversion of natural uplands to agriculture or grazing may decrease water quality. Boating, swimming, and other recreational use of aquatic habitats may result in early termination of basking by turtles. This reduction in basking may negatively affect the development of eggs in female turtles during the critical spring period.

Incidental catch by fisherman may account for losses of turtles in some areas. Turtles have been caught on a variety of tackle including floating and bottom-set baits. Those that do not die from trauma associated with ingesting fishing tackle may starve to death later.

Hatchling turtles appear to require special habitats to survive. They are relatively weak swimmers and remain in shallow waters to feed, using emergent vegetation or rocks for basking sites and cover. Many aquatic habitats (for example, canals and especially concrete-lined ones) lack shallows, emergent vegetation, or still-water zones that are suitable for hatchlings. Large lakes and constructed ponds, irrigation canals, and reservoirs have little or no emergent vegetation and shallow areas for hatchlings.

Conservation measures.—Large-scale projects to restore river floodplains, such as the Willamette River Floodplain Restoration Initiative (Hulse and others 2002) and the Sacramento

River Conservation Area (California Resources Agency 2003), are important for long-term survival of indigenous turtle populations. In fact, the status of pond turtle populations could provide an excellent biometric for measuring the ecological success of such projects. Turtle survival likely will be improved by the protection or creation of sloughs, ponds, and backwaters along large rivers, restoration of floodplain habitat, creation of large wetland complexes, and other similar efforts by federal, state, and local agencies.

Coordination should occur with the agencies responsible for reservoir operation to determine which flow manipulations may be used to benefit pond turtles while still accomplishing the goals of the operator. The use of in-stream minimum flow requirements should be incorporated into the existing water law system (Young 2000). This would reestablish aquatic habitat in many streams that currently become dry during part of the year.

In areas with levees, the use of setbacks (for example, 10–25 m) from the channel will allow the river area to meander without undercutting the levee. The use of riprap along channels typically alters stream morphology and natural fluvial process, such as floodplain connectivity, but may provide basking areas for turtles. We recommend the dissemination of information on pond turtle habitat requirements to planners and biologists involved in developing watershed management plans and habitat projects within river corridors or those associated with wetlands, lakes, and ponds throughout the range of the turtle. The identification and establishment of protection buffers for overwintering and nesting areas can be determined by attaching radio transmitters to adult turtles.

Newly constructed ponds and wetland developments should provide areas of shallow water and emergent habitats for hatchling turtles. Add floating objects such as logs or wood rafts away from shore. These are especially important when located in proximity to nesting areas. Ponds that do not now provide emergent zones can be reconfigured to provide these features. In Lane County, Oregon, small berms were pushed up from indigenous soils, and these were favored nesting areas. Leave small, shallow adjacent ponds, and attempt to encourage establishment of indigenous emergent plants. These small waters are expected to provide suitable hatchling habitat until they become dry in late summer. Further, they are expected to provide security from Bullfrog (*Lithobates catesbeiana*) predation because the nearby larger permanent water body should be more attractive to large Bullfrogs than the small shallow ponds. Wetland development and management may be promoted on private lands by providing information on turtle biology and habitat needs through state and federal natural resource agencies, watershed councils, informational brochures, posters, slide shows, and volunteer site visits.

Prevention of spills of oil and other contaminants is a difficult problem to correct. Most major roads and railroad tracks run alongside streams and rivers as these cut through mountains. Thus, truck traffic and railroad cars with pollutants are transported in close proximity to water. There have been several spills that impacted turtles (for example, see Bury 1972b). Faster response time is needed on spills as sometimes the materials can be contained or absorbed. Increased effort is also needed to better understand the effects of contaminants from roadway stormwater runoff. Federal and state laws have raised treatment requirements over time, but we are only just now identifying the environmental effects of some contaminants, such as copper from vehicle brake pads (Trombulak and Frissell 2000; Croteau and others 2008).

Introduced species such as Bullfrogs and Largemouth Bass (*Micropterus salmoides*) may eat young pond turtles, but there is little evidence as to the extent of such predation. Another concern is the possible introduction of parasites or pathogens from introduced species of turtles. For example, the nonnative Red-eared Slider (*Trachemys scripta*) is increasing in numbers in the west, especially near urban areas (Spinks and others 2003; Patterson 2006; Bury 2008a). Although this and other nonnative species of turtles may compete with the Western Pond Turtle (see Spinks and others 2003; Bury 2008a), this relationship needs further study and better documentation. The introduced Red-eared Slider appears to have a negative impact on freshwater turtles native to Europe (Luiselli and others 1997; Cadi and Joly 2004; Polo-Cavia and others 2008). We need studies on the extent of occurrence and impacts of these invasive turtles in western North America.

Terrestrial Habitats

Habitat loss or degradation.—Turtles use terrestrial habitat for overwintering, nesting, and movement to and from waterways. Western Pond Turtles frequently overwinter on land near their aquatic habitats. In northern California, Reese (1996) documented overwintering at sites averaging 162.9 m (range 38.8–422.8 m; $n = 18$) from aquatic habitat. These upland habitats included conifer, mixed conifer, hardwood forest, riparian areas, and grasslands. Nesting habitat is characterized by sparse vegetation, a southerly aspect, and a generally gradual slope. Roads parallel to watercourses result in mortality of turtles when moving to and from watercourses during terrestrial journeys (Holland 1994).

Impact to overwintering habitat varies depending upon the specific location of turtle sites, the type and scope of activity or development in the area, and the timing of the activity. Our current understanding of habitat relations is inadequate to allow definition of specific habitat requirements or the complex factors that could influence them. Habitat alterations of concern include 1) road-building; 2) mowing; 3) conversion to agricultural uses; 4) off-road vehicle use; 5) industrial or urban development; and 6) prescribed burning and timber harvesting. Any activities that remove duff, downed logs, or ground vegetation could reduce overwintering sites for the Western Pond Turtle. For example, prescribed burning usually occurs in the spring and fall when temperatures are cool and soil and vegetation moisture are relatively high. These conditions make fire control much easier than in the hot, dry conditions of summer when most natural fires occur. However, a prescribed burn at an overwintering site may harm some turtles. To date, there are no studies on this issue. Turtles that live in rivers, streams, and flood-control reservoirs (with major drawdown seasonally) generally overwinter on land, whereas those that live in ponds or lakes may overwinter either on land or in the mud at the bottom of the lake or pond (Holland 1994; Holte 1998; Rathbun and others 2002).

Nesting habitat appears to have more specific microenvironmental conditions than other habitats used by pond turtles. Nesting habitat is associated with the turtles' most vulnerable life stage (the egg); therefore, maintaining and protecting nesting areas is critical to survival of populations. Threats to nesting habitat include 1) direct human or mechanical alteration and disturbance; and 2) vegetative changes.

Substantial loss of nesting habitat has occurred from road construction. Nesting habitat is often in the same locations where roads exist or are planned along waterways and lakes. Soil disturbance from any number of activities including road building and maintenance, and other construction or human development can impact or remove nesting habitat. Alterations of hydrological processes due to management of water regimes may result in flooding of nest chambers, killing eggs or hatchlings.

Nesting habitat is compromised or lost when native plant communities are converted to agricultural uses (that is, land that is frequently plowed). Also, the conversion of indigenous grasslands, shrubland, or desert habitat to highly maintained turf or other uses in urban or suburban areas may be detrimental to pond turtles. In some cases, vegetation has changed from sparse grasses and forbs to shrubs and trees due to lack of natural disturbance regimes, such as fire and floods. Of recent concern is the occurrence of invasive shrubs such as Himalayan Blackberry (*Rubus discolor*) and Scotch Broom (*Cytisus scoparius*) crowding out open areas. These plants can form dense thickets that block direct sunlight on soils and potentially eliminate nesting habitat for turtles. Other problems that could affect nesting success include increases in human recreation and associated camping and picnic areas that may lead to more garbage in nesting areas. Refuse attracts turtle predators such as Skunks (*Mephitis mephitis*), Raccoons (*Procyon lotor*), and Opossums (*Didelphis virginiana*).

Conservation measures.—Terrestrial slopes adjacent to occupied aquatic habitat provide overwintering sites for turtles and selected areas should not be disturbed. In South Carolina, Burke and Gibbons (1995) reported that federal wetland protection buffers along waters, offset at 30.5 m, were inadequate to protect freshwater turtles. Burke and Gibbons (1995) suggested a buffer of 335 m for freshwater turtles; development within upland buffer zones may be feasible if small in scale and limited to landward edges of the buffers. Rathbun and others (1992) suggested that buffer areas for Western Pond Turtles could extend up to 500 m from water.

Determination of such protected areas needs to be based on data, which are now best obtained by attaching radio transmitters to turtles prior to the winter season and then tracking their movements to overwintering sites. Our current knowledge of this behavior is minimal.

We recommend a 2-tiered buffer: 1) limited disturbance between 100 and 500 m of aquatic habitat, and 2) more intensive measures at <100 m of aquatic habitat, including protection of soil and vegetation from disturbance activities such as development, vehicle use, and road construction. Further, we need to better determine which areas along linear systems (streams, rivers) or shorelines of standing water offer the best nesting and overwintering habitat of turtles. Turtles may avoid some areas (for example, stands of dense conifers or north-facing slopes). Turtles concentrate at certain aquatic sites (for example, at deep pools with cover in streams) and their adjacent uplands will have the most use by turtles. These are priority areas for protection.

Many pond turtles show nest-site fidelity and we need to identify and protect these nesting areas (Holte 1998). Most nest sites are <50 m from the watercourse (see Holland 1994). We recommend the same 2-tiered buffer as in the overwintering section, with limited protection within 100 to 500 m and more protection at <100 m.

It may be possible to apply limited timber harvesting and other vegetation management activities to open up tree canopies near nest areas if it is determined that such actions will increase or improve existing nesting habitat. Mowing and application of prescribed fire can be used to maintain early succession of plant communities that favor nesting areas (Holte 1998; K Beal, pers. obs.). Prescribed fire was used in an active nesting area in the Willamette River valley, Oregon, to retard shrub growth and promote indigenous prairie grasses while eggs were present in the nests. Temperatures recorded just below the nest plug indicated that heat from the grass fire did not extend deep enough into the soil to affect the temperature of the eggs (K Beal, pers. obs.). This situation needs further study to determine if prescribed fire may be used at any time without harm to the eggs or hatchlings.

Emphasis should be placed on control of invasive plants; however, even succession by native plants may need to be controlled by mowing, hand cutting, pulling, grazing by livestock, and treatment with herbicide in critical nesting areas. Whatever method is used to remove the initial plant growth, the key to success will be repeated treatments to allow grasses to become reestablished or open area maintained. Because little is known about herbicide use in nesting areas, it should be used rarely and monitored to avoid unwanted effects on turtles and other biota.

In areas with heavy human impact, protection of nest areas may require seasonal closure or relocation of human activity to other recreation sites. A minimum level of mitigation would use fencing to exclude disturbance from nesting areas. Suitable fence designs will preclude the disturbance (vehicle, pedestrian, domestic animals, or livestock) without excluding turtles. The use of an electric fence with an 8-cm gap at the bottom has been used successfully for many years at a nesting area in Lane County, Oregon (K Beal, pers. obs.). A more secure fence may be constructed that may not encircle an entire nesting area, but only discourage disturbance from humans or pets.

Predator exclusion devices can be installed to protect nests from predators. Raccoons, Skunks, and Foxes (*Vulpes* sp.) can have a significant effect on nest success. Exclusion devices may be especially important when nesting areas are located near human activity, such as campgrounds or towns that have elevated predator populations (for example, feral dogs). A wire mesh cage can be partially buried around or staked down over the nest (Fig. 18).

Graham (1997) used a circular mesh cage partially buried beneath the ground and around the nest to protect nests of the Redbelly Turtle (*Pseudemys rubriventris*). The cage was made of black or dark green 1.2×2.5-cm vinyl-coated wire mesh. A piece of wire mesh was cut to produce a 1-piece rolled cylinder 0.5 m in diameter and 0.5 m tall. Another square piece was cut just large enough to cover one open end of the cylinder. The edges of the cylinder and end closure were secured with wire or hog rings, and the 4 overhanging corners of the end closure were bent over the cage. A circular imprint of the cage was made on the ground by centering the open end of the cage over the nest, pressing it into the soil, and twisting to leave an imprint of the cage perimeter. A 30-cm-deep

FIGURE 18. Wire cage enclosure surrounding a nest of a Western Pond Turtle. Note hole in center of picture where hatchlings dug out of nest chamber. Near Eugene, Oregon. Photograph by Kat Beal.

trench was carefully excavated with a trowel, using the imprint as a guide. The cage was lowered into the trench and soil packed tightly around it. The exposed portion of the cage extended 20 cm above the ground surface.

Similar to exclusion cages made for Redbelly Turtles, an effective predator exclusion device for nests of Western Pond Turtles is a cage that is constructed from 1-cm^2 hardware cloth cut into a 0.5 × 0.5-m cross shape (Fig. 18). The cross is bent into a box shape, with one open end, and the edges are attached with wire or hog rings from the closed top to 25 cm from the bottom. Make an imprint of the cage over the nest and press down lightly. Carefully remove about 5 cm of soil from beneath the imprint, and then fold the unattached sides of the cage outward flat against the ground. Wooden or rebar stakes are pounded into the mesh to hold the cage down, and the flattened sides and stakes should be covered with soil. The soil can be tamped down by firmly stepping on it. The cage should extend 20 cm above the ground surface.

Exclusion devices can successfully protect nests from predators, but they may also trap hatchlings at their time of emergence. Trapped hatchlings can succumb to heat and desiccation stresses, so it is important to provide a shady refuge within the cage. A piece of burlap or other heavy fabric can be wired or hog-ringed to the cage to provide shade in one corner. While access to shade is important for hatchlings, the nest itself should not be shaded. Shade may cool the nest microclimate sufficiently to alter development, emergence, and sex ratio. For example, incubation temperature influences sex of hatchlings in species such as the Western Pond Turtle (Ewert and others 1994). Hatchlings may appear 90 to 120 d after nesting (Holland 1994; Goodman 1997a), when wire-protected nests should be checked daily to release hatchlings from cages (Graham 1997).

Another way to assist escape of hatchlings from the wire cage is to construct a small 1-way door in the side of the cage. The opening should be a 30 × 30-mm square opening, cut at ground level. In areas where hatchlings remain in the nest over winter, the door is a 35 × 35-mm square piece of hardware cloth that is attached with hog rings along the top edge of the opening on the outside of the cage. Be certain that the door can be pushed open easily from the inside. The door should be clasped shut during the fall and winter to exclude predators, but can then be unclasped during the period of spring emergence to allow hatchlings to escape. Some emergence occurs in fall and winter (K Beal, pers. obs.), so this design allows year-long escape of hatchlings.

Many predators feed on turtles, especially on nests and smaller turtles. Known or suspected predators on Western Pond Turtles include Bullfrog, Bass, Osprey (*Pandion haliaetus*), Golden Eagle (*Aquila chrysaetos*), Striped Skunk, Raccoon, Coyote (*Canis latrans*), and River Otter (*Lutra canadensis*) (Holland 1994; Hays and others 1999; Bury and Germano 2008). Still, there is little empirical evidence of the proportion of eggs or hatchlings lost each year to predators. Adult turtles often show scarring (tooth marks) on the shell and missing limbs, which indicates attempted predation. In Lewiston Lake in California, a turtle was found with a mammalian canine tooth embedded in its carapace (D Ashton, pers. obs.). With loss of larger predators in some ecosystems (for example, Cougars [*Puma concolor*]), smaller carnivores such as Raccoons and introduced Opossums proliferate, a process known as mesopredator release (Soulé and others 1988). Such predation is documented as impacting hatchling success at sea turtle nesting beaches (Ehrhart 1979).

CONCLUSIONS

The Western Pond Turtle appears to be experiencing severe declines or population losses at the northern and southern ends of its range as well as some other areas in-between. To the north, it is listed as ''Endangered'' in the State of Washington and protected in Oregon. It seems to be uncommon in northern Oregon, but a rigorous assessment of its status is lacking in the Willamette Valley. To the south, populations have been eliminated and are disappearing in southern California and, likely, Baja California. Other losses have been noted in areas with heavy agriculture or urbanization.

Although large populations remain in the core of the species' range (mostly from the San Francisco Bay Area north to the Umpqua River basin in Oregon), these populations are not secure or protected because there is increased human population growth and development in many of these areas. On the positive side, Western Pond Turtles readily inhabit artificial aquatic habitats such as stock ponds, which have proliferated in many areas within its range. The turtle is also flexible in its habits, with occurrence from isolated pristine waters to settling ponds in wastewater treatment plants. Therefore, there is room for some hope and ample opportunity to effectively protect the Western Pond Turtle from extirpation if we expend the energy to protect these remaining large populations and better assist those in decline. This chapter provided a review of conservation and management measures that may assist or enhance populations of the Western Pond Turtle. Where populations may be in jeopardy, we can employ a suite of management tools to reverse the situation, including preservation (protection), restoration, rehabilitation, and mitigation of habitat. Head-starting turtles may assist efforts at selected sites, but should be considered a last-ditch enterprise after other in situ efforts fail. Also, we need to recognize both the aquatic and terrestrial environs used by the turtle and then develop conservation measures for them in concert.

CHAPTER 9

FUTURE RESEARCH AND MANAGEMENT ACTIONS

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INTRODUCTION

Thirty years ago, one of us (Bury 1979) stated that information on the population ecology of freshwater turtles was wholly inadequate for their conservation and management. In turn, these words of Gibbons (1990b) still ring true:

> *Why are there so many unanswered questions about freshwater turtles? Certainly, one of my primary disappointments is that we do not have more data on certain aspects of their ecology.*

Our knowledge on the biology and conservation of freshwater turtles has considerably advanced in recent years. Accordingly, there is much new information available on the Western Pond Turtle (*Actinemys marmorata*) (Bury and Germano 2008) and related freshwater turtles (see Klemens 2000a; Ernst and Lovich 2009). This may lead to the impression that the ecology, status, conservation, and management of Western Pond Turtles are well understood. There may be enough information to understand the natural history and ecology of some populations of this turtle, yet we lack sufficient knowledge to provide effective management and protection at regional or range-wide levels.

The Western Pond Turtle has an extensive north-south range and occurs in a wide range of primarily aquatic habitats; however, it also has particular life-history requirements, including spending considerable periods of time in the terrestrial environment for some populations. This turtle is adapted to many environmental conditions, yet what is known in one area or region may not be applicable at another, nor at a wider spatial scale. Further, recent evidence (Spinks and Shaffer 2005) indicates that there are at least 4 distinct genetic groups (clades) within this species, with 3 occurring south of the San Francisco Bay Area in California. We lack information on how each of these clades, or other localized geographic populations, may differ in their ecology and behavior, and in their response to threats to their persistence.

Some biologists and managers may resort to using information on Western Pond Turtles that is found in unpublished or ''gray'' literature that may lack critical peer review and that are often difficult to obtain. It is important to base decisions that may affect this turtle on published findings in the scientific literature. The published literature has been vetted by peer review, which lends credibility and accuracy to both the results and interpretations.

Earlier, two of us (Germano and Bury 1994) listed a set of topics about future research needs for North American tortoises (genus *Gopherus*), a group that also had been studied for decades, yet for which much gray literature abounds and for which important areas of research had been neglected. Here, we consider many of the same topic headings but focus efforts on the Western Pond Turtle. Then we integrate these questions with issues raised in other summations of knowledge on freshwater turtles (Bury 1979; Gibbons 1990b; Klemens 2000b). We synthesize these various approaches into a proposed plan of action to improve our understanding of the biology, life-history traits, ecological role, status, and protection of the Western Pond Turtle.

We review the key research and management needs stated by ourselves or colleagues to set the stage for future work. In this concluding chapter, we attempt to build a framework to solidify and organize our collective efforts. We include needs to conduct research on Western Pond Turtle populations and their environments, employing 2 approaches: basic (for example, more theoretical questions) and applied (for example, conservation issues). We also offer a critical evaluation of our current understanding of the ecology and conservation of this turtle and offer suggestions for improving studies and management of this species and its habitat.

Adequacy of the Research: Critique of Publications and Reports

The quantity and quality of research on Western Pond Turtles differ widely across its geographic range but, overall, there is a moderate amount of information for this reptile. There is more information available on the Red-eared Slider (*Trachemys scripta*) than any other freshwater turtle, including an in-depth book of its ecology by Gibbons (1990b). In North America, there are also books on the Alligator Snapping Turtle (*Macrochelys temminckii*) by Pritchard (2006), Common Snapping Turtle (*Chelydra serpentina*) by Steyermark and others (2008), and Box Turtles (*Terrapene* spp.) by Dodd (2002). There is considerable scientific literature on the biology of the Painted Turtle (*Chrysemys picta*), although there is no book on this species. All of these books and articles provide a wealth of ideas for the study of specific issues relevant to Western Pond Turtle research and conservation. We believe a review of this literature can provide an abundance of approaches and techniques for scientific studies and management principles for the Western Pond Turtle.

There are several major bibliographies on the Western Pond Turtle (see Chapter 3), including 1) from M Bettelheim (n = 200 entries; available online); and 2) from F Slavens and K Slavens (n = 216, and 63 additional papers; online). Besides many research papers, these bibliographies list numerous unpublished reports, anecdotal observations, 1-page news notes, and online information about this species. Many of the references in these compilations are gray literature and difficult to obtain.

We found that major published articles on Western Pond Turtles constituted only 13.1% (range 8.7–15.7%) of the available information in these bibliographies. Published notes and minor contributions were 34.8% (range 30.3–33.4%). Although these notes were numerous, they generally are only a paragraph or two and often are specific to a single topic at one place at one point in time. Most of the information (52.1%) was gray literature (not in peer-reviewed outlets). Moreover, we found many of the reviews and reports were rehashes of published literature or continuation of dogma (reported as facts but not based on scientific evidence). Such assessments or reviews of the biology of the Western Pond Turtle should not be needed for some time because of a recently released synopsis on the species (Bury and Germano 2008), and we provide a review here based primarily on published information. Thus, we suggest that time would be better spent on field studies of the Western Pond Turtle, which will add to our knowledge base, rather than on more compilations of existing information.

There are serious downsides to the use of unpublished information. A report or data set from a study residing in the files of an agency or consultant may satisfy local or regional needs or answer a specific question, but it hides the information for use elsewhere. Biologists on other projects often reinvent the wheel as there is no convenient way to access all this gray literature. This reality renders the use of these reports questionable when it comes to furthering our knowledge of Western Pond Turtles. Also, much speculation and poorly supported conclusions are common in reports lacking peer review. We suggest that creating such material is often a disservice to those trying to obtain factual, available material.

Despite our criticism of unpublished reports, some of these may contain valuable and important data. We recognize that in many cases, a field biologist or manager may lack access to the published literature, specialized equipment, or expertise to conduct a rigorous scientific study. We strongly recommend that biologists who do not feel comfortable submit-

TABLE 5. Major published papers by primary topic on the Western Pond Turtle. Bold are key contributions.

Topic	Reference
Species accounts (many topics)	Carr (1952); Stebbins (2003); **Bury (1970);** Ernst and Barbour (1989); Nussbaum and others (1983); Jennings and Hayes (1994); Storm and Leonard (1995); Buskirk (2002); **Bury and Germano (2008)**
Taxonomy, nomenclature	Seeliger (1945); Smith and Smith (1979); Gray (1995); **Spinks and Shaffer (2005); Spinks and others (2010)**
Growth	**Bury and Germano (1998); Germano and Rathbun (2008); Germano and Bury (2009); Germano (2010); Bury and others (2010)**
Home range	**Bury (1972a, 1979); Goodman and Stewart (2000);** Reese and Welsh (1997)
Overland movements	**Storer (1930); Rathbun and others (2002);** Reese and Welsh (1997)
Diet	**Bury (1986);** Holland (1985); Goodman and Stewart (1998)
Behavior	**Bury and Wolfheim (1973)**
Habitat selection	**Reese and Welsh (1998a)**
Reproduction	Ewert and others (1994); **Goodman (1997b); Rathbun and others (1992, 2002); Lovich and Meyer (2002); Scott and others (2008); Germano and Rathbun (2008); Germano (2010)**
Population size and structure	**Bury (1979); Goodman and Stewart (2000); Germano and Bury (2001, 2009); Reese and Welsh (1998b); Germano and Rathbun (2008); Germano (2010); Bury and others (2010)**
Sex ratios	**Bury (1979);** Germano and Rathbun (2008); **Germano and Bury (2009); Bury and others (2010)**
Parasites, commensals, mutualists	Ingles (1930); Thatcher (1954); **Bury (1986); Germano (2000)**
Effects of invasive species	**Lubcke and Wilson (2007); Lovich and Meyer (2002); Spinks and others (2003); Bury (2008a); Thomson and others (2010)**
Conservation and management	**Brattstrom (1988);** Jennings and Hayes (1994); **Bury and Germano (2008)**

ting manuscripts to peer-reviewed outlets team up with scientists at universities and agencies who publish papers and create a partnership to increase the likelihood that useful information is submitted for publication. Further, partnering with scientists can ensure that studies are well designed and rigorously conducted so they may later merit acceptance in peer-reviewed journals. We also suggest that managers become familiar with the importance of scientific literature as the primary source of information and, in turn, recognize the pitfalls of using gray literature to support decisions.

We tabulated the major literature (for example, published peer-reviewed articles and historic studies) as a means to assess the advance of science or conservation of the Western Pond Turtle (Table 5). We excluded reports, unpublished documents (even when sizeable), news notes, and anecdotal information because of their lack of scientific rigor, peer review, or failure to make a major contribution to the understanding the species. Surprisingly, we found only 27 papers that we consider as major literature on the Western Pond Turtle. These were written by 11 scientists (as lead authors) with 5 biologists authoring 1 paper each, 4 biologists authoring 2 papers, 1 as lead author on 5, and 1 biologist authoring 9 papers. Although this appears impressive, it is work over 3 decades and at sites widely dispersed across the range of the Western Pond Turtle.

Research and conservation of the turtle have increased rapidly in recent decades: there was 1 major paper in the 1930s, 4 in the 1970s, 2 in the 1980s, 6 in the 1990s, and 12 since year 2000. We are aware of several other manuscripts recently submitted to journals. Thus, research papers on the Western Pond Turtle have increased rapidly and this is an encouraging trend. At the same time, there is also a surge in the release of news notes, unpublished reports, and other gray literature. We suggest that biologists attempt to reduce production of gray literature and, instead, consolidate observations and properly address questions such that these queries can result in published peer-reviewed papers in the future.

FUTURE STUDIES

Estimates of Occurrence and Density

It is essential to the conservation of the Western Pond Turtle to make accurate and scientifically valid estimates of the abundance and populations trends of the species throughout its range. There is need to determine population sizes of this species (for example, based on mark-recapture techniques). This is about to change as we have several of these efforts underway, yet at only a few sites. Although turtles (except small-sized ones) are easily marked along the edges of the carapace for long-term assessments of numbers and trends in populations, no one has conducted a critical review of the pros and cons of this technique (for example, compared to passive integrated transponder tags). There are various code systems, yet no centralized depository exists by region or statewide. Also, the results of sampling by trapping or snorkeling versus visual encounter surveys have not been rigorously compared across any region within the range of the turtle (see Chapter 5).

Geographic Variation

Better understanding of the biology of Western Pond Turtles from the major habitats (for example, Central Valley versus the Coast Range of California) and the bioregions within its range is needed. For comparative studies a minimum of 3 study sites is recommended in each major ecoregion (for example, Central Valley) so that the means and ranges of important variables can be better determined. Representative or random areas can be selected to serve as intensive ecological research foci with an emphasis on year-to-year variation in population parameters, with animals at these sites followed for 5-y periods or longer to better detect their responses to environmental variability over time.

Western Pond Turtles appear to have eggs or hatchlings that overwinter in the nest (Chapter 2). These observations are based on turtles from the northern portion of its range where females nest primarily in June. At approximately 90 d later (average time for incubation), it is September and temperatures are starting to drop. Heavy rains usually start at the end of October. Nests in clay soils may become hardened chambers that, in essence, trap hatchlings until the soils loosen. Further, a hatchling emerging in late summer would face the driest, hottest period of the year and likely place the small animal at considerable risk of dehydration and thermal stress until it reaches water. Emergence from the nest the following spring would present wet, cool conditions. Southern regions appear markedly different from the northern situation. Turtles in southern sites may nest in May, perhaps earlier. Eggs have been detected in females using x-ray photographs taken in mid- to late April at some sites (Scott and others 2008; DJ Germano, unpubl. data). If in loose or sandy soils, the hatchlings could emerge in late summer or early fall. These hatchlings would probably need to find water as they would face hot, dry environs on land during this season.

Today, we have mostly conjecture because of the lack of published papers about these patterns. Empirical evidence is sorely needed to resolve these key questions: When are nests deposited? How many per year? When do eggs hatch? When do hatchlings emerge from the nest? Do turtles enter a diapause during cool-weather periods? Is there one or are there several patterns related to local or regional environmental cues? Do patterns vary by geographic differences along the north-south continuum or low-elevation to mountainous areas?

Studies of Habitats

Definitions of quality and quantity of habitats used by turtles are basic information required for effective management of turtles and their habitats. Moreover, this information is critical for defining the minimum and optimal habitat requirements of the Western Pond Turtle in the next few decades due to rapid human expansion in or near its habitats. However, there is little information available about how turtles use aquatic and terrestrial environs on a daily or seasonal basis. Increased use of radiotelemetry in focused studies could assist in gathering these needed data: Do individuals return to the same cover object (for example, a large partly submerged log) every night? If turtles have preferred use areas, what are the features used? How much of a pond is explored each day (presumably in search of food or mates)? How many hours a day do turtles bask out of water? Do these features vary over different seasons, habitats, or geographic areas? Are turtles occurring in aggregations in aquatic habitats? How much time does this species spend on land for nesting or overwintering? What is the extent of area next to waters that are required to protect terrestrial environments used for the turtle?

Life-History Traits

We need better information on the growth, fecundity, longevity, and survivorship of Western

Pond Turtles. Studies of their fecundity may be patterned after major studies on Desert Tortoises, *Gopherus agassizi* (Turner and others 1986) and freshwater turtles in eastern North America (Congdon and Gibbons 1990; Gibbons and Greene 1990; Vogt 1990). Also, Gibbons (1990b) suggested that it is important to determine the relationships among egg size, clutch size, and clutch frequency of female turtles because each characteristic has a direct bearing on reproductive success and fitness of individuals. A change in one characteristic potentially has a direct effect on others. This basic information has been published only for a few sites for Western Pond Turtles.

Eggs in females of the Western Pond Turtle can be detected by palpation (see Chapter 7). If eggs are detected, numbers of eggs can be counted using radiography. Females may need to be checked biweekly for 2 to 3 mo to determine the period of reproduction over an activity season. Smaller individuals must be checked for eggs to determine the size and age at which females can first reproduce. Females in most populations may not have eggs until they reach 130 mm or more in carapace length (CL), yet this basic information, which has a great effect on the growth rate of a population, has not been quantified across the range of the turtle.

Similarly, sexual maturity of males has to be better quantified (by carapace size and known age) by determining either when they engage in sexual behavior or by the detection of sperm production. Cloacae can be injected with water to flush sperm into vials for later examination in the laboratory. Size and age at first reproduction should not be assumed to be the same as when males start to show secondary sexual characteristics. Males may start to be distinguished from females when CL is 115 to 120 mm, but that may not mean that males are also producing sperm at that size. Although we do not know if age of sexual maturity of males and females vary in different regions, southern populations grow much faster than those in northern latitudes (Germano and Rathbun 2008; Germano 2010; Bury and others 2010).

The age and longevity of individuals are important for determining population viability. Counts of growth rings (where 1 growth ring is evident each year) are accurate for determining ages of Western Pond Turtles up to 15 y (Bury and Germano 1998). Thin scute sections may be useful for counting ages of older individuals (Germano 1992). Scute rings of most turtles ≤15 y old can be counted in the field and compared with those of individuals whose ages are known from mark-recapture studies.

Survivorship in wild turtle populations has not yet been assessed. Captive-raised turtles of approximately 90-mm CL had high survivorship when released into the wild (Vander Haegen and others 2009). Once adults, most turtles have high survivorship (Bury 1979; Gibbons 1990b). Recently, one of us (RB Bury, unpubl. data) captured 2 turtles marked 41 to 42 y earlier and 4 others 38 to 39 y after marking. Several were adults (15 y old minimum) when first marked. Although preliminary, these data suggest that a small proportion of adults lives for considerable periods of time in the wild.

Large sample sizes are best to accurately determine rates and patterns of hatchling and juvenile survivorship, but young turtles are difficult to find in the wild. The life-history requirements of hatchlings and small juveniles appear to be markedly different from those of adults. For example, small turtles are secretive and are rarely active away from shallows. One of us (HH Welsh) has twice observed hatchling turtles in shallow riffles of small tributary streams more than 100 m above where they merged with the mainstem river, where adults were commonly observed. The absence of reliable techniques to locate juveniles also precludes assessment of accurate age structure and trends in populations. We need to develop and test new techniques to increase the captures of young turtles. Intensive surveys at relatively small study areas (for example, 1 × 25-m belts in shallow waters next to shore) could reveal more juveniles. This also forces the observer to pay heed to animals in shallows. It would also be useful to attach small radio transmitters to captured juveniles to quantify their habitat use and daily activities.

Analyses of both the age and size classes of turtles in an area can identify the population structure. Based on size determinations, most turtle populations seem to consist of high numbers of adults and few or no juveniles. This structure is sometimes assumed to represent populations with little or no recruitment (Berry

1986; Holland 1994). However, there are alternative explanations for skewed adult size structure in turtle populations. A disproportionate number of adults may be due to a subjective division of Western Pond Turtles into 2 general categories of juvenile and adult. The juvenile stage is a relatively brief period, including only the first 5 to 10 y of life. The adult group consists of a larger group of age or size classes (Fig. 19) because the adult category usually spans from 20 to more years of life. Thus, there are more adults than juveniles simply due to the bias in this system based on the creation of 2 categories.

The skewed nature of population structure in prior studies is compounded by using only sizes and not ages. Often, up to 50% of a population may be less than 10 y old, whereas only 10 to 20% of turtles may be in the juvenile size category of less than 120-mm CL (Germano and Rathbun 2008; Germano and Bury 2009; Bury and others 2010; Germano 2010). Also, we need to recognize that adult survivorship may be equally or more important for the continuity of a population over the long term (Doak and others 1994; Heppell and others 1996). Even if skewed towards a high proportion of adults, these distribution frequencies do not always equate to declining populations. Mortality typically is high in hatchlings, moderate to high in juveniles, and low in adults (Bury 1979; Frazer and others 1990; Gibbons 1990b). Adult chelonians often live a long life and thus population structures are naturally skewed toward more adults (Fig. 19). It is important to determine the age of turtles and compare population structures based on this characteristic (see Germano 2010; Bury and others 2010).

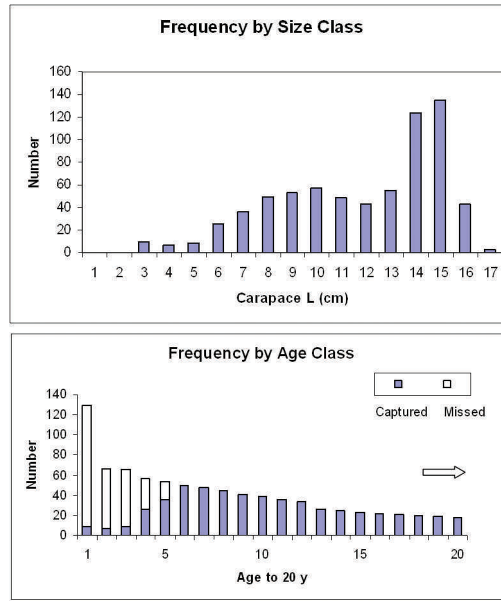

FIGURE 19. Comparison of turtle numbers based on numbers from 1 population in northern California (Bury 1972a; Bury and others 2010; RB Bury, unpubl. data). Top: By size class (10 mm each). Note high proportion of large-sized turtles. Bottom: By ages, but only shown up to 20 y. Missed individuals are numbers that presumably were not found in the field. Western Pond Turtles may live more than 55 y in the wild, and turtles more than 20 y of age may represent a major component of the population.

Daily and Seasonal Activities

We are just beginning to know the daily and seasonal pattern of the Western Pond Turtle. This species can spend considerable time on land, perhaps the majority of the year (Rathbun and others 2002; Bondi 2009). In some ways, it may help our thinking to consider this a semiaquatic turtle with the capacity to spend long periods out of water.

In northern California, turtles emerged from a stream early in the day (07:00) to bask, with a peak number of turtles basking at 09:00 to 10:30 (Bury 1972a). In contrast, turtles in the San Joaquin Valley of California may not emerge to bask in the summer (DJ Germano, pers. obs.). Thus, the species appears flexible in the amount of time spent engaged in atmospheric basking.

Turtles can escape from traps left for extended periods (Frazer and others 1990), but we do not know if this occurs with Western Pond Turtles. We set traps in the evening and, over the next day or two, we find most of the catch during morning checks. However, we do not know if turtles enter and escape traps more often during the day than overnight. Would fresh bait and sets in afternoon periods work well?

Diet

The diet of the Western Pond Turtle is based on only a few local studies. We need to investigate geographic variation in diet as well as food selection and seasonal changes in different regions. New studies should employ stomach flushing which, if done properly, is not harmful to the animal (see Legler 1977; Spencer and others 1998; Ford and Moll 2004; Lindeman 2006). Understanding food requirements may be important for managing viable populations and maintaining their ecological functions. Due to their high abundance in certain waters, Western Pond Turtles may be a major predator on invertebrates (for example, copepods, caddisflies, etc.) and, perhaps, on small vertebrates such as tadpoles or small fishes. So far, it appears these turtles are not major predators on fishes. Currently, we have little knowledge of how turtles interact in food webs of streams and ponds, but some work has started (see Bodie 2001; Moll and Moll 2004).

USING THE SCIENTIFIC METHOD

Science involves making careful observations and, in many cases, testing these observations. One might use the comparative method to statistically compare size structures and growth patterns of Western Pond Turtles among sites. Often one may want to test a hypothesis based on manipulating the environment or animal and recording the outcome. In either case, the scientist would predict what the outcome would be, but the data would determine if the predictions were met and, therefore, whether one accepts or rejects the hypothesis. In other words, interpretation of the data should avoid a preconceived notion of what one thinks should occur. In many ways, uncritically using gray literature can lead to unfounded conservation measures that divert attention from true problems. Such gray literature usually should be avoided because the scientific method may not have been followed. As an example, it is often stated in reports that American Bullfrogs (*Lithobates catesbeiana*) are eating small-sized Western Pond Turtles and, thus, reducing recruitment into populations. Yet, these species co-occur in many waters where turtles persist in large numbers and young turtles are regularly found (DJ Germano, pers. obs.). There is no evidence in published literature, where the scientific method was followed, to conclude that Bullfrogs are causing declines in Western Pond Turtles. Instead of being stated as a factor in declines of turtles, this speculation should be posed as a hypothesis that needs testing. Further, if Bullfrogs are predators on small turtles, effects may vary seasonally, by habitat type, or by geographic location. We are not stating that Bullfrogs are not a problem. Rather, this anecdotal speculation has become fact or dogma for some, yet no rigorous data have been gathered to support this conclusion.

Although resource managers abhor duplication of effort, replication is an important component of scientific research. Too often, data or evidence are collected at a site and may be suggestive of a problem or a concern, but without additional corroboration, often transform into dogma. Because of low funding levels, studies are restricted to only 1 area or for 1 sampling season. The nature of biology is that variation abounds. Still, is it better to sample 1 population for 3 to 5 y or sample 3 to 5 ponds for 1 y as these approaches help define variation in populations of turtles and key attributes of their environments? Although funding limitations can be a problem, it is best to do both. Replication is a crucial part of the scientific method and, when well designed, is not duplication but rather confirmation or rejection of prior experiments or observations. Three study sites are the minimum sample to calculate a mean, standard deviation, and range of key values between populations. The scientific study of animals equates to an analysis of variation because complex biological systems change over time (temporal) and space (spatial).

Relatively large sample sizes appeared to reduce the difference in sex ratio of freshwater turtles (Bury 1979; Gibbons 1990a). This suggests that small sample sizes tend to differ due to a variety of factors, perhaps including biased sampling, insufficient effort, or biology of the species. For example, traps set in one area may catch more adult males than females where the home ranges of males are twice as large as females (Bury 1972a). The males are moving more than females and juveniles, so they are more likely to encounter traps. With continued trapping or wider scope of sampling, proportionally more females appear in the sample.

A larger sample also roughly translates into the amount of effort expended at a site. A snapshot or minimal sampling will likely yield biased sex ratios and capture of mostly larger-sized animals. Continued effort will not only locate more females (that tend to be sedentary except when travelling to nest or overwinter) but assist in the discovery of a higher proportion of smaller turtles that tend to be cryptic and secretive. Results and interpretations on sex ratio, size structure, and other features based on small samples or few sites may be of little or no use. For accurate reporting of the population features of turtles, we need large sample sizes (for example, >30 turtles at a single site) or several populations in the same region.

We urge investigators to obtain larger sample sizes prior to making interpretations and conclusions about populations. We realize that there are some small populations in certain locations, and these isolated turtles need special considerations. Still, use caution in reporting differences in population features where sample sizes are small or the scope of the study is limited.

Lastly, the employment of the scientific method for management purposes must be addressed. Conservation is the wise management of natural resources, and meaningful conservation depends on sound biological information. When or where advocacy groups seek results that support their preconceived stance or ideas, we believe that there is no need to pretend that biological studies are being performed. The mixing of advocacy with scientific goals often clouds the entire enterprise. Science is based on the objective collection and testing of ideas and hypotheses. When we recognize our biases from the outset and clearly state what we do, advocacy roles and objectivity (science) can be compatible human traits or endeavors. The goal should be to separate these disciplines to provide clarity of purpose, sound interpretations, and improved biology and conservation of the species under study.

CONSERVATION ISSUES

Collecting and Sale of Turtles

Illegal collection of Western Pond Turtles for the pet trade occurs, but the significance of this to population losses remains undetermined (Holland 1994; Bury and Germano 2008). Sale of many native reptiles and amphibians in California has been prohibited since the early 1980s by the California Department of Fish and Game. It is now illegal to keep Western Pond Turtles as pets in California, Oregon, and Washington.

In recent years, the species has been advertised for sale on several Internet reptile sites. Individual turtles command prices of US$200 to $400 each, likely due to a perception of scarcity. The legality of such practices is suspect because the species is now widely protected in its native range. Some claim young turtles are from captive breeding. Still, the presumed rarity of the Western Pond Turtle appears to drive up their prices and, perhaps, this fosters increased interest in illegal collecting and trade in the species.

To us, the prices for Western Pond Turtles appear inflated. We have heard that wildlife law enforcement agencies are now cognizant of the situation. Overall, there is an incorrect assessment of the status of the Western Pond Turtle. Numbers of Western Pond Turtles are reduced in the southern and northernmost parts of its range. Yet, many populations of large size (>1000 individuals) persist in the core of the species' range in central and northern California and southern Oregon. For example, one of us (RB Bury) has collected, measured, marked, and released more than 1200 turtles in one northern California watershed while another researcher (Holland 1994) has marked more than 5000 individuals across the range of the species. Several populations have more than 500 individuals, including areas along the coast of Central California, the Central Valley of California, and northward to southern Oregon. Many streams and stock ponds throughout foothill regions contain hundreds of turtles. This is not to imply these populations are secure or well protected, but to indicate that this species persists in fair abundance at many sites where they are not bothered by people. Further, the Western Pond Turtle requires presence of water for at least part of each year and water is a scarce resource in the American West, particularly in the southern portion of the turtle's range.

Head-Starting and Manipulation

There have been several head-starting projects (where captive hatchlings are raised to larger size) which have increased local populations (see Chapter 8). Eggs or hatchlings were taken from one locality, head-started, and released to the same, nearby, or distant areas. Most of these efforts occurred in Washington State (Vander Haegen and others 2009) and, on an experimental basis, in northern Oregon.

Head-starting is now occurring in 3 areas of California (Lake and Sonoma counties north of San Francisco; Kern County in the southern Sierra Nevada; and in the San Diego area).

There are some concerns about head-starting of turtles. Seigel and Dodd (2000) warn that highly manipulative programs, such as head-starting, relocation, and translocation are at best unproven conservation techniques for the majority of turtles for which they have been undertaken. Frazer (1992) pointed out that our attempts to conserve sea turtles involve ''half-way technology'' (for example, head-starting), which does not address the causes of or provide amelioration for the actual threats turtles face. Programs often are successful in raising small turtles yet may serve only to release more turtles into a degraded environment in which their parents have already demonstrated that they cannot flourish. Even if head-starting is shown to be a benefit in some situations, biologists still need to identify the specific causes of declines in Western Pond Turtles if society wishes to reverse them in the wild and ensure survival of the species. We must guard against what Klemens (2000b) called ''conscience-clearing expediency . . . replacing sound wildlife management.''

Another problem is that captive-breeding programs often produce animals of unknown genetic and geographic provenance that are maintained under conditions that do not allow for development of natural behaviors (Meylan and Ehrenfeld 2000; Seigel and Dodd 2000). There also remains the threat of spreading disease from captive animals to wild populations. One concern is upper respiratory tract disease. It appeared to be spread from captive specimens of the Desert Tortoise when tortoises were released into the wild (Jacobson and others 1991; Johnson and others 2006). Upper respiratory tract disease or a similar disease has appeared in several populations of the Western Pond Turtle (Holland 1994; Hays and others 1999; RB Bury, unpubl. data). We do not know where the disease originated or how it spreads in Western Pond Turtles. Still, its presence merits our full awareness and a cautious approach to release of any turtles to the wild.

Network and Monitoring Issues

Surveys of turtle populations are critical to determine whether they are in decline and, if so, to identify any human-related causes of the decline (Burke and others 2000). Currently, however, there is no network of permanent sampling transects in place to track changes in numbers of Western Pond Turtles over time. A number of populations were tracked over multiple years (Holland 1994) but, today, there apparently is no follow-up work or achived location information for these sites with accompanying data (size, sex, identification code). Several populations have been under study for a relatively long time, but each is by a different investigator and their objectives vary. Most other studies to date were one-time events (for example, an MS thesis of 1 population of turtles). On a positive note, the California Department of Fish and Game has funded the development of a conservation strategy for the turtle statewide. It will result in a statewide plan including guidelines for inventory and monitoring, and data collection and achive standards to facilitate the detection of changes in distribution and abundance of turtles over time.

Terrestrial Habitat and Effects of Roads on Turtles

Mitchell and Klemens (2000) pointed out that protected habitat such as wetland buffer zones is often 30 m or less around wetlands and such buffers do little to conserve terrestrial habitat required by many freshwater turtles. Turtles may move or nest 200 m or more from wetlands. Further, conversion of terrestrial habitat around wetlands often occurs for agriculture and urban purposes. Because Western Pond Turtles often aggregate in certain sections of waters where there is cover, perhaps they also spend most of their time on land adjacent to these aquatic areas. Radiotelemetry is useful to track terrestrial movements of Western Pond Turtles (for example, Reese and Welsh 1997; Rathbun and others 2002). Further studies are needed to better define which upland habitat areas are used most by the Western Pond Turtle. Identification of specific quality habitats (for example, where most of the turtles nest or overwinter on land) that would be needed for species conservation should be a priority question for telemetry studies.

Vehicular traffic on roads near wetlands leads to the death of many turtles (Mitchell and Klemens 2000; Gibbs and Shriver 2002; Aresco 2005b; Gibbs and Steen 2005; Andrews and others 2008). There are means, such as fencing, to reduce road mortality (see Dodd and others 2004; Aresco 2005a), but they need to be evaluated in western North America. Further, there are inherent issues over biases in recording mortality of herpetofauna on roads (see Steen and Smith 2006). To our knowledge, there is no published study on vehicular effects on the Western Pond Turtle.

Introduced Species

Wetlands and aquatic communities can be altered by the presence of introduced species. Most ponds, reservoirs, and other quiet waters in western North America are now occupied by invasive species of fishes (for example, Bass [*Micropterus* spp.], Catfish [*Ictalurus* spp.], and Sunfish [*Lepomis* spp.]), American Bullfrogs, and turtles, such as Red-eared Sliders and Snapping Turtles (Bury 1995). Bullfrogs and Largemouth Bass (*Micropterus salmoides*) are reported to eat hatchling and young of Western Pond Turtles (Moyle 1973; Nussbaum and others 1983), although experimental studies on eastern turtles show live turtles are not consumed by Bass (Semlitsch and Gibbons 1989; Britson and Gutzke 1993). The effects of these introduced predators on turtle populations, if any, are poorly documented. All of these invasive species often coexist in lowland waters of the West (Bury and Germano 2008). Although Bullfrogs eat hatchling turtles (Bury and Whelan 1984), we currently lack evidence of the magnitude and consequences of Bullfrog predation on the Western Pond Turtle.

Red-eared Sliders now frequent many urban waters in the West (Spinks and others 2003; Patterson 2006; Bury 2008a). Several studies suggest that this invasive species negatively impacts native turtles in Europe (Luiselli and others 1997; Cadi and Joly 2003, 2004; Ficetola and others 2009; Polo-Cavia and others 2009, 2010a, 2010b). How introduced species interact with Western Pond Turtles is largely unknown and merits further study.

Habitat Loss and Alteration

Habitat destruction continues to be a primary cause of turtle population decline and extirpation around the globe (Mitchell and Klemens 2000). We have stressed throughout this book that habitat loss and alteration are the principal threats to the long-term survival of the Western Pond Turtle. To date, biologists, managers, and decision makers seem not to have faced up to the magnitude of these losses and their future implications. Although Western Pond Turtles can reach high densities in habitats such as ponds and slow-moving streams, natural water bodies are becoming a scarce resource in many parts of the turtle's range. Many rivers have dams to regulate water flow and those reservoirs that have rapid drawdown (for example, drop of 50 m in 1 summer) likely lack aquatic plants and invertebrates comparable to more natural, permanent water bodies. Water downstream from dams and reservoirs is often diverted into irrigation canals. We have observed turtles in these modified waters, but we do not know of any studies published on their numbers or status. This is fertile ground for future research.

Further, ways to ensure survival of turtles in these modified waterways need to be considered. How can the turtle adapt and persist in waterways in and adjacent to human centers? What are the responses to additional cover objects such as fallen trees? How can we prevent habitat fragmentation and isolation of populations from one another? Are there ways to construct road crossings in areas where turtles are now frequently killed on highways?

Mitigation is one option to provide turtle habitat. For example, if a marsh in an urban area is to be lost to development, there may be an exchange of lands to create a wetland elsewhere. What are the optimal or best conditions for turtles in the new or constructed wetland? Too often, created wetlands are circular, deep "duck" ponds with an island in the middle. These may be overrun with invasive species and human disturbances, but we lack studies of such impacts, except for a few cases. The creation of more temporary or ephemeral waters may be useful (see Bury 2008b for review) because Western Pond Turtles are opportunistic and can move between water bodies. Many of the introduced species (for example, fishes) perish when marshes or small ponds dry up on occasion.

There is a need to experiment with new approaches and test new ideas, and in gaps of knowledge (Table 6). Is it feasible to clear vegetation next to waters with turtles as a

TABLE 6. Relative level of our knowledge about key population and other features of the Western Pond Turtle across its range. Scale: * = some information, ** = fairly well studied, *** = published research or in-depth studies (yet studies may be few or limited scope). Empty cells indicate no published literature or minimal information.

	Northern Oregon/ Washington	Southern Oregon	Northern California	Central California coast	Central Valley	Southern California	Baja
Taxonomy and nomenclature	*	*	*	**	**	**	*
Distribution	**	**	**	**	**	***	*
Habitat selection			**	**		*	
Diet	*		***	*		*	
Growth		**	**	**	***		
Home range—aquatic			***				
Overland movements			**	***			
Reproduction, clutch size	*		*	***	***	**	
Nesting areas	*		*	**			
Social behavior			**				
Sex ratios		*	***	**	**	**	
Longevity and mortality			**				
Parasites and commensals	*		*		***		
Predators	*	*	*	*		*	
Effects invasive species	*		*			*	
Conservation and management	**	*	**		*	*	

means to attract females to nest there? Which specific areas should be afforded the highest protection for a turtle population? With increasing numbers of people projected to occupy the Pacific states in the next 100 y, how can wetlands be spared from development or draining? How does recreational activity by people interfere with turtle behavior or use of a waterway? Are there ways to mitigate or resolve these issues?

Although public education is not a focus in this handbook, most turtles are highly visible and charismatic species that can receive widespread public support for protection. We urge those with public relations skills to build better outreach or educational information to help society make informed decisions about the management and conservation of Western Pond Turtles. If the management goal is to protect the Western Pond Turtle, then we hope that information provided here can help biologists, managers, and conservationists to better understand the species and develop effective management practices. Lastly, we wish to close with some words of wisdom by Whit Gibbons (1990b) about research studies:

> *. . . we can rest assured that by identifying the gaps in our knowledge about life history and natural history, the way is paved for future investigators who would do more and better than we have done.*

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PLATES

PLATE 1. Western Pond Turtles from northern California. Top: Adult male from Trinity River (approximately 35 km southwest of Redding); with pale and yellowish chin and side of snout, angular profile to large head, and shell is relatively flat. Photograph by Gwen W Bury. Bottom: Adult female from Whiskeytown National Recreation Area (approximately 10 km west of Redding); showing no light color on chin or sides of snout, and dome-shaped shell. Photograph by R Bruce Bury.

PLATE 2. Western Pond Turtles from interior Central California. Top: Male from Fresno. Bottom: Female from Tehachapi Mountains. Photographs by David J Germano.

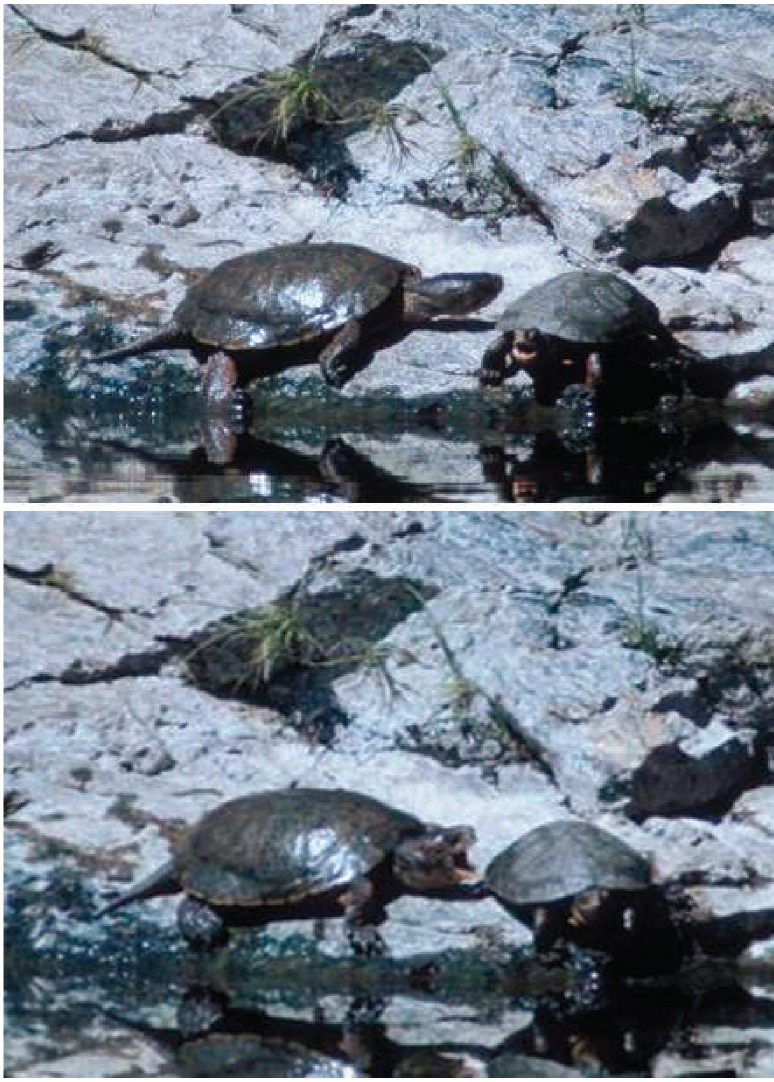


PLATE 3. Western Pond Turtles engage in social interactions. Top: Female (left) emerges from water and juvenile (right) presents an open-mouth gesture. Bottom: The female returns the open-mouth gesture and the smaller turtle turned away. Photographs by Robert C Stebbins and Nathan Cohen.

PLATE 4. Turtles frequent a variety of habitats in central and southern California. Top: Isolated cattle stock ponds in Coast Range, central California, can harbor many turtles. Middle: Fresno Waste Water Treatment facility in the San Joaquin Valley, California, is home to many turtles. Bottom: Man-made canals and ponds in San Joaquin Valley, California, have populations of turtles. Photographs by David J Germano.

PLATE 5. Top: Turtles may occur in roadside ditches such as in the Klamath Lake basin, Oregon. Photograph by David J Germano. Bottom: Turtles basking on rocks and boulders in a stream flowing into Whiskeytown Reservoir, northern California. Photograph by Doug DeGross.

PLATE 6. Turtles basking on boulders and rocky slopes of a deep pool in a stream, northern California. Photograph by R Bruce Bury.

PLATE 7. Secondary sexual characteristics of the Western Pond Turtle. Top: Adult male (left) with pale or yellowish chin and throat plus a relatively flat shell versus female (right) with darker markings underneath and a dome-shaped shell. Umpqua River basin, southern Oregon. Photograph by David J Germano. Bottom: Adult female of Western Pond Turtle with cloaca opening (arrow) close to plastron and thin tail. This turtle has a leech. Northern California. Photograph by Gwen W Bury.

PLATE 8. Secondary sexual characteristics of the Western Pond Turtle in the South Fork Trinity River basin, California. Top: Adult male with concave plastron and a thick, long tail. Photograph by James Bettaso. Top Right: Extended penis of adult male turtle. Photograph by Donald Ashton. Bottom: Plastrons of males. Middle turtle has cloaca far away from plastron end. Two on left have pale or yellowish chins; one on right has dark chin (rare condition). Turtle on far left has one front leg reduced to a bud (likely from predator attack). Photograph by James Bettaso.

PLATE 9. Hatchlings of Western Pond Turtle. Carapace and plastron of hatchling, northern California. Photograph by James Bettaso.

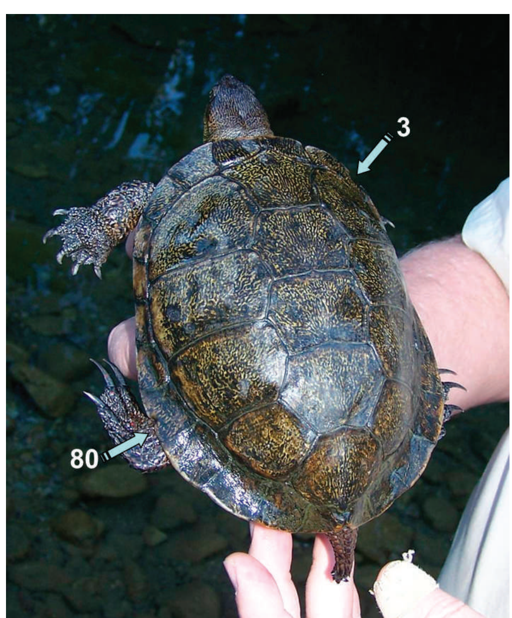


PLATE 10. Some Western Pond Turtles may live a long time. This is adult female Code #83 marked in 1968 in a tributary of the Trinity River, in northern California (Bury 1972a). She was recaptured in 2008 and was the same carapace length. Further, she was in the same pool in the stream where first marked. Note excellent condition: clear eyes, intact long claws, and solid and mostly unblemished shell. Photographed by Gwen W Bury.

PLATE 11. Obtaining field data on the Western Pond Turtle. Top: Dental alginate is quickly mixed and spread on the largest scute on the plastron and carapace. Bottom: The alginate dries in a few minutes and records the growth rings, and later these can be examined in the lab. From left to right: Kat Beal, US Army Corps of Engineers; Gwen Bury, Oregon State University; RB Bury, US Geological Survey; and William Castell, Oregon Department of Fish and Wildlife. Fern Ridge Reservoir, Lane County, Oregon. Photographs by Stephanie Wessell.

APPENDICES

APPENDIX 1. INSTRUCTION SHEETS FOR DATA COLLECTION

Mark-Recapture Data and Codes

Date and time.—Date and time that the captures occurred.

Names of observers.—Record of who made capture and recorded data.

Exact location.—Field notes describing site of capture (for example, 21 m down from project inlet).

Max. carapace length.—Length of each captured individual was measured using calipers held over the carapace.

Weight.—Weight measured to the nearest gram (g) using a Pesola scale and large plastic bag (remember to subtract the bag weight) or a portable electronic scale.

Age.—Estimate of age by counting rings (accurate only on turtles up to approximately 15 y old). Start count at zero ring (smallest) on the scute and count rings outward. Obtain counts from abdominal on plastron and/or 3rd costal on carapace. This is an approximate age estimate.

Size.—Size class determined by maximum carapace length (CL), which can be used to place animals into approximate age classes: Hatchling = 25 to 69 mm, Juvenile = 70 to 125 mm, Adult more than 125 mm.

Sex.—Sex is determined by using a set of characteristics, which include carapace shape, plastron concavity, cloaca position, beak orientation, and head coloration. Juveniles are not identifiable as males or females because turtles do not display sexually dimorphic characteristics until more than 125-mm CL.

Reproductive.—Reproductive condition of females is determined by palpation of the inguinal cavity and feeling for oviductal eggs.

Turtle number.—Record as ''N'' = New or ''R'' = Recapture, and turtle number (code).

Marking Systems and Codes

Comparison of 3 marking systems to mark freshwater turtles based on Cagle (1939), Bury (1972a), and Holland (1994) (Figs. A1-1 to A1-3). The outer scutes (marginals) of the carapace are notched. Number systems start with the first Left Marginal (LM) or Right Marginal (RM) just behind where the head is extended. There often is a single scute called the nuchal at the front juncture of the marginals.

Nest Searching Data and Codes

Obs.—The initials of the observers.

Time. In military hours (24-h clock).

Reach/station.—Identifier for the reach or station that is searched.

Percent cloud cover.—Estimate of the average cloud cover for day.

Compass bearing.—The direction in which the turtle is facing.

Side.—River ''R'' = right or river ''L'' = left.

Distance from shore.—Turtle's position from the nearest river's edge (unless other aquatic edges are closer, like a pond, then make note of that). Estimate the distance by pacing.

Precipitation.—P = downpour, R = rain, D = drizzle, I = intermittent precipitation, N = no precipitation.

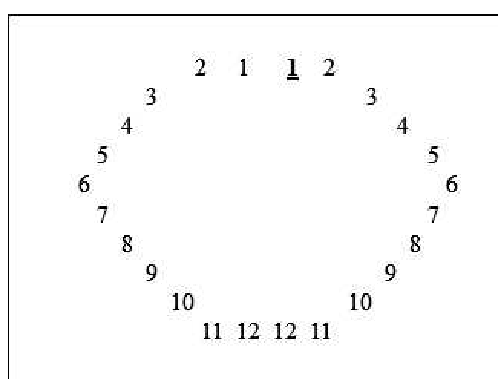


FIGURE A1-1. The Additive Code System, redrawn from Cagle (1939). This systems counts from #1 to #12 down each side. Usually the marginals along bridge (#4, 5, 6, 7) are excluded. Count is Left-Right side, such as: Code 0-1 (1 mark on RM1). Code 6-0 (1 mark on LM6). Code 9-9 (1 mark on LM9, RM9). The system can reach 2516 combinations using just 4 notches. If more are needed, Cagle (1939) suggested notching one of the plastral scutes (two most anterior and two posteriorly).

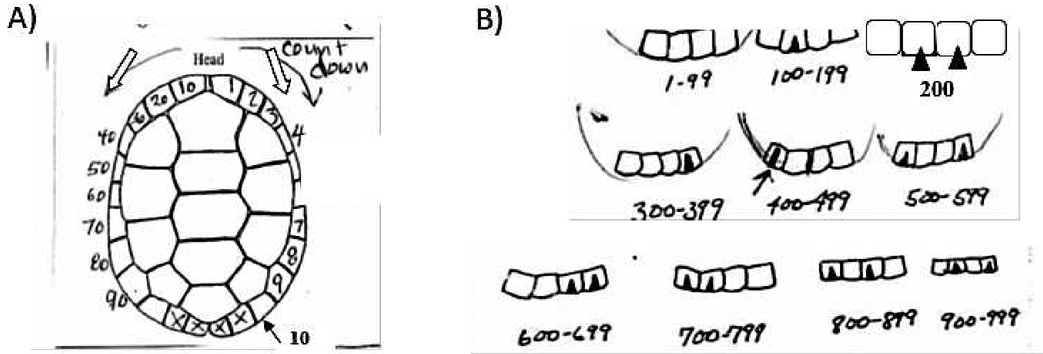


FIGURE A1-2. The Additive Code System (Bury 1972a). This system records tens on left marginals (LM), and #1 to #9 on right marginals (RM). (A) Two down on each side is 20 + 2 = Code 22. (B) Posterior 4 marginals are for hundreds series: combination of marks in RM12 and 11; LM 11 and 12.

Location.—A = above water, U = underwater, P = partly underwater, L = on land.

Buried under.—D = duff/leaves, S = soil, L = log, R = rock, O = other (specify).

Orientation or travel direction.—U = upstream, D = downstream, T = towards shore, A = away from shore.

River habitat.—B = backwater pool, E = edgewater pool, G = glide, R = run, L = low-gradient riffle, H = high-gradient riffle.

Light.—U = full sun, M = mixed/filtered light, SH = .

Behavior.—S = swimming, D = digging, B = basking, T = travelling, X = stationary, F = foraging, M = mating, N = nesting, U = buried, P = partly buried, H = For U and P, add H if the turtle's head is visible.

Habitat Assessment Data and Codes

Start and end time.—Start time of the first site surveyed and the end time of the last site surveyed.

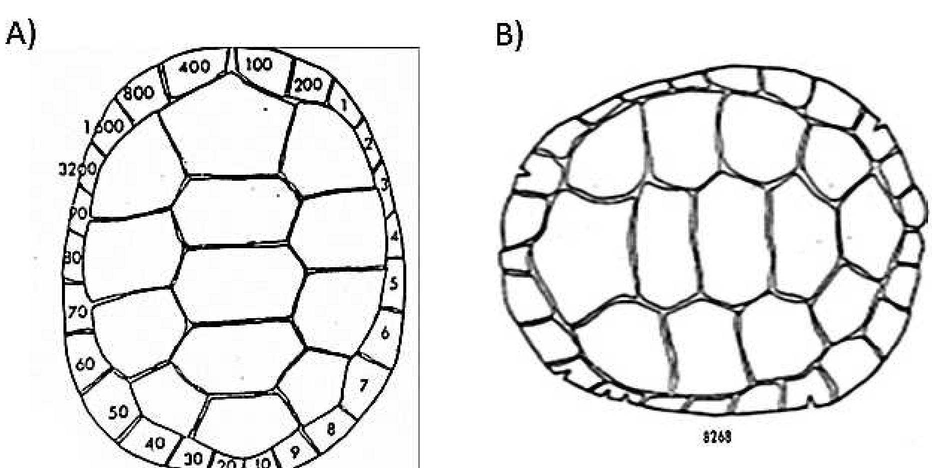


FIGURE A1-3. The Multiple Additions System (Holland 1994). Low numbers start on 3rd right marginal (#1 to #10, then clockwise to #90 on 5th left marginal). Hundreds and thousands are in upper left quarter of carapace. Note: Double marks used for 400, 800, 1600, 3200 become 800, 1600, 3200, 6400. For juveniles or small turtles, the bridge area is not used and only the anterior 2 and posterior 3 marginals are marked.

Start air and water.—Record of air temperature (°C) within 4 m of the water's edge on land but not in direct sunlight. Record of water temperature within 4 m of the water's edge just below the surface of the water.

End air and water.—Same as for ''Start air and water.''

Observers.—Record of surveyor's initials.

Location.—Location of captured turtle or random location is based on a visual estimate to the nearest station flag. Enter the exact reach number, river side (enter R or L), and indicate if the distance is upstream or downstream from the station number (enter U or D).

Site ID.—Enter either the turtle number or ''R'' for randomly chosen locale comparison.

Shore vegetation.—Immediate riparian type on bank. 1 = Gravel/Cobble bar—More than two-thirds of the area is gravel or sandy substrates. 2 = Willow dominant—More than two-thirds of the vegetation is willow. 3 = Willow/Alder mix—At least one-third of the vegetation is willow and at least one-third is alder. 4 = Mature/Alder dominant—More than two-thirds of the vegetation cover is alder or cottonwood. 5 = Other, specify.

Bank slope.—Determine the angle of the immediate bank by placing the slope meter on the edge above the water line.

Bank distance.—Measure the distance from the turtle location to the nearest bank. If the turtle was basking on the bank, then the distance is zero and M2 of the quadrat would be set on the basking locale. If the turtle was found beneath an undercut bank, use a negative number to represent distance to bank and place the quadrat so that M2 is at the bank.

Aspect.—Record aspect of the bank slope.

Channel type.—Identifies the location on the river the data were collected. Circle one: Mainstem (MS) Side Channel (SC) Feathered Edge (FE).

Percent river type.—Determine the proportions (by percent) of river habitat types by envisioning a transect line that goes from the turtle locality across to the opposite bank. Write the percentage of each river habitat to equal 100% combined for the following types: edge pool, glide, run, and gradient riffles.

Bank to riffle.—For each habitat type, determine the ratio of bank to riffle present in the sample quadrat. Combined percentages should equal 100%.

Depths.—Record the depth in meters at the center of the sample quadrat. Zero is recorded when M2 is positioned above water (when turtles are caught basking on bank or outcrops).

Flows.—Measure flow halfway between the surface and river bottom (when possible). Record as a positive (+) or negative (−) flow in meters per second (m/s).

Basking site.—For each size class (1, 2, and 3) record presence or absence of basking sites in the sample quad. To qualify as a basking site, the object must make contact with the water, be $<$ 3 m above the water surface, and have a slope of 70 degrees or less. Banks do qualify if they meet the slope requirement. If the only available Class 3 object is a bank, record a ''B'' instead of a check mark. Class 1 = 0 to 4 mm, Class 2 = 5 to 24 mm, Class 3 = 25 to 100 mm.

Temperature.—Record the water temperature in Celsius at the center of the sample quadrat (M2).

Bank cut.—Record 3 bank undercuts, in centimeters (cm), from the ''B'' side of the sample quad (B1, B2, and B3) using the depth pole. Zero is recorded when there is no bank undercut.

Canopy.—Record the percent open canopy while standing at the center of M2 quad (if possible). Hold the densiometer in right hand with elbow anchored against your hip. Keep your forearm parallel to river surface. To calculate percent open canopy, in your mind divide each square into 4 smaller squares. Then count the number of smaller squares NOT filled by canopy. Repeat this 4 times by rotating your position upstream, downstream, across the river, and towards the bank, and average the values.

Cover objects.— Record presence or absence of suitable turtle cover for each sample quad that is present on the river bottom. Use a check mark in the appropriate box to indicate if cover is present. The following qualify as cover—rocks, logs, debris piles, crevices, and sand. If all the available cover is just sand, put an ''S'' instead of a check mark to show that sand is the only available cover. If you are unable to see the river bottom, even with a mask, enter ''U.''

Habitat Data—Side Channels and Feathered Edges

Date.—Date of the observations.

ID.—The river mile identification number used by the US Fish and Wildlife Service (USFWS) or other.

Riparian type.—Classify macrohabitat riparian vegetation zone (Evans 1980) after the line transect is completed. 1 = gravel/cobble bar, 2 = willow dominant, 3 = willow/alder mix, 4 = alder/mature.

Water.

Sand/silt.

River rock.—River rock (gravel to boulder).

Bedrock.

Litter and detritus.

Grass/herbs.

Willow (<2 m high).—Small willows.

Willow (>2 m high).—Large willows.

Alder (<2 m high).—Small alders.

Alder (>2 m high).—Large alders.

Other (<2 m high).—Other small shrub or tree species.

Other (>2 m high).—Other large shrub or tree species.

Open (<2 m high).—Open understory from the tape up 2 m.

Open (>2 m high).—Open overstory at 2 m or greater.

Radiotelemetry Data and Codes

Observer.—Obs. The initials of the observer.

Time.—In military hours (24-h clock).

Compass bearing. The direction in which the turtle is facing.

Distance from shore.—The turtle's position in relation to the nearest river's edge (unless other aquatic edges are closer, like a pond, then make note of that). Estimate the distance by pacing.

Precipitation.—P = downpour, R = rain, D = drizzle, I = intermittent precipitation, N = no precipitation.

Location.—A = above water, U = underwater, P = partly underwater.

Position.—L = on land, W = in water, N = on a substrate (basking).

Orientation or direction of travel.—U = upstream, D = downstream, T = towards shore, A = away from shore.

River habitat.—B = backwater pool, E = edgewater pool, G = glide, R = run, L = low-gradient riffle, H = high-gradient riffle, P = pond (not connected to river), S = side channel.

Behavior.—S = swimming, D = digging, B = basking, T = travelling, X = stationary, F = foraging, M = mating, N = nesting, U = buried, P = partly buried, H = For U and P, add H if the turtle's head is visible.

Turtle Health Assessment Data and Codes

Note the general condition (past or present injuries) of each animal captured using the following checklist:

Ears.—Injury or swelling.

Eyes.—Clarity, swelling, and condition of lids.

Nose.—Injury or discharge nose bubbles, rattling respiration.

Mouth/jaw.—Injuries, discharge, gaping, color of skin, beak length, and fit of upper and lower jaw.

Feet.—Nail condition/length, injury, and skin condition.

Legs.—Skin condition, wounds, and broken or missing limbs.

Vent.—Injury or prolapse.

Skin.—Dryness, flakiness, parasites, lesions, and wounds.

Shell.—Fractures, flaking, necrotic tissue, infection, local or general discoloration, softness, and curling margins, overall condition.

APPENDIX 2. FIELD DATA SHEETS AND FORMS: SELECTED EXAMPLES

Habitat Assessment Form

Western Pond Turtle Habitat Assessment Survey Form

FOR BASIC AND ENHANCED MONITORING Date ________

Site # ______ **UTM x** ______ **UTM y** ______ **USGS HUC** ______

T, R, S, 1/4 ______ **Landowner** ______ **Observers** ______

Type of System: ______ **SITE, Width** ______ **Length** ______ **Photo record: y/n #** ______
(stream, river, pond, lake, reservoir) (m) (m)

TERRESTRIAL HABITAT

RIPARIAN

Moisture: wet/mesic/dry **Forest:** young/mat/old

List the 2 most common tree, shrub, forb, grass species present:

Shrub ______ **Tree** ______

Grass ______ **Forb** ______

UPSLOPE

Moisture: wet/mesic/dry **Forest:** young/mat/old

List the 2 most common shrub, forb, grass species present:

Shrub ______ **Tree** ______

Grass ______ **Forb** ______

AQUATIC HABITAT

List the 2 most common aquatic and emergent plant species present:

Aquatic ______ **Emergent** ______

Types of Basking Structure Available ______

Types of Aquatic Cover Structure Available ______

Shade: **open** ______ **light** ______ **mod** ______ **heavy** ______
(0-10%) (11-40%) (41-70%) (>71%)

ROADS

Type: dirt/gravel/paved Use level: low/med/high Proximity to aquatic site ______

POTENTIAL DISTURBANCE ______ Intensity ______
(activity type) (low,med,hi)
Comments ______

Nesting Habitat Survey Form

Western Pond Turtle Nesting Habitat Survey Form

Date ______________

Site # ________, **UTM x** ________________, **UTM y** ____________________.

Observers ___________________________, **USGS HUC** ____________________.

T, R, S, 1/4 ___________________________, **Photo record: y/n #** _____.

Type of System: _______________, **SITE, Width** ______ **Length** ______

(stream, river, pond, lake, reservoir) (m) (m)

Landowner: USFS/BLM/state/private/other

TERRESTRIAL HABITAT

Moisture: wet/mesic/dry, Elevation _________, Slope (%) ______, Aspect ________. Dimensions of opening _____ m X _____ m, Percent cover of grass/forbs _________. Dominant vegetation: grass/forb, low shrub, high shrub, tree

List 2 most common shrub, forb, grass species present: Shrub ______________________,

Grass ____________________________, Forb ______________________________.

ROADS

Type: dirt/gravel/paved, Use level: low/med/high, Proximity to nesting habitat ____________.

POTENTIAL DISTURBANCE _________________________, Intensity ______________.

(activity type) (low,med,hi)

NESTING HABITAT DETERMINATION:

Nesting detected/Nesting not detected, but possible/Nesting not detected, poor habitat quality

Comments ____

____

____.

Nesting Habitat Form

Western Pond Turtle Nest Site Survey Form Date ________________.

Site Number _______, Watercourse Name ______________________, Basin Name _________.

Temp.; Air _____C, Water _____C. Weather __ __ __, Event no. _____, Type: pond/river.

Observers _______________________, Affiliation __________, Phone ________________.

Township _________, Range _________, Section _________, 1/4 _______, 1/16 _______.

UTM x _____________, UTM y _____________. Land ownership ____________________.

Bullfrogs detected Y/N; Bass detected Y/N,species Smallmouth/Largemouth/Unk; Other exotic Y/N

Nest #	Distance to water (m)	Percent vegetative cover	Soil type	Intact or predated	Predator exclosure	# Eggs	Comments

Field Computer System (example)

Fields used for direct entry of data from turtles to a data base.

Names: RB.Bury DJ Germano	Western Pond Turtle Trapping	Date 22 June	Year: 1994
Location: Whiskeytown National Recreation Area	**Shasta Co.**	**Calif.**	

Location: Little Bear Creek Arm of reservoir.

Notes: 6 collapsible traps set 6/21 ca. 1800 hrs; checked 6/22 start 0800 h, end at 0830 h.

Date	**ID #**	**Sex**	**Age**	**CL**	**CW**	**HS**	**PL**	**MPL**	CLCL	CLCW	Mass	Notes
6/22/2004	1	M	20+	178	137	59	163	154	197	173	764	
6/22/2004	2	M	7	164	123	53	149	142	174	152	521	
6/22/2004	3	M	15+	163	126	53	149	141	178	160	559	
6/22/2004	4	M	14	170	132	57	153	142	185	173	655	
6/22/2004	5	M	15+	162	125	54	143	134	178	160	565	Many claws short
6/22/2004	6	M	20+	155	120	52	135	128	169	148	449	Algae on carapace
6/22/2004	7	F	7	148	113	52	140	133	162	146	454	
6/22/2004	8	F	20+	165	125	60	153	143	181	165	616	Plastron worn
6/22/2004	9	F	20+	166	127	63	152	144	182	162	648	

Codes

CL	Carapace length (max)	calipers (to mm)
CW	Carapace width (max)	" "
HS	Height shell (max)	" "
PL	Plastron length (max)	" "
MPL	Medical PL - down center	" "
CLCL	carapace length over the shell	soft ruler or cloth tape
CLCW	carapace width over the shell	" "
Mass	g	

Capture/Trapping Form:
Oregon Department of Fish and Wildlife

WESTERN POND TURTLE
COOPERATIVE MONITORING PROJECT 1994

BIOSE CASCADE - BLM - ODF&W - USFS

CAPTURE /TRAPPING FORM Pg___of___

Site Name______________________ **Primary Obs.**___________________________

Affiliation________________________ **Phone #**____________________

County (circle): Jackson Josephine **T**_____ **R**_____ **S**_____ **QS**_____ **SS**_____

Aquatic System (circle): pond reservoir lake river creek other_______________

Land Ownership_____________________ **Activity Level** (circle): low med high

Bullfrog (circle): yes no **Bass** (circle): yes no Other exotic Sp.___________

Age = H (hatchling) J (juvenile) A (adult) Sex = M (male) F (female)
Gravid = Y (yes) N (no) Recapture = Y (yes) N (no)

#	Age:	Sex:	Gravid:	Wt (g):	Lth (mm):	Recap:	Code #	Comment:

Capture/Trapping Form—Individual Turtles: Oregon Department of Fish and Wildlife

Western Pond Turtle ___/___/1993 **Code No.:**______
(Mo) (Day)

Collector:____________________ Recorder:____________________

Location:____
________________ Co., Oregon Drainage:____________________

Trap No.:____ Time Caught:____h Release:____h Weather:________________

Shell: Mass (g) _______ CL_______ CW_______ CF_______ HT_______

PL_______ pl_______ TL_______ pl to Vent_______

Size & Sex: H J M♂ F♀ (Eggs:Yes__No__) Age:_____ (Cast:Yes__No__)

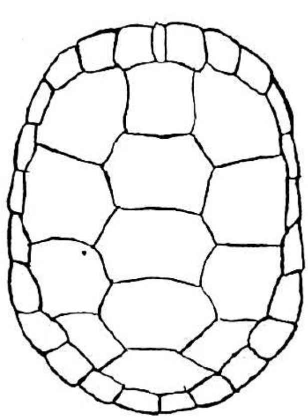
Color
C:____________________
Pl:____________________

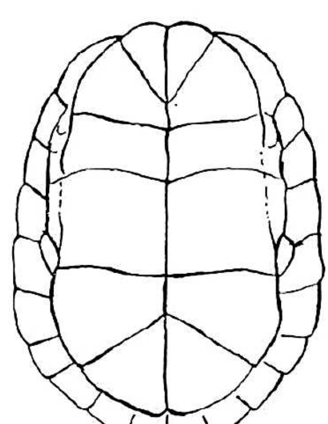
L R Abd. (in mm):
O:____ 1:____ 2:____ 3:____ 4:____
5:____ 6:____ 7:____ 8:____ 9:____
10:____ 11:____ 12:____ 13:____ 14:____

Claws: Fore R:_ _ _ _ _ L:_ _ _ _ _
Hind R:_ _ _ _ _ L:_ _ _ _ _

Condition	Clear	Other
Eyes:	____	________________
Mouth:	____	________________
Resp. Tract:	____	________________

Anomalies:
No: ____
Yes:____
(draw)





Capture/Trapping Form—Series of Captures: Oregon Department of Fish and Wildlife

WESTERN POND TURTLES

SITE ______________________________ DATE __________

COUNTY __________ STATE __________

			AGE									SCUTE LENGTH			
CODE	SEX	MASS	CLASS	#	CL	CW	HT	PL	pl	CLCL	CLCW	COSTAL	ABDOM.	CAST	

Appendix 3. Equipment List

Visual Surveys
Binoculars (8 × 40 power)
Clipboard
Emergency radio
Spotting scope (optional)
Flagging
First aid kit
Data forms
100-m-long tape
Extra water
Thermometers (air, water)
Field clothes (tan/no color)
Hat

Habitat Assessment
Mark-recapture locations
Random number list
Data and code sheets
Clipboard
Marking pen
Notebook
Pencils and leads
Maps
Canopy densiometer
Thermometers
Compass
Turtle number series
Flagging
Slope meter
Depth pole
Large floating quadrat
Clinometer
Mask and snorkel
Velcro straps
Pencils and leads
Flow meter, pole, and batteries
Mark-recapture data sheet
Small tape (measure)

Mark-Recapture Study
Data board
Plastic bags
Field notebook (waterproof paper)
Turtle number series
Data and code sheets
Calipers (large sliding)
Pencils
Small scissors
Permanent marker
Meter string
Maps
Global Positioning System unit
Watch
Triangular file (2+)
Field maps
Flagging
Turtle holding bag
Tackle box (equipment)
First aid kit
Funnel traps
Disinfectant
Diving equipment
Silver nitrate
Gloves (nonlatex)
10% bleach solution
Cuticle or iridectomy scissors
Emery board
Flagging
Binoculars (small pair)
Thermometers (air, water)
5-gal plastic buckets (or other)
Mesh nylon bags
Emergency radio

FIGURE A4-1. View of plastron showing rings from natal (0) to 4th year of growth. Photograph by David J Germano.

APPENDIX 4. COUNTING ANNULI AND AGE DETERMINATION DAVID J GERMANO (Department of Biology, California State University, 9001 Stockdale Highway, Bakersfield, CA 93311)

Determining the age of Western Pond Turtles 0 to 15 y old is based on growth rings that are deposited annually (see text). To count annuli, I recommend using the largest plastral scales (or scutes) because annuli will often be easiest to see on these scales. On the Western Pond Turtle, the abdominal scales, the 2 large scales adjacent to the upper part of the openings in the shell for the hind limbs, are largest and often best. Wear on the plastron may sometimes make other scales preferable for counting annuli. If the abdominals are too worn, one should choose the scale that makes counting easiest.

Once a readable scale has been chosen, the hatching or zero (0) line must be recognized within it (Fig. A4-1). The ''0'' line defines the size and shape of the scale at the time the turtle hatched. Annuli radiate outward from the 0 line in asymmetric concentric fashion, making it easy to recognize. On abdominal scales of Western Pond Turtles, the hatching scute is asymmetrically positioned toward the lateral and posterior edges of this scale. In young turtles (<4 y old), the region bounded by the 0 line can also be recognized from its distinctive, rough-textured or ornamented surface. However, this distinctive texture wears smooth rapidly as a young turtle ages, so identification of the 0 line in most individuals will require looking for the line around the smallest polygon on the scale from which the annuli radiate outward.

Count annuli in a lateral to medial direction (from the 0 line toward the midline of the animal). Counting in this direction is recommended because spacing between annuli is greatest along this axis, which makes individual annuli easier to distinguish. A count of annuli should exclude the 0 line, but include all annuli between the 0 line and the midline of the body. Because the turtle for which age is determined will probably have been captured during its active season, the last, or current, annulus (the one that lies with its edge on the midline suture) will be separated from the immediately adjacent annulus by a distance that reflects the amount of growth up to the capture date. If the capture date is early in the season, the current annulus will be only a short distance from its adjacent one. Still, the last annulus should be counted with the understanding that only part of a year of growth may be represented. A total count in this fashion (excluding the 0 line) will estimate the number of years since hatching.

The greatest difficulty in counting annuli is simply recognizing them and distinguishing yearly annuli from false annuli or growth rings. False annuli are lines that do not represent annual growth increments, but are either an aberration in the way the scale keratin was laid down or reflect periods of stress or arrested growth within an animal's typically active season. False annuli can be relatively easily distinguished from true annuli because they are usually less prominent and have a much less complete concentric pattern than true annuli. False annuli often have a more irregular spacing pattern than adjacent true annuli. Still, some difficulties can be experienced by novices attempting to count annuli. I recommend that individuals inexperienced in counting annuli have at least some training with an experienced individual. The best way to confirm that annuli counts reflect age is to use the technique in a marked turtle population in which recaptured turtles have their annuli recounted. I recommend implementing this approach because it will also allow a better characterization of the nature of false annuli so that future application of annuli counting can be refined. Start by determining the age of younger turtles and then attempt counts on older individuals, keeping in mind there is an upper limit (10–15 y depending on the part of the range where you are working).

To create a record of the annuli for later inspection and measurement of annuli more conveniently, castings can be made using dental alginate material (available through dental supply businesses). The following are instructions to create these casts:

1. I make alginate casts from the 2nd costal and abdominal scutes because the medial edges of annuli are straight (better to measure than curved lines). I use the right scute in both cases unless they are particularly damaged and the corresponding left scute is better.
2. Make enough alginate to completely cover each scute and about one-half to one-third of the adjacent scutes. Make casts thick enough so they do not easily bend. On smaller turtles, this probably means using 1 scoop of alginate for both casts, but 1 scoop each on large adults.
3. Place each cast on top of a moistened paper towel and fold up gently. Place each set (1 turtle) inside a single ziplock or plastic bag. Do not allow the casts to touch each other (they will meld together).
4. Put an ID tag into the bags with casts. The ID tag (piece of paper) should be written in pencil on write-in-the-rain paper and include the location, date, and turtle identification number. Place all samples from one day and area into a larger plastic bag, and write locality information on the outside of the bag with a permanent marker ink. Keep refrigerated or the towels and impression will be invaded by mold.
5. Each set of casts should be uniquely identified to a data sheet that contains detailed information on the turtle, including: carapace length (CL), plastron length (PL), sex of turtle (juvenile if too small to determine sex), and the number of scute rings (if you are fairly confident of the number). The data sheet helps the alginate reader (if not you), especially when the cast scutes have some missing rings because of wear.
6. If you are sending casts to someone else to read, only cast scutes if they have rings present. Many older turtles have worn shells with no rings visible, and their age can be given as 15+ or 20+, indicating an unknown older age.
7. For those who will read the casts in the lab, a positive of the alginate casting is recommended using a plaster-of-paris mix (Denstone is one brand from dental suppliers that is excellent) to create a permanent cast. Attempt to count rings or make permanent casts within a few weeks or the alginate impression may become too moldy to use, even when refrigerated.

APPENDIX 5. USE OF SURF EPOXY FOR ATTACHING TELEMETRY TRANSMITTERS TO TURTLES DON T ASHTON AND JAMES B BETTASO (US Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, 1700 Bayview Drive, Arcata, CA 95521; and U. S. Fish and Wildlife Service, 2951 Coolidge Road, Suite 101, E. Lansing, MI 48823)

A variety of techniques have been employed to attach telemetry transmitters to the carapace of freshwater turtles (see Boarman and others 1998). Here, we report on a modification to existing techniques by use of surfboard repair epoxies. Some biologists use a quick-drying or 5-min epoxy (Rathbun and others 2002), but most fast-setting epoxies are exothermic which release heat as they cure and have the potential to burn underlying tissues (Renaud and others 1993). Belzer and Reese (1995) used PC-7® epoxy because it is nonexothermic while curing and the bond endures for years. However, the slow curing time (several hours) results in increased time in handling and captivity, which may add to stress on the study animals. Further, its strong adhesive bond makes removal of the equipment a difficult, time-consuming process, even when using power tools. For long-term attachments, PC-7's enduring bond may be useful, but for shorter studies (<6 mo) we tested alternative adhesives.

We employ nontoxic putty epoxies recently introduced for repair of epoxy surfboards. We collectively refer to these as surf epoxies because several products are available at surf shops or over the Internet. Kneading the 2-part epoxy forms a putty which sets quickly (about 20 min) in a nonexothermic reaction. Surf epoxies can finish curing underwater, allowing the turtle to be released within half an hour of capture. Upon recovery, we are able to remove the equipment with only a pocketknife in a few minutes, and often less than 1 min. We have successfully used surf epoxies to attach radio transmitters and other equipment to the carapace of Western Pond Turtles.

Attachment Procedures

1. Clean carapace where radio is to be applied and allow it to dry completely. (We apply radio to straddle the 2nd and 3rd costal scutes, with the antenna trailing free behind.)
2. Activate transmitter and check signal.
3. Test fit on carapace. Fit radio onto 1 costal scute if possible. We recommend applying the radio to the 2nd or 3rd costal scutes. If the radio straddles 2 or more scutes, apply thin strips of masking tape to the sutures between scutes to keep epoxy away from growth zones. We prefer keeping the radio to one side or the other to minimize increase in vertical profile, so the turtle can still fit into crevices. For females, be sure to keep the radio away from the posterior end so it does not interfere with mating.
4. Knead the 2-part epoxy together for about a minute. You have about 15 min to work with the surf epoxy.
5. Firmly press the epoxy-covered radio onto the carapace. Firmly smear and press the epoxy into position to get a complete bond between radio attachment and carapace. Form exposed epoxy into a streamlined shape and remove excess epoxy to minimize bulk and weight. In rocky environments we completely cover the radio to protect it from abrasion. The epoxy will wear over the course of the season, so leave a little extra epoxy covering prominent points formed to fully encase the equipment.
6. As the epoxy starts to set it will get sticky. To darken the color, knead xerographic toner into the epoxy surface; then, wet your fingers with water for final smoothing. Rathbun and others (1993) used toner to tint dental acrylic used on Western Pond Turtles. Additional camouflage can be achieved by working native soil into the surface of the epoxy.
7. Tape the antenna in place and protect from disturbance for about 10 more minutes, until epoxy is rigid. To further aid in camouflage, reticulations can be added with a permanent maker. Remove exposed masking tape (leave the tape strips protecting the sutures beneath the epoxy, cut and remove exposed ends of tape strips) and release the turtle.

For detachment, recover the turtle up to 6 mo later, and remove the equipment with a pocketknife. First whittle away at the edges of the epoxy and then gently pry the unit off. Scrape off any remaining epoxy residue.

We find these surf epoxies not as durable in thinner applications such as attaching a transmitter antenna in a semicircle around the carapace (see Belzer and Reese 1995). Boarman and others (1998) report an increase in transmission range of approximately 20% by leaving the antenna straight, rather than partially encircling the carapace. We find that leaving the antenna straight, trailing back along one side of the carapace reduces the amount of epoxy used and thus weight and removal time. We have no indication that the free antenna resulted in any entrapment. If the antenna is to be left free, it is important to be sure there is no bead at the distal tip of the antenna, which could get trapped between rocks.

Surf epoxies have the advantages of nontoxic, nonexothermic, underwater curing and they are easy to mix and use, and easier to remove; these features combine to reduce handling time and minimize stress on the animals. We have not tested surf epoxies for long-term transmitter attachment. The surf epoxy bond is not as enduring as PC-7 epoxy, although in our short-term study telemetry study (6-mo battery life), we have no evidence of a turtle losing its transmitter due to epoxy failure (n = 41, mean = 98 d). We have recovered transmitters via telemetry up to 160 d after deployment, with 18 turtles carrying transmitters for more than 100 d. In a few cases, the radio transmitters had failed before we were able to recover the equipment via radiotelemetry, but we later located the turtles in snorkel surveys and recovered equipment from turtles up to 23 mo after initial deployment. The equipment was very easily removed, however, suggesting 2 y may be the maximum duration for these epoxies in this application. We do not recommend surf epoxies for use on hatchlings or juvenile turtles, which may exhibit rapid shell growth within a season.