Turtle Conservation

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CONSERVATION OF FRESHWATER TURTLES

Nonriverine freshwater turtles and semiaquatic turtles are commonly grouped together as those species that predominantly inhabit small streams, slow-flowing tributaries, or **lentic** (nonflowing) freshwater habitats for substantial portions of their life cycles. Turtle species in this category constitute a diverse assemblage that contains 160 species, or almost 60% of the world's approximately 270 turtle species (Iverson 1992a, as amended by descriptions of new species, e.g., Lovich and McCoy 1992; McCord et al. 1995). All of the species termed freshwater spend part of their life cycles, generally the nesting and incubation phases, in terrestrial habitats.

For the sake of brevity, nonriverine freshwater turtles and semiaquatic turtles will be collectively referred to as freshwater turtles throughout this chapter. Our categorization of freshwater turtles is phylogenetically artificial because the grouping includes many unrelated lineages. In addition, several species can be argued to be both riverine and freshwater turtles, for example, sliders (*Trachemys scripta* ssp.) and alligator snapping turtles *(Macroclemys temminckii).* Turtles that are more typically riverine are considered separately in Chapter 5, a logical distinction from the standpoint of ecology and conservation because riverine and freshwater turtles generally differ with regard to both habitat use and threats to their survival.

The goals of this chapter are threefold. First, we will define, classify, and provide basic background information on freshwater turtles through a discussion of the families that contain such species. Second, we will discuss the concept of the life cycle as it applies to freshwater turtles and their conservation. Finally, we will generally and specifically describe the status of freshwater turtles, outline case studies of conservation problems, and provide recommendations for future conservation efforts. Our taxonomy is largely based on Iverson (1992a), although there are some amendments and disagreements that are largely inconsequential from the standpoint of ecology and conservation.

GENERAL ECOLOGY AND CLASSIFICATION

Although freshwater turtles generally share a dependency on slow-moving or stagnant freshwater habitats, they are composed of a variety of distinct taxonomic lineages. Both turtle suborders, Cryptodira and Pleurodira, contain freshwater species. Several families of cryptodirans are represented exclusively or almost so by freshwater turtles. However, no freshwater turtles occur in five cryptodiran families: Cheloniidae (hard-shelled sea turtles), Dermochelyidae (leatherback sea turtle), Carettochelyidae (pig-nosed or New Guinea plateless turtle), Dermatemydidae (Central American river turtle), and Testudinidae (tortoises).

The snapping turtle family, Chelydridae, contains two species of freshwater turtles, the snapping turtle *(Chelydra serpentina)* and the alligator snapping turtle. Both are generally carnivorous, opportunistic foragers (Ernst et al. 1994; Sloan et al. 1996) confined to the New World. Snapping turtles are relatively large (carapace length to 47 cm), lay 30 or more round, soft-shelled eggs, and predominantly inhabit marshes and similar types of wetlands. However, snapping turtles are also commonly found in rivers and can survive in estuaries for substantial periods of time. Alligator snapping turtles attain sizes exceeding 100 kg, lay up to 44 round eggs, and inhabit a variety of aquatic habitats, including rivers, swamps, and estuarine waters (Ernst et al. 1994). This species is the world's largest freshwater turtle.

All 22 species of mud (*Kinosternon* spp.) and musk (*Sternotherus* spp.) turtles in the family Kinosternidae contain populations that are either aquatic or semiaquatic. This family contains small- and moderate-sized carnivorous turtles that lay clutches which contain from 2 to 10 hard-shelled, ovoid eggs. Kinosternids generally inhabit lentic habitats, but some species prefer slow-flowing streams. Diet in this family generally consists of small prey items such as insects, amphibians, and small fishes. Two species, common mud turtle *(Kinosternon subrubrum)* and yellow mud turtle *(Kinosternon flavescens),* are known to spend extensive amounts of time on land during nesting forays (V. J. Burke et al. 1994a); the yellow mud turtle nests underground and remains with the eggs for up to 38 days (Iverson 1990). Several species, including the common and yellow mud turtles, overwinter in upland habitats (Bennett 1972; Christiansen et al. 1985; V. J. Burke and Gibbons 1995). Some mud turtle species may feed on land, but clear evidence of terrestrial foraging has not been established (however, see evidence presented in D. Moll 1979).

The sole species of the family Platysternidae, the big-headed turtle *(Platysternon megacephalum)*, is thought to be a semiaquatic species and has been reported to feed along streambanks in addition to streambeds. It is a small- to moderate-sized carnivore that usually lays two ovoid, soft-shelled eggs and inhabits cool mountain streams in southeastern Asia.

Softshell turtles of the family Trionychidae contain several freshwater species that are carnivorous and highly aquatic. All trionychids lay round, hard-shelled eggs; the number of eggs per clutch range from 15 to over 25. The freshwater trionychid species inhabit a variety of habitats such as marshes, drainage ditches, irrigation canals, streams, ponds, and lakes. Softshells are moderate- to large-sized turtles that feed on a variety of faunal prey. Modern softshell turtles are indigenous to Asia, Africa, New Guinea, and North America and appear to have descended from a lineage that once inhabited most of the temperate world.

The most diverse turtle family, the Emydidae, contains approximately 97 species (including species sometimes assigned to the separate family Bataguridae) of temperate, tropical, and subtropical turtles that are indigenous to Asia, Africa, Europe, and North and South America. The family includes many terrestrial and riverine species but is primarily composed of freshwater species. Most of the freshwater species are omnivorous at some point during their life cycle. Clutch size among freshwater emydids varies from about 2 eggs to over 20. Most species lay soft-shelled eggs, but some lay hard-shelled eggs. The freshwater emydid species range from being strongly aquatic (e.g., map turtles [*Graptemys* spp.], diamondback terrapin *[Malaclemys terrapin]*, and cooters [*Pseudemys* spp.]) to being primarily terrestrial but still dependent on aquatic habitats to complete their life cycles (e.g., wood turtle *[Clemmys insculpta]*).

Although river-dwelling turtles are common in the second turtle suborder, Pleurodira, some species inhabit lentic waters. Pleurodirans include two turtle families, the Chelidae and the Pelomedusidae. Chelids are indigenous to Australia, New Guinea, and South America. Clutch sizes for chelids range from 1 egg per nest to over 20. The eggs may be spherical or ovoid and hard shelled or soft shelled depending on the species. Most chelids appear to be primarily carnivorous, although several species are known to consume fruits and plant matter. Most of the chelid species inhabit slow-flowing nonriverine habitats, and many are strongly aquatic.

The Pelomedusidae are restricted to South America, Africa, and Madagascar. Pelomedusid clutches range from 6 to over 20 leathery-shelled eggs. The freshwater pelomedusids generally appear to be carnivorous; however, the habits of some species are poorly known. They occupy a wide variety of habitats; however, most species are riverine. Many of the tropical freshwater pelomedusids estivate during the dry season. Species of the diverse pelomedusid genus *Pelusios* (African mud turtles) occupy lentic marsh waters, flowing tributaries, and rivers depending on the species or population.

LIFE CYCLE REQUIREMENTS

The success of any conservation effort is dependent on a variety of factors. Perhaps the most critical factor in the maintenance of self-sustaining, free-living populations is the preservation of habitat and conditions required for completion of the life cycle (V. J. Burke and Gibbons 1995; Lovich and Gibbons 1997). In general terms, life cycle requirements include any elements needed by an organism to proceed from hatching (or birth) to reproduction.

Life cycles of freshwater turtles span years and involve multiple habitats (Congdon et al. 1993, 1994; V. J. Burke and Gibbons 1995). Because freshwater turtles are long lived, disruption of the life cycle may not be immediately obvious. Thus, proactive recognition of life cycle requirements and preservation of required habitats and conditions is clearly the most prudent method of conserving populations and species. Here, we outline the components of the life cycles of freshwater turtles. We include recommendations on ways of addressing these components during conservation efforts.

Eggs

The developing egg represents the beginning of the turtle life cycle. Eggs of many freshwater turtles for which we understand nesting patterns are laid in upland habitats within a few hundred meters of aquatic habitats. For example, a study of nest sites of three freshwater turtle species in a southeastern U.S. wetland suggested that all nests were in upland habitats within 275 m of the wetland (V. J. Burke and Gibbons 1995). In contrast, however, Blanding's turtles *(Emydoidea blandingii)* in Michigan regularly nest substantial distances (>1 km) from the aquatic habitats used by the nesting females (Congdon et al. 1983). Conversely, in some regions, eggs of the Northern Australian snake-necked turtle *(Chelodina rugosa)* are oviposited underwater in marshes that are subject to periodic drying (Kennett et al. 1993). It should, however, be noted that we have reliable documentation of nest site selection patterns for only a small subset of freshwater turtles.

As the above examples demonstrate, protecting nesting grounds for some species may be accomplished by simply protecting habitats adjacent to aquatic habitats. However, prudent conservation at the nest site requires a species-specific, and perhaps a population-specific, understanding of nest site patterns.

To develop, many, and perhaps most, freshwater turtle eggs require some exposure to sunlight at the nest site (Congdon and Gibbons 1990). Sun exposure can be attained in a variety of natural microhabitats, but turtles often make use of human-altered habitats as nest sites. Although freshwater turtles exploit periodic human disturbances at nesting sites, high levels of human activity in terrestrial habitats adjacent to aquatic habitats can be deleterious to freshwater turtle populations. This is particularly true for turtles such as the spotted turtle *(Clemmys guttata)* and the bog turtle *(Clemmys muhlenbergii)*, which live in shallow wetland complexes (Lovich 1990). Populations inhabiting wetlands may be isolated from each other by surrounding croplands or pastures (Lovich 1989). Although some agricultural fields may provide suitable sites for developing eggs, the effects of plowing may doom nests and, ultimately, populations. Thus, small-scale human activities near freshwater habitats may be relatively benign to turtle eggs, but large-scale agricultural and urban development may be destructive. Kaufmann (1992) suggested that some agricultural activities were beneficial to wood turtle populations because they provided a mixture of different cover types and food sources near wooded streams.

Several laboratory and field studies have examined the effects of nest site microclimate (Bull and Vogt 1979; G. C. Packard and Packard 1988; Bodie et al. 1995). Prolonged inundation by water (Ewert 1985), lack of moisture (Ewert 1985), and exposure to subfreezing temperatures (Obbard and Brooks 1981) are probably the most common climate-related causes of embryo mortality for freshwater turtles. However, predation appears to account for the vast majority of egg mortality for many species. Predation rates of nests in freshwater turtle populations studied for three or more years can be very high, with up to 100% of observed nests destroyed in some years (Congdon et al. 1983, 1987, 1994; V. J. Burke 1995).

Human-related activities have increased the size of some predator populations (i.e., subsidized predators; see Mitchell and Klemens, Chapter 1) and, as a consequence, apparently have increased predation rates on some turtles. Boarman (1993) documented an increase in raven *(Corvus corax)* populations and discussed the potential impact on desert tortoise *(Gopherus agassizii)* populations due to high rates of predation on juveniles. W. S. Clark (1982) has documented that freshwater turtles are preyed upon by bald eagles *(Haliaeetus leucocephalus)*, and it is possible that recovery efforts for bald eagles in the United States could increase predation pressures on some turtle populations. For most freshwater species it is unknown if similar scenarios are being played out in their populations, but many traditional predators of turtle eggs and hatchlings are widely considered to have increased in abundance in many areas due to human activities (Goodrich and Buskirk 1995). Congdon et al. (1993, 1994) suggested that decreased trapping of furbearers in Michigan was correlated with increased predation rates for two turtle species living in a preserve. Similarly, Lovich (1989) noted the coincidence between an increase in raccoon *(Procyon lotor)* numbers and a decrease in spotted turtle numbers over a period of several decades at a preserve in Ohio. Thus, even species within the protected confines of preserves may be subject to high rates of predation, particularly in the nest (Congdon et al. 1993, 1994). In any case, perpetual control of egg predators is costly, does not address root causes (i.e., the human-related causes of artificially high predator densities), and, in the absence of data concerning historic predator abundances, may result in unforeseen and unwanted consequences on other components of the ecosystem (Goodrich and Buskirk 1995; Ratnaswamy 1995). However, limiting predator subsidization (i.e., the root of the problem) would appear to be a low-cost method to reduce the threat of increased predation on incubating eggs. Examples of such a method would be locking lids on refuse dumpsters and covering trash at landfills.

Neonates

Upon hatching, neonate freshwater turtles either leave the nest or remain in the nest until the following year (Gibbons and Nelson 1978). Many populations display either prompt emergence or delayed emergence, but some populations may exhibit both patterns (e.g., the common musk turtle *[Sternotherus odoratus]*; Gibbons and Nelson 1978). The period of time that resource managers must be concerned about disturbances to nest sites is prolonged for neonates that remain in the nest. For example, autumn plowing may be benign to species that exhibit prompt emergence but may doom populations that display delayed emergence. Similar concerns may also apply to forestry activities such as prescribed burns and harvest.

Little is known about the behavior of freshwater turtle neonates immediately after leaving the nest, but it is generally assumed that most species proceed directly to aquatic habitats (Anderson 1958; B. O. Butler and Graham 1995; see E. O. Moll and Legler 1971 and Jansen 1993 for alternative strategies). Neonates may inhabit different portions of the same aquatic habitat that is occupied by juveniles and adults (e.g., common slider *[Trachemys scripta]*, Hart 1983; diamondback terrapin, Lovich et al. 1991; painted turtle *[Chrysemys picta]* and snapping turtle, Congdon et al. 1992; Blanding's turtle, Pappas and Brecke 1992). However, the paucity of data on this life cycle stage makes reliable inferences impossible. Turtle studies focusing on the first year after emergence would greatly enhance our understanding of turtle life cycles, habitat requirements, and conservation issues. The recent advances in telemetry, coupled with diligent trapping and searching efforts, could help fill this enormous gap in our understanding of turtle ecology in the same way that Witherington and his colleagues (Witherington and Salmon 1992; Witherington 1994b) have done for early life stages of sea turtles.

Juveniles

The onset of the juvenile stage can be arbitrarily assigned as 1 year after emergence from the nest (i.e., after the neonate stage). For freshwater turtles the juvenile stage may persist from 3 years (e.g., common mud turtle; Frazer et al. 1991) to more than 15 years (e.g., Blanding's turtle; Congdon et al. 1993). Early juvenile years may be subject to high predation risk, but this risk often diminishes with increased body size (Frazer et al. 1990; Iverson 1991b; Congdon et al. 1994).

Juveniles of some freshwater turtle species are known to change habitat use patterns as body size increases (Congdon et al. 1992) and consume different prey items than are consumed by adults (Georges 1982; Parmenter and Avery 1990). These two findings indicate that spatially heterogeneous freshwater ecosystems may be critical to the functioning of self-perpetuating populations of freshwater turtles. The transformation of much of the world's freshwater habitats into relatively homogeneous reservoirs, agricultural ponds, and channelized rivers may be a serious threat to the developmental habitats required for completion of freshwater turtle life cycles. For example, the Missouri River, located in the central United States, was once a meandering, braided **lotic** (flowing) system that fed numerous lentic wetlands within the floodplain. Humans transformed the river into a series of reservoirs (upper Missouri River) and an extremely fast-flowing channel (lower Missouri River). Currently, extensive and costly efforts are being discussed that would reestablish some of the complex wetland and lentic components of the floodplain (Galat et al. 1996). Increasing the heterogeneity of aquatic habitats such as the Missouri River could provide needed developmental habitats for many species, including freshwater turtles.

Understanding the shifting habitat needs of juvenile freshwater turtles can be a daunting task. However, a simple method of managing for complexity may be available if two steps are followed: (1) document the habitat components in ecosystems and landscapes containing self-perpetuating populations, and (2) assure that those components are not destroyed in ecosystems occupied by other turtle populations. In altered habitats, restoration of damaged components of the ecosystem or landscape based on historical observations or healthy ecosystems may be the only viable method of restoring freshwater turtle populations.

Adults

Maturity in freshwater turtles is caused by and coincident with a number of physiological and behavioral changes. For some species, the onset of maturity marks the first time since hatching that females venture into terrestrial habitats. Maturation may also induce males to move overland to other freshwater habitats in search of females (Morreale et al. 1984). In addition, adults of some species hibernate in upland habitats (Netting 1936; Bennett 1972). Thus, the conservation of suitable terrestrial habitats again appears to be critical to the maintenance of self-perpetuating turtle populations.

The amount and types of terrestrial habitats that adult freshwater turtles require certainly vary among species and landscapes. For example, the observation that seemingly self-sustaining populations of freshwater turtles inhabited a wetland within a successional old-field landscape led V. J. Burke and Gibbons (1995) to suggest that agricultural and real estate development within 275 m of similar wetlands should be minimized. Most semiaquatic turtles use terrestrial habitats for nesting, overwintering, and, occasionally, foraging. During terrestrial activities, semiaquatic species are vulnerable to high frequencies of encounters with humans. These encounters increase the probability that free-ranging freshwater turtles will be collected as pets (Garber and Burger 1995) or killed on roadways by vehicles. While overwintering and estivating, semiaquatic populations may be particularly vulnerable to disturbances in any of several habitat types. For example, draining of aquatic habitats or plowing or paving of terrestrial habitats both have serious negative impacts on a population.

In summary, each component of a freshwater turtle's life cycle is at risk in human-dominated landscapes. The reliance of freshwater turtles on heterogeneous landscapes (Kaufmann 1992) necessitates integrated conservation efforts. Failing to protect a single life cycle stage will ultimately doom the entire population to extinction. Conservation of freshwater turtles, from a life cycle perspective, does not mean that complete understanding of the life cycle is needed before any conservation action can be taken. However, it is obviously preferable to have as much species- and population-specific information as possible.

THREATS TO FRESHWATER TURTLES

Turtles in general are poor candidates for sustainable-harvesting programs and, like many long-lived species, are especially vulnerable to population declines if exploited (Congdon et al. 1993, 1994; V. J. Burke et al. 1994b). A large number of freshwater turtle species appear on conservation and regulatory lists of threatened and vulnerable species (Lovich 1995). Thus, freshwater turtles appear to be faring poorly in the modern world. Of the 160 turtle species that can be considered aquatic or semiaquatic (i.e., at least some populations are freshwater turtles), 62 (including species in which only a certain population or race is classified as sensitive) have been designated as requiring some conservation action. These 62 species include 33 species or populations rated as sensitive on the International Union for

Conservation of Nature and Natural Resources' (IUCN) "Red List" (IUCN 1996); 50 species listed in the action plan of the IUCN's Species Survival Commission (IUCN 1989); 18 species (or populations thereof) listed under the U.S. Endangered Species Act of 1973 (16 U.S.C. §§ 1531 to 1544); and 14 species listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1973). (Note that summing the numbers listed above does not total to 62 because many species are listed in more than one of the conservation designations.)

Compared with the other groups of turtles, freshwater species have received much less attention from conservation organizations than their numbers dictate. In part this situation may have resulted from freshwater turtles being of lesser economic importance than are river turtles and having less charisma than do tortoises and sea turtles.

Habitat Alteration

The reasons for the high proportion of freshwater species that are in need of conservation are varied. Alteration and exploitation of freshwater habitats are major causes of decline for many species. For example, Buhlmann (1995) found that isolated populations of chicken turtles *(Deirochelys reticularia)* in Virginia were threatened with extinction due to the loss of 80% of the interdunal bald cypress *(Taxodium distichum)* habitat that represents its historical range. The interdunal habitat was converted into residential housing and a four-lane highway. The presence of a four-lane highway further complicated matters because the remaining populations were subject to high levels of traffic-related mortality (Mitchell 1994; Buhlmann 1995).

Gibbs (1993) predicted widespread extinctions of turtle populations to be likely if only large wetlands were preserved. Gibbs used computer simulations to predict the effects of the loss of small wetlands in the northeastern United States. He suggested that many turtle species in the study region have established populations in wetlands smaller than those protected by legal statutes (wetland habitats less than 0.4 ha are not protected by federal statutes in the United States). In general, loss of habitat has been a major threat to most, if not all, threatened and endangered turtles, including the western pond turtle *(Clemmys marmorata)* (Brattstrom 1988), the spotted turtle (Lovich 1989), and the western swamp turtle *(Pseudemydura umbrina)* (Burbidge et al. 1990), to name only a few documented cases.

Disease

A new and growing threat to turtle populations worldwide is disease-induced mortality (Dodd 1988; Herbst 1994; E. R. Jacobson 1994a; E. H. Williams et al. 1994;

Flanagan, Chapter 3). Lovich et al. (1996) noted that 35% of a sample of common sliders from Lake Blackshear, Georgia, were affected by a severe shell disease characterized by necrotic lesions. The exact cause of the disease is unknown, but toxic or immunosuppressive chemicals may be predisposing factors. The existence of relatively large numbers of dead common sliders along the shoreline of the impoundment suggests that this shell disease may be fatal.

Human Exploitation of Turtles

Although direct exploitation of turtles as a food resource is mainly thought of as a threat to riverine and marine species, it is also a threat to many of the larger freshwater species and to generally riverine species that contain lentic populations. The Madagascan big-headed turtle (*Erymnochelys madagascariensis*), an endemic turtle species that inhabits lakes, slow-moving rivers, and marshes of Madagascar, has suffered dramatic declines in numbers due to local exploitation as a food source (Kuchling 1988; Kuchling and Mittermeier 1993). In Bangladesh, local consumption has added to the depletion of many freshwater turtle species (M. A. R. Khan 1982), and Kuchling (1995b) observed several turtle species for sale in South China markets, generally for use as food.

In the United States and Canada, members of the freshwater turtle family Chelydridae have been heavily exploited for years, and in many places the exploitation continues. H. W. Clarke and Southall (1920) reported that the wholesale market in Chicago handled 10,000 snapping turtles per year. Demand continues to be very high as evidenced by data summarized by Brooks et al. (1988), who noted that the annual commercial catch in Minnesota alone is estimated at 36,000 to 40,800 kg, or approximately 6,000 to 6,800 average-sized adults. Brooks et al. (1988) reported that in southern Ontario annual catch was 30,000 to 50,000 kg, or 5,000 to 8,300 snapping turtle adults (based on estimates from a 1982 Ontario Ministry of Natural Resources report). In Virginia, approximately 1,350 snapping turtles are slaughtered annually at the state's only known processing center, and an unknown number of Virginia snapping turtles may be processed in other states (J. Mitchell, personal communication). However, the snapping turtle remains an abundant species in Virginia. The alligator snapping turtle has also been heavily exploited as a food source, particularly in Louisiana. Sloan and Lovich (1995) noted that a single wholesale buyer in Louisiana purchased 17,117 kg of alligator snapping turtle from 1984 through 1986.

The overall scenario of exploitation has been the same for most freshwater turtles around the world (Thorbjarnarson et al., Chapter 2). Heavy exploitation is rapidly followed by stock depletion and market collapse. For example, freshwater turtles in the Amazon were once part of a thriving turtle meat industry, but overexploitation has reduced turtle numbers to the point that the industry has collapsed (Alho 1985; Klemens and Thorbjarnarson 1995).

Exploitation of turtles for the pet trade is a serious threat to the persistence of many freshwater turtle species. The trade in freshwater turtles is a worldwide phenomenon that is part of the larger fashion of keeping exotic animals as pets. As pets, turtles are generally marketed in economically developed countries such as the United States, Japan, and those of Western Europe. One need only log on to the Internet and search for "turtle" to understand how extensive the marketing of turtles as pets has become. It should be recognized, however, that the Internet represents only a small portion of the marketing efforts.

The Humane Society of the United States (HSUS 1994) summarized existing knowledge on the live turtle trade in the United States, reporting that U.S. Fish and Wildlife Service records documented the export of at least 25 million turtles through U.S. ports between 1989 and mid-1994. Common sliders, destined for the pet trade, made up the bulk of these exports with an estimated value of over US$17 million (HSUS 1994). During 1993, South Korea imported over one million hatchling common sliders from the United States, followed by Italy and Japan (the latter importing over 600,000).

In terms of numbers, the red-eared slider *(Trachemys scripta elegans)*, a species indigenous to the southern United States (Ernst et al. 1994), appears to be the most heavily exploited species for the pet trade. Annual exports of this species from the United States number between three and ten million individuals depending on the year (Feehan 1986; Warwick 1986; Warwick et al. 1990; Ernst et al. 1994). Red-eared sliders have been the focus of captive-breeding efforts in an attempt to economize the trade and make it more conservation oriented (Warwick 1986; Pritchard 1993). However, the breeding efforts have never been demonstrated to replace collection from free-ranging populations, and there is widespread concern among turtle ecologists that red-eared slider populations are becoming rapidly depleted (Warwick 1986). In general, turtles do not fit the criteria established for candidate species for aquaculture (Webber and Riordan 1976). An additional problem is the establishment of red-eared slider populations as a result of releases in nonnative habitats (e.g., Israel, Bouskila 1986; Singapore, Ng et al. 1993; South Africa, Newbery 1984; South Korea, Platt and Fontenot 1992; Spain, da Silva and Blasco 1995). Although introductions of slider turtles have been cast as a threat to the continued existence of turtles native to the areas where sliders have been introduced (D. C. Holland 1994; da Silva and Blasco 1995), little scientific evidence is available to support the claim.

Although the pet trade represents a large share of the traffic in freshwater turtles, many are also sold for cosmetic and purported medicinal purposes (E. O. Moll 1982; Alho 1985). Das (1990) suggested impetuses for turtle export from Bangladesh were food and medicinal markets.

General solutions to the problems of exploitation of and trade in freshwater turtles have not been satisfactorily offered. The paucity of general solutions may be, in part, the result of a lack of consensus among turtle biologists regarding the desirability of comprehensive action. The idea put forth by Das (1990), that turtle populations should be surveyed first to determine if they are suitable candidates for collection, is one method of more tightly controlling exploitation. His method, if applied, could relieve pressure on populations that have been negatively affected by the trade in both products and pets. However, monitoring such collection is often difficult. During an international conference on the conservation, restoration, and management of turtles and tortoises (Van Abbema 1997), numerous accounts of the deleterious effects of collection for the pet trade were voiced. An eloquent argument against exploitation of turtles, because they are made so vulnerable by their life history strategies, was given by Congdon et al. (1994). They suggested that sustainable exploitation of animals that take years to mature and have long generation times is probably an unrealistic goal. Given the widespread belief among turtle ecologists that the pet trade is detrimental to many freshwater species, the authors of this chapter can find no compelling reasons to support its continuance as presently regulated. Perhaps turtle conservationists should consider the words of Bartlett (1997) on the subject: "The time for a change has come. Let us all have the foresight and courage to begin that change."

There have been several specific attempts to deal with conservation problems faced by freshwater turtles. The remainder of this chapter will describe those efforts for selected species and conclude with conservation recommendations.

CASE STUDIES

We devote this section to examining the conservation status of examples that represent particular situations faced by freshwater turtles. The case studies chosen were selected because they represent particular species or groups for which adequate and reliable data and data analyses are available from which reasonable conclusions can be drawn. Throughout this section, we have avoided building scenarios based largely on speculation.

Madagascan Big-Headed Turtle: Conservation of Taxonomic Relicts

Found only in Madagascar, the Madagascan big-headed turtle is the sole extant Old World member of the subfamily Podocneminae. The species attains a size of up to 43.5 cm and lives in slow-flowing rivers, swamps, lagoons, and marshes (Ernst and Barbour 1989). In western Madagascar, the Madagascan big-headed turtle is heavily exploited as a subsistence by-catch by fishermen who slaughter any turtle caught (Kuchling 1992).

The conservation biology of the species in western Madagascar was reviewed by Kuchling (1988). Considered to be very abundant formerly, its use as a food source by native peoples appears to have caused serious population declines. In fact, the best-studied population of the species was extirpated between 1987 and 1991 (Kuchling 1992). Although large females can produce more than 60 eggs per year (Kuchling 1988), the Madagascan big-headed turtle may not be able to maintain a stable population due, in part, to a possibly biennial reproductive cycle (Kuchling and Mittermeier 1993).

Cast against the rapid population growth of Madagascar, the prospects for survival of this endemic species are dim. A conservation strategy incorporating elements of public education, law enforcement, research and monitoring, habitat protection, and development of less damaging fishery practices has been proposed, but successful implementation will be difficult (Kuchling 1997b).

Diamondback Terrapin: A Coastal Species

The diamondback terrapin is a turtle that resides primarily in tidal creeks of estuaries along the Atlantic and Gulf of Mexico coastlines of the United States. It inhabits only brackish waters, which differentiates it from other freshwater species, but in many respects its behavior and morphology appear similar to those of some map turtles. According to R. Conant (1975), diamondback terrapin are the "most celebrated of [North] American turtles." Conant's comment was based on the fact that the diamondback terrapin has long been exploited as a source of food by all classes and cultures within the species' range. According to Carr (1952) tidewater slaves in the United States once went on strike to protest a diet too heavy in diamondback terrapin. Sometime after that incident the diamondback terrapin found a place on the table of the privileged members of society. With increased demand for diamondback terrapin by epicures, prices soared, and a market was born to supply the big eastern cities of Baltimore, Philadelphia, and New York. The diamondback terrapin became one of the most economically important reptiles in the world.

Records kept in the state of Maryland suggest that the legal trade in diamondback terrapin ranged from 13,608 kg during 1880 to a high of 40,438 kg during 1891 (Figure 6.1). Between 1880 and 1936, the Maryland trade processed over 139,706 kg of diamondback terrapin (McCauley 1945), which translates into the processing of approximately 200,000 diamondback terrapin. Females were the most coveted because of their relatively larger size (adult female mass averages about 700 g; Lovich and Gibbons 1990).

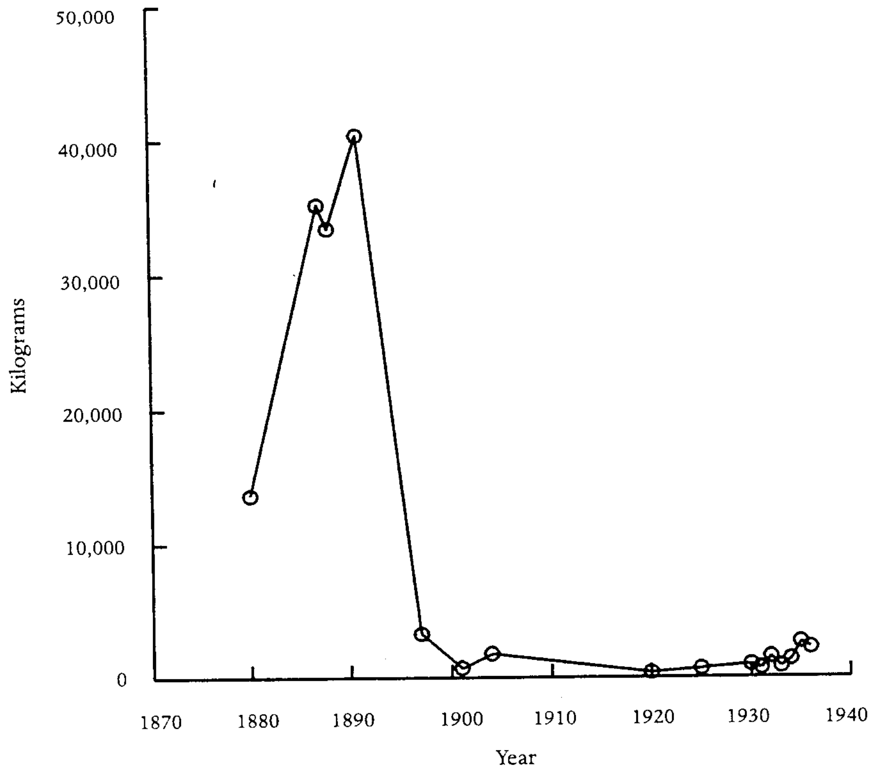

Figure 6.1. Historical exploitation of diamondback terrapin in Maryland (data from McCauley 1945). The *y*-axis represents the weight of the known commercial diamondback terrapin catch.

In recognition of the demand for diamondback terrapin, in 1878 the state of Maryland enacted a law providing a closed season and a size limit for the species (McCauley 1945). As demand increased, prices soared, and wild stocks became depleted. In response, the United States government initiated studies of captive propagation (Coker 1906; Hildebrand and Hatsel 1926; Hildebrand 1929). Eventually the diamondback terrapin fad died out, and populations recovered from the several decades of exploitation. In addition, the vast salt marshes in which diamondback terrapin lived provided them with a level of protection due to their relative inaccessibility.

Today the diamondback terrapin faces new threats, including mortality by drowning in blue crab *(Callinectes sapidus)* traps (Bishop 1983; Roosenburg 1990), habitat degradation (past and present), and detrimental interactions associated with human recreation. Burger and Garber (1995) documented a negative relationship between human beach use in New Jersey and both the number of nests and number of nesting females. Their studies suggested that heavy beach use may reduce nesting by diamondback terrapin. They also noted increased rates of propeller injury on nesting females as boat use increased in the study area. As a result of human impacts, diamondback terrapin populations are declining in some areas (Seigel and Gibbons 1995). Significant local declines have been documented in Florida (Seigel 1993) and some parts of South Carolina (Lovich and Gibbons, unpublished).

A market still exists for diamondback terrapin, particularly in the Chinese restaurants of New York City. Vendors admitted to selling between 2,000 and 3,000 diamondback terrapin in a single year. Most were collected in Virginia, the Carolinas, Maryland, and New Jersey, but some were collected from local areas, including Jamaica Bay and other parts of Long Island, New York. It is conservatively estimated that over 10,000 diamondback terrapin are sold in New York each summer, with females retailing for up to $20 each (Garber 1988). Continued exploitation, coupled with all the other problems the diamondback terrapin faces in the modern world, bodes poorly for the future of the "most celebrated of American turtles."

Coahuilan Box Turtle: Threats to Species with Restricted Ranges

The genus *Terrapene* contains four species of predominantly terrestrial emydid turtles. Only one, the Coahuilan box turtle *(Terrapene coahuila),* is truly aquatic. Although historically not uncommon in its remote habitat, it is perhaps one of the most endangered turtle species in the world by virtue of its extremely small geographic range. Found only in an isolated intermountain basin in the northern Chihuahuan Desert of Mexico, its entire range is confined to no more than 800 km^2. Virtually everything that is known of this unusual species is the result of research conducted by W. S. Brown (1974).

Unfortunately, the isolated nature of the Coahuilan box turtle's habitat is no hedge against endangerment. Water is a priceless commodity in arid regions and is often exploited to the detriment of wildlife. Researchers cited in W. S. Brown (1974) suggested that extensive habitat was destroyed in 1964 by canals that carried water away from Coahuilan box turtle habitat for irrigation. The surface area of one studied marsh–pool complex reportedly decreased from about 10 km^2 to less than 0.2 km^2, virtually eliminating the entire population of the Coahuilan box turtle. W. S. Brown considered the amount of habitat lost to be an exaggeration and suggested that only 0.25 to 0.50 km^2 of habitat was lost. The amount is still significant when considering the number of turtles affected. Assuming a population density of 148 turtles per hectare, then 3,700 to 7,400 Coahuilan box turtles died or emigrated.

W. S. Brown (1974) proposed several conservation measures for the Coahuilan box turtle: (1) adopting measures to review the feasibility of planned irrigation projects in prime aquatic habitats, (2) restricting the indiscriminate construction of canals to drain major aquatic habitats, and (3) establishing special protection for the species in the form of legislation that limits collecting to scientific purposes only. The continued survival of this species ultimately depends on protection of the wetlands in which it occurs.

Clemmys: Conservation Concerns at the Genus Level

Turtles of the genus *Clemmys* have long been popular with reptile fanciers. They are hardy, intelligent, and attractive species. However, the attraction has been fatal from the standpoint of the survival of many turtle populations. Combined with habitat destruction and other modern threats, overcollecting has had a serious impact on these turtles. For example, they are among the most popular species of turtles exported from the United States: 4,692 specimens were shipped overseas between 1989 and mid-1994 at an estimated value of $102,658 (HSUS 1994).

The spotted turtle is widely distributed in shallow wetland habitats across the Great Lakes region southward, east of the Appalachians, and southward to northern Florida (Ernst et al. 1994). Lovich (1989) listed several probable reasons for the decline of spotted turtles, including (1) overcollecting by the pet trade, (2) habitat destruction, (3) predation by subsidized predators (see Mitchell and Klemens, Chapter 1), (4) overgrazing by livestock, (5) agricultural cultivation, and possibly (6) pollution. Populations are often patchily distributed in shallow wetlands, which are highly susceptible to ecological succession (Lovich and Jaworski 1988; Graham 1995). Once the habitat becomes overgrown with successional species of plants, it may be unsuitable for spotted turtles. If impediments such as large distances or human developments prevent the turtles from migrating to acceptable habitats once their former habitat becomes unsuitable (Netting 1936; Ward et al. 1976; Lovich 1990), the species may become extirpated from a local area. Population declines have been noted even in the protected confines of nature reserves (Lovich and Jaworski 1988; Lovich 1989).

The wood turtle has also suffered serious declines in many portions of its range. Although the species was exploited for food in the past (Harding and Bloomer 1979), the most serious threats to the long-term survival of wood turtle populations are habitat destruction and collection for the pet trade. As populations are protected in some states, collectors have started "laundering" specimens by claiming that the wood turtles were collected in adjoining states, states not even occupied by the species (A. Salzberg, personal communication). For example, several specimens recently offered for sale were supposedly from Ohio, a state that does not protect wood turtles because none live there (Ernst et al. 1994). The literature does contain several old and dubious records of wood turtles in Ohio (R. Conant 1951; F. G. Thompson 1953) that have been perpetuated in some accounts (e.g., Iverson 1992a), but the evidence strongly suggests that these individuals originated from populations in Pennsylvania or the release of captives (R. Conant 1951).

The best study to document declining wood turtle populations was conducted over 20 years by Garber and Burger (1995). They studied two **allopatric** populations (i.e., not overlapping) in a fenced-off and presumably undisturbed (by humans) area in Connecticut. During the first 9 years of the study the area was closed to recreation, and both populations were stable with a mean of 94 turtles. In 1982 the area was opened to recreation (fishing and hiking), and both wood turtle populations declined 87% over the next 9 years. Despite a constant level of collecting effort, no wood turtles were collected during the last 2 years of the study. Throughout the investigation forest size remained the same, road building was restricted, and air and water quality remained constant. The authors suggested that people may have removed turtles from the area. Whatever the cause, it appears obvious that wood turtle populations are extremely sensitive to increased human presence (Burger and Garber 1995).

The bog turtle is one of the smallest and most secretive turtles in North America. Although it is found from eastern New York and western Massachusetts south to Georgia, it is common nowhere, often existing in disjunct small populations of only 38 to 250 individuals (Herman 1994). Like other members of the genus, bog turtle populations have been declining due to habitat destruction and overcollecting for the pet trade. Destruction and modification of wetlands have particularly devastated bog turtle populations. For example, Torok (1994) documented the extirpation of a New Jersey population within 1 year following construction of a storm water outfall into bog turtle habitat and subsequent discharges of storm runoff.

A detailed survey in North Carolina located only 48 populations statewide (Herman 1994). Of these, 11 (23%) were considered to be viable, 18 (37%) were potentially viable, 10 (21%) were nonviable, and 9 (19%) were of unknown status. Populations were judged to be viable if the population supported 30 or more turtles, sufficient core habitat was available, and evidence of reproduction or recruitment was observed. The estimated statewide population is between 1,260 and 2,500 bog turtles. Only about one-half of the populations from Virginia to Georgia are considered to be viable (Tryon and Herman 1990). A similar survey of eight historic bog turtle sites in western New York found only a single viable population (Collins 1990).

As with other eastern members of the genus *Clemmys*, habitat succession is a problem for bog turtles. Tryon and Herman (1990) and Herman (1994) discussed the beneficial value of cattle and horse grazing in removing "nuisance" vegetation and keeping bog habitats in early-seral stages favorable to the bog turtle. Invasion of bogs by dense thickets of exotic pest plant species, such as multiflora rose *(Rosa multiflora)* and honeysuckles (*Lonicera* spp.), is also perceived as a threat to southern bogs and the bog turtle (Herman 1994). In New York and New England, the exotic Eurasian pest plant purple loosestrife *(Lythrum salicaria)* is a threat to bog turtle habitat (Bury 1979a; Klemens 1993a).

In recognition of the isolated nature of bog turtle habitats, emphasis should be placed on creating and protecting wetland networks that allow movement and gene flow among populations to prevent local extinctions (Chase et al. 1989; Buhlmann et al. 1997). Connecting bog turtle habitats will not be possible in every area due to the widely scattered nature of some populations. Buhlmann et al. (1997) suggested that long-term protection of bog turtle populations in Virginia will require involvement of all affected groups (e.g., landowners, developers, and conservation biologists) to develop effective management plans.

The western pond turtle is found along the west coast of North America from Washington to northern Baja California, Mexico. Although not as popular in the pet trade as its eastern congeners, the western pond turtle has its share of conservation problems. The western pond turtle was used as a source of food in San Francisco until at least World War II. With the development of agriculture in California's Central Valley, vast wetlands containing populations of western pond turtles were drained or channelized (Buskirk 1990). Urban development in southern California destroyed most populations of western pond turtle late in the twentieth century. In 1960 there were 87 known localities for the species in California south of Ventura County. By 1970 these were reduced to 57. As of 1988, viable populations of the species were found in only 20 or fewer localities in southern California (Brattstrom 1988). Populations have also experienced significant declines in the northern portion of the range, including the Willamette drainage of Oregon (D. C. Holland 1994). An additional complication in the conservation of the species is the recent recognition that northern populations exhibit low genetic diversity (Gray 1995), a possible consequence of habitat fragmentation and isolation.

Yellow Mud and Red-Bellied Turtles: Disjunct Populations

Extralimital populations (i.e., those outside the primary range of the species) and **disjunct populations** (separated by large areas) of wide-ranging species have long been considered to be at risk. Quite often they are also the subject of taxonomic controversy. The Illinois mud turtle *(Kinosternon flavescens spooneri)* provides a classic example of such a situation. Originally described as a new subspecies by P. W. Smith (1951), the Illinois mud turtle is restricted to isolated relict populations in the central Midwest of the United States (Seidel 1978). These **relict populations** appear to be the remnants of a once larger species range. Originally reported from 13 localities, by the late 1970s only three populations were considered to be extant, having an estimated total population size of 650 or fewer individuals (L. E. Brown and Moll 1979). Habitat destruction associated with agriculture, industry, and recreation contributed to the suggestion to list the species as endangered under the U.S. Endangered Species Act (L. E. Brown and Moll 1979; Dodd 1982b).

The proposal to list the Illinois mud turtle was met with considerable opposition by members of the industrial community. Their challenge was based on the contention that populations were not thoroughly surveyed and that the subspecies was not taxonomically valid (Dodd 1982b). In his review of the systematics of the yellow mud turtle *(Kinosternon flavescens)*, Iverson (1979) recognized the validity of *K. f. spooneri*, but later investigators (Houseal et al. 1982; J. F. Berry and Berry 1984) found *K. f. spooneri* to be indistinguishable from, and synonymous with, the yellow mud turtle. Amidst the controversy the U.S. Fish and Wildlife Service decided against listing the turtle (Dodd 1982b). However, the Illinois mud turtle did receive protection from each of the three states encompassing its range (T. Johnson, personal communication).

Although there are several examples of specific turtle populations being listed under the U.S. Endangered Species Act (e.g., Plymouth populations of the red-bellied turtle *[Pseudemys rubriventris]* and western populations of the desert tortoise), such was not the fate of the Illinois mud turtle. Fortunately, the state governments encompassing its range had the wisdom to act without the collaboration of federal agencies.

Each species of red-bellied turtle can itself be considered a disjunct member of what has been termed a natural grouping of allopatric species (Alabama red-bellied turtle *[Pseudemys alabamensis]*, red-bellied turtle, and Florida red-bellied turtle *[Pseudemys nelsoni]*) (Seidel 1994). This group seems to have evolved from a more wide-ranging species but is now composed of three species, some of which have disjunct populations themselves. A relict population of the red-bellied turtle in Massachusetts, the so-called Plymouth red-bellied turtle, was described as a separate subspecies *(P. r. bangsi)* by Babcock (1937). The taxonomic distinctiveness of the group was questioned for many years (see review by Browne et al. 1996), and recent research has demonstrated that the Massachusetts populations are no different from others of the red-bellied turtle (Iverson and Graham 1990; Browne et al. 1996).

Regardless of its taxonomic status, in 1980 the Plymouth red-bellied turtle was listed as an endangered "species" (the U.S. Endangered Species Act allows the listing of populations). Presently, it is estimated that there are about 300 individuals restricted to 17 ponds and one river site in Plymouth County, Massachusetts (Amaral 1994). Threats to the continued survival of the relict populations include genetic isolation and habitat alteration. This situation underscores the importance of maintaining populations in our efforts to maintain species. Some would hold that there is no need to conserve Plymouth red-bellied turtles because the same turtle can be found elsewhere. However, in evolutionary terms, extralimital populations can be a first step in the evolutionary process, and they are components of the local biodiversity. It seems more appropriate to consider efforts to protect the extralimital population of the red-bellied turtle as a model of how conservation should work.

At the southwestern limit of the red-bellied turtle distribution, the Alabama red-bellied turtle was listed as an endangered species in 1987 (Dobie and Bagley 1990). The species is restricted to the Mobile Bay of Alabama (C. J. McCoy and Vogt 1985), which is at the mouth of the Alabama River. This species may be the result of allopatric speciation, demonstrating the evolutionary importance of disjunct populations. Predation on nests by pigs *(Sus scrofa)* and fish crows *(Corvus ossifragus)* and impacts of human recreation in this coastal area are cited causes of decline of this species (Dobie and Bagley 1990).

Western Swamp and Black Softshell Turtles: The Rarest Turtles in the World

The western swamp turtle and the black softshell turtle *(Aspideretes nigricans)* are the two freshwater species with the most restricted ranges. These are arguably the most endangered turtles in the world. The former is restricted to a small nature reserve in western Australia and by 1980 was reduced to a population of 20 to 30 turtles (Burbidge 1981; Kuchling and Dejose 1989; Kuchling et al. 1992). An intensive population manipulation was instituted during 1987, and the captive and wild stock was increased to well over 100 individuals. There are current plans to begin a second population of the species.

The black softshell turtle is restricted to a pond associated with a religious shrine in Bangladesh, but its historic range is completely unknown, and it is assumed to be extinct in the wild. The entire species is represented by only about 300 individuals (Ahsan et al. 1991). Although some details of its biology are known (Ahsan and Saeed 1992), much more is unknown regarding this enigmatic relict.

Efforts to deal with conservation issues related to the black softshell and western swamp turtles have generally encouraged establishment of additional populations. Unfortunately, the impacts of such translocations on other species, including other turtle species, are unknown. The western swamp turtle was likely restricted to its present habitat primarily as a result of ecological factors (Groves and Ride 1982), including drought and increased predation by an introduced predator (Burbidge et al. 1990). Issues related to the advisability of captive breeding are discussed by Kuchling and Dejose (1989) and Kuchling et al. (1992), and translocations are discussed in other chapters of this volume (e.g., Seigel and Dodd, Chapter 9). We advise extreme caution when establishing populations in areas not known to be part of the species' historic range (see Dodd and Seigel 1991).

Leyte Pond and Cochin Forest Cane Turtles: Poorly Known and "Rediscovered" Species

Other freshwater turtles have relatively small distributions or are exceedingly poorly known (Lovich and Gibbons 1997). For example, the Leyte pond turtle (*Heosemys leytensis; Geoemyda* fide McCord et al. 1995) is known from only a single surviving neotype (Buskirk 1989). The original specimens from which the species was described were collected from the Philippine island of Leyte near Cabalian but were destroyed during World War II. Subsequent searches have failed to find additional living specimens. The conservation status of this species is obviously a mystery, if it even survives in the ravaged ecosystems of the Philippines. The plight of these and other "covert" species was discussed by Lovich and Gibbons (1997).

Another poorly known but "rediscovered" species is the Cochin forest cane turtle *(Geoemyda silvatica)*. Described in 1912 from two specimens collected near Kerala, India, the species remained virtually unknown to science until 1982, when additional specimens were collected (E. O. Moll et al. 1986). The rarity of the Cochin forest cane turtle is difficult to ascertain given that individuals are difficult to find even when present in an area. However, the small range of the species, coupled with deforestation of its habitat and local use of the turtle for food, does not enhance its prospects for long-term survival (Groombridge et al. 1983).

CONCLUSIONS AND RECOMMENDATIONS

One challenge to those involved in freshwater turtle conservation will be finding conservation solutions that are neither costly nor difficult to implement. Unlike turtles with broad charismatic appeal (sea turtles and tortoises) or economic impact (e.g., river turtles), it is unlikely that many freshwater species will engender substantial funding. Two examples of simple solutions are those proposed by Mount (1976) and at the Conservation of Florida Turtles Conference in 1993 (Eckert College, St. Petersburg, Florida). The shooting of turtles is a problem that has been recognized in many areas of the United States (e.g., Missouri; Johnson 1982).

Mount suggested that conservation of the Alabama red-bellied turtle would be greatly enhanced by going beyond bans on shooting turtles. He encouraged banning the possession of 0.22-caliber rifles by boaters. Recreational shooting is an unnecessary and common source of human-related mortality for Alabama red-bellied turtles. The threat of citation and weapon confiscation could quite likely deter possession of these firearms by anglers and recreational boaters and thus remove the temptation to shoot turtles for "fun."

During the Conservation of Florida Turtles Conference, a simple solution was proposed to the problem of abandoned or underchecked **trot lines,** which are baited fishing lines tied to overhanging branches. The trot lines often incidentally kill turtles, especially when the lines are abandoned or infrequently checked. The proposal born at the meeting would require identification tags on all trot lines. This practice is already in place in some states such as Missouri. Under the proposal, untagged lines would be cut and destroyed by wildlife rangers during routine patrols. Tagged lines that were obviously abandoned or underchecked (i.e., those with rotting carcasses or excessive debris) would be confiscated, and the owner would be fined. Both of these solutions are low cost and could even generate revenue (via fines). The recommendations also address root causes of problems, a primary goal of conservation solutions (Frazer 1992; Lovich 1996; Seigel and Dodd, Chapter 9).

In this chapter we have endeavored to describe the various types of freshwater and semiaquatic turtle species, discuss their life cycle requirements, and outline general and specific conservation issues related to them. The freshwater turtles represent a broad spectrum of species and concomitantly face varying levels and types of threats. Because many species take several years or more to mature, recovery efforts may be costly and the effectiveness of such efforts may be difficult to justify on time scales relevant to political consensuses. In general, late-maturing animals such as freshwater turtles are poor candidates for both harvest and aquaculture. Therefore, the best conservation strategy may be a proactive stance that prevents them from becoming depleted in the first place.

Surveys of freshwater turtle populations are critical, both to determine if populations are in decline and to identify any human-related causes of the decline early. The foundation of any conservation effort for a specific taxonomic group is, based on the best available data, establishment of whether a population or species is in decline, is in imminent danger of decline, or is greatly reduced below historic levels. It is now safe to say that the best available data suggest that large-scale exploitation of freshwater turtles will eventually lead to dramatic population declines. Thus, we warn against exploitation of freshwater species that exceeds small-scale collections for local use by indigenous peoples.

For already reduced stocks, efforts to reestablish populations should be organized such that self-perpetuating populations are the ultimate goal. Of course, reestablishment is aided by some knowledge of the population's life cycle, life history, and natural history, including adult sex ratios (Lovich 1996). Local causes of the depletion should be identified, albeit they are sometimes difficult to establish clearly. In such cases, identification of likely human-induced mortality factors should be identified, and attempts should be made to eliminate them. Of course, such prescriptions are more easily written about than implemented. However, the collected chapters in this volume provide the information needed to frame arguments for freshwater turtle conservation.

A few specific steps may greatly enhance the long-term outlook for freshwater turtle populations. First, we encourage strong consideration of an elimination of the pet trade based on wild-caught turtles. Turtle farming has yet to achieve a convincingly high degree of success, or even independence from wild populations (Klemens and Thorbjarnarson 1995). However, if tightly controlled and monitored, farming may be a potential alternative to the wholesale collection of wild turtles. Although our recommendation will not be enforceable everywhere, we consider the elimination or tight regulation of the turtle trade to be clearly preferable to the open-market system in operation today. There is certain to be an underground trade in turtles following any ban on open-market trade, but the number of individuals traded should decline dramatically. One has only to look at the decline in trade of sea turtle products that resulted from a wide-ranging ban to realize that legal protection can have impacts. In addition to being prudent, a move to restrict the pet trade in turtles severely would greatly increase public notice of their plight and would allow a more public forum for discussion of the many issues that turtles face.

The second step involves increasing awareness about the importance of slow-moving (lentic) waters to nongame wildlife. Wherever and whenever marshes, sloughs, swamps, and similar habitats are threatened, conservationists must take a strong stand against unbridled development and misuse. Turtle biologists must make conservationists, educators, community leaders, and politicians aware of and sympathetic to the habitat needs of freshwater turtles and their aquatic associates. Even fish and game departments, which would seem to be logical allies, may need to be educated regarding the effects of fisheries practices on turtles. With regard to the public, arguments based on aesthetics and awareness that the turtles are part of the local culture (e.g., Sloan and Lovich 1995) and history may be the most convincing (see also Leopold 1949:201–226).

Finally, development of cheap, simple, and optimistic solutions to local conservation problems must be encouraged. In this sense, many sea turtle biologists have excelled. For example, in Mexico one researcher established a "Festival of Turtles" in an effort to reduce egg exploitation (G. Ruiz, personal communication).

She collected a few eggs and incubated them. During the festival, the hatchlings were released into the waves. After a few short years of the festival, local children refused to allow the adults to exploit the local sea turtles. As demonstrated by several other chelonian conservation efforts worldwide, similar efforts hold great promise for freshwater turtle conservation. Currently there is very little sympathy for freshwater species in many quarters. Hands-on experiences with hatchlings could engender needed sympathy.

Simple and inexpensive laws will help in many areas but may be ineffective in others. Legal solutions must be considered as part of the arsenal used to decrease exploitation of freshwater turtle stocks. We are optimistic about the future of freshwater turtle species because the interest and effort that has long been needed are becoming commonplace. However, there is no time to be lost, and turtle biologists and conservationists must vigilantly find and implement solutions to the dilemmas faced by freshwater and semiaquatic turtle species. Nature centers and conservation educators throughout the world are the most important vehicle for spreading information related to conservation efforts. Biologists studying freshwater turtles must join forces with such entities to garner the public support needed to parlay the conservation needs of freshwater turtles into meaningful actions.

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