

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Some biologists and managers may resort to using information on Western Pond Turtles that is found in unpublished or “gray” literature that may lack critical peer review and that are often difficult to obtain.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).

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

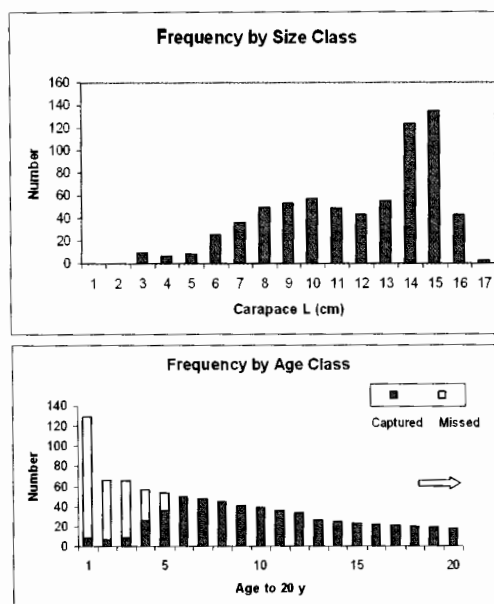


FIGURE 19. Comparison of turtle numbers based on numbers from 1 population in northern California (Bury 1972a; Bury and others 2010; RB Bury, unpubl. data). Top: By size class (10 mm each). Note high proportion of large-sized turtles. Bottom: By ages, but only shown up to 20 y. Missed individuals are 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.

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 archived 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 archive 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.