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Conservation, Management, and Rehabilitation

Profile 7. For ages it has been a practice of the Sultans of Perah to reserve certain waters for their own fishing, and certain jungle tracts (usually surrounding a hot spring of mineral water) for their own hunting. There they would resort, annually or oftener, and with their relatives, chiefs, and followers take their kingly pleasure, as it was duly chronicled had been the custom of their ancestors.

In the lull after the first heavy rains, that is, about the month of December, when the river has been swollen to flood-height for a couple of months, the turtong or river-turtles ascend the Perah River in considerable numbers and lay their eggs on certain convenient sand stretches in the neighbourhood of Bota, about 100 miles from the river’s mouth.

The most frequented of these laying grounds is a place called Pasir Telor (egg-sand), just below Bota, and it is here that the ladies of the Court annually assemble to dig up the eggs, which the Malay considers one of the greatest delicacies known to him.

The river-turtle is a great deal smaller than the sea-turtle, but it lays a larger egg, and one much more valued by Malays.

As soon as the river rises, watchers are stationed on the sands, and the turtles are said to lay three times. The nests are dug between two and three feet under the sand, and contain from about fifteen to thirty-five eggs each. During the laying season boats are not allowed to stop at the sands for fear they should disturb the turtles.

When the first set of eggs has been laid and the turtles have returned to the river, the watchers open the nests and send the eggs up to the Sultan. The second set of nests is opened by the royal party, and the third is left to hatch, an operation that takes six months. There is no sitting, the young turtles simply emerge from the sand, walk down into the river and swim away.

It is said that if the first and second boats open them and scatter and destroy the departure, having accomplished their task Directly the watchers report that the third boat has passed and his family, with the neighbouring villages, have been launched across the stream to Pasir Telor.

Fifteen or twenty large house-boats, drawn by a hundred and fifty people make an impromptu house, with mat walls and a high thatched roof, sixteen poles; but the boats are gracefully light and is a long dug-out of hard wood drawn by the breadth of one or two planks, and over it is a covering on a slight wooden frame, with a roof of which rises in a sharp curve towards the owner and his family or friends. The canoes sit to paddle down stream or stand to, from whence he is able to see clear up.

The covered portion of the barges is decorated with scarlet-bordered mats, just outside the state-room, holding others are in the bows with long bamboo bugler sits on the extreme end of the antique silver trumpet of the regaling drums, and altogether the pleasure-boat attracting the attention of all the dwellers.

The journey from the Sultan’s palace on the morning of the third day all the ladies, children (a good many still in arms) and turtle-eggs.

The ladies are in their smartest gowns of brilliant-coloured silks, of painted gauze veils; of bright sunshades, gold braids, brooches, massive hair-pins, and rings.

The men appear in jackets, trousers, the horror of Western dyes and Western Malay’s innate sense of beauty and fit of bravery moves slowly across the stage.

A scorching sun shines down on the jungle, on the yellow sands and sparkles, giving light and shadow to a charming sight.

The watchers have marked with their little crowd of attendants, makes for the sand in search of the eggs. But the way of falling in on the digger, so a man makes things easy for the lady. The over
Conservation, Management, and Rehabilitation

It is said that if the first and second nests are left untouche, the turtles themselves open them and scatter and destroy the eggs; but that, after the third 'lay,' they take their departure, having accomplished their task.

Directly the watchers report that the turtles have made the second nests, the Sultan and his family, with the neighbouring chiefs and their families, take boat and paddle down the stream to Pasir Telor.

Fifteen or twenty large house-boats and several bamboo rafts containing about one hundred and fifty people make an imposing procession. The rafts are simply floating houses, with mat walls and a high-thatched roof, and are manned by crews of from four to sixteen polers; but the boats are graceful and picturesque barges, of which the foundation is a long dug-out of hard wood drawing very little water, the freeboard is raised by the breadth of one or two planks, and over the stern half of the boat is built a palm-thatched covering on a slight wooden frame, while curtains secure privacy. Inside this house, the roof of which rises in a sharp curve towards the stern, sit and lie on mats and cushions the owner and his family or friends. The crew occupy the forward half of the boat, where they sit to paddle down stream or stand to pole up. The steersman has a high seat in the stern, from whence he is able to see clear of the cabin-roof.

The covered portion of the barge which carries the Sultan's principal wife is decorated with six scarlet-bordered white umbrellas. Two officers stand all day long, just outside the state-room, holding open black umbrellas with silver fringes, and two others are in the bows with long bamboo poles held close together and erect. The royal bugler sits on the extreme end of the prow, and from time to time blows a call on the antique silver trumpet of the regalia. Flags are flown, other boats carry gongs and drums, and altogether the pleasure-fleet makes a brave show and a considerable noise, attracting the attention of all the dwellers on the riverine.

The journey from the Sultan's palace at Kuala Kangsar occupies two days, and on the morning of the third all the ladies of the party, with all their attendants and children (a good many still in arms), disembark for the ceremony of digging out the turtle-eggs.

The ladies are in their smartest garments and wear their costliest jewels. It is a blaze of brilliant-coloured silks, of painted sarongs, cloth-of-gold scarves, and embroidered gauze veils; of bright sunshades, gold bracelets, necklaces, and bangles; of curious jewelled brooches, massive hair-pins, and rings flashing with the light of diamonds and rubies.

The men appear in jackets, trousers, and sarongs of hardly less striking hues; but the horror of Western dyes and Western schemes of coiffure has not yet demoralised the Malay's innate sense of beauty and fitness, and nothing offends the eye as all this wealth of bravery moves slowly across the strand.

A scorching sun shines down on the gaily-clad figures with their background of dark jungle, on the yellow sands and sparkling river, with its burden of picturesque boats, and gives light and shadow to a charming picture.

The watchers have marked with twigs the various nests, and each lady of rank, with her little crowd of attendants, makes for one of these, and with her hands begins to dig up the sand in search of the eggs. But the nest is deep down, and the sides of the hole have a way of falling in on the digger, so a man or boy is desired to remove the overburden and make things easy for the lady. The overlying sand is quickly scooped out until one or two
of the white eggs are disclosed, and then the lady, sitting on the edge and stooping far down, can just manage to reach the nest, and the eggs are carefully handed up.

Besides the pleasure of actually removing the eggs with one’s own hand, of displaying to admiring eyes a vision of taper fingers and rounded wrist, of showing how little it matters that the costliest garments should trail in the sand, there is the rivalry of whose nest yields the largest number of eggs. Anything over twenty-five is considered a satisfactory find.

By the time all the nests have been rifled, the sands are growing so hot under the rays of the fiery sun that bare feet can hardly endure what is little short of torture. There is an almost hurried return to the boats, the finery is exchanged for simpler garments, and all the men and many of the ladies take to the river, and there disport themselves in a manner that is refreshing to sun-scorched bodies and the eyes of the Western spectator who is fortunate enough to see how it is possible to be unconventionally natural and yet perfectly modest.

It is only on such occasions as this that a strange man can see these ladies unveiled and even so he is not expected to look at them or go very near them; but their bathing-costume differs hardly at all from that which they commonly wear, and they thoroughly enjoy this opportunity of reveling in the clear waters of the sand-beded stream.

Then every one scrambles back into the boats, which are pushed off into deep water, the rowers seize their paddles and with beat of song and the musical notes of the silver serpent, with jest and laughter, pennons waving, and bright eyes sparkling behind the rainbow-coloured blinds, the picturesque flotilla glides on its course down the long sunny reach, in and out amongst the islets, round a heavily wooded, deeply-shadowed headland, past the riverside hamlets and the orchards, the stately palms, the clusters of bamboo that overhang the water like great plumes of pale green feathers, and so ever onward through sunlight and shadow till another bourne is reached.

Excerpt from *With a Casting Net*, by Sir Frank Swettenham [1895]
reprinted in Roff [1967].

It is interesting to note in Swettenham’s account that the Malays were already practicing conservation methods for the river terrapins in the nineteenth century. By protecting the beaches from poachers and leaving the third laying to hatch, they maintained moderate recruitment to offset the egg harvest. Similar conservation measures existed on the Amazon River in the nineteenth century to protect the heavily exploited giant South American river turtle, including the protection of females and leaving a third of the eggs laid on the beach to hatch (Goeldi, 1906 in Parsons, 1962; see also a brief history of exploitation patterns of this species in chapter 5, this volume).

Unfortunately, conservation actions such as these have been the exception rather than the rule in human interactions with river turtles. As emphasized in earlier chapters, populations of most riverine turtle species have seriously declined from nineteenth century levels, but unlike the general declines reported for amphibians, most of the causes are obvious. The burgeoning commercial exploitation for food, traditional medicines, and introduced predators, and extraction practices as sand mining, damming, and diking have been key factors. We know how we did it, but how can we reverse the trend?

Since the early beginnings of conservation, Swettenham and Goeldi, a variety of programs have been undertaken world-wide. As there are few programs that clearly were what seemed logical or was simply trial and error, many programs have been developed and used without the theoretical framework required to ensure that programs are effective.

Conservation methodologies, some emphasizing in-situ (in the wild) and ex-situ (off site) techniques. The former, while minimizing intrusion into the habitat, are more manipulative, requiring the identification of natural habitat for varying periods of time, and protective laws, and predator control. The latter, starting, captive breeding, transplanting, and other techniques.

For the most part, existing conservation programs have been neither long enough, nor have their results been evaluated or compared to determine the best combination of methods. This chapter looks at the conservation of river turtles, declining turtle populations and the potential of using ebbing populations along with other programs.

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**In-Situ (On Site)**

In the absence of sure-fire techniques, many conservationists choose these techniques as a last resort. Since methods that have been dictated by trial and error can be largely eliminated, their effectiveness can be improved. Also, as turtles cannot exist in many...
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legs are carefully handed up.
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the sand, there is the rivalry of whose
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itive’s choice. These techniques allow turtles to carry out their life histories in the
fashion that has been dictated through eons of natural selection, and so human
error can be largely eliminated. In-situ methods are strongly advocated by the
Also, as turtles cannot exist in nature without suitable habitat, habitat protection,
acquisition, and maintenance should be priority inclusions in any conservation plan, including those emphasizing the ex-situ approach.

Protected Areas

These can be one of the most effective means of conserving river turtles because habitat and community remain intact. Inasmuch as the target species and its ecosystem are preserved, a protected area is the quintessential in-situ technique. Ideally, everything remains in a natural state, and the organisms carry out their life histories in the time-tested manner. Also all age groups receive protection, a key criterion in the conservation of long-lived, slow-maturing species (see section on Conservation Philosophy, this chapter). Some positives and negatives associated with protected areas are summarized in table 7.1.

Questions that arise when planning for protected areas are typically ones that theorists have been debating for over two decades since conservation biologists first considered practical application of the equilibrium theory of island biogeography (MacArthur & Wilson, 1967) to the design of nature reserves: What shape? How big? How many? In a riverine reserve, the question of shape is dictated in large part by the river itself, but this becomes a more valid question should buffer zones be included. As a river is an open system, the health of the reserve is heavily dependent on the watershed lying upriver. Ideally, buffer zones could be set up protecting this watershed from such dangers as deforestation, and organic and chemical pollution. The security of the reserve would be further strengthened if upriver buffer zones were established that prevented damming and sand mining of the river.

The question of how large has at least two components. Of foremost importance are the autecological requirements of the species. The reserve needs to be large enough to include all of the species of the reserve is required to adequately buffer from predators, small populations are more likely to go extinct and loss of heterozygosity may occur at smaller population size.

Apropos to this subject are the MVP (minimum viable population) and population viability analysis (PVA); number of organisms that can survive, and answer this question, did so by definition. The best known are the figures by Soule (1980). The former number was thought necessary, to (at least temporarily) prevent extinction become likely and therefore the minimal number necessary to prevent extinction were readily embraced by many conservation groups as absolute goals for which to strive. However, population size for species as diverse as beavers, river terrapin and MVP has shifted to trying to estimate the minimum viable population size for a viable population. For example, the genetic effective size of a metapopulation can be considered a viable population, extinction and colonization of local patches and rate of gene flow until minimum population size is reached. Approaches should be used to estimate MVP.

Population viability analysis is a concept but does not attempt to predict population viability. Rather, the MVP is a population viability analysis (PVA) tool that estimates the probability that a particular population can remain viable into the future (e.g., 100 years). A population (and reserve size) needed for a certain length of time into the future. PVA is a technique that a variety of problems need to be addressed. Available data are often insufficient (when threatened species are concerned). To estimate genetic and stochastic demographics.

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**Table 7.1**

Positives and negatives associated with protected areas.

**Positives**

1. The community and habitat are protected entire, thus maintaining conditions naturally. Emphasis is synecological rather than autecological.
2. All age groups receive protection.
3. Moderately high-profile action advertising that conservation is being done.

**Negatives**

1. May be expensive to purchase, protect, and maintain a long-term financial commitment that many poorer countries will be unwilling or unable to keep (see Gomez, 1982).
2. Protected areas become a predictable location for those interested in finding endangered species whether these be predators, poachers, scientists, or tourists.
3. Long-time residents may have to be evicted. Traditional hunting and fishing grounds may be lost.
of conserving river turtles because such as the target species and its role in the evolution of its ecosystem. The organisms carry out their life cycles in groups receive protection, a key component of the reserve is heavily dependent on the maintenance of the reserve is heavily dependent on the protection the reserve is heavily dependent on the protection of the reserve is heavily dependent on the protection. How can this be achieved? By setting up buffer zones between the reserve and the surrounding areas. Of foremost importance is the concept of minimum viable population (MVP) and population viability analysis (PVA). An MVP is an estimate of the lowest number of organisms that can maintain a viable population. Early attempts to answer this question, did so by deriving a few magic numbers for general application. The best known are the figures 50 and 500 offered by Franklin (1980) and Soule (1980). The former number was touted as the minimal population size necessary, to (at least temporarily) avoid problems with inbreeding and the latter, the minimal number necessary to maintain long-term adaptability. Such numbers were readily embraced by many conservation organizations, anxious to have absolute goals for which to strive. However, it has become evident that using a universal population size for species as diverse as desert pup fish, fruit flies, Indian rhinoceros, and river terrapin is probably too simplistic. More recently, the goal of an MVP has shifted to trying to estimate the size at which a population's chances of extinction become likely and then attempt to keep populations well above that size (Meffe & Carroll, 1994; Meffe et al., 1997). Debate on criteria for calculating minimum viable population size continues. Today, the term "minimum viable population" is often replaced with less absolute terminology (e.g., genetic effective population) and the realization that a number of factors can affect the critical size of a viable population. For example, Hedrick and Gilpin (1997) point out that the genetic effective size of a metapopulation is influenced by the carrying capacity of a patch, extinction and colonization rates, abundance and source of founders, total local patches and rate of gene flow between patches. Schafer (1990) suggested that until minimum population size for species can be better estimated, other approaches should be used to estimate reserve size.

Population viability analysis (PVA) is a process that incorporates the MVP concept but does not attempt to estimate a minimum size required to keep a population viable. Rather, the PVA uses simulation models to examine a profusion of interacting factors that can put a species at risk of extinction in order to predict the probability that a particular population will survive for a certain period of time into the future (e.g., 100 years). Alternatively, it can be used to predict the size of a population (and reserve size) necessary to withstand predicted adversities for a set length of time into the future. PVA is still relatively new, and like any new technique, a variety of problems need to be addressed. They are limited by the fact that available data are often insufficient and time is critical (particularly where threatened species are concerned). To date, the majority of PVAs have been based on genetic and stochastic demographic data, while a large percentage of the causes
and threats of extinction are ecological in nature (e.g., habitat destruction). Certainly one of the reasons for this discrepancy is that ecological systems tend to be highly complex and can confound making accurate estimates of time to extinction, but if PVAs are to be made more cogent, this is a key area that needs to be addressed. PVAs are being prepared for a growing number of species, and even with the aforementioned shortcomings the process appears to have considerable potential for the future. A review of population viability analysis including its practical difficulties can be found in Boyce (1992).

Inasmuch as PVA may not be practical in all situations, alternative methods of determining the size of the reserve are needed. Here again, the autecological requirements of the group can continue to serve as a guide as to what needs preserving. A less precise but useful methodology is to determine the distribution of the target turtle(s) on a particular river while identifying the area or areas having the largest subpopulations. These areas are presumably closest to optimal on the river for maintaining the species, and so are logical sites to consider for reserves. Using a core or source population design, a river turtle sanctuary should include a large breeding nucleus along with optimal nesting and feeding habitats (E. Moll, 1985c, 1990a). The core or source population(s) in these favorable habitats will serve to supply sink populations in less favorable habitats throughout the river. Conservation goals of this methodology would be best served if the target species is totally protected from exploitation over the entire river but allowing limited subsistence hunting outside of the sanctuary may also be workable. Ideally, the protected population grows to a level where population pressure forces excess individuals from the protected area where they can continue to be taken by subsistence hunters. So long as the breeding nucleus is maintained intact, the survival of the species is maintained. The larger the breeding nucleus that can be protected, the fewer the problems with inbreeding depression and loss of heterozygosity.

Wilcox (1984) suggested another strategy for determining the size of a reserve. First, identify the target species with the most comprehensive habitat needs, then consider the pathway:

species → minimum viable population → habitat
requirement → minimum area requirement

Again, this method hinges on adequately calculating the minimum viable population of a key species. If this is successful, the area selected will then be more than ample to also protect smaller species with less demanding requirements (once again the minimum viable population of these species must be determined). This umbrella approach protects a variety of species simultaneously and is exemplified by the crocodile reserves in India (see Case Study 1). In these reserves all species are protected and so river turtles reap the same benefits as its patron species, the crocodile (Moll, 1985c, 1990a).

Case Study 1: India’s Crocodile Conservation Program. India’s crocodile conservation program offers an instructive example of melding in-situ and ex-situ techniques to achieve a desired conservation result, and although this program was not aimed at river turtles per se, it has implications for crocodilian target species.

The exploitation of Indian crocodilians is mainly as a result of more sophistcated methods of capturing crocodylian hides to fuel the leather-making industry. A number of the three species of Indian crocodilians (Crocodylus palustris), the saltwater crocodile (Crocodylus porosus), and the false gharial (Gavialis gangeticus) had suffered considerably from the hide trade but only the gharial was significantly impacted by indirect factors. Despite intensive habitat destruction from dam building and pollution (Bustard, 1990).

In an initial effort to stem the decline of the gharial, under the law. Legislation also states that no further habitat should be converted to agricultural or industrial use. In 1970, Crocodile Conservation Society, the first lampoon researcher—was brought in as a consultant for the new study. Bustard conducted the study in 1971, which served as the basis for the Crocodile Breeding Centre Act, 1975.

The multi-pronged action plan included:

1. Setting up captive breeding centres for gharial to replenish the adult breeding stock that was deemed safe from the major threat of hunting.
2. Establishing eleven sanctuaries (Manjira in Andhra Pradesh, Chambal River Gharial Sanctuary in Madhya Pradesh, Chambal River Gharial Sanctuary in Rajasthan) to provide suitable habitats for the gharial.
3. Creating programs to train local people in the use of alternative techniques needed to operate Central Crocodile Breeding Centres as recommended by Bustard.
4. Organizing publicity and awareness campaigns for crocodile conservation.

Throughout the remainder of the 1970s, the program was successful in replenishing crocodilian populations in India. In 1982, the program reported an estimated 60–70 adult and sub-adult crocodylian individuals in 1993 (Anon., 1993) and in 2002, the crocodile population in Bhitarkanika National Park was estimated at more than thirty in 1974 (Bustard, 1990).
RIVER TURTLES

Nature (e.g., habitat destruction). It is that ecological systems tend to be accurate estimates of time to restore, this is a key area that needs further study appears to have consideration of viability analysis including its importance.

In these situations, alternative methods of selection. Here again, the nucleological resource as a guide as to what needs to be determined is the distribution of species identified can help determine areas having habitat closest to optimal on the basis, several sites to consider for reserves. These should include areas within the river valley, and feeding habitats (E. Moll, 1986) in these favorable habitats will be reserved habitats throughout the river. The target species should be with the target species in the river but allowing limited sub-species to be workable. Ideally, the population pressure forces excess individuals can continue to be taken by subsistence hunting, but maintaining the survival of the gene pool that can be protected, increasing genetic diversity and loss of heterozygosity.

By determining the size of a reserve, the most comprehensive habitat needs, then calculating the minimum viable area selected will then be included with less demanding requirements (these species must be determined). These species simultaneously and is exemplified Study 1). In these reserves all species will benefit as its patron

The multi-pronged action plan for the project included:

1. Setting up captive rearing stations where eggs from wild nests and captive adult breeding stock are hatched and the young head-started to sizes deemed safe from a majority of predators.

2. Establishing eleven sanctuaries ranging in size from 20 square kilometers (Manjira in Andhra Pradesh) to 12,568 square kilometers (National Chambal River Gharial Sanctuary in Uttar Pradesh, Madhya Pradesh, and Rajasthan) to provide suitable habitat for the release of the captive-reared animals.

3. Creating programs to train Indians in the captive rearing and management techniques needed to operate the conservation program. In particular, the Central Crocodile Breeding and Management Training Institute was established at Hyderabad for the purpose.

4. Organizing publicity and awareness programs promoting public involvement in the management program.

Throughout the remainder of the 1970s and much of the 1980s, the crocodile conservation program successfully carried out its mission of re-establishing crocodilian populations in India. The wild Gharial population increased from an estimated 60–70 adult and sub-adult individuals in 1974 (Bustard, 1990) to 1500 individuals in 1993 (Anon., 1993). A restocking program for the saltwater crocodile in Bhitarkanika National Park in Orissa had increased the numbers from less than thirty in 1974 (Bustard, 1990) to 584 in 1994 (Kar, 1994). And while
there were no accurate estimates of the numbers of the widespread mugger in 1974, its populations were greatly depleted from former times and they were considered rare through most of the range (Saharia, 1982). In 1993, muggers were reported from over fifty localities and the numbers were estimated at 3000 to 5000 (Anon., 1993). The success of this conservation program cannot be measured only in terms of increases within crocodile populations. By prohibiting hunting, fish nets, and egg collection, the sanctuary system benefited wildlife in general. Crocodile and religious sanctuaries were the only sites where E. Moll (1985b,c), regularly saw large numbers and a wide variety of riverine chelonians in India, including rare species such as the red-crowned roofed terrapin.

The Indian Crocodile Conservation Program exemplified how successful conservation could be achieved by combining in-situ and ex-situ techniques. From 1975 to 1988 it was a showpiece of conservation action and was touted as a model for other countries in the region to follow. However more recently, it better illustrates the problems of maintaining successful conservation programs once achieved. By 1988, the novelty of the project had begun to wear off and funding was beginning to dry up. During the glory years of the project, a number of Indian nationals had been trained as researchers to study and carry out crocodile conservation in the country. But now with less publicity and flagging government interest, a second-line of professionals trained to take their place was largely absent. High costs of captive-rearing and the protection and maintenance of the sanctuary system, along with a paucity of additional sites for release of captive bred crocodilians, have made increasing or even maintaining the program problematic. Initially the project was a joint venture of India, the FAO, and the UNDP of the United Nations, but eventually most of the costs of maintaining the program fell to the Indian Federal and State governments alone. The costs of operating the program spiraled far above those initially projected.

Consider the National Chambal River Gharial Sanctuary, one of the project's great success stories. The estimated budget for the Sanctuary was 10 lakhs per annum (ca. U.S. $23,500) in 1979, but the cost during the sixth five-year plan has been estimated at Rupees 1.3 Crores (ca. U.S. $306,000). By the early 1990s, with less money available for enforcement, the effects of the cutbacks were already apparent. Fishermen were openly using gill nets which had been outlawed in the Sanctuary since its inception. Sand miners, obtaining sand for construction, were destroying sand nesting banks within the Sanctuary well beyond the two-mile stretch adjacent to the Rajasthan/Madhya Pradesh highway that they had been allotted. Poisoning was also on the rise.

Captive rearing centers have also suffered from reduced funding, but a bigger problem is that they have become too successful. More crocodiles and gharials have been produced than there are places to locate them, and so rearing facilities are badly overcrowded, with over 12,000 muggers presently stockpiled in the rearing centers. One of the obvious solutions would be to harvest the excess crocodiles for leather and other products. Sustainable use has become a key element in the conservation strategies for crocodile species worldwide (Ross 1998). However, the Indian government prohibits commercial use of captive-bred crocodiles, thus leaving no current viable market. The Indian government has instructed fishermen to kill crocodilians and the project has ceased.

Recently, future projections are somewhat brighter. In 1998 the Bureau of Indian Crocodiles (Asia Region subgroup) held a conference in Madhya Pradesh, India to discuss the plight of crocodiles in the region, and the need for plans to re-establish a liaison with India. The conference aimed to identify research priorities that will help establish public and awareness among local populations; train and educate managers to carry out the conservation plan; and seek the renewed interest in India's crocodiles so that they can survive and return to its former crocodile-rich habitats.

In some cases, multiple reserves are established in an area. Instances habitat type becomes more restrictive, and crocodiles are found in typical habitats. They feed in estuaries and rivers, and nest on riverine sandbars above the reach of the high water. Reservoirs as a reserve for the river terrapin and crocodile turtle no matter how large it is. In India, these reserves include both feeding and nesting areas for crocodiles. Reserves, protecting each of these nesting areas, are unimportant. If a reserve can be found at a mangrove tree (Sonneratia), then more is better. The larger the area of the population that can be supported, the better. However, the more widespread the nesting grounds, the more widespread crocodile terrapins can be recognized. Their nests are less likely to be destroyed by human activities.

Multiple reserves on a river can be created to facilitate recolonization if one or more suitable locations exist. Some conditions indicate a need for multiple reserves:

- All habitats used in the current distribution of the species
- Feeding areas, nesting areas, and hibernation areas
- Areas of unused habitat, (ex...
of the widespread muggle in former times and they were (Malik, 1982). In 1993, mugger was estimated to 3000 to 5000 crocodiles. By prohibiting hunting, the project sites where E. Moll (1985b,c), 1985d), of riverine chelonians in India, poole and terrapins. Examples of how successful situ and ex-situ techniques. From 1989 and was touted as a model for other countries to follow, in 1993, the project's planned conservation programs once begun to wear off and funding was cut. The project, a number of Indian riverine species and the crocodile poole, and the UNDP, had taken their place was largely abandoned and maintenance of the species sites for release of captive breed remained problematic. The FAO, and the UNDP, had taken over the program’s funding. The costs of operating the project's Mangrove Sanctuary, one of the project's highlights, was 10 lakhs per year during the sixth five-year plan had increased to 26 lakhs. By the early 1990s, with the construction of the cutbacks were already in place. The mangrove area was already being used for the mining of sand for construction, were still well beyond the two-mile buffer zone around the highway that they had been set aside for. A reduction of funding, but a bigger picture of the problem. More crocodiles and gharials needed them, and so the rearing facilities were already in place. It’s presently stocked in the project for the purpose of harvesting the excess captive-bred populations are key conservation tools for some species worldwide (Ross 1998). crocodiles, thus leaving no current solution to the burgeoning problem. Hence, the Indian government has instructed breeding centers to stop producing any new crocodiles and the project has ground to a halt.

Recently, future projections for crocodile conservation in India have become somewhat brighter. In 1998 the IUCN/SSC Crocodile Specialist Group (Western Asia Region subgroup) held a conference at Jiwaji University in Gwalior, Madhya Pradesh, India to discuss the plight of Indian crocodiles. The meeting resulted in a six-part action plan for dealing the present problems (Aron, 1998). Included in the plan are: re-establish a liaison with the Ministry of Environment and Forests; identify research priorities that will further the crocodile conservation effort; establish publicity and awareness campaigns to change the crocodile image among local populations; train a new generation of crocodile researchers and managers to carry out the conservation program; develop regional interaction and coordination; and seek necessary funding to carry out the action plan. Hopefully this renewed interest in India's crocodile conservation will allow the conservation program to survive and return to its former status as a prototype that other countries can emulate.

In some cases, multiple reserves may be desirable on the same river. In certain instances, habitat type becomes more important than refuge size. Consider the river terrapins of tropical Asia. River terrapins are river specialists that rarely utilize lentic habitats. They feed in estuaries near the sea, but migrate long distances upriver to nest on riverine sandbanks above tidal influence. Obviously, setting aside a large reservoir as a reserve for the riverine terrapins is unlikely to benefit the turtle, no matter how large it is. Further, a large reserve in the river that does not include both feeding and nesting areas will likely be less effective than two smaller reserves, protecting each of these critical habitats. This does not mean that size is unimportant. If a reserve can be gazetted in an unpolluted estuary lined with the mangrove tree (Sonneratia), the fruits of which are a staple food of the terrapins, then more is better. The larger the food resource, the larger the terrapin population that can be supported and the fewer small population problems will be experienced. Similarly, a reserve upstream, among the extensive sand banks used for colonial nesting by the terrapin, should set aside as much of this crucial habitat as possible. The more sand banks that can be protected from destruction, the more widespread nesting can be. With more dispersed nesting, predators cannot concentrate their efforts, later cohorts of nesting females will dig up fewer nests of previous cohorts, and catastrophes such as unseasonable floods are less likely to destroy all of the annual reproductive output.

Multiple reserves on a river serve as insurance to catastrophes allowing for recolonization if one or more subpopulations are extirpated. The following situations indicate a need for multiple reserves:

- All habitats used in the course of the turtle's life history are not contiguous. Feeding areas, nesting areas, and/or nursery areas are separated by large areas of unused habitat, (except during movement between these habitats)
For wide-ranging or migratory species, such as giant South American river turtles, river terrapins, and painted terrapins exemplify species that move moderate to long distances between feeding and nesting areas as discussed above.

- Local or sub-populations of a species occur in habitats separated by long stretches of unsuitable habitat (e.g., the Fitzroy River turtle of Australia inhabits riffles which may be some distance apart along the river [Cann, 1998]). Its nesting sites appear to be in the vicinity of the riffle habitats. If the Fitzroy River turtle is the only target species, several small reserves each protecting a set of riffles (feeding area) and nesting sites may be as effective and more economical than gazetting a large area of river containing relatively small amounts of critical habitat.

Perhaps the most compelling arguments against choosing a series of small nature preserves over a large contiguous one are rooted in genetics. Multiple small reserves may assume a classic metapopulation structure—a metapopulation being a series of local populations in scattered habitat patches with intermittent or regular gene flow that periodically become extinct and then recolonized from other patches. Using a simulation model, Gilpin (1991) has demonstrated that even though a population may be relatively large overall, a metapopulation structure will lead to rapid losses of genetic variability characteristic of small populations. Each time a local population becomes extinct and is recolonized from another patch, some heterozygosity is lost. He further states that since few species in the wild possess the low heterozygosity predicted from this process, they presumably do not have or at least maintain a metapopulation structure for extended periods. It is more likely that somewhere in the range of most, one or more large populations survive extinction and serve as a refugium protecting genetic variation. In a freeflowing river, the metapopulation problem becomes less significant. The river serves as a natural corridor permitting dispersal between populations thus increasing colonization and gene flow. Dams, however, exacerbate the problem by increasing fragmentation and isolation (Dodd, 1990; Gibbs & Amato, 2000; Mitchell & Klemsen, 2000). In such human-created metapopulations, human intervention may be required to maintain heterozygosity, reduce inbreeding depression, and recolonize extirpated populations.

Genetic considerations should thus be given adequate consideration when weighing decisions concerning the size and number of nature reserves (see section on Genetic Considerations below). Economics will certainly have to be considered as well. More often than not, final decisions will be based more on economic and less on biological arguments. Reserves can be expensive to set up and maintain. Potential expenses include purchasing large tracts of real estate and then hiring a permanent staff to enforce rules and protect species from exploitation. What is best for the animals involved may be too expensive for some countries or agencies to consider. Furthermore, rivers tend to be multiple use areas serving a variety of human needs including transportation, recreation, and food supply, and governments may be unwilling to limit competing uses of a stretch of river solely for conservation purposes.
For wide-ranging or migratory species, establishing reserves in both feeding and nesting areas may prove impractical. If only one area can be protected, then usually the nesting area is the best choice. While it can be argued that turtles require adequate food resources to survive, generally river turtles appear to be considerably more flexible in their food habits than in their reproductive habits. Protecting the nest site is especially favored for large colonial nesting river turtles (e.g., giant South American river turtles, river terrapin) whose concentrations and predictable returns to specific beaches make them highly vulnerable to exploiters and predators. Nesting sites are typically characterized by a high mortality of females, hatchlings, and eggs. While eggs and hatchlings are to some extent expendable, there can be no more damaging loss to a population than the large, reproductive females. Each large female river turtle can potentially lay hundreds (even thousands) of eggs in a life time but on average only two per turtle have to survive and become adults if the population size is to remain stable. The importance of adult females will be a recurring theme in this chapter.

Existing protected areas are as varied as the turtles that they protect. Examples of existing programs include:

- Belize has designated a series of protected zones for Central American river turtles in major waterways of the northern part of the country, aimed at incorporating all major habitats of the turtle (Polisar & Horwich, 1994).
- In the United States, Mississippi has designated approximately 13 kilometers of the Pearl River as a Ringed Sawback (Eupatagus oculifera) Sanctuary (George, 1990). Presently, the philosophy of the sanctuary is to simply protect the turtle and its habitat but not actively to manage the population.
- Brazil’s strategy has been to protect nesting sites in order to conserve their giant South American river turtle populations. History and descriptions of the program can be found in Vogt (in press) and IBAMA (1989). As a result of efforts of a turtle biologist named Jose Alfinito, the Brazil government in 1975 established a program through the agency IBDF to protect the turtle and its nesting beaches. In 1990, IBDF had become IBAMA and established a national center for freshwater turtles (CENAQUA). From 1975 to 1992 the program reported releasing some 18 million hatchlings from the protected beaches. Today, there are 115 protected nesting areas, on fifteen rivers in nine states.
- In India, turtles reap the benefits of refuges established for other species, particularly crocodilians and tigers, and in religious sanctuaries associated with Hindu temples (see Case Studies 1 and 2).
- The Project Tuntung Sanctuary, which was established to protect river terrapin on the Perak River in Malaysia, exemplifies an extractive reserve. Adult river terrapins are protected here, but egg collectors are allowed to exploit major nesting beaches and sand mining is allowed along the entire nesting region (see Case Study 3).
Case Study 2: Indian Religious Sanctuaries and Refuges. It is difficult to imagine a setting more picturesque and peaceful than that of the Bateshwar riverfront on that afternoon in early April. In this small city of temples, the Yamuna flowed slowly along a lengthy line of immaculately white buildings of varied shapes and structure (fig. 7.1). The rays of the descending afternoon sun transformed the town into a glowing waterside jewel sharply in contrast with the otherwise stark landscape. Actually, our primary purpose in coming to Bateshwar had not been to witness the unusual beauty of this striking scene but to view an especially large assemblage of turtles which inhabited this site.

The Yamuna River has long been famous for its turtles. Whereas ancient statuary depicts Mother Ganga as standing on the back of a crocodile, the vahana or vehicle of Mother Yamuna has traditionally been the turtle. Today, few parts of this river can be said to teem with turtles but at Bateshwar it still does. Here one can see what India's 'river of turtles' must have been like in the past.

Scanning the river with binoculars we could see turtles basking, floating and swimming almost everywhere; peaked silhouettes of Indian tent turtles in ludicrous basking poses on logs and protruding sticks in the river. These sun-worshippers were balanced precariously on their perches, with neck, limbs and toes maximally outstretched to gather the warm, soothing rays of the sun. On the riverside sandbanks, ponderous snails and hard-shelled cousins.

From a vantage point on the temple roof, a score more turtle heads protruded from the water below me. I recognized the painted roof terrapins (Kachuga harmotoma) and other visitors came to bathe in the river and wash rice and vegetables to the turtles. There were no funerals that day.

The remarkable number and diversity of turtles at Bateshwar is due to at least two factors. Foremost, this is a traditional turtle sanctuary where the turtles are not disturbed and an abundance of food is available from the nearby fields. In India, the faithful from the steps of their temples have offered help to the turtles by providing them with an important food supply. Although data are not available, it is likely that throughout much of India today, turtles have undergone a serious decline, especially in their breeding areas. At Bateshwar, a breeding nucleus of these important river turtles is still able to live harmoniously along with our human neighbors (E. Moll 1985b).

Religious shrines or sanctuaries are scattered throughout Asia where major religious traditions, such as Islamic, and Hindu religions (Anand 1978). Other examples of these in India, Bangladesh, and Pakistan have concluded that only those found along rivers have undergone a serious decline, especially in their breeding areas. At Bateshwar, a breeding nucleus of these important river turtles is still able to live harmoniously along with our human neighbors (E. Moll 1985b).

The Indian sanctuaries are often hidden but frequently remain in contact with their wild populations. One common type is a hatchery in which a population of large turtles is maintained in an enclosed area where some of these a river runs nearby. The hatchery enables offspring from returning to the village. For example, in Andhra Pradesh near the mouth of the Godavari River, Moll observed a number of Leith's terrapins, a large river turtle species. The sanctuary is managed by local villagers who maintain a secluded and protected area of the river. A similar sanctuary can be found in the Chilka Lake sanctuary, a section of river near the mouth of the river. In both cases, river sanctuaries are far better for the turtles than the local population. Bateshwar and the other sanctuaries in conserving river turtles.

Figure 7.1
The Yamuna, known as India's "river of turtles," flows past a Jain temple in the village of Bateshwar which provides food and sanctuary for river turtles in its vicinity.
RIVER TURTLES

Refuges. It is difficult to imagine a view of the Bateshwar riverfront on that warm autumn afternoon as the sun transformed the town into a patchwork of variegated colors with the otherwise stark landscape.

Bateshwar had not been to witness the slow flow of the Yamuna as it meanders through fields of varied shapes and structure. Perhaps the riverfront is more than a place of refuge for its turtles. Whereas ancient texts describe the river as the vahana or vehicle of the turtle, today, few parts of this riverfront still do. Here one can see the Bateshwar riverfront as seen from the terrace of the Jain temple.

One could see turtles basking, floating and sometimes even swimming in the river. These suntan turtles bask in the sun, soaking in the sunbeams, with necks and limbs outstretched, soaking in the soothing rays of the sun. On the riverside sandbanks, ponderous soft-shells mimicked the behaviour of their tiny, hard-shelled cousins.

From a vantage point on the steep steps of the bathing ghat at a Jain-Hindu temple, a score more turtle heads continually appeared and then disappeared in the water below me. I recognized at least five species including a number of rare, painted roof terrapins (Kachuga kachuga). Throughout the day villagers, pilgrims and other visitors came to bathe in the holy waters and to feed doughballs, puffed rice and vegetables to the turtles. Though aquatic burials also took place here, there were no funerals that day.

The remarkable number and variety of chelonians at Bateshwar is attributed to the management of a sanctuary where the turtles are neither exploited nor harmed. Secondly, an abundance of food is available from the aquatic burials and the offerings provided by the faithful. The sanctuary has been well managed with the help of local villagers.

River turtles are being heavily exploited throughout much of India today, and as a result, populations of certain species have undergone a serious decline. Therefore, to find areas such as Bateshwar, where a breeding nucleus of these important species is being protected and the turtles are living harmoniously along with one of their chief predators, is indeed encouraging.

(E. Moll 1985b)

Religious shrines or sanctuaries dedicated to turtles or including turtles are scattered throughout Asia where they may be associated with the Buddhist, Islamic, and Hindu religions (Annade & Shastri, 1914). We have visited examples of these in India, Bangladesh, Thailand, and Malaysia and have concluded that only those found in India benefit the turtles. In most, the turtles are kept captive in concrete or tiled ponds lacking nesting sites where they remain until they die.

The Indian sanctuaries are often truly that. The turtles are fed and protected, but frequently remain in contact with wild populations. Basically there are two variations. One common type is a tank (pond) associated with a Hindu Temple in which a population of large softshells are kept, fed, and protected. In at least some of these a river runs nearby and no barriers prevent the turtles or their offspring from returning to the wild. One such temple is located at Kotipalle, Andhra Pradesh near the mouth of the Godaveri River. In the temple pond, E. Moll observed a number of Leith's softshells eating puffed rice and hibiscus flowers provided by local villagers (E. Moll, 1990a). In the second type of sanctuary, a section of river near a temple or group of temples is given protection. Bateshwar (described above) is an excellent example of such a sanctuary. A similar sanctuary can be found at Mathura on the same river. The river sanctuaries are far better for conservation than the first type. All species of turtles are protected, not just the large softshells. Other than being fed, the turtles live under entirely natural conditions. The large numbers of the rare red-crowned roosted turtle at Bateshwar testify to the effectiveness of these sanctuaries in conserving river turtles.
Habitat Improvement and Restoration

This can be beneficial to both protected and unprotected areas. It is important to remember that sanctuaries on rivers are open systems. Just protecting the area of a reserve does not prevent damage due to chemical pollution or siltation originating upstream. Management of a river must consider what is happening throughout the entire watershed, particularly upstream and immediately downstream from the site of interest. Hence, the most beneficial forms of habitat improvement involve improving water quality for the entire river, including the tributaries, throughout the drainage basin. River restoration projects are gaining in popularity in developed nations (National Research Council [NRC], 1992). Such projects attempt to remove sources of silt, sewage, and chemical pollution, while re-creating former river flow patterns and flood plains (see chapter 6, this volume). Natural materials are used to reinforce the channel and hold the banks (i.e., tree trunks, boulders, roots and vegetation) as opposed to the concrete and steel that has typically been used in the past. Some plans include the reversal of channelization and even the removal of dams. In regard to the latter, many hydropower dams in the United States will require re-licensing by the federal government in the coming years offering an important opportunity to restore natural hydrologic conditions to some rivers (Richter et al., 1997).

On a smaller scale, a variety of actions can be used to improve nesting sites. Many river turtles seem to be attracted to extensive stretches of open sand for nesting purposes. Females can thus be enticed to particular nesting beaches by removing debris and vegetation that covers the sand. Prior to the river turtle nesting season on the Perak River in Malaysia, the Department of Wildlife and National Parks and individual egg collectors remove tropical grasses from nesting beaches and break up the silt crust that forms following floods (E. Moll, 1984a).

Part of the IBAMA conservation program for South American river turtles consists of clearing logs and debris from the nesting beaches (IBAMA, 1989).

The creation of artificial nesting beaches has been tried with some success. In one experiment begun in 1950, juvenile giant South American river turtle that had been headstarted for 10 months were translocated to Lake Valencia in the Andean highlands west of Caracas and north of the Orinoco River. Parsons (1962) reported that the turtles were growing well and had begun nesting on artificial beaches constructed on several of the islands in the lake. However, a later report by Smith (1973) stated that no significant nesting had occurred on the lake's artificial beaches. In a more recent attempt, artificial beaches were constructed below the dam at Balbina on the Rio Uauma to accommodate giant South American river turtles blocked from reaching their natural nesting areas. Turtles have begun nesting on these man-made sites (Vogt, 1997, in press).

Habitat improvement is not limited to nesting sites. Providing basking sites and improving feeding areas exemplify other approaches. Lindeman (1999) found that map turtle density is positively correlated with deadwood density of the habitat. He concluded that anthropogenic removal of deadwood from rivers is likely harmful to populations of map turtles. An innovative program on the Pearl River in Mississippi removes snags and deadfall trees from water skiers, but deposits them near threatened ringed sawback (map turtles). Moderate logging of riverside forests is conducive to wood turtle food plants (Harding, 1990). Planting fruit trees (Sonnentia) in riparian areas and especially those tropical areas where they are lacking.

A sound approach for planning and the ecology of the target organism essay. Comparing habitat features of areas where populations are depleted to improve the turtle's environment.

Genetic Considerations

Genetics should be viewed as "the basis of habitat protection has been established. Conservation biologists are increasing the populations of rare species. To a large extent problems concerning habitat degradation are first-priority actions, it has been likely to fail if the genetic health of a species' recovery program (Frankel & Soulé). Genetics and conservation biology have become closely intertwined. Conservation genetics, has emerged as a major tool and concept of protein electrophoresis and nuclear DNA analysis (e.g., DNA fingerprinting, examines the roles that genetics can play.

A primary concern of conservation is biodiversity. In a more analytical sense, the survival of the fittest and thus becomes the ultimate measure of extinction reduces the extant genetic resource (Levin, 1983). Gene pools are becoming fragmented at three levels, the genetic variation within a population; the variation within a population; and the variation within a population. Each level must be considered in its entirety. At the individual level the genetic potential or pool of genetic variation within a population's ability to adapt to new or changing environmental conditions between populations results in co-evolution of species.
removes snags and deadfall trees from the river channel to accommodate boats and water skiers, but deposits them nearer the bank to serve as basking sites for the threatened ringed sawback (map turtle) and other basking turtles (George, 1990). Moderate logging of riverside forests in Michigan can open up clearings that are conducive to wood turtle food plants such as raspberries, strawberries, and willows (Harding, 1990). Planting fruit trees such as hips (Ficus) or the mangrove tree (Sonneratia) in riparian areas and estuaries respectively would be potentially beneficial to those tropical areas where many chelonians are herbivorous.

A sound approach for planning effective habitat improvement requires studying the ecology of the target organism and in particular the limiting factors. Comparing habitat features of areas where the target organism is abundant with areas where populations are depleted can provide clues as to what could be altered to improve the turtle's environment.

**Genetic Considerations in River Turtle Conservation**

Genetics should be viewed as “fine tuning” to be done after the “coarse tuning” of habitat protection has been accomplished. (Meffe & Caroll, 1994)

Conservation biologists are increasingly faced with maintaining declining populations of rare species. To a large extent, their initial efforts must be focused toward problems concerning habitat degradation and loss as these typically are the ultimate causes leading to the decline. But while habitat protection and improvement are first-priority actions, it has become clear that long-term conservation efforts are likely to fail if the genetic health of the target species is not considered in the recovery program (Frankel & Soule, 1981). Over the past two decades, the role of genetics in conservation decisions and planning has continually grown, and genetics and conservation biology have become so interwined that a new subdiscipline, conservation genetics, has emerged. Simply put, conservation genetics applies the tools and concepts of protein electrophoresis, mitochondrial DNA analysis, and nuclear DNA analysis (e.g., DNA fingerprinting and microsatellites). This section examines the roles that genetics can play in river turtle conservation.

A primary concern of conservation biology today is the preservation of biodiversity. In a more analytical sense, genetic diversity is the source of biodiversity and thus becomes the ultimate concern for conservation biologists. Each extinction reduces the extant genetic diversity a little more. As observed by Foose (1983), gene pools are becoming gene puddles. The diversity is displayed at three levels, the genetic variation within individuals (heterozygosity); the genetic variation within a population; and the genetic variation between populations. Each level must be considered in conservation biology (Meffe & Caroll, 1994). At the individual level the genetic problems of interbreeding develop, and knowledge of variation within a population (the gene pool) will determine the population's ability to adapt to new or changing conditions, while the loss of variation between populations results in coalescence of populations and a narrower range
of options for the species. Both within- and between-population variability must be maintained to allow the full potential of evolutionary change of threatened species.

Heterozygosity is a concern for both captive and small wild populations. High heterozygosity is typically (though not always) associated with fitness (Hedrick & Miller, 1992), but too much or too little can lower fitness. For example, outbreeding depression can result when individuals from differing geographic areas are brought together in captive breeding or translocation programs. Matings between genetically dissimilar individuals can break up adaptive gene combinations and lower rather than raise fitness (Templeton, 1990, 1996). If at all possible, organisms to be reintroduced or translocated should come from nearby populations occupying similar habitats and, ideally, ones that previously shared some gene flow. Homozygosity can also bring about a reduction in fitness. Along with genetic drift, inbreeding can lead to increased deleterious traits in the progeny ("inbreeding depression"). The latter phenomenon commonly affects those characters that are closely tied to an individual's ability to survive and reproduce (Frankel & Soule, 1981).

Inbreeding and inbreeding depression are not synonymous. Some species seem able to cope with frequent inbreeding without serious consequences. For example, inbreeding depression appears less common in populations having a long history of inbreeding (Charlesworth & Charlesworth, 1987). In at least some of the cases, inbreeding may have come about slowly, allowing selection time to weed out many of the deleterious alleles (Frankel & Soule, 1981). Many endangered species are outbred, however. Small population sizes with increased inbreeding are a recent occurrence that can be accompanied by high levels of inbreeding depression (Hedrick & Miller, 1992). Inbreeding depression likely is less of a threat to historically small populations (or to species that naturally exist in metapopulations; Simberloff, 1988; Hanski & Gilpin, 1997; Hedrick & Gilpin, 1997) than to historically large populations that have been rapidly transformed into small ones.

As mentioned previously, habitat destruction and dam building are examples of factors that have fragmented previous large wild river turtle populations into smaller ones. Even if protected, the genetic health of these populations may suffer. Each fragment likely represents a "bottleneck" (less diversity than the population as a whole), and genetic drift can be expected to further reduce the remaining genetic diversity. Genetic translocations (introducing animals from compatible captive or wild populations) may be a useful management technique to maintain genetic diversity in cases where natural gene flow between fragments no longer exists. The initial step is to make a genetic status survey (heterozygosity assessment) of existing populations and determine if reduced heterozygosity is a problem and, if so, to determine the best approach to remedy the problem.

For example, Gray (1995) used DNA fingerprinting to analyze the genetic status of the western pond turtle (Clemmys marmorata) in Washington, Oregon, and California. She confirmed the genetic break between a northern and southern subspecies of the turtle. The northern populations, which are threatened with extinction, showed a high degree of genetic similarity within populations.

Between-populations variability was significantly higher between inland populations within southern populations.

Gray recommends that recovery efforts move cautiously against genetic translocations from southern populations. She also recommends preservation of local gene pools through captive breeding and reintroduction of populations.

Genetic management is typically implemented for wild populations, because captive populations, although not gene-pool rich in the wild, and problems related to genetic drift are magnified. One can learn from captive populations. Captive populations are pedigreed, thus making it possible to track the genetic flow. Captive-raised individuals that are reintroduced into the wild should be tracked after they are released.

Although the most common approach for river turtle conservation has involved maintenance of gene flow, genetic founder effects and loss of genetic variation have been significant in conservation efforts for river turtle species (Hamrick, 1996). Several additional viewpoints on river turtle biology include:

- Recognition of cryptic species has been more common in the past. Efforts have been focused on recognizing and naming them.
- Molecular genetic approaches have been used to examine patterns and determine relationships of individuals (e.g., the Chinese alligator [Gang and Zhang, 1995]; roughly 150 alleles were identified).
- Molecular approaches have illuminated the geographic distribution of species and subspecies and their relationships.
Between-population variability must be considered in conservation efforts. High levels of inbreeding are often associated with fitness (Hedrick & Hamrick, 1987). In at least some of the riverine species studied, inbreeding depression has been observed (e.g., Miller, 1996). If at all possible, organismal diversity should be preserved in species that previously shared some gene pool. Genetic variation in fitness. Along with genetic diversity, traits that affect reproductive success (Frankel & Soulé, 1986) are not synonymous. Some species may have a greater potential for survival and reproduction if they are adapted to a specific environment. Others may have a greater potential for survival and reproduction if they are adapted to a more general environment.

River turtles are examples of species that may suffer from inbreeding depression. Inbreeding depression may reduce population size, and problems related to small population size (e.g., interbreeding, genetic drift) are magnified. One of the tools being used in the genetic management of river turtle populations is genetic diversity. By making detailed pedigrees of the captive population, breeding programs can be designed to reduce inbreeding and thus inbreeding depression. In addition, the distribution of founder genes within the population can be tracked. As a primary goal of captive breeding is to reintroduce a species into its original habitat, it is important to maintain the founder alleles that adapted that population to that habitat (Hedrick & Miller, 1992). Captive-raised individuals that have been inbred are likely to have poor survivorship when reintroduced into the wild (Jiménez et al., 1994).

Although the most common application of genetic information in conservation has involved maintenance of genetic variation in and between populations, the number of conservation uses for genetic information is growing (see Avise & Hamrick, 1996). Several additional uses and potential uses for the conservation biology of river turtles include:

- Recognition of cryptic species requiring conservation attention. Avise (1989) recognized two types of systematic errors that could misdirect conservation efforts. One of these populations may suffer from high levels of inbreeding depression and lack of recognition of phylogenetically distinct forms. Lovich and Gibbons (1997) referred to the latter as "covert species" and emphasized their importance to the conservation effort. As an example of such covert forms, consider snapping turtle species. Phillips et al. (1996) recognized three distinctive groups of *Chelydra* (common snapping turtles) rather than one widespread polytypic species. This may have conservation significance in that now attention will be focused on the poorly known and seemingly rare middle and South American species.

- Determining population sources of migratory individuals and natal homing. Molecular genetic approaches have been important in revealing migratory patterns and natal homing (i.e., return to the same beach or beaches in that general area where they hatched) among sea turtles (Bowen & Avise, 1996; Gibbs & Amato, 2000). These same techniques could be beneficial in illuminating similar information in river turtles, and they are beginning to
be used to answer such questions (e.g., Sites et al., 1999; Bock et al., 2001; see chapter 2, this volume). Large vagile turtles living in major rivers often nest colonially on beaches far from their feeding areas. For example, the giant South American river turtle nests on over a hundred known sand beaches throughout the Brazilian Amazon, but during the rest of the year they spread out into flooded forests and oxbows to feed. From a conservation standpoint, it would be helpful to know if the turtles from one nesting beach are also concentrated in a particular feeding area. For example, should the nesting numbers decline, the cause may be found in the feeding area. Similarly it is not known whether hatchlings show natal homing. Such information could be significant in attempting to reintroduce nesting populations on depleted beaches.

- Determining demographic features and natural history of populations. Molecular genetic methodology can give researchers a handle on the numbers of individuals actually mating, the females producing the most offspring, and multiple paternity of clutches. These data can all be significant in calculating the genetic effective size of a population, which in turn allows researchers to predict the rate at which genetic diversity will be lost in populations. Galbraith et al. (1997) have demonstrated the utility of DNA fingerprinting in determining paternity and other aspects of freshwater turtle mating systems.

- Identifying biological material confiscated in illegal trade. Products from protected species can lack the superficial diagnostic characteristics needed for positive identification, but with molecular genetic methods it is often possible to identify the material not only to species but also to river systems from which it came.

**Antipredator Techniques and Other Methods to Improve Recruitment**

Most readers are probably well aware of the tremendous mortality that takes place on the colonial nesting beaches of sea and river turtles. Even if they have not actually visited a nesting beach during the reproductive season, they may have been taken there through the magic of television, courtesy of Jacques Cousteau, Marlin Perkins, David Attenborough, the Discovery Channel, or the Public Broadcasting System. The typical documentary begins with a scene showing one or more large female turtles laboriously moving up the beach, digging their nests and laying their eggs. At this point predators do not play an important role, as the adult turtles are large enough to deter most predators (jaguars, tigers, and humans excepted). However, in subsequent scenes predators take the starring role. Depending on the locality, multitudes of eggs are shown being exhumed, then consumed by raccoons, monitor lizards, hyenas, wild pigs, vultures, and the like. Then, just as one thinks things cannot get much worse for the turtles, the scene switches to reveal hatchlings exploding out of the surviving nests and running for the water as frigate birds, jabiru, shorebirds, cranes, and eagles follow them as foxes, coyotes, and hawks chase them over the sand. And just as they reach the water, the scheme is stopped by a group of predaceous teleost fishes, snakes, and finally a group of terrestrial predators.

If a poll were taken of the videotaped reviewers, featuring the question, "What is the near-unanimous answer would be - poaching. Actually as we shall see shortly, the removal of long-lived animals such as reptiles and birds can be controlled by several techniques have been devised to remove reproductive females at nesting beaches.

Predator control is one obvious way to prevent the turtle from becoming one of the most damaging species in the world. Gallaway (1984) reported that, following the removal of raccoon pelt and elimination of raptor predation in Iowa, the sea turtle population increased over the next two years. Stuckenrath (1987) concluded that removal of predators on loggerhead sea turtle nests was effective in reducing predation rates. Stancik (1994) concluded that removal of raccoons from turtle nesting beaches in situations where immigration of new predators (or where manpower and equipment is removed) or where manpower and equipment is removed effort.

Goodrich and Buskirk (1995) described several methods of controlling predator removal may not be possible in many programs. It is often the least expensive where other options need to be considered.

Nest protection can be a simple and effective method. For example, nest survival rates can be increased by covering eggs a few meters from the original nest with a layer of sand. This has been found using a broom to shift sand and moving the eggs. Adding a layer of metal lid or plastic film to the nest. Addition (1997) described in detail how this can be done while Graham (1997) and Ewert (1998) described constructing predator excluder cages out of wire mesh or plastic, which can be transplanted to a beach hatchery for hatching nests (see section on Hatcheries, this volume).
turtles, Bock et al., 1999; Bock et al., 2001; turtles living in major rivers often feeding areas. For example, the cover a hundred known sand but during the rest of the year to feed. From a is unusual to know if the turtles from a particular feeding area. For instance, the cause may be found in whether hatchlings show natal instinct in attempting to reintroduce natural history of populations. Researchers have found that females producing the most of these data can all be the size of a population, which in which genetic diversity will be have demonstrated the utility of is now illegal trade. Products from diagnostic characteristics needed involving genetic methods it is often species but also to river systems

**Other Methods**

The tremendous mortality that takes place other turtles. Even if they have not reproductive season, they may have other predators, courtesy of Jacques Cousteau, The Discovery Channel, or the Public Channel begins with a scene showing one up the beach, digging their nests not play an important part, as the predators (jaguars, tigers, and humans) predators take the starring role. are shown being exhumed, then wild pigs, vultures, and the like. Worse for the turtles, the scene is the surviving nests and running for the water as frigate birds, jabirus, storks, caracaras, crows, or gulls swoop out of the skies to snatch them as fooses, coyotes, jackals, dogs, wild cats, or ghost crabs chase them over the sand. And just as the viewers are ready to cheer the scant few that have reached the water, the scene cuts away once more to an underwater view of predaceous teleost fishes, sharks, caiman, and crocodiles completing the banquet begun by the terrestrial predators.

If a toll were taken of the viewers immediately following one of these documentaries, featuring the question, “What is the best way to conserve these turtles?” a near unanimous answer would be—protect the eggs and baby turtles from predation. Actually as we shall see shortly, this probably is not the surest approach to conserving long-lived animals such as turtles, but certainly it would help. Several techniques have been devised to increase survival of the eggs, hatchlings, and reproductive females at nesting beaches.

Predator control is one obvious action. In North America the raccoon has become one of the most damaging predators of turtle eggs (Mitchell & Klemens, 2000; chapter 2, this volume). Changes in land use patterns, a decline in value of raccoon pelts, and elimination of raccoon predators during this century have resulted in a population boom for this proficient nest robber. Christiansen and Gallaway (1984) reported that, following raccoon removal in 1979, a yellow mud turtle population in Iowa experienced markedly reduced nest and hatchling predation over the next two years. Stancyk (1982) reviewed efforts to control raccoon predation on loggerhead sea turtle beaches in the United States. Although intensive removal of raccoons greatly reduced first-night predation of nests temporarily, if predator removal was not continued, predation soon returned to former levels. Stancyk concluded that removal of mammalian predators is most effective in situations where immigration of new recruits is impeded (such as an island situation) or where manpower and equipment is available to carry out regular intensive removal effort.

Goodrich and Buskirk (1995) discuss a number of problems with predator control programs. In sanctuaries or reserves, where all species are protected, predator removal may not be possible. Cost and manpower needs can be excessive for many programs. It is often the least socially acceptable alternative, and in such situations other options need to be considered.

Nest protection can be a simpler and less costly alternative to predator control. For example, nest survivorship can be increased simply by transplanting eggs a few meters from the original nest site (Stancyk, 1982). We have also found that using a broom to sweep away tracks and nesting signs can be effective in deterring sight-oriented predators, including human poachers. Covering the nest with metal or plastic cages is effective for a variety of predators. Addison (1997) described a type of wire cage used with sea turtles, while Graham (1997) and Ewert and Jackson (1994) provide directions for constructing predator excluder cages that were effective in protecting hatchlings of red-bellied turtles and alligator snapping turtles, respectively. Eggs can also be transplanted to a beach hatchery where a common fence protects all of the nests (see section on Hatcheries, this chapter).
Predation is not the only factor leading to mortality at nesting sites. Depending on the locality, flooding and automobile traffic exemplify other serious hazards (see also chapters 2 and 6, this volume). Páez (1995) found that flooding rather than predation was the greatest source for nest mortality of yellow-spotted Amazon river turtles on the Caquetá River in Colombia. Pezzuti & Vogt (1999) recorded that approximately 56% (111 nests) of the (mainly) six-tubercled Amazon river turtle nests that they monitored on a nesting beach on the Japura River in Brazil were destroyed by flooding. Von Hildebrand et al. (1988) and Soini (1995) also recorded quite variable, but often high, levels of egg mortality (to 100%) due to flooding in South American Podocnemis river turtles in Colombian and Peruvian populations they studied. Transplanting eggs to higher ground or to beach hatcheries to protect them from flooding has proven beneficial to both giant South American river turtles (IBAMA, 1989; Soares, 1995; Vogt, 1997) and yellow-spotted Amazon river turtles (Páez, 1995; Páez & Bock, 1997).

Highways separating turtle nesting and feeding habitats are often killing grounds of the highest order (e.g., Gibbs & Shriver, 2002). One study of roadkilled terrapins recorded 4020 casualties along a 35-km stretch of New Jersey shoreline from 1989 to 1995 (Wood & Herlands, 1995, 1997). Perhaps the most reliable solution to such a problem is to stretch fencing between the road and the turtle habitat and, if necessary to construct artificial nesting sites along the fence. Alternately, fencing can be used to funnel nesting females to an underpass or culvert that would allow them to safely reach the other side. Preliminary studies on tortoises (Fusari, 1982; Ruby et al., 1994; Boorman, 1995; Boorman et al., 1997) suggest that fencing and culverts can be beneficial conservation techniques, but to date the method has not been tried with river turtles.

Due to the expense and a host of other factors, fencing and culverts may not always be feasible. Turtle crossing signs have been tried in certain areas such as Portage, Wisconsin (Jones, 1994), Wabasha Co., Minnesota (Levell, 1995) and Spring Lake, Illinois to alert motorists (fig. 7.2). Such signs—particularly those coupled with reduced speed zones—could potentially reduce mortality in critical areas, but to date this has not been confirmed. A major problem is vandalism and theft of signs. For example, the Spring Lake experiment failed because the signs were continually stolen. Indeed, in Minnesota and Wisconsin the signs are removed following the nesting season for this reason.

Finally, conservationists should be aware that the loss of a female does not have to include the loss of all of her eggs. Unbroken eggs can remain viable for one to several hours depending upon the environmental conditions. If roads are regularly patrolled, eggs from road kills can be salvaged and hatchled artificially (Lardie, 1976; Tucker, 1995; Wood & Herlands, 1995, 1997). A few eggs hatched will not compensate for the loss of an adult female, but at least the death will not be a total loss.

Sometimes a simple technological innovation can play a major role in the conservation of a species. The addition of turtle excluder devices or "TEDs" to commercial shrimping nets (in conjunction with the rigorous enforcement of laws which require their use) has reduced sea turtle by-catch and drownings as a result (see Meylan & Ehrenfeld, 2000).

Wood (1997) proposed a crab trap that works by frightening the crab from entering the trap, but not impeding its passage out (fig. 7.3). Such a modified trap by commercial fishermen may reduce the threat to a thousand of terrapin annually.

**Protective Laws, Conventions, and Treaties**

Various laws, conventions and organizations exist to protect turtles or their habitats. Available protective conventions. Some of the most important are:

- **International Treaties**, such as CITES, the Convention on International Trade in Endangered Species. Established in 1973, CITES has protected many species threatened with extinction by listing them under international law.
mortality at nesting sites. Depending on the site, other serious hazards (see Festa-Bianchet, 1995) found that flooding rather than roadkills are the main cause of mortality of yellow-spotted Amazon river turtles (N. tetracerus, 1999) and six-tubercled Amazon river turtle (N. urostris, 1999). Other hazards include higher ground or to beach hatchlings beneficial to both giant South American species (Wood, 1995; Vogt, 1997) and yellow-spotted Amazon river turtles (Bock, 1997).

Feeding habitats are often killing grounds for turtles. One study of roadkills along a 35-km stretch of road in Peru (Wood, 1995, 1997). The problem is to stretch fencing between culverts to protect nesting sites from the dangers of traffic. The solution is to construct artificial nesting sites to funnel nesting females to an area where they can safely reach the other side. Ruby et al., 1994; Boarman, 1995; and Meylan & Ehrenfeld, 2000). Similarly, diamondback terrapins are killed in large numbers as a result of drowning in commercial crab traps (Wood, 1997). Wood (1997) proposed a crab trap design which would exclude most terrapins from entering the trap, but not impede the entry of crabs. Widespread adoption of such a modified trap by commercial crabbers could save the lives of tens of thousands of terrapins annually.

**Protective Laws, Conventions, and Organizations**

Various laws, conventions and organizations contribute to protecting river turtles and their habitats. Available protection ranges from local game laws up to international conventions. Some of the most important are reviewed here along with their strengths and weaknesses.

**International Treaties, Rules, and Conventions**

CITES, The Convention on International Trade in Endangered Species, is arguably the best known and most wide-reaching of the international conventions. Established in 1973, CITES has now been ratified by 164 nations. The Convention regulates trade in those species (and their products) perceived to be threatened with extinction by listing them on three appendices. Appendix I species...
are considered most threatened, and no trade is allowable except under special conditions of a non-commercial nature (e.g., scientific study). Appendix II species are not imminently threatened with extinction, but could soon become so; trade is allowed only with export permits from the country of origin. Appendix III can include any species that a member nation wants to protect no matter what its status. Numerous river turtles are currently listed on CITES appendices (see IUCN Action Plan, 1989 and table 2.1, this volume).

CITES has been an extremely important tool for protecting wildlife that is being traded internationally. However, it has a number of limitations, the most obvious being that it can only protect species being traded across foreign borders—it is powerless to protect declining species being traded within a country. Also, CITES cannot be completely effective until all nations become members and are able and willing to enforce the convention within their own country. Countries also can sign the convention but take an exception on certain species which they want to continue to trade.

The International Union for Conservation of Nature and Natural Resources (IUCN) or World Conservation Union is a union of sovereign states, government agencies, and non-governmental organizations. Although the Union cannot legislate statutes, it does play a key role in conserving animals and plants on the international scale. Founded in 1948 under the auspices of UNESCO, the objectives of the IUCN are to promote and assist cooperation between governments, national and international organizations involved with the protection of wildlife and especially declining species. The World Wildlife Fund (now World Wide Fund for Nature) was initiated in 1961 to fund the programs of the IUCN. Among its many contributions to the global conservation effort, the IUCN publishes the Red Lists formerly (the Red Data Books) that categorize the conservation status of threatened species in selected animal and plant groups, a practice begun in the mid-1960s. The present system of classification uses eight categories: Extinct (EX); Extinct in the Wild (EW); Critically Endangered (CR); Endangered (EN); Vulnerable (VU); Lower Risk (LR); Data Deficient (DD); and Not Evaluated (NE) (Baillie & Groombridge, 1996–2001). The threatened categories (CR, EN, and VU) are determined by quantitative criteria involving population size, population structure, rate of decline, and area of distribution. Table 2.1 lists the species of river turtles included in the CR, EN, EW, VU, DD, and LR categories. The latter is subdivided into conservation dependent (cd), near threatened (nt) and least concern (lc) (Baillie & Groombridge, 1996–2001).

The Species Survival Commission (SSC)—one of the volunteer commissions of the IUCN—has been particularly important relative to river turtle conservation. A key objective of the SSC is to conserve biodiversity by developing and executing programs to study, save, and wisely manage species and their habitats. To carry out this expansive mission, the SSC has organized an extensive network of knowledgeable volunteers into specific “specialist groups.” The Tortoise and Freshwater Turtle Specialist Group advises the SSC on matters concerning the conservation of river turtles. Begun in 1981, the group presently contains 105 members representing 27 countries. In addition to their advisory role, the group has participated in the publication of two action plans for river and freshwater turtles (IUCN, 1985 and 1995) and has summarized the available information on the world’s tortoises in a book (Swingland & Klemens, 1989). The conservation biology of riverine species also continues to improve.

Most recently, a partnership between the IUCN’s turtle specialist Group, the IUCN, and the World Wide Fund for Nature was initiated in 1996 to fund the programs of the IUCN. Among its many contributions to the global conservation effort, the IUCN publishes the Red Lists formerly (the Red Data Books) that categorize the conservation status of threatened species in selected animal and plant groups, a practice begun in the mid-1960s. The present system of classification uses eight categories: Extinct (EX); Extinct in the Wild (EW); Critically Endangered (CR); Endangered (EN); Vulnerable (VU); Lower Risk (LR); Data Deficient (DD); and Not Evaluated (NE) (Baillie & Groombridge, 1996–2001). The threatened categories (CR, EN, and VU) are determined by quantitative criteria involving population size, population structure, rate of decline, and area of distribution. Table 2.1 lists the species of river turtles included in the CR, EN, EW, VU, DD, and LR categories. The latter is subdivided into conservation dependent (cd), near threatened (nt) and least concern (lc) (Baillie & Groombridge, 1996–2001).

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of Nature and Natural Resources of sovereign states, government Although the Union cannot legislate for animals and plants on the auspicies of UNESCO, the objectionation between governments, and with the protection of nature and the Fund (now World Wide Fund for Iran of the IUCN. Among its many the IUCN establishes the Red Lists the conservation status of threatened practice begun in the mid-1960s. Categories: Extinct (EX); Extinct in remnants (ER); Vulnerable (VU); Not Evaluated (NE) (Baillie & categories (CR, EN, and VU) are determination size, population structure, rate and lists the species of river turtles categories. The latter is subdivided renewed (nt) and least concern (lc)

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in the publication of two action plans to promote conservation action for tortoises and freshwater turtles (IUCN, 1989 and Turtle Conservation Fund [TCF], 2002), and has summarized the available conservation and status information concerning the world's tortoises in a book entitled The Conservation Biology of Tortoises (Swingle & Klemens, 1989). Two similar volumes summarizing the conservation biology of riverine species and other freshwater turtles are in preparation.

Most recently, a partnership between the IUCN/SSC Tortoise and Freshwater turtle specialist Group, the IUCN/SSC Turtle Survival Alliance (a newly established [2001] alliance between organizations and individuals that share an interest in building a structured network of captive management and breeding programs into turtle and tortoise conservation efforts), and Conservation International's Center for Applied Biodiversity Science has been forged to provide a coordinated effort focusing on the conservation of the world's endangered chelonians (TCF, 2002). Briefly, the Turtle Conservation Fund, as the partnership is called, has produced an action plan (TCF, 2002) (see also the section concerning education in this chapter), which proposes funding support and conservation action in prioritized phases (see also Georges, 1993 for guidelines for setting conservation priorities for freshwater turtles). Phase 1 targets the requirements of the most critically endangered species, and then gradually expands in Phases 2 and 3 to address problems faced by less endangered forms and to ensure the survival in the wild of all extant chelonians. The phases incorporate coordinated Action Components which include in-range and out of range "assurance colonies" to provide breeding stock for those species where such is deemed warranted, field surveys and ecological research concerning targeted species, and the development of range country capabilities for enhancing the survivability likelihood of wild populations of targeted species within their borders. While we continue to urge restraint in over-exploitation on captive breeding methodologies where in-situ approaches still offer hope for recovery of species, this coordinated effort by dedicated chelonian biologists and conservationists seems to us to be the best chance yet for reversing the tide of chelonian destruction over the past two decades, and of maintaining current levels of chelonian diversity for the foreseeable future.

Another noteworthy international convention in regard to turtles, The Convention on Wetlands of International Importance (or Ramsar Convention), is exclusively concerned with protection of habitat. The convention obligates member nations to select at least one wetland that they will manage so that human activities will not destroy the ecological characteristics.

An example on a smaller scale is the 1997 ruling by the EC Council of Ministers (the European Parliament) prohibiting the importation of red-eared sliders throughout Europe because of the serious threats which they pose to endemic wildlife such as European pond turtles (Salzberg, 1998a).

National Legislation

A growing number of countries are establishing laws to protect declining species within their own borders. The U.S. Endangered Species Act of 1973 (ESA) is a
good example of such legislation. The Act lists both species from the United States and abroad and prohibits the import or trade in any endangered species or its product. Listed species cannot be hunted, killed, injured or collected in the United States. The ESA prohibits federal agencies from authorizing projects that would jeopardize endangered species or their habitat. It provides for setting aside critical habitats (areas essential to the organisms survival) and authorizes the Fish and Wildlife Service to prepare recovery plans for each.

The Indian Wildlife Protection Act (1972) is another example of national legislation that protects some river turtles. The Act contains a number of schedules offering various levels of protection. River turtles are listed in Schedule I (rare and endangered species) and Schedule IV (small game species). The former are completely protected, while species in the latter category can only be captured or killed with a permit. Schedule I species include river terrapin, red-crowned roofed river turtle, Indian roofed turtle, Indian softshell, peacock softshell, Indian flap-shells, and Asian giant softshell. Two additional softshells, Leith's softshell and Indian narrow-headed softshell, currently reside on Schedule IV (Choudhury & Bhupathy, 1993).

Most Southeast Asian countries have similar acts, but the number of river turtles included varies considerably (Jenkins, 1995; van Dijk et al., 2000a). For example, the Asian giant softshell is the only river turtle protected on China's 1989 amended "List of Important Protected Wild Animals" (Zhao & Adler, 1993) and by Vietnam's Rare and Precious Forest Flora and Fauna Decree (Le Duc & Broad, 1995). Laos protects the Asiatic softshell, black swamp turtle and Malayan box turtle. Indonesia's Conservation of Living Resources and Ecosystems Act of 1990 protects river terrapin, Malaysian giant turtle, narrow-headed softshells and Indian and New Guinea giant softshells.

Thailand's 1992 Wildlife Reservation and Protection Act offers one of the most comprehensive types of legislation for the protection of turtles in the region. This Act makes it illegal to capture, possess, or trade any chelonian except the Asiatic softshell. With any of the laws and conventions, the provisions are only as good as the enforcement. According to Thirakhupt and van Dijk (1995 "1994"), this Act is not being fully enforced in the countryside and in fact no one they interviewed even seemed aware of any turtles' protected status. Similar problems plague the efficiency of laws on the books in many other Asian countries and in other geographic locations also (e.g., see van Dijk et al., 2000a for specific regulations and recommended legislation and enforcement in these and other Asian nations they considered).

Mexico's official list has the impressive title of "NORMA Oficial Mexicana NOM-56-ECOL-1994. Que determina las especies y subespecies de flora y fauna silvestres terrestres y acuáticas en peligro de extinción, amenazadas, raras y las sujetas a protección especial, y que establece especificaciones para su protección especial, y que establece especificaciones para su protección especial, y que establece especificaciones para su protección especial, y que establece especificaciones para su protección especial." Listed species are designated P for endangered, A for threatened, R for rare, and Pr for special protection. In regard to river turtles, the Central American river turtle is listed as P and Pseudemys gorzugi as R. A number of other species, that may utilize riverine habitats are listed Pr, E. scripta, Stauracopus salvini, and

State Legislation

In Malaysia, turtle exploitation is regulated by the respective Sultan of each state, and hence the river turtles. Seven states in peninsular Malaysia protect river turtles and regulate the taking of terrapin, painted terrapin, and Malayan giant turtles and regulate the taking of terrapins. Limits are set on the numbers of riverine marine turtles are not protected. Malayan giant turtles are totally protected under Ordinance of 1963 (Jenkins, 1995).

The United States offers both federal and state protection for river turtles. Many states have their own laws and regulations concerning species. The river terrapins, Pseudemys alabamensis, and Sternotherus coeruleogriseus receive both federal and state protection. In the United States, the most protection of river turtle population is found in states that list thirty-four states with legislation concerning their exploitation.

Game Laws

Other than the endangered/threatened species of river turtles comes in the form of trammel net licenses, and set possession and harvesting.

Closed seasons usually are related to reproductive cycles of species, especially vulnerable such as the Missouri softshell. The state of Missouri, for example, has a set possession for Missouri softshell turtles from September 1 to November 30, and nesting females from June 15 to August 15. Closed seasons in Florida and Georgia are from March 1 to April 30. The United States Military District of Washington, D.C., prohibits fishing or taking of any turtle species between April 1 and October 31, or from December 1 to March 31. The Mexican government has a set possession for P. vogli in the Yucatan, and P. blandingii in the rest of the country, the latter listed as Endangered. The Canadian government, for example, listed P. blandingii in the Northwest Territories, P. Blairi in Labrador, and P. floridana in Nova Scotia as Endangered.

E. Moll (1990a) suggested a possible way to address the problem of turtles that would offer protection from sport hunting and undue hardship on market value. This plan includes distinctly different nesting periods, and most hard-shells from December to May in one group during their nesting period, and others from the other group throughout the year.

Licenses help to regulate exploitation of turtles, and some of the money generated is invested in conservation projects.
both species from the United States in any endangered species or its
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especies para su protección
protección.” Listed species are
L for local, R for rare, and Pr for special
A riverine turtle is listed of other species, that may utilize
riverine habitats are listed Pr, including Apalone ater and spinifera, Trachemys
scripta, Snaurotypus salvini, and triporcatus and nine species of Kinosternon.

State Legislation
In Malaysia, turtle exploitation has traditionally been the prerogative of the ruling
Sultan of each state, and hence the federal Wildlife Protection Act does not include
turtles. Seven states in peninsular Malaysia now have laws that protect some river
turtles and regulate the taking of the eggs. Usually these laws are aimed at river
terrapin, painted terrapin, and Malaysian giant turtles. They typically protect adult
turtles and regulate the taking of turtle eggs (e.g., licensing). However, typically no
limits are set on the numbers of eggs that can be taken. In East Malaysia, non-
marine turtles are not protected in Sabah, but painted terrapins and Malaysian
giant turtles are totally protected in Sarawak under the Fauna Conservation
Ordinance of 1963 (Jenkins, 1995).

The United States offers both federal and state level protection to certain river
turtles. Many states have their own list of endangered, threatened, and special
concern species. The river turtles, Graptemys flavigastra, G. oculifera,
Pseudemys alabamensis, and Sternotherus depressus are examples of species with
both federal and state protection as endangered or threatened species. However,
most protection of river turtle populations comes at the state level. Levell (1995)
lists thirty-four states with legislation protecting river turtles or at least regulating
their exploitation.

Game Laws
Other than the endangered/threatened lists, most national and state protection of
river turtles comes in the form of game laws that dictate closed seasons, require
licenses, and set possession and size limits.

Closed seasons usually aim at protecting species during periods when they are
especially vulnerable such as the time of reproduction. In the United States, eight
states have closed seasons for certain river turtles (Levell, 1995). For example, the
open season for Missouri softshells is July 1 to December 31. As softshells nest
from April to July in Missouri, this law exemplifies the use of a closed season to
protect nesting females. In Venezuela, Podocnemis unifilis and P. vogli can be hunted
from February 1 to March 31 (Pritchard & Trebbau, 1984). P. vogli nests from
November to January, and P. unifilis from January to March. In this case, only
females of P. vogli will be protected during their nesting season.

E. Moll (1990a) suggested a bimodal system of closed seasons for turtles in
India that would offer protection to commercially exploited species without putting
undue hardship on market vendors. Softshells and hard-shells in India tend to
have distinctly different nesting peaks. Most softshells nest from June to December
and most hard-shells from December to May. Setting a closed season for each
group during their nesting period would still allow market vendors to sell one or
both the other group throughout the year.

Licenses help to regulate exploitation, but benefit conservation only when some
of the money generated is invested in conservation action or when the license
includes limitations on take and/or areas to be hunted. In the United States, twenty-four states require some type of license (usually a fishing license) to collect turtles. In most Malaysian states, the collecting of turtle eggs requires a license, as discussed previously. In the State of Pera, the license stipulates that a third of the eggs collected must be given to the Department of Wildlife for their hatchery program. Unfortunately, this requirement has not been rigidly enforced and eggs obtained for conservation purposes must be purchased at market price. The common licensing system in Malaysia actually encourages over-exploitation rather than conservation of turtles. On the East Coast of Malaysia, sea turtle/painted terrapin nesting beaches are licensed out to the highest bidder. As considerable money is expended for the license (ca. U.S. $1000–2000), the egg collector, in order to make a good profit, attempts to excavate as many nests as possible (fig. 7.3), and consequently nearly all of the nests are found and excavated. Recruitment from such beaches is virtually nil. This heavy exploitation to some extent will be self-regulating, in that eventually nesting populations will decline to the point that it will no longer be profitable to expend time and effort collecting the eggs. However, once painted terrapins nest on the same beaches as the far more abundant marine turtles, it will be the crash of the latter populations—not painted terrapins—that will determine when a beach is abandoned. Painted terrapin populations will be extirpated long before the sea turtle egg supply gives out.

Reasonable possession limits, however, are lost from the environment during the hunting season for Podocnemis unifilis and a possession limit of two. Podocnemis expansa in the game laws of thirteen states in the East, the daily bag limit is a hundred turtle eggs or up to 12 dozen (as in South Dakota).

Size limits for river turtles can be difficult to design. The philosophy of such laws is to prevent poaching and to protect the species, and the laws are generally effective in maintaining populations above threshold levels (Fund 1997; Congdon et al., 1993; 1997). From the conservation point of view, such laws are important in maintaining populations at a high level, particularly since they protect all life history stages (see section 2).

Ex-Situ (Off Site)

Ex-situ techniques involve removing species from the wild in order to propagate them. These techniques are generally preferable, they may be used where adequate protected areas are not feasible, and they can be used on their own, or if individuals are lost, to complement other efforts. They allow for the maintenance of genetic variability, and when populations are small, can be more cost-effective than ex-situ. They can also be used for long-term conservation, such as in the case of the Mississippi's Pascagoula River, which is a critical nesting site for the vulnerable (i.e., in-situ) and manipulative (i.e., ex-situ) populations. The advantage of ex-situ techniques is that they can be used to maintain viable populations in the wild. They can also be used to reintroduce species to their natural habitats, and they can be used to protect species from extinction.

Figure 7.3

Harvesting painted terrapin (Caliagur borneensis) eggs on a Malaysian sea beach nesting site.
be hunted. In the United States, (usually a fishing license) to collect of turtle eggs requires a license, as license stipulates that a third of the of Wildlife for their hatchery not been rigidly enforced and eggs purchased at market price. The encourages over-exploitation rather than Malaysia, sea turtle/painted terrapin bidder. As considerable money is the egg collector, in order to make as possible (fig. 7.3), and con-excavated. Recruitment from such to some extent will be self-regulating decline to the point that it will no collecting the eggs. However, since is the far more abundant marine —not painted terrapins—that hinged terrapin populations will be gives out.

Reasonable possession limits for river turtles can at least slow the rate at which they are lost from the environment. The aforementioned example of the Venezuelan hunting season for Pseudemys unifilis and vogli includes a daily limit of one turtle and a possession limit of two. Possession limits for river turtles also are included in the game laws of thirteen states in the United States (Levell, 1995). However, when the daily bag limit is a hundred turtles (as in West Virginia) or the possession limit is 12 dozen (as in South Dakota), the conservation value of the law is negligible.

Size limits for river turtles exist in seven U.S. states (Levell, 1995). The typical philosophy of such laws is to protect juveniles and harvest adults. Such a philosophy is significantly flawed, however, as larger, older individuals are most important in maintaining populations of long-lived species such as turtles (Frazer, 1992, 1997; Congdon et al., 1993, 1994; Galbraith et al., 1997; Tucker & D. Moll, 1997). From the conservation perspective, the best laws provide total protection to all life history stages (see section on Conservation Philosophy).

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Ex-Situ (Off Site) Techniques

Ex-situ techniques involve removing one or more life history stages of the turtle from the wild in order to propagate the species. Although in-situ techniques are generally preferable, they may not always be viable options. For example, if protected areas are not feasible, if remnant populations are too small to persist on their own, or if individuals are too scattered for the sexes to find one another, then ex-situ techniques may be the best hope for survival. Ex-situ and in-situ strategies need not be considered mutually exclusive but can be complementary approaches to the problem. The major ex-situ techniques for turtles, hatcheries, headstarting, and captive breeding, should be regarded as temporary measures aimed at increasing species numbers in the wild to the point that the population becomes self-supporting without them. As such, in-situ actions such as setting up refuges, habitat restoration, reduction of pollution, etc., must be part of the total program providing suitable places for the turtles to go when they are released. Seigel and Dodd (2000) discussed the use of a “gradient approach” in the management program for endangered yellow-blotched map turtles of Mississippi’s Pascagoula River, where the costs and benefits of non-manipulative (i.e., in-situ) and manipulative (i.e., ex-situ) approaches are considered and weighed carefully in the determination of an appropriate course of conservation action. They concluded that the more non-manipulative approaches were more likely to be successful and should be tried first in this, and almost every other case. They recommend that a similar decision-making procedure should be applied in the formulation of all conservation planning for threatened species. The need for incorporating the most current knowledge of conservation strategy and cost-benefit analyses into management and recovery plans was further stressed by Klemens (2000a).

Unfortunately, ex-situ techniques are not always chosen for the right reasons. They are often selected because of their high visibility and not because they are
necessarily the most effective method for preserving the species. High visibility in this case means that hatcheries, headstart and captive breeding programs, by keeping large numbers of eggs, young or adults available at the project site, can impress the public, the media, and visiting officials that conservation is indeed going on. This, in turn, helps to assure that additional funding will be forthcoming and the program will be perpetuated. If this same money were being funneled into in-situ techniques, the results might be less visible to the public but more beneficial to the species.

**Hatcheries**

Hatcheries are one of the most widely used and least controversial of the ex-situ techniques. They have long been a mainstay of sea turtle conservation programs, and have been especially popular in river turtle conservation programs in Asia. Examples of such large-scale hatchery programs are the river terrapin and painted terrapin programs in Malaysia and Thailand. The oldest of these is the river terrapin hatchery on the Perak River that has operated continuously since 1967 (see Case Study 3).

**Case Study 3: Last Curtain Call for the Drummer.**

With the coming of December, the drumming of the tuntong will again resound along the banks of the Perak. The trumpets, brightly decorated boats and bejeweled ladies with their fancy silks will be gone. The drumming will be softer now, for the turtles number in the hundreds rather than in the thousands. Still the drumming persists—and with it, the hope that the herds will someday regain their former magnificence so that future generations will have the opportunity to marvel at the tuntong's annual nesting spectacular. (E. Moll [1978a] “Drumming along the Perak.”)

As described previously in chapter 5, the drummer, a.k.a. river terrapin, tuntong, and *Batagur baska*, has had better times. Once river terrapins ranged from East India to Cambodia, but now Malaysia, Cambodia, and Sumatra appear to be the last theaters that annually replay the river terrapin nesting spectacular, albeit on a much more modest scale than formerly. In India, Bhupathy (1997) could find only three sets of tracks and no natural nests in an extensive 1994 survey of river terrapin nesting sites of the Indian Sunderbans, the last remaining stronghold for the species in India. Similarly, a survey of reported nesting sites in the Bangladesh Sunderbans (December 1989 to April 1990) by S. M. A. Rashid (in E. Moll, 1990b) found no wild river terrapin. Direct evidence of river terrapins was obtained only from four markets along the periphery of the Sunderbans where four live males and three shells were located (Moll, 1990b). This despite Whitaker's (1983) report of a turtle collector in the region that was taking 200 river terrapin annually on hooks baited with mangrove fruit during the early 1980s.

The huge nesting aggregations described by Maxwell (1911) in Burma have also disappeared. Recent surveys of former nesting areas in the Ayeyarwady basin and delta region of Myanmar in the Wildlife Conservation and Recovery Program and in 1995 by Whitaker for the Wild Life Conservation Society, however, do not exist. Heavy egg exploitation and the use of hooks with adults with hooks baited with mangrove have been key factors in the decline of the terrapin are also thought to be the cause (Moll, 1990b). The decline continues.

This leaves Malaysia, Cambodia, and Thailand's viable river terrapin populations, partly due to the predation of people on the eating of amphibious animals for food and the protection of property. The extinction of their terrapin populations is a factor that has been Malaysia's primary reason for the river terrapin. Hatchery programs started on the Perak River as early as 1967 for populations on the Kedah, Teluk Rubiah, Kajang, and Malaysia's Conservation Project, Khan bin Momin Khan. As chief of the hatchery on the Perak River in the Department of Fisheries, Malaysia, this position made him responsible for all the hatcheries that occupy the Malayan Peninsula. The hatchery was a new position and the hatchery was just a fenced portion of the beach. It was first moved to a site away from the distance from the nesting beaches and the transport difficult. In the early 1980s the hatchery was known as Project Tuntung and then Tuntung 2 (fig. 7.4). The facilities comprised of a simple shed by a roof where adult river terrapin were held for captive breeding and an adjoining nursery. Two parts. One part serves as a receiving area where terrapin eggs, are hatched in a pit on the beach, or by purchases from local collectors. Next to the comb and nesting beach, a roofed nursery enclosure is operated. It is under the supervision of young groups of river terrapin juveniles.

Egg collectors in the region are required to provide a certain number of eggs, and the same number of eggs, as in the program, licensees were required to provide a certain number of juveniles from the eggs collected, one third was to be given to the hatchery of Perak. However, the hatchery
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and delta region of Myanmar in 1993 by van Dijk (1994) sponsored by the Turtle Recovery Program and in 1999 by Thorbjarnarson (personal communication) for the Wild Life Conservation Society found no evidence that the population still exists. Heavy egg exploitation along with siltation of nesting beaches, fishing for adults with hooks baited with mangrove fruit and extensive drift netting appear to have been key factors in the demise of the Ayeyarwady population. Wild river terrapin are also thought to be extinct in Thailand (Thirakhup & van Dijk, 1995 "1994").

This leaves Malaysia, Cambodia, and perhaps, Sumatra as the last harbors for viable river terrapin populations (E. Moll, 1990b). This circumstance is at least partly due to the predominant Islamic religion of these countries that discourages the eating of amphibious animals such as turtles. While this ban does not apply to the turtle eggs, the protection of adults appears to have been sufficient to stave off extinction of their terrapin populations, at least for the time being. Another positive factor has been Malaysia’s pioneering efforts in establishing conservation programs for the river terrapin. Hatchery and head start programs for the turtle were initiated on the Perak River as early as 1967 and have since been expanded to include populations on the Kedah, Terengganu, and Dungun Rivers.

Malaysia’s Conservation Program for the tuntong was begun by Mohamed Khan bin Momin Khan. As chief of the Perak Game Department, he began a small hatchery on the Perak River in 1967. Mohamed Khan went on to become Director General of the Department of Wildlife and National Parks in Malaysia. Although this position made him responsible for the impressive array of large game animals that occupy the Malay Peninsula (e.g., tigers, Sumatran rhino and elephants, etc.), the chief (as he is known) never lost his interest in terrapins. The first Perak hatchery was just a fenced portion of the nesting beach which proved vulnerable to flooding. It was first moved to Game Department headquarters at Batu Gajah, but the distance from the nesting beaches (>15 miles over bumpy roads) made egg transport difficult. In the early 1980s, the Perak conservation program became known as Project Tuntung and was relocated near the river at Bota Kanan, Perak (fig. 7.4). The facilities comprised a concrete enclosure with a shallow pool shaded by a roof where adult river terrapin (62 females, 6 males in 1990) are kept for captive breeding and an adjoining large open area of sand divided by a fence into two parts. One part serves as a nesting beach for the captives. The other is used as a hatchery where terrapin eggs, obtained from captures, from a government nesting beach, or by purchases from local egg collectors, are incubated under semi-natural conditions. Next to the combination captive breeding enclosure and hatchery is a roofed nursery enclosure that includes four shallow concrete pools where different age groups of river terrapin juveniles are raised prior to release.

Egg collectors in the region must buy a license that assigns them a beach where they have exclusive collecting rights. In exchange for the license, collectors are required to provide a certain percentage of their eggs to the hatchery. Early on in the program, licensees were allowed to keep only a third of the eggs they collected, one third was to be given to the hatchery, and another third to the Sultan of Perak. However, the hatchery (and presumably the Sultan as well) found they
were consistently shortchanged by this system. Even with the eggs obtained from the government beach and from captive stock, the numbers were inadequate to meet hatchery needs. Eventually, the hatchery resorted to paying market prices to the egg collectors in order to obtain adequate numbers of eggs.

When the eggs hatch, the young are moved to a concrete pool in the nursery facility. Here the young may be raised for anywhere from 1 to 3 years or more prior to release. Releases are usually made at the government beach and the young are allowed to run down the beach into the water.

Attempts to evaluate the success of the program have been hampered by various problems. The young are not marked in any way prior to release, so there is no way of telling when and if they return to the nesting beaches. In addition, egg collectors not wanting the government and competitors to know how many eggs they are taking annually, often do not provide accurate information to interviewers. Nevertheless, attempts have periodically been made to census tuntung nesting.

As suggested by the data presented in chapter 5 concerning the history of exploitation of river terrapins, the number of Perak River nesting females and nests showed no signs of increasing and a nesting census of Bota Kanan nesting beaches on the Perak River in 1986/1987 recorded only 190 nests and 4137 eggs (E. Moll, 1987b, 1989, 1990b). However, E. Moll had to rely on reports from the egg collectors who would not allow him to observe on the nesting beaches for fear of disturbing the females, and he thought the actual number of nests might be underestimated. Mohamed Khan collectors must pay the State a royalty. If they collect, they are likely to underestimate the effort by the Department of Wildlife Rangers at all of the nesting beaches. An accurate estimate of nesting.

In these two censuses (believed to be 20,768 eggs were reported in 1989/90, Depending on whether the tuntung are (this has not been established as second clutch), the number of nesting to 923 females. If we compare that range of 2000 to 1204 (based upon Game numbers of females would range between progress has been made in increasing anything, the numbers have declined.

What is the reason for the lack of the positive side, there is some information very slowly to maturity. Therefore the longest running for any freshwater fish, enough to have hatchery-produced fish.

On the other hand, there are fewer, certain questionable practices connected to be responsible for the lack of success of important negative forces. River terrapins of estuaries. On the lower Perak, estuarine mangroves on which the turtles feed and to control erosion. They have also built the small tributary streams where adults (1984a) and where juveniles seek shelter. Dams built upriver from the nesting area replenishes nesting banks as they erode, sand mining in the nesting area which hastens erosion. Although excessive sand mining in the Perak has already happened on the Terengganu Kenyir Dam on Malaysia’s east coast.

Regarding hatchery practices, hatching, aspect of the program (fig. 7.5a, b). Young proved in both sea turtle and river terrapin (Headstarting in this chapter). By hatchery conditions, it is conceivable that the return to the ancestral nesting sites could has seldom marked juveniles prior to survivorship and recruitment of the favored.
be underestimated. Mohamed Khan (in Moll, 1989) suggested that as egg collectors must pay the State a royalty based on the numbers of eggs that they collect, they are likely to underestimate egg numbers. To rectify the problem, he pledged an effort by the Department of Wildlife and National Parks to station rangers at all of the nesting beaches in 1989/90 and 1990/91 to obtain an accurate estimate of nesting.

In these two censuses (believed to be the most accurate to date), 923 nests and 20,768 eggs were reported in 1989/90 and 849 nests and 20,608 eggs in 1990/91. Depending on whether the turtong average one, two, or three clutches per year (this has not been established as discussed previously, but at least some lay a second clutch), the number of nesting females in 1989/90 would range from 308 to 923 females. If we compare that range with the early 1970s, when the maximum nests were 1204 (based upon Game Department records), and an estimate of numbers of females would range between 401 and 1204, it is evident that little progress has been made in increasing river terrapin numbers on the Perak River. If anything, the numbers have declined.

What is the reason for the lack of success? There are several possibilities: On the positive side, there is some information suggesting that wild river terrapin grow very slowly to maturity. Therefore the conservation program, despite being one of the longest running for any freshwater turtle, may not have been in operation long enough to have hatchery-produced females returning to nest in any number.

On the other hand, there are forces operating against population survival and certain questionable practices connected with the conservation program that could be responsible for the lack of success. Habitat alteration is one of the most important negative forces. River terrapin are heavily dependent on the productivity of estuaries. On the lower Perak, estates (plantations) have cleared riverside mangroves on which the turtles feed replacing them with brick brack (large rocks) to control erosion. They have also built tidal barrages that block entry into many of the small tributary streams where adult river terrapin feed during high tide (Moll, 1984a) and where juveniles seek shelter from the hazards of the river’s main stem. Dams built upstream from the nesting areas have shut off the supply of sand that replenishes nesting banks as they erode. The problem is exacerbated by continued sand mining in the nesting area which removes sand from the river proper and hastens erosion. Although excessive sand loss is not an immediate problem, the Perak may someday experience the loss of high-quality turtong nesting sites that has already happened on the Terengganu River following construction of the Kenyir Dam on Malaysia’s east coast.

Regarding hatchery practices, headstarting of young prior to release is a major aspect of the program (fig. 7.5a,b). Yet the success of this practice remains to be proven in both sea turtle and river turtle conservation programs (see section on Headstarting in this chapter). By hatching and rearing the young under unnatural conditions, it is conceivable that the instinctive processes necessary for survival or return to the ancestral nesting sites could be affected. As the conservation program has seldom marked juveniles prior to release, there is no sure way of determining survivorship and recruitment of the headstarted turtles into the wild population.
Similarly, captive breeding of the atelocetus had produced a captive population of 62 females in 1990/91. These eggs were not produced naturally, but hatching success according to the captives. Mollusk collectors from the wild population took samples of males (six), and the diet (chiefly, chlorella, individuals is mollusks), and tissue samples were kept. E. Moll (1987b) recommended maintaining a high calcium in the diet, and the built a circular enclosure with a corrugated roof with the captive population. Sharma (1989) found that the captive’s diet has helped to maintain the species. An initial problem was that the enclosure became too hot. The solution was to build a roof for the facility. As of 1990, there were 21,530 painted terrapins in the Perak Hatchery and 21,379 in the Endau (1999) noted that the juveniles are being fed a diet of bread and fruits from unknown bacterial and fungal species. There was concern that the release of infected juveniles could threaten the wild painted terrapin population.

Two additional programs have been funded to increase the painted terrapin population in Terengganu. These programs are aimed at

Figure 7.5
(a) A box full of headstarted yearling river terrapin (Batagur harda) from the Bota Kanun facility; (b) their release into the Perak River, Malaysia.

Figure 7.6
Hatchery facilities for painted terrapin.
Similarly, captive breeding has had little success in the Perak program. The captive population of 62 females produced only 113 eggs in 1989/90 and 370 eggs in 1990/91. These eggs were unnaturally brittle-shelled and have had a low hatching success according to hatchery personnel (25% versus 45% from eggs collected from the wild population). Part of the problem may be the small number of males (six), the diet (chiefly plants whereas nearly a third of the diet of wild individuals is mollusks), and the shallow tank (0.67 meter depth) where they are kept. E. Moll (1987b) recommended increasing the number of males, the protein/calcium in the diet, and the building of a larger/deeper aquatic enclosure to house the captive population. Sharma (1999) reported that an increased ration of fish in the captive’s diet has helped to rectify some of these reproductive problems. A large circular enclosure was built in 1988 with a nesting area in the middle. However, an initial problem was that the enclosure was not sheltered from the sun and the water became too hot. The solution to this problem has been to provide a netting roof for the facility. As of 1990, approximately 50,000 eggs had been incubated at the Perak Hatchery and 21,530 juveniles had been released into the river. Sharma (1999) noted that the juveniles in captivity in 1994 were dying in large numbers from unknown bacterial and fungal infections, and we are obviously concerned that the release of infected juveniles could spread the disease(s) to the wild population.

Two additional programs have been established in the states of Kedah and Terengganu. These programs are smaller, comprising only a hatchery (fig. 7.6) and

Figure 7.6
Hatchery facilities for painted terrapins (Callagur borneensis) near Terengganu, Malaysia.
headstarting facility. In the Kedah program all eggs are obtained from egg collectors, and juveniles may be raised for nine years or more prior to release. From its inception in 1978 to 1989, the Kedah hatchery purchased 6505 eggs and hatched 3881 (60% hatching success rate). However, the eggs are incubated in styrofoam boxes kept in a building which could skew sex ratios in TSD species, and if the river terrapin is found to have temperature-dependent sex determination this could prove to be a problem. No information on sex ratios of hatchlings is available. Over this 11-year period 1629 turtles have been released into the wild.

The Terengganu Program, initiated in 1976, differs in that most of its eggs have been obtained from a government nesting beach rather than from egg collectors. Until recently this was an island in the Terengganu River, but following the construction of the Kenyir Dam the island has eroded away to the point that most turtles have abandoned it for nesting. The Terengganu hatchery at Kuala Brang has shifted its egg collection to a new government beach on the Dungan River. Like the Kedah hatchery, eggs are incubated in styrofoam boxes (fig. 7.7). Between 1976 and 1989, 7403 eggs were collected, 6038 were hatched (81.6% hatching success rate), and 5217 turtles were released into the wild (see also Sharma, 1999). In 1991 with the shift to the Dungan River, 1120 eggs were obtained (267 from the government beach and 853 from egg collectors). Only 391 eggs were obtained from the old government beach on the Terengganu River.

Outside of Malaysia, only four conservation efforts for river terrapins exist: for populations of both river terrapins at the Preservation Station on Klong Sa, and at the Elephant Conservation Breeding Centre in Ayutthaya, Thailand. In 1990, the river terrapin was hatched from 13 eggs laid and 133 hatched (62% hatching success rate). The breeding program has been maintained as of 1994 (Thiravittaya et al., 1994) and reintroductions have occurred.

In 1988, following the establishment of the Satun Tiger Reserve, the West Bengal River terrapin breeding program for river terrapins was initiated at two hatcheries in Pakhiralaya and Jirania. From 1988–1991, twenty-one nests were collected and transported to Sazakhali in Satun Province. The hatching success rate was 48.9% and juveniles in several size classes were obtained (Bhupathy et al., 1994; Bhupathy, 1995). In 1991, thirty eggs were collected and transported to Sunderban Tiger Reserve (Bhupathy, 1995). By 1995, eleven individuals at the captive breeding center in Alipur Zoo in Calcutta. The facility is managed by the Zoological Survey of India (BSI). Bhupathy (1997) also reported that about 39% of the captive breeding center. Currently, the captive breeding center. Currently, the captive breeding center.

Hatcheries can be as simple as a beach, or as complex as research facilities. The technique reduces the percentage of nests destroyed before they are collected from egg collection by human intervention by more than half. The Indian Kachuga (Rao, 1986, 1987) and the Painted terrapin (Batzias, 1983; 1985; Batzias & Bock, 1985) hatchery can be found in Primates Research and Conservation Technology (PRCT).

Hatcheries should not be a source of danger that establishing a hatchery when it is not likely to palliate the condition without them. Until there is little accurate information about the turtle's decline in order to maintain constant power.ела: eggs laid is sometimes used, but
Inside of Malaysia, only Thailand and India have initiated token conservation efforts for river terrapin. Thailand maintains captive breeding populations for both river terrapin and painted terrapin at the Freshwater Wildlife Preservation Station on Klong Langu River in Satun Province of peninsular Thailand. In 1990, the river terrapin population comprised 52 adults (29 females, 23 males). Breeding records from the 1987/88 and 1988/89 seasons indicated 210 eggs laid and 133 hatched (63% hatching success) and 394 eggs laid and 143 hatched (36% hatching success), respectively. The population was still being maintained as of 1994 (Thirakhupt & van Dijk, 1995 "1994"), but apparently no reintroductions had occurred.

In 1988, following the discovery of a nesting beach at Mechna in a Sunderban Tiger Reserve, the West Bengal Forest Department of India established a captive breeding program for river terrapins at Saznakhali and River terrapin Rearing Centres in Pakhiralaya and Jindhahali (Ghosh & Mandal, 1990). Over the period 1988–1991, twenty-one nests were found in the wild and 645 eggs were collected and transported to Saznakhali for artificial incubation and captive rearing. The hatching success rate was 48%. In 1992, the project was head-starting 175 juveniles in several size classes and maintained twenty-five adults as breeders (Bhupathy et al., 1994; Bhupathy, 1995). By 1994, the Forest Department reported that forty captive raised terrapins had been released in the Harinbanga River, in the Sunderban Tiger Reserve (Bhupathy, 1997). As of 1994, Bhupathy could find only eleven individuals at the captive rearing facilities, and ten were being kept at the Alipur Zoo in Calcutta. The fate of the other head-started turtles is unknown. Bhupathy (1997) also reported that twenty-five river terrapin remained at the captive breeding center. Currently interest and funding in the project appears to have dwindled however.

Hatcheries can be as simple as moving the eggs to a nearby protected area of beach, or as complex as rearing eggs in elaborate, environmentally controlled facilities. The technique reduces egg mortality at nesting sites where a high percentage of nests are destroyed each reproductive season. This mortality may result from egg collection by humans, as in the case of Burmese or Malaysian River terrapin (Maxwell, 1911; E. Moll, 1976a,b,c, 1978a, 1984a), by predators as in Indian Kachuga (Rao, 1986, 1991), or by flooding as in Colombian river turtles (Páez, 1995; Páez & Bock, 1997). Simple instructions for setting up a beach hatchery can be found in Pritchard et al. (1983) the Manual of Sea Turtle and Research and Conservation Techniques.

Hatcheries should not be considered a cure-all, however. There is always the danger that establishing a hatchery will be perceived as solving the problem of a turtle's decline when in fact it more often than not is a band-aid type approach that palliates the condition without addressing the underlying causes of the decline (i.e., exploitation of adults, pollution, habitat destruction, etc.). For most species there is little accurate information available concerning how many eggs must hatch in order to maintain constant population levels. A convenient figure of 10% of the eggs laid is sometimes used, but this has little scientific basis. Nevertheless, if 10%
translates into hundreds or thousands of young turtles being released into the environment, the sheer numbers might convince conservationists that ample conservation effort is being made. However, presuming that simply releasing large numbers of hatchlings into the wild will solve all conservation problems can be a dangerous supposition. The demise of the leatherback sea turtle (Dermochelys coriacea) in Malaysia is a sad reminder of how a hatchery program can lull conservationists into a false sense of security (see Case Study 4).

Case Study 4: Malaysian Dermochelys coriacea – A Conservation Effort That Failed. In the 1950s, the leatherback sea turtle rookery at Rantau Abang on the east coast of Terengganu, Malaysia boasted over 10,000 nests annually and ranked as one of the five largest in the world (Hendrickson & Alfred, 1961; Mortimer, 1989). This claim to fame was short-lived, however. By the mid-1990s the number of nests had plummeted to fewer than 100 per year or approximately 1% of the population levels in the 1950s (Chan & Liew, 1996). This catastrophic decline occurred despite a Fisheries Department hatchery for the species which had been in place since 1961. The fall of the Malaysian leatherback population from world class to endangered is examined herein.

Realization that the population was seriously declining developed slowly. Following an estimate of 10,000+ nests for 1956 by Hendrickson and Alfred (1961), few records were kept of nesting until the Fisheries Department began a ten-year tagging program in 1967. An analysis of these data was not published until the late 1980s when Chua (1988) calculated an average 3765 visits (nests) per annum between 1967 and 1976. Prior to this, a significant decline had been suggested by the findings of Siow and E. Moll (1982), who estimated 3500 nests in 1978 based on records of licensed egg collectors. Subsequent nesting surveys (1979 to 1984) were commissioned by Esso Oil Company to determine the environmental impact of off-shore oil development in the South China Sea. Since 1984 the Fisheries Department of Terengganu has collected nesting statistics for the leatherback. Chan and Liew (1996) assembled the data from all of the above sources and calculated that the decline, from 1956 to 1995 averaged 260 nests per year over the 39-year period. In graphing the decline, they observed two periods of particularly steep decline between 1972 and 1974 and again between 1978 and 1980. The first period coincided with the advent of trawlers in Malaysian waters and the rapid rise of the fishing industry in the region. The second period coincided with the development of the Japanese squid drift net fishery in the North Pacific.

Certain causes for the leatherback's decline are apparent. The close coincidence between major periods of decline and the use of new and more efficient fishing techniques strongly suggests incidental capture and drowning by fishing gear as a major contributor to adult mortality. At the other end of the life history scale, over-harvesting of eggs has likely been the most significant mortality factor. Excavating of turtle nests has been a time-honored tradition among the coastal Malays. The great popularity of turtle eggs extends beyond mere taste and nutritional value, as they are reputed to have aphrodisiacal properties. Demand for the eggs typically approached 100% on the island. Indeed, the State Government moved to close the Enactment of 1951,” which authorized collecting tracts that could be a concern. Although the law protected adults from eggs that could be collected and those suffering high mortality at sea as the issue became inevitable.

Concern for the future of the leatherback turtle resulted in the first turtle conservation effort in Malaysia. The Turtle Society in 1960, a hatchery was established and remained the only conservation effort for a number of years. It is now obvious that the task was not as simple as initially thought. However, this knowledge was at least better than nothing. The hatchery was beginning, resources were stretched to the limit, and protection of the relatively small population was deemed adequate to maintain the population (Chan & Liew, 1996). By this time, however, it was clear that the protection of the relatively small population was inadequate to halt the decline. A high degree of adult mortality due to a sex ratio imbalance (overproduction by the hatchery techniques further exacerbates the situation) and high juvenile mortality from incidental capture by trawlers and replaced by such limited recruitment.

The rate of survival from egg to adult varies by region, but scholars occasionally make educated guesses. For example, Frazier from the United States has suggested that one adult female may replace five eggs laid. Mortimer reported that in 1956 Rantau Abang incubated an average of 33 eggs, a hatch rate typical at Rantau Abang, or as few as two, new females may arise within a 25-year stretch if either Frazier’s estimate of survival or recruitment would help explain the population decline.

In So Excellent A Fishe: A Nat Frazer's book, Naissse asserted that sea turtles could not
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... properties. Demand for the eggs has long exceeded supply, and egg harvests have typically approached 100% on Terengganu beaches. In 1951, the Terengganu State Government moved to control egg collecting by passing the “Turtles Enactment of 1951,” which authorized the division of nesting beaches into egg-collecting tracts that could be auctioned off annually to the highest bidder. Although the law protected adult turtles, no limits were placed on the number of eggs that could be collected and near-total egg harvests continued. With adults suffering high mortality at sea and negligible recruitment, a population crash became inevitable.

Concern for the future of the leatherback prompted Malaysia to begin its first turtle conservation effort in West Malaysia. Proposed by the Malayan Nature Society in 1960, a hatchery was set up at Rantau Abang, Terengganu in 1961 and remained the only conservation measure for the turtle over the next 25 years. It is now obvious that the measures taken were inadequate to meet the task at hand. However, this knowledge was late in coming. At the time the hatchery was beginning, resource managers argued that almost all of the eggs laid would be naturally taken by predators, and so protecting 2-3% of the eggs laid was deemed adequate to maintain a stable population (Hendrickson & Alfred, 1961). Recognizing that adult mortality was increasing due to intensified fishing pressure, in 1978 an effort was made to incubate at least 15% of the eggs being laid (Siow & Moll, 1982). This percentage continued to increase until 1988 when all consumption of leatherback eggs was banned in Terengganu and the hatchery began to incubate all (or nearly all) of the eggs being laid (Chan & Liew, 1996). By this time, however, the population was in free-fall, and total protection of the relatively small numbers of eggs still being laid was inadequate to halt the decline. A high degree of infertility among eggs laid at the rookery due to a sex ratio imbalance (over-production of females) that resulted from hatchery techniques further exacerbated the problem. Chan calculated that hatch rates at Rantau Abang could not exceed 56.4% (Chan & Liew, 1996). Adult mortality from incidental capture and other factors had become too great to be replaced by such limited recruitment.

The rate of survival from egg to adult is unknown, but respected turtle scholars occasionally make educated guesses on the subject. Mortimer (1989) quotes two estimates based on a 75-85% hatch rate made by sea turtle biologists Nat Fraser from the United States and Colin Limpus from Australia. Fraser suggested that one adult female might survive out of 1000 eggs, whereas a more pessimistic Limpus thought one adult female might be produced out of 10,000 eggs laid. Mortimer reported that between 1961 and 1986 the hatchery at Rantau Abang incubated an average of 33,263 eggs annually. After adjusting for the 50% hatch rate typical at Rantau Abang, she concluded that as no more than twenty, or as few as two, new females might have been produced each year over this 25-year stretch if either Frazer’s or Limpus’ estimate was accurate. Such low recruitment would help explain the crash of the rookery over this time. In So Excellent A Fishi: A Natural History of Sea Turtles, Archie Carr (1967) asserted that sea turtles could not be saved by controlling only one phase of the...
life cycle. *Dermochelys* conservation problems in Malaysia affirm this conclusion. A growing number of computer models simulating turtle population dynamics have reached similar conclusions: increasing the survival of early life history stages of long-lived vertebrates is unlikely to be effective in rebuilding declining populations unless the survivorship of older individuals is first returned to high levels (see discussion under Conservation Philosophy, this chapter). Rescuing a declining population of a long-lived species necessitates protection of all stages of the life history (Congdon et al., 1993).

The plight of the leatherback in Malaysia is bleak but not hopeless, as at least one other leatherback population recovered from even lower numbers. Nesting leatherbacks on the Tongaland Coast of Natal South Africa reached a low point of five nesting females in 1966, but with vigorous protection these numbers have increased to 124 in 1995 (Hughes, 1996).

A number of additional conservation measures are now in place to augment the hatchery effort in Malaysia. There has been a moratorium on the use of high seas drift nets since 1992. Large-mesh drift nets are also banned in Malaysian coastal waters, and a 14-km stretch of nesting beach at Rantau Abang has been gazetted as a sanctuary to prevent further development. A complete ban on egg consumption remains in effect, and hatchery procedures have been improved to increase hatching success (including incubating a certain percentage of the eggs at male-producing temperatures). Whether these measures will suffice to rebuild the rookery at Rantau Abang remains to be seen.

Unfortunately, in the case of the long-lived species such as sea and river turtles, the effects of over-harvesting eggs or of hatching too few eggs in a hatchery are not immediately obvious. Rather, the population is covertly undermined from the bottom up. Recruitment is too low, but the young have cryptic habits and are seldom seen so their decline is not obvious. Adult females, being long-lived, continue to return to the nesting beaches each year and superficially the population may appear healthy for many seasons. When large cohorts of females finally begin to die off from old age, the nesting population, lacking recruitment of young adults, then declines rapidly. By then additional conservation action may be too late. Mortimer (1995a) has clearly described how overharvesting of eggs can destroy a green turtle population.

A variety of other problems can plague effective hatchery operation, among the more significant being reductions in egg viability from transplantation and negative effects resulting from altered hydric and thermal conditions of artificial nests. For these reasons, particular care should be taken in transporting the eggs and with duplicating the natural temperature and moisture environment of the wild nests as closely as possible. van Dijk (1990) noted that special care may be required during the incubation of hard-shelled eggs in particular.

Transferring eggs typically results in some reduction in viability. Data from sea turtles indicates that moving eggs lowers hatching success from 20 to 70% (Mortimer, 1988). Obviously, a technique is only warranted if the survival of transplanted eggs exceeds that of eggs that are transported can greatly enhance their viability. Plastic cards but some fracturing of the shell may make it brittle to moderately pliable. Incubation in Styrofoam boxes, separated by centimeters of sand-filled plastic garbage cans, packed in sand-filled plastic garbage cans, success was 83%.

Unlike chicken eggs, which should be kept in the same position and not turned over after that time the embryo adheres to the upper surface of the egg, it is a good idea to move them as soon as the shell is broken and the egg with a soft pencil to move to the surface. Other potential problems can arise if the natural nests are not duplicated accurately, for example in a favorable water environment a turtle may better utilize calcium from the water, increasing the hatching success than embryos developing in terra firma (Packard et al., 1981a; Thayer, 1983; Packard et al., 1981a, b, 1983; 1984; this volume). The benefits of duplicating the nests extend beyond hatching. For example, Woodard et al. (1994) observed that common snapping turtles hatched from artificial nests were faster swimmers and had a stronger and more developed heart than those reared on drier substrates (see also Fish et al., 1996).

Another potential problem is that the sizes can be altered if character. Mortimer and Vogt (1994) determined that snapping turtles are larger from nests when hydric conditions are better (turtles have temperature-dependent development). In other words, the environment determines the sex of the hatchling. Temperate turtles if incubation temperature is near the middle of the range, sex may be male-biased; and if incubation temperatures are near the extremes, nests are dug deeper than normal, the males are less likely to be produced. The leatherback produces predominantly females, and under conditions of high levell. Incubating eggs in containers of high temperature with increased humidity results in higher ratios of hatchlings, Many sea
River turtles

Malaysia affirm this conclusion. Rebuilding turtle population dynamics for the survival of early life history stages is effective in rebuilding declining populations. It is first returned to high numbers, this chapter. Rescuing a species is a complex, expensive process that necessitates protection of all stages of the species’ life cycle. The outlook appears bleak but not hopeless, as at least one species, the South Africa, reached a low point of less than 50 individuals and protection these numbers have increased.

New technologies are now in place to augment conservation efforts. A moratorium on the use of pesticides is also in place in Malaysia. While beach at Rantau Abang has been closed as of 2011. A complete ban on egg harvesting is in place. New procedures have been improved to ensure a certain percentage of the eggs survive. These measures will suffice to rebuild the population.

All species, such as sea and river turtles, face the problem of hatching too few eggs in a breeding season. The population is covertly undermined. While the young have cryptic coloration, adult females are more obvious. Adult females, being larger, are more obvious. When large cohorts of adult females are seen, the nesting population, lacking females, is not obvious. By then additional conservation measures have been implemented. The nesting season begins with the hatching of eggs. The hatching success of eggs is low but there is an egg hatching success. Hatching success of eggs is low but there is an egg hatching success.

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River terrapin eggs range from brittle to moderately pliable. In the latter type, thumb pressure produces indentation but some cracking of the external layer of the shell usually results. Both types are easily damaged and require particular care during transportation. E. Moll (1978b) reported having packed 425 semi-pliable eggs of painted terrapins in styrofoam boxes, separated by layers of sand and transporting them over five miles of unpaved roads strapped to a bicycle. Individual clutches were then stored in sand-filled plastic garbage cans or styrofoam boxes until hatching. The hatching success was 83%.

Unlike chicken eggs, which should be turned as they incubate, turtle eggs should be left alone. In the same position throughout incubation. Early in development, the embryo adheres to the upper portion of the egg shell, and should the egg be turned over after that time then the weight of the eggs contents may rest on the embryo, leading to unnatural development or death. When transporting eggs, it is a good idea to move them as soon as possible after laying and to mark the top of the egg shell, using a soft pencil to maintain the orientation.

Other potential problems can occur if the hydric and thermal characteristics of the natural nests are not duplicated. Hydric conditions can be particularly significant for species with flexible-shelled eggs. Embryos developing from eggs with a favorable water environment are able to metabolize more of their energy reserves, better utilize calcium from the egg shell, grow larger, and have greater hatching success than embryos developing in an unfavorable environment (Morris et al., 1983; Packard et al., 1981a, 1983b; Packard & Packard, 1986; see also chapter 2, this volume). The benefits of developing in a favorable hydric environment may continue beyond hatching. For example, experiments by Miller et al. (1987) indicated that common snapping turtles hatching from eggs incubated on wetter substrates were faster swimmers and runners than those hatching from eggs incubated on drier substrates (see also Filoramo & Janzen, 2002).

Another potential problem of hatcheries is that sex ratios and hatching sizes can be altered if characteristics of natural nests are not duplicated. Souza and Vogt (1994) determined that hatchlings of the yellow-spotted Amazon River turtle were larger from nests with eggs incubated at higher temperatures, even when hydric conditions among all nests was similar. Many, but not all, river terrapins have temperature-dependent sex determination (see chapter 2, this volume). In other words, the temperature at which the eggs are incubated determines the sex of the hatchlings in many species. Typically, in most river turtles if incubation temperatures are too cool, the resulting hatchlings will usually be male-biased; and if too warm, female-biased. Thus, if artificial nests are dug deeper than normal, they could produce all males, and if too shallow all females. The leatherback hatchery in Terengganu, Malaysia may have produced predominantly female hatchlings for many years, leading to male impoverishment and a high level of infertility in nests (Chan & Liew, 1996). Incubating eggs in containers or in buildings can similarly alter the natural sex ratios of hatchlings. Many sea turtle conservation programs probably suffered
significant set backs in the 1970s and early 1980s when eggs were routinely incubated in styrofoam boxes stored in shaded buildings—a process now known to promote masculinization of hatchlings (e.g., Morreale et al., 1982; Mrosovsky, 1982, 1983; Spotila et al., 1983; Dutton et al., 1985). Although biasing sex ratios can be damaging to a population, it is also being debated as a possible tool in turtle conservation (see Case Study 5).

Case Study 5: Debate: Manipulating Sex Ratios of Turtles. Biologists have the ability to control sex ratios of hatching turtles being produced in hatcheries. Over the past two decades, the problems and potential problems of altering sex ratios through hatchery practices have received most of the attention (see Hatcheries, this chapter). More recently, the discussion has shifted to whether sex ratio manipulation can have positive applications as a tool for conservation. Before looking at opposing views on this subject, a brief review of the technology may be useful.

Two methods of environmental sex determination (ESD) are available to manipulate sex ratios of turtles. Temperature-dependent sex determination (TSD) was reported for reptiles by Charnier in 1966 based on a study of an agamid lizard, Pteau (1971) first reported the phenomenon in turtles, though not all turtles have TSD, as discussed previously in chapter 2. TSD has been demonstrated in many hard-shelled species, but is not known among soft-shelled species. In those turtles having TSD, the sex of the embryo is determined by incubation temperature during the middle third of development (critical period). The threshold temperature (the incubation temperature that will produce equal numbers of each sex) varies with species and geographic locality. Generally, however, temperatures above the threshold produce females, and those below produce males. In some turtles there are two pivotal temperatures whereby females are produced at high and low temperatures but males are produced at intermediate temperatures (see chapter 2, this volume).

Hormonally induced sex determination is an alternative method of manipulating the sex ratio of turtles, that has been reported by a number of authors including Pteau (1974), Gutzke and Bull (1986), Gutzke and Chymny (1988), Bull et al. (1988), Crews et al., (1989), and Vogt (1991, 1994). With this method, estradiol injected into the egg or applied topically during the middle third of the developmental period, produces all females.

The manipulation of sex ratios is already receiving some commercial application. For example, on Iowa turtle ranch snapping turtle eggs are being incubated at male-producing temperatures because males attain market size more rapidly than females (Horine, 1996). Can manipulation of sex ratios also benefit conservation? Mrosovsky (1981) first suggested that feminizing of sea turtle populations was worthy of study. More recently, Vogt (1994) discussed the advantages of increased artificial incubation in turtle conservation programs. Under the assumption that female turtles are more valuable than males in the population, he argued that feminizing sex ratios would augment declining populations.

Vogt's advocacy of sex ratio manipulation and Godfrey (1995) cautioned against considering hormonally induced sex determination a "superficially attractive" conservation tool. They suggested that hormonally induced sex determination should be evaluated as a potential tool to reveal a potential problem in populations. However, they thought as to how it should be used. The current model to reveal a potential problem in populations is to evaluate the sex ratio of hatchlings. If the sex ratio is skewed towards a male-biased proportion of the population, then the population may be feminized. In the hormonal method to feminize hatchlings, Mullerian ducts and in the operation to feminize hatchlings, males, they recommend actions that promote the manipulation of sex ratios of hatchlings to protect nesting sites and improve the future of populations.

Lovich (1996) argued that the potential for feminizing sex ratios which may be adaptively male-biased hatching could have negative results. Lovich (1996) suggested that feminizing sex ratios could result from fewer males: a reduction in sperm competition in promoting offspring fecundity. In addition, Lovich suggested that biological consequences (imbalance of inter-sexual resources) of feminizing sex ratios could result in a reduction in the number of males present in the population. Lovich concluded that there was currently little information available on the impact of sex ratio manipulation on the population, and that more information argued against it.

Vogt's paper has already set the stage for a debate on the use of manipulating sex ratios to increase productivity. On one hand, ex-situ techniques such as artificial incubation and technological fixes, treating symbiotic and mechanical problems. On the other hand, feminizing sex ratios by hormonally manipulating the sex ratio of hatchlings, are not without drawbacks, but they do offer solutions to problems. Vogt's paper has also established a platform for in-situ methods of conservation, and the need for additional information on the impact of sex ratio manipulation on the population.

Headstarting

Whereas hatcheries attempt to manipulate sex ratios to protect them from natural predation, hatcheries trap and manipulate the hatchlings to make them more attractive to predators. Vogt (1994) discussed the advantages of increased artificial incubation in turtle conservation programs. Under the assumption that female turtles are more valuable than males in the population, he argued that feminizing sex ratios would augment declining populations.
of Turtles. Biologists have the
being produced in hatcheries.

Vogt’s advocacy of sex ratio manipulation elicited a rapid response. Mroosovsky
and Godfrey (1995) cautioned that risks of feminizing populations be carefully
considered, and that informative experiments should be carried out prior to wide-
scale adoption of this technique. They drew parallels with headstarting—another
“superficially attractive” conservation tool that was undertaken without sufficient
thought as to how it should be evaluated. Girondot et al. (1998) used a theoretical
model to reveal a potential problem with feminizing turtle populations (i.e., a
selection for masculinizing alleles that can lead to a long-term increase in the male
proportion of the population). They also found that the exogenous estrogens used
in the hormonal method to feminize can also cause arrest of lengthening in the
Müllerian ducts and in the opening of the tube’s caudal end in the Wolffian ducts.
In either case, females would be unable to expel eggs from the oviducts. Hence,
they recommend actions that protect adults and in-situ techniques such as
protecting nesting sites and improving natural conditions of incubation instead of
feminization.

Lovich (1996) argued that many turtle populations have naturally unbalanced
sex ratios which may be adaptive to the species, and that alteration of these ratios
could have negative results. Lovich included a number of potential problems that
could result from lowering males: a diminished effectiveness of multiple paternity
and sperm competition in promoting fitness; reduced genetic diversity due to lowering
the genetically effective population size; and decreased fertility of eggs. He also
suggested that ecological consequences of excess females such as upsetting the
balance of inter-sexual resource partitioning, need to be considered. Lovich
concluded that there was currently inadequate evidence to evaluate fully the
impact of sex ratio manipulation upon chelonian populations, but that available
information argued against it.

Vogt’s paper has already served as an important stimulus eliciting discussion
on the use of manipulating sex ratios and more opinions likely will follow. On the
one hand, ex-situ techniques such as these tend to be criticized as short-term
technological fixes, treating symptoms rather than causes and replete with hidden
problems. On the other hand, for many turtles these are desperate times and, if
used judiciously, ex-situ techniques may be able to buy the time needed to
establish in-situ methods of conservation. While agreeing with the aforementioned
pleas for caution concerning the use of these techniques, we also feel that each
deserves its day in court, and that ex-situ methods should not be eliminated from
consideration just because they are controversial.

**Headstarting**

Whereas hatcheries attempt to improve survivorship of the eggs by protecting
them from natural predation, headstart programs attempt to improve the sur-
vivorship of the hatchlings by growing them in captivity to a size that theoretically
protects them from the high rates of predation they presumably face in the wild.
If all this sounds innocuous enough, you will probably be surprised to learn that
“headstarting” has become one of the more controversial methods in turtle
conservation biology. Much of the debate has been waged in the sea turtle arena, and at the core of the debate has been the lack of evidence that headstarted turtles will return to their nesting beaches. In 1996, two Kemp's Ridley turtles became the first documented headstarted sea turtles to return to an experimental imprinting site when they nested at Padre Island in Texas (Shaver, 1996). In 1998, three additional headstarted turtles returned. Editorials in the Marine Turtle News Letter (Allen, 1990, 1992; Woody, 1990, 1991) and an article in Science (Taubes, 1992a) with letters of response (Wibbels, 1992; Shaver & Fletcher, 1992b) provide the essentials of the headstarting debate. Proponents argue that these programs should be promoted because they increase the survival of juveniles and because the high visibility of headstart programs enlists public concern and interest. Critics argue that headstarting is expensive, the benefits remain to be demonstrated, and that it treats symptoms of the problem rather than the basic problem(s) causing the decline. They maintain that the method may even be harmful to turtles citing a number of biological questions including:

- Will headstarted turtles be able to properly imprint to nesting sites if they are released a year or so beyond hatching?
- Will an extended period of captivity with limited exercise and unnatural foods affect the turtles' ability to survive in the wild?
- Are turtles raised under crowded conditions likely to spread captive-borne diseases to wild populations?
- How will the absence of hatchlings affect natural ecosystems?

For reviews of headstarting as a tool in sea turtle management, see Mortimer (1995b) and Frazer (1994).

Headstarting is not strictly a technique of sea turtle biologists, however. Examples of headstarting programs and experiments among freshwater turtles include giant South American river turtles in Brazil (Vogt, 1995), Indian softshelled turtles on the Ganges River (Sinha, 1995); painted terrapins in Malaysia (Moll, 1990b); river terrapins in India (Bhupathy, 1995) and Malaysia (Moll, 1984a, 1985c); diamondback terrapins (Wood & Herlands, 1995, 1997) and American red-bellied turtles in the United States (Haskell et al., 1996); and Thai narrow-headed softshells in Thailand (D. Moll, pers. obs.). At certain beaches in Brazil, giant South American river turtle hatchlings are collected upon emergence from natural nests and kept for only one or two fortnights until the shell hardens and conditions are right for release (IBAMA, 1989). At the other extreme, in Malaysian programs some cohorts of juveniles may be kept for several years before release (fig. 7.8a,b). One year seems to be the most common period of headstarting.

The debate about headstarting is also not confined to the sea turtle biologists. In a review of turtle survivorship patterns, Iverson (1991) reported that turtles typically show type III survivorship in which most of the mortality occurs in the egg or juvenile life history stages. From this he deduced that reductions in mortality at these stages should have a greater impact on population increases than

Figure 7.8
(a) Tanks of headstarted young river terrapin and painted
In the sea turtle arena, a substantial amount of evidence that headstarting is effective has been presented in Texas (Shaver, 1996). In contrast, editorials in the Marine Technology Society (1990, 1991) and an article in the marine (Wibbels, 1992; Shaver & Shaller, 1992) have argued against headstarting, citing a number of biological and practical reasons for this approach. The initial costs of headstarting are high, and the success rate is difficult to quantify. However, the potential benefits of increasing population numbers and genetic diversity make headstarting a worthwhile endeavor. Sea turtle biologists, however, have differing opinions on the effectiveness of headstarting (Vogt, 1995). Indian softshell turtle and terrapin programs in Malaysia (Moll, 1984a, 1984b; 1995, 1997) and American terrapins in the southeastern United States (Shaler et al., 1996) have shown promising results. However, breeding programs need to be carefully managed to ensure genetic diversity and to avoid inbreeding depression. Headstarting is also criticized for the potential impact on natural ecosystems and the potential for captive-borne animals to spread diseases to wild populations. 

(a) Tanks of headstarted young river terrapin at Bota Kanan; (b) a mixture of older juvenile river terrapin and painted terrapin at the Kedah facility, Malaysia.
reductions in adult mortality. In conclusion, Iverson recommended that "headstart programs" be applied more aggressively to terrestrial and freshwater turtles. Iverson's conclusions on the importance of early life history stages and the promotion of head starting were later challenged by several studies utilizing life-tables and computer models (Congdon et al., 1993, 1994; Galbraith et al., 1997; Heppell et al., 1996). The basic conclusions of these studies are that survival of adults and sub-adults are most critical to population stability in the long-lived turtles, and which conservation programs (such as hatcheries and headstarting) which concentrate on protecting a species only through the first year of life are unlikely to be successful until the causes of adult mortality are addressed. Heppell et al. (1996) found that headstarting can be helpful in rebuilding turtle populations when the survival of adults is maintained at high levels (with the proviso that headstarted juveniles are as viable as wild turtles).

Critics of headstarting programs (e.g., Pritchard, 1979; Dodd, 1982; Mrosovsky, 1983; E. Moll, 1984a, 1985c, 1989; Mortimer, 1988, 1995b) argue that headstarting remains an unproven/experimental procedure and thus should not be used as the sole basis for any conservation program involving long-lived species that may require many decades to prove effective. Despite the first documented returns of headstarted sea turtles to a nesting beach, headstarting remains a controversial procedure. In regard to freshwater turtles, there is some evidence that headstarting can improve juvenile survivorship (Haskell et al., 1996), but little evidence exists to indicate that it can be effective in rebuilding depleted populations of freshwater turtles. The Malaysian conservation effort—a 30-year-old ex-situ program—still shows no evidence of having reversed the decline of the river terrapin (E. Moll, 1989; see Case Study 3, Sharma, 1999). Until existing headstarting programs demonstrate some definite successes, the large sums of money required to run a headstarting program might better be spent on hatcheries, in-situ methods of conservation, and protecting more advanced life history stages.

**Captive Breeding**

Captive breeding for conservation purposes involves raising and reproducing species in captivity with the goal of releasing captive-bred specimens back into the wild to restock depleted populations (fig. 7.9). It is another high-visibility, ex-situ technique currently being used in some river turtle conservation programs and being considered for others. Captive breeding programs are part of the river terrapin conservation program for river terrapins in Malaysia and for Thai narrow-headed softshells (Kitimasak, 2002), river terrapins and painted terrapins in Thailand (see Case Study 3). In Thailand, the Thai narrow-headed softshell is critically endangered, and both terrapin species are thought to be extinct in the wild (Thrakhupt & van Dijk, 1995 "1994"). If the latter is correct, then all of the surviving members of both terrapin species are now in captivity at the Department of Fisheries facility in Satun Province. Case study 3, Sharma (1999), Moll and Moll (2000), and Kitimasak (2002) describe the Malaysian and/or Thai conservation programs which exemplify some of the problems discussed in this chapter (e.g., Naidoo, 1995, Rabbe, 1993). In addition, Watters (1996) list several additional problems of these problems in context with captive breeding:

- Establishing self-sustaining populations of their species and predilection for large populations as opposed to more and as captives in ponds and marshes (see Case Study 3).
- Genetic problems: using small percentage of the recruitment population in a captive population, bottleneck in the gene pool, introgression and deleterious effects (outbreeding depression, inbreeding depression). Techniques to alleviate this include selective breeding from the wild and extra-captive Asian river turtle populations. Some species that do not breed well in captivity.
Son recommended that "headstart terrestrial and freshwater turtles use life history stages and the promiseful points (Pritchard, 1979; Dodd, 1982; 1989; Mortimer, 1988, 1995b) as an experimental procedure and thus serve as a test case to prove effective. Despite the disadvantages of these programmes and the uncertainties concerning the effectiveness of a headstarting program might improve juvenile survivorship in turtles, it is likely that some programmes could be effective. The Malaysian conservation programmes show no evidence of having been effective (Moll, 1989; see Case Study 3; Moll et al., 1988). It is possible that a headstarting program might improve conservation, and protecting these programs which exemplify some of the problems of captive breeding of large river turtles.

Captive breeding and rearing are expensive, manpower-intensive, and suffer from many of the same problems discussed for headstarting (E. Moll, 1985c; Philippart, 1995; Rahbek, 1993). In addition to the expense and labor requirements, Snyder et al. (1996) list several additional problems of captive rearing. Herein, we look at several of these problems in context with river turtle conservation.

- Establishing self-sustaining captive populations. Large river turtles, because of their size and predilection for flowing waters, may not survive or breed well as captives in ponds or tanks, particularly when they are crowded (see Case Study 3).
- Genetic problems: using small captive populations to provide a high percentage of the recruitment for wild populations can produce a significant bottleneck in the gene pool (Philippart, 1995). There are also potential deleterious effects (outbreeding depression) of mixing gene pools through translocating captive-bred individuals to different river systems (Reinert, 1991). Long-term breeding within captive populations can lead to inbreeding depression. Techniques to alleviate inbreeding depression such as selective breeding from founding family lines are not being done in captive Asian river turtle populations, and may be impractical for many species that do not breed well in captivity (Snyder et al., 1996).

Figure 7.9
The river turtle captive breeding enclosure at Kuala Berang, near Terengganu, Malaysia.
• Introduction: a recent review of programs to reintroduce captive bred animals into the wild reported low success rates (Beck et al., 1994). However, Snyder et al. (1996) suggested that animals whose behavior is largely instinctive (turtles?) may have the best chance of being successfully reintroduced (also see Case Study 1 concerning the Indian Crocodile Project). Whether reintroduction should be used as a conservation technique for reptiles has been debated by Burke (1991), Dodd and Seigel (1991), Reinert (1991), and Seigel and Dodd (2000), and will be discussed further below.

• Disease: due to the crowded conditions of many captive breeding facilities, contagious disease is a serious concern for captive stocks. The Cayman turtle farm has provided a wealth of information on diseases of captive-held sea turtles. Among the diseases recorded in green sea turtles at the farm were mycotic pneumonia (Jacobson et al., 1979), herpesvirus infections (Jacobson et al., 1985a,b; Kleese, 1980), chlamydiosis (Homer et al., 1994), and the coccidial parasite, Caryospora chelonae (Jacobson, 1995). A profusion of viral, bacterial, mycotic, and protozoan, caused diseases are also known among captive freshwater species (Highfield, 1994; Izadjo et al., 1987; Murphy & Collins, 1983). A serious consideration from the standpoint of conservation is infecting wild populations with such diseases by releasing asymptomatic captive individuals (Cunningham, 1996; Jacobson, 1993, 1996). A virulent upper-respiratory mycoplasma in the desert tortoise (Gopherus agassizii) is thought to have been introduced into wild populations of the Mojave Desert by the release of infected captive individuals (Jacobson, 1993). The presence of bacterial and fungal infections in headstarted captive Batagur juveniles noted by Sharma (1999) could be similarly introduced into wild populations.

• Preemption of other techniques: an expensive, high-profile technique such as captive breeding can divert attention away from the underlying problems causing the species decline and become a "technological fix" that delays solutions rather than remedy problems (Frazer, 1992; Rahbek, 1993; Phillips, 1995).

Advocates of captive breeding programs can point to some notable successes (e.g., crocodiles [see Case Study 1]). Nevertheless, due to the expense, problems, and uncertainties in removing river turtles from the wild and then later reintroducing captive-bred animals, captive breeding is recommended here only as a last resort, when attempts to recover species or reduce threats to populations in the wild prove inadequate. When captive breeding is employed, it should be connected with recovery objectives for wild populations and should not be proposed as a long-term solution (Snyder et al., 1996). The IUCN/SSC Tortoise and Freshwater Turtle Specialist Group (1989) provides useful guidelines concerning captive breeding and the release of captive bred animals into the wild.

Where captive populations of river turtles already exist, we encourage breeding them, and the TCF Conservation plan described previously relies heavily upon coordinated captive breeding efforts (Fanti, 2002). The Centre for Herpetological Conservation, oriented organization in 1976, the MCB has made great progress, and they now have a stable of over 2000 captive-hatched individuals but, as stated above, such care is necessary to prevent disease and maintain the spread of disease and other threats to such species. The Zoologico Guadalajara—an organization of Mexican giant musk turtles and the Department of the liberated offspring at the心血,
Coordinated captive breeding efforts to rehabilitate severely depleted species (TCF, 2002). The Centre for Herpetology/Madras Crocodile Bank (MCB) exemplifies a conservation oriented organization with turtle breeding programs. Since its inception in 1976, the MCB has maintained breeding groups of Indian turtles and tortoises, and they now have a total of 300 individuals of twenty-two species (Whitaker & Andrews, 1997). The results of such breeding can provide important knowledge of husbandry techniques, and can serve to supply zoos and other collections, thus reducing the drain on wild populations. Under carefully controlled conditions such programs may also be useful in restocking wild populations but, as stated above, such actions are fraught with potential dangers such as the spread of disease and outbreeding depression. The Herpetarium of the Zoologico Guadalajara—an organization practicing captive breeding and release of Mexican giant musk turtles and ornate sliders—has been careful to release most of the liberated offspring at the same sites where their parents were collected (Fanti, 1995).

Turtle Farming and Ranching

Turtle farming and ranching schemes usually involve captive breeding for commercial objectives. However, in some instances, they also are touted as conservation techniques under the claim that supplies of captive-bred turtles will reduce the demand on wild stocks and that hatchlings and/or headstarted juveniles from the project will be returned to the wild (e.g., Reichart, 1995; Vogt, 1995). Farms are distinguished from ranches by virtue of being self-sustaining. In a farm, the breeding stock, once acquired, is replaced by captive-bred individuals rather than wild-caught animals. In a ranch, eggs may be obtained in the wild and then hatchlings raised to marketable size. Wild females may be continually incorporated into the captive population to replace those that die.

Commercial farms/ranches for freshwater turtles either supply hatchlings for the pet trade or supply adults for food. Red-eared sliders and painted turtles from farms/ranches in the United States exemplify species being raised chiefly for the pet trade (Warwick, 1986; D. Moll et al., in press; as discussed in chapter 5). Central American sliders (Trachemys scripta emolli) were also being raised primarily for the San José pet trade in Costa Rica (Pritchard, 1993a). Pritchard saw some merit in this operation as local people were involved, and adult turtle hunting had ceased in the area (see Mora & Ugalde, 1991), a third of the hatchlings from the wild-harvested eggs were released, and the internal trade in T. s. emolli was thought to reduce the importation of exotic red-eared sliders to meet the demand for pets.

The most successful of the commercial food species is the fast-growing Chinese softshell. Aqua-culture projects with this species can be found scattered throughout eastern and southeastern Asia (van Dijk et al., 2000a), and the culture of this species has even spread to Brazil (Anon., 1981). In the United States, snapping turtles are occasionally grown commercially in farm ponds. A farm/ranch in southeast Iowa, sells over 125,000 lb (56,000 kg) of snapping turtle meat annually at a wholesale price of $3–4.75 per pound (Horine, 1996).
The large South American river turtles (P. expansa and P. unifilis) are among the species often touted for such projects. Smith (1974, 1979) felt that both of these species had potential for domestication. Although the giant South American river turtle requires eight years to attain a marketable size of 23 kg, Smith (1975) calculated that a well-managed turtle pond could provide some 3960 kg of meat per hectare (22,000 pounds per acre) compared to 9 kg per hectare (50 pounds per acre) of cattle on the Amazon's nutrient poor pastures. Alho (1985) also estimated the market potential of raising the turtle, suggesting that a farmer starting with 5000 hatchlings could have 1500 mature turtles to sell in eight years. At the market prices of that time he predicted that the farmer would make $22,000 in gross income each cycle, or a net profit of $10,000 per cycle. Illegal farms/ranches have existed in Brazil for some time, but because the turtle was declared endangered in 1967 all trade in the species was clandestine. Now, conservation efforts have raised species numbers to the point that the Brazilian government has decided to reopen domestic trade and allow existing farms to trade turtles legally (Traffic International, 1997). In addition, IBAMA, the conservation arm of the Brazil government, has begun a program to formulate methodology for commercial farming of P. expansa and other species in order to slow the harvest of wild stock (Vogt, 1995). These farms can serve as experiments to determine if farming actually can benefit turtle conservation. Within some countries there is some evidence that such may be the case. In Taiwan, farmed Chinese softshells are the source of almost all turtle meat and eggs eaten, and some of the shell used for traditional Chinese medicine (although tremendous quantities of shell are still imported for the latter purpose [see chapter 5]). In addition, huge amounts of meat and live turtles from farms are exported abroad (Chen et al., 2000). The risks of the effects of establishing feral populations of native species remains to be determined, however.

Based on recent studies involving exploitation of long-lived turtles (Coughdon et al., 1993, 1994; Galbraith et al., 1997), attempts at achieving an economically feasible and sustainable harvest of wild adults may be an unattainable goal. However, as the species that have been modeled to date are of omnivorous/carnivorous forms from northern populations, future studies should more closely examine tropical herbivorous species before completely dismissing the possibility. While we are not optimistic that conclusions will be different, we support a "leave no stone unturned" philosophy in this regard, and believe that this extremely important issue and conservation and management decisions related to it require a broader base of knowledge than currently exists. A question more apropos to this section of this chapter is whether farming/ranching has significant potential for conservation, and whether its development may alleviate or replace the need for harvesting wild river turtle stocks to meet market requirements.

As with startheading, the verbal wars concerning the conservation value of farming were first fought within the framework of sea turtle management. Elements of the debate can be found in Reichart (1995) and Mrosovsky (1983) who supported the conservation benefits, and Ehrenfield (1974, 1980) and Dodd (1982) who found few conservation benefits. The two are reviewed in Table 7.2. The Turtles and Conservation Action Plan (IUCN/SSC, 1989), which included commercial farms or ranches for conservation, offered little potential benefit for any species. Most recently, the pros and cons of softshells in Asia have been discussed.

Table 7.2
Selected arguments for (pros) and against (cons) using farming and ranching of sea turtles

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<th>Pros</th>
<th>Cons</th>
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<td>1. Farming/ranching provides economic</td>
<td>1. Farming/ranching of endangered species</td>
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<td>strategy that is particularly important</td>
<td>undermines local conservation laws</td>
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<td>2. They can reduce pressures on wild</td>
<td>2. Commercial aquaculture will suitable</td>
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<td>quantity that will satisfy the market</td>
<td>to exploitation of wild-caught individuals</td>
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<td>3. Using doomed eggs and releasing them</td>
<td>3. &quot;Doomed eggs&quot; require a subjective</td>
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<td>to the wild should mitigate the impact</td>
<td>decision, could be more beneficial to</td>
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<td>on population</td>
<td>conservation than to a commercialization</td>
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<td>4. Useful research will result in an</td>
<td>4. Although some research beneficial,</td>
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<td>improvement of conservation techologies</td>
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<td>schemes that detract attention away</td>
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<td></td>
<td>5. Escapes which establish feral</td>
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<td></td>
<td>populations, disease, or reduce genetic</td>
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</table>

Based on conservation methods proposed in Mrosovsky (1983); Reichart (1982). All of these issues still exist in relation to farming river turtles.
are among the South American marketable size of 23 kg, Smith (1975) could provide some 3960 kg of meat, ready to 9 kg per hectare (50 pounds per acre). Small-scale farmers often do so. Alho (1985) also mentions the turtle, suggesting that a farmer could sell 1500 mature turtles in eight years, predicting that the farmer would make a profit of $10,000 per cycle. Illegal at the time, because the turtle was known to be edible, this trade was developed by a local tribal group for the local market. In addition, IBAMA, the Brazilian government agency responsible for the management of the turtle trade and allow existing farms to continue operations (1997). In addition, IBAMA, the concessionaire, has begun a program to formulate the management plan for the geographical area, including the conservation of the species (Ewing and Wanner, 1985). These actions can serve as examples of successful conservation efforts, especially considering the low population densities of many turtle species. Our approach has been successful in reversing the trend in the past, but ongoing efforts are necessary to ensure the success of these programs.

Table 7.2
Selected arguments for (pros) and against (cons) the use of sea turtles for farming and ranching.

<table>
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<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>1. Farming/ranching provides economic incentives to protect wild populations (a strategy that is particularly important in less affluent countries).</td>
<td>1. Farming/ranching of endangered species to supply a foreign luxury trade undermines local conservation laws and regulations.</td>
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<tr>
<td>2. They can reduce pressures on wild stocks by providing superior goods in large quantity that will satisfy the market demand.</td>
<td>2. Commercial aquaculture will stimulate markets for turtle products, not reduce them.</td>
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<tr>
<td>3. Using doomed eggs and releasing a percentage of the hatch or head-started turtles to the wild should mitigate the impact of the operation and ultimately benefit the wild population.</td>
<td>3. &quot;Doomed eggs&quot; require a subjective determination, but no matter how determined could be more beneficial to conservation if they were removed to safe parts of the beach rather than to a commercial operation. Recent computer models indicate that the release of hatchlings and juveniles will be inadequate to rebuild depleted populations.</td>
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<tr>
<td>4. Useful research will result in closed-loop farming operations and improvement of conservation techniques.</td>
<td>4. Although some research beneficial to conservation can result from commercial farming/ranching, most will be directed at raising sea turtles for the market. Small operations may provide no beneficial contributions.</td>
</tr>
<tr>
<td>5. Farms/ranches may contribute ill-conceived yet well-publicized conservation schemes that detract attention away from better conservation methods.</td>
<td>5. Farms/ranches may contribute ill-conceived yet well-publicized conservation schemes that detract attention away from better conservation methods.</td>
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<tr>
<td>6. Escapes which establish feral populations may compete with native species, spread disease, or reduce genetic fitness of wild conspecific populations.</td>
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Based on conservation methods proposed by Ehrenfeld (1974, 1980); Dodd (1982); Mrosovsky (1983); Reichert (1982). All of these issues, and specifically cons #6 (added by us) may also apply to farming river turtles.
Certainly, the type of ranching operations involved in supplying the pet trade or supplying turtle meat to local epicures, with their continued drain on local populations and potential to infect distant communities with introduced species, have few redeeming qualities for conservationists. However, certain types of closed-system farming operations, particularly those involving non-threatened species, may have more conservation potential.

For example, consider the situation in Bangladesh and West Bengal, India, the centers of turtle consumption in South Asia (E. Moll, 1990a; Choudhury & Bhupathy, 1993; Whitaker, 1997). The Bengali people of this region are notoriously fond of turtles, and animals from much of India and Bangladesh are shipped to markets in West Bengal to satisfy their chelonian cravings. However, the long-distance shipping of turtles by rail to West Bengal is expensive, and losses during shipment are considerable. Several species listed as protected on the Indian Wildlife Protection Act are included in the trade. E. Moll (1990a) and Whitaker (1997) have suggested that captive rearing of non-threatened species (either commercially or for home consumption) might prove to be more economical and reduce the demand for out-of-state turtles. Much of West Bengal and Bangladesh is peppered with ponds, and most villages have one to several within their confines. Some of these ponds are already used for raising fish, but it has been the practice to remove turtles from the ponds prior to stocking fish. However, some of the hardy Indian river terrapin could peacefully coexist with the fish (e.g., crowned river turtles, Indian roofed turtles). The feasibility of raising these turtles would depend upon a number of biological factors including age at maturity, growth, and fecundity of the species chosen. Whitaker (1997) has developed a pilot scheme to test the feasibility of rearing Indian flap-shells in village ponds.

E. Moll (1990a) and D. Moll (1995) have also suggested the possibility of raising a tried and proven turtle for farming projects in order to reduce demand on wild stocks. Considerable information is already available about the husbandry of the Chinese softshell, Pelodiscus sinensis, for example (e.g., Mitsukuri, 1905; Chen, 1976; Choo & Chou, 1983, 1984; Chou & Choo, 1983), and it is currently being raised profitably in many Asian locations (van Dijk, et al., 2000a). If non-endangered species can be raised profitably on a large enough scale to supply local turtle markets, then pressure on wild stocks theoretically can be reduced, and if these are truly closed-cycle farming operations, then humans and river turtles would both benefit. Chinese softshells have been used in Thai farms in place of the native softshell (Amyda cartilaginea) because of their greater fecundity and smaller space requirements (Thirakupt & van Dijk, 1995 “1994”), and presumably this has benefited the native softshell. However, any benefits of importing Chinese softshells must be weighed against the problems that may result should they escape and become established in new environments. We feel that the situation in Asia is desperate enough that the risks associated with feral populations must be considered as the lesser of the evils, and that it is time to determine the full potential of closed-farming operations before wild stocks are completely gone.

Translocation

Moving organisms from one location to another for conservation purposes. Templeton (1986) divides conservation goals into three categories: to reestablish a population at a site where it has been extirpated; to introduce an endangered species at a site where it is not native; and to develop a captive population that might eventually be reintroduced to the wild. Conservationists are increasingly concerned about the value of translocating Podocnemis expansa (the Orinoco river turtle) and Podocnemis unifilis (the Amazon river turtle) to the Caribbean. Although there are many instances of Podocnemis (probably P. expansa) having been translocated to the Lower Orinoco basin by rubber planters and gold miners, the number of females introduced into new areas was insufficient to cause nest density to be significantly increased. Conservationists have also advocated the translocation of Podocnemis expansa from the Orinoco basin to the Caribbean. These translocations have been successful in restoring turtle populations that had been extirpated by hunting, and have been carried out on a large scale in the Orinoco basin. However, the number of females introduced into new areas was insufficient to cause nest density to be significantly increased.

Results from the few attempts at translocation are not conclusive concerning the value of the approach. In one instance, the population of Podocnemis expansa at the Caquetá River in the Colombian Amazon was translocated. The authors reported that the population of Podocnemis expansa at the Caquetá River had been extirpated by hunting. They translocated Podocnemis expansa from the Orinoco basin to the Amazon basin, and the population was successfully reintroduced. However, the number of females introduced into new areas was insufficient to cause nest density to be significantly increased.

Alternatively, Alfinito et al. (1976a) reported that translocation of American river turtles from the Orinoco basin to the Caribbean was a success. However, many of the translocated turtles died during the journey, and there were no signs of a successful reproduction in the Caribbean. Conservationists have also advocated the translocation of Podocnemis expansa from the Orinoco basin to the Caribbean. These translocations have been successful in restoring turtle populations that had been extirpated by hunting, and have been carried out on a large scale in the Orinoco basin. However, the number of females introduced into new areas was insufficient to cause nest density to be significantly increased.

The Thai Fisheries' Department has also reported the successful translocation of terrapin terrapins from their hatchery. Thirakupt and van Dijk (1995) reported that these large, poorly vegetated rest areas appeared unlikely to provide suitable habitat for the terrapins.

Arguments for and against translocation have been made by many authors. Dodd and Seigel (1991), Dodd (1994), and Dodd (2000). The advantages of avoiding the extinction of species are obvious but must be weighed against the disadvantages of introducing new species and the possible risks of disease, social disruption, and biodiversity loss. arguments in favor of translocation include the possibility of increasing the genetic diversity of the populations, the possibility of controlling the spread of diseases, and the possibility of controlling the spread of invasive species. However, arguments against translocation include the potential for the introduction of new diseases, the potential for the introduction of new invasive species, and the potential for the introduction of new genetic diseases.
Translocation

Moving organisms from one location to another is frequently proposed for conservation purposes. Templeton (1996) listed four uses of translocation to achieve conservation goals: to reintroduce a species into areas where they have become extirpated; to introduce an endangered species into satellite populations as insurance against catastrophes; to augment numbers in natural populations; and to increase the genetic heterogeneity of small populations. The latter usage may develop into a particularly important procedure as riverine populations become increasingly fragmented.

Results from the few attempts at translocating river turtles to date are inconclusive concerning the value of the technique. Medem (1969) reported that a viable population of Podocnemis expansa had been introduced above the rapids on the Caquetá River in the Colombian Amazon. Smith (1974) reported the following instances: Podocnemis (probably expansa) were introduced into Venezuela's Lake Valencia after being headstarted for 10 months. As of the time of Smith's report, no significant nesting had occurred on the lake's artificial nesting beaches. In 1965, “Operacion Tortuguillo” rescued some 80,000 hatchlings (apparently still in nests) from rising flood waters, relocating them in swamps and floodplain channels. The program was discontinued in part due to concerns that translocated turtles, deprived of normal nest emergence behavior, would be unable to imprint on their natal beach for future nesting.

Alifinto et al. (1976a) reported on an effort to translocate adult giant South American river turtles from the Rio Trombetas to the Rio Tapajós in Brazil. Pollution due to bauxite mining, along with unseasonal flooding, was destroying much of the reproduction on the Trombetas. To alleviate the situation, 130 adults were captured on the Trombetas, tagged and translocated to the Rio Tapajós. The authors reported that nesting increased on the Tapajós beaches in proportion to the numbers of females introduced, and some marked turtles had been identified on the Tapajós beaches. None of the introduced females was observed returning to the Trombetas beaches, but marked turtles did turn up in the cities of Obidos in Para and Itacoatira in Amazonas (distances from the release sites were not given).

The Thai Fisheries Department has been relocating juvenile river terrapin and painted terrapin from their hatchery in Satun into reservoirs throughout the country. Thirakkupht and van Dijk (1995 “1994”) criticized the effort on the grounds that these large, poorly vegetated reservoirs lacking suitable sand banks for nesting appear unlikely to provide suitable habitat for a species adapted to a lotic estuarine environment.

Arguments for and against translocation of species were discussed by Burke (1991), Dodd and Seigel (1991), Reinert (1991), McDougall (2000), and Seigel and Dodd (2000). The advantages of being able to reintroduce river turtles into formerly occupied habitats, or to translocate them from doomed to viable habitats, are obvious but must be weighed against possible consequences. Among the more serious problems are the low success rate in previous projects, the potential for spreading disease, social disruption, and genetic pollution. Still another potential
problem of using translocation is that a few cases prove successful, politicians will want to use this easy “solution” anytime a population of threatened or endangered species stands in the way of a favored project. Should translocation be necessary, the following actions can improve the chances of success:

- Causal factors of the original decline should be understood and rectified prior to release (IUCN/SSC, 1989).
- Releases should be timed to coincide with optimal environmental conditions (IUCN/SSC, 1989).
- Use wild-caught as opposed to captive-bred individuals (Griffith et al., 1989).
- Translocate from populations in the same general area (Templeton et al., 1986; Griffith et al., 1989; IUCN/SSC, 1989).
- A larger number of releases increases the probability of success (Griffith et al., 1989). However, simply using a large number of founders does not necessarily ensure that genetic diversity is being preserved. In order to design a sampling program that assures preservation of genetic diversity, genetic surveys of source populations should precede translocation (Templeton, 1990, 1996).

Conservation Philosophy

We suggest that turtles may be especially vulnerable to population decline because they exhibit reproductive strategies incompatible with exploitation or significant loss of habitat. (Burke et al., 1994)

Successful management and conservation programs for long-lived organisms will be those that recognize that protection of all life stages is necessary. (Congdon et al., 1993)

Technology and Halfway Technology

Thanks to Nat Frazer, one of our most eloquent chelonologists, “halfway technology” has become a household word among conservation biologists worldwide. The term actually originated with Lewis Thomas (1974), in his popular book, The Lives of a Cell, who used it to describe medical technology that treats symptoms but not the underlying causes of the disease. Frazer (1992, 1997) borrowed the term to describe conservation methods such as hatcheries, headstarting and captive breeding that also focus on symptoms of the problem (too few turtles) while ignoring basic causes of the decline (e.g., exploitation, habitat destruction). Frazer noted that how a problem is defined can be a major factor in arriving at an appropriate solution. If we perceive the major problem of today’s threatened river turtle populations to be inadequate numbers, then we are likely to seek solutions that aim at increasing numbers of turtles. Hatcheries, headstarting, and captive breeding are methods that visibly can add numbers of turtles to the dwindling populations (hence their popularity). However, it is highly unlikely that these animals have been ameliorated of the decline; ex-situ techniques also assume their narrow focus on early life stages below.

Hatcheries and headstart programs raise young juveniles respectively. Hatcheries have long-term capture release data, (Congdon et al., 1993, 1994; Cross et al., 1996; Tucker & Moll, 1997) In long-lived species such as turtles, a decreasing population growth rate and reproduction rate approaches sexual maturity. However, their “reproductive value” increases. Future reproduction correlates positively with population size, and models all imply that methods that increase adult stages are unlikely to be effective in increasing the survival of older individuals in increasing populations.

Heppell (1998), in an attempt to apply across taxa, compared life cycle elasticity analysis, a method that includes factors as age-specific survival rate and reproduction rate. Despite large variations in age and age at maturity, she found that the species of freshwater turtles of low fecundity elasticity indicate that conservation efforts must aim at preventing decline of populations.

This does not mean that conservation programs (Heppell, 1998) for freshwater turtle population should focus but once the survival rates of these species is increasing the survivorship of new recruits, increasing population growth (Heppell, 1998). Successful conservation programs (Congdon et al., 1993, 1994; Cross et al., 1996) is that they are chiefly technology-dominated, however increasing technology-driven ever-increasing technology-driven, computers are facile for technological solutions. Technology is usually a palliative rather than a permanent solution, ex-situ techniques will likely stay with us (Frazer, 1992), and their most important use is to buy the time needed.
OF RIVER TURTLES

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place. Even here, some authors believe that technological solutions should be used only as a last resort in preserving biodiversity (Conway, 1988; Frazer, 1992). Proponents of ex-situ techniques argue that in-situ techniques are often ineffective in developing countries and may alienate local peoples to conservation practices in general (Gomez, 1982; Paez & Bock, 1997). Paez and Bock (1997) argue that in such situations ex-situ techniques (hatcheries, headstarting, and captive breeding) projects should be encouraged so long as they include mechanisms for evaluation. They point out that such programs can be a valuable source of biological information that can be helpful in future conservation efforts, whether or not the techniques prove successful.

**Sustainability**

Exploitation of river turtles becomes a conservation problem when it is unsustainable, but can it also be a conservation solution? Are there sustainable uses of river turtles that can promote their conservation, or is this concept best categorized as an oxymoron? The idea that economic incentives may be necessary to drive conservation efforts for turtles has been around for a long time. Most often it is applied to conservation in developing countries, the argument being that in poorer countries those people who are concerned about how they can adequately feed their own families will not be swayed to protect animal species unless there is something profitable in it for them. But show them that conserving species can be economically advantageous, and they will respond positively. Farming and ranching schemes have frequently been proposed as a means of improving local economies while concomitantly benefiting turtle populations (see section on Farming and Ranching above). Slogans such as “saving them through use” (Mittermeier, 1978) or “save them by eating them” (Vogt, 1995) are scattered throughout the conservation literature, but are they appropriate in light of modern conservation philosophy?

Over the past decade the notion of wildlife management programs combining economic development of human communities with the conservation of wildlife populations has grown in popularity (Klemens & Thorbjarnarson, 1995). This appears to correlate with the growth of the concept of “sustainable development”—terminology which was first presented in a 1987 United Nations report, *Our Common Future* (World Commission on Environmental Development, 1987). It has since spread to become one of the most influential contemporary concepts dominating local, national, and world policies and actions including planning and funding of scientific, conservation, and management activities (Frazier, 1995). Initially, the term was defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987). However, Willers (1994) contends that the term is actually code for perpetual economic growth, a concept that is generally antithetical to conservation goals. Nevertheless, if the purse strings of the agencies involved in funding conservation projects are controlled by this philosophy, investigators working to conserve chelonians must deal with the concept.

With regard to turtles, are sustainable use programs? Based on the few long-term studies of reproductive strategies that are available, these findings are applicable to management of exploitation schemes involving turtles that are destined for failure (fig. 7.10).

Sustained yield was one of the key principles in the management of renewable resources over the long term, and is still true today. It is important to maintain a balance between the needs of today's populations living in the environment and the future needs of future generations (Dietz & Singer, 1995). “Sustainable use of turtle harvests, once the environments critical to the survival of a desired species. Others argue that the use of turtles is a more feasible. In developing nations where turtles are an important part of the local economy, it is often more practical than to ban exploitation entirely.”

Central American river turtles (e.g., *E. borneensis*)—the age/size cohorts that are to be maintained.

*Figure 7.10*  
Harvest of large adult river terrapins (*E. borneensis*)—the age/size cohorts that are to be maintained.
With regard to turtles, a key question is, "Are they suitable subjects for sustainable use programs?" Based on information gleaned from computer models and the few long-term studies of turtles discussed above, chelonians appear to have reproductive strategies that are incompatible with exploitation or habitat loss. If these findings are applicable to river turtles at all latitudes, then most "sustainable" exploitation schemes involving regular removal of adult turtles from populations are destined for failure (fig. 7.10).

Sustained yield was one of the earlier scientific doctrines for managing resources over the long term, and it worked well as long as the resource was abundant relative to human demand (Salwasser, 1990). It will not work with depleted populations living in degraded environments. As stated by Frazier (1995): "Sustainable use of turtles (if it is possible) can only be accomplished once the environments critical to them are managed in ways appropriate to long-lived species." Others argue that total protection of river turtles may not always be feasible. In developing nations where turtles may be important protein resources or an important part of the local economy, it may be politically more feasible to limit rather than to ban exploitation of a species entirely. The conservation plan for the Central American river turtles (see Case Study 6) exemplifies this philosophy. If harvesting cannot be prevented, then protection should be provided in the follow-

Figure 7.10
Harvest of large adult river terrapins (Batagur basia) and painted terrapins (Gallagur borneensis)—the age/size cohorts that river turtles can least afford to lose if viable populations are to be maintained.
ing order of priority based on the value of each group to the population: large adults, adults, large juveniles, small juveniles, eggs. The harvesting of eggs from nests which are constructed in locations which are likely to be flooded, or of those constructed late in the dry season nesting period and temporarily close to the beginning of rising water levels would cause little problem for affected river turtles. This has been suggested as a type of sustainable exploitation which may be possible for several South American river turtle species (Fachín-Terán et al. 1996; Pezzuti & Vogt, 1999).

Case Study 6: Conservation of the Central American River Turtle. The Central American river turtle is a large (up to 65 cm carapace length), herbivorous, highly aquatic turtle inhabiting Atlantic drainages in Mexico, Belize, and Guatemala. The species is chiefly found in large, deep, lowland rivers and large, freshwater lagoons; however, they also occur in small tributary streams and brackish water estuaries (D. Moll, 1986). Chiefly a solitary nester, Dermatemys lays multiple clutches (1–4) of large, brittle-shelled eggs (10–13 per clutch) during periods of high water (Vogt & Flores-Villela, 1992b; Polisar, 1995, 1996, 1997). Nesting occurs from September to March in Chiapas, Mexico (Vogt & Flores-Villela, 1992b), and from late September to December in Northern Belize (Polisar, 1995, 1996).

Due to the diffuse nesting habits of the species, exploitation of eggs is insubstantial. Rather, most exploitation is directed at meat with adults and large juveniles emphasized (Vogt & Flores-Villela, 1992b; Polisar, 1995, 1997). Serious declines in Mexican populations were reported by Alvarez del Toro et al. (1979), and hunting has now virtually eliminated the species from much of its former range in southern Mexico (Vogt, in Polisar, 1994; Vogt et al., in press). In 1984, D. Moll observed that Dermatemys was still common to abundant in thinly populated areas of Belize, but had seriously declined in areas around certain human population centers (D. Moll, 1986) (fig. 7.11). Exploitation occurs year-round in Belize, peaking in April and May when rivers are low and turtles are easiest to catch. Demand is particularly great at this time as Dermatemys is a traditional Easter dinner in northern Belize. Currently, the species is listed as endangered by the United States (Levell, 1995), as an Appendix II species on CITES, APR 1 (highest priority for specific conservation action) by the IUCN/SSC (1989), and EN (endangered) on the IUCN’s most recent Red List (1996).

Following studies of the status of Dermatemys in Belize, D. Moll (1986) recommended that the remaining intact populations of the species in the country be used to obtain the data needed to manage this unique turtle. In 1989, John Polisar was provided such an opportunity (Polisar, 1990a,b, 1991, 1994, 1995, 1996, 1997; Polisar & Horwich, 1994). Seven villages that comprise the Community Baboon Sanctuary, a grass-roots wildlands management project aimed at maintaining habitat for black howler monkeys, became concerned about over-harvesting of the turtle in their area, and invited him to study the population inhabiting a 32-km section of the Belize River which bisected the sanctuary. Over the next two years, Polisar studied this site as well as a variety of other areas in the country emphasizing reproductive biology, exploitation patterns, marketing patterns, and cultural traditions. A lengthy project report and a short presentation about his recommendations for conservation were prepared. Polisar’s work further promoted his recommendations with slide presentations in villages and non-government offices, radio interviews, and media reports.

Polisar felt that with the lack of monitoring, previous harvesting would be unfeasible at the Baboon Sanctuary site. Instead, he promoted allowing a limited number of the activities of commercial fishermen for personal profit. This was important to maintain the good will of the populace. He also promoted the idea that small-scale hunting would be allowed. The village leaders agreed to this in 1993 to protect and manage Dermatemys under the following key elements:

- Year-round possession limits without affecting subsistence use.
- A short closed season (May 1–31)
- Establish several protected areas
- Dermatemys is completely protected during the closed season.

Figure 7.11
A Central American river turtle (Dermatemys mawii), Belize, and destined for the dinner table during the closed season.
with group to the population: large eggs. The harvesting of eggs from
these likely to be flooded, or of those
period and temporally close to the
problem for affected river turtles.
the exploitation which may be pose-
pecies (Fachin-Terán et al. 1996);

American River Turtle. The Central
(680 mm length), herbivorous, highly
Mexico, Belize, and Guatemala. The
and large, freshwater lagoons;
isms and brackish water estuaries
lay multiple clutches (1–4)
during periods of high water (Vogt
1997). Nesting occurs from
(Flores-Villela, 1992b), and from
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2b; Polisar, 1995, 1997). Serious
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became concerned about over-
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ich bisected the sanctuary. Over
as a variety of other areas in the
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patterns, and cultural traditions. At the conclusion of his study, Polisar sent a
lengthy project report and a short illustrated summary to the government detailing
his recommendations for conservation action that could function in a rural,
developed region with minimal wildlife enforcement. Additionally, Polisar
further promoted his recommendations and educated legislators and the public
with slide presentations (in village community centers as well as government and
non-government offices), radio interviews, and multiple meetings and discussions.

Polisar felt that with the lack of enforcement capability, a complete ban on
harvesting would be unfeasible and would merely lead to general non-compliance.
Instead, he promoted allowing subsistence hunting to continue while restricting
the activities of commercial fishermen who removed large numbers of the turtle for
profit. This was important to maintain the continued support of the majority of the
populace. He also promoted the establishment of sanctuary areas where no
hunting would be allowed. The recommendations led to nationwide legislation in
1993 to protect and manage Dermatemys. Included within this legislation were the
following key elements:

- Year-round possession limits that eliminate large-scale removals without
  affecting subsistence use.
- A short closed season (May 1–31).
- Establish several protected zones where selling and purchasing of
  Dermatemys is completely prohibited.

Figure 7.11
A Central American river turtle (Dermatemys mawii), purchased in the Belize City market,
Belize, and destined for the dinner table of guests of the Hotel Mopan, Belize City.
Although it is too early to determine whether this legislation will have the desired result, certainly it ranks as a positive step toward the conservation of this important chelonian.

Education and Research

Education is an important tool for shaping attitudes conducive to conservation projects as well as a key element in the success of any specific conservation program. Without widespread local support, few conservation programs can survive. For the most part such support can only be gained once the people of the region understand the necessity for the project and how they or their region may ultimately benefit. Education should occur at several levels categorized herein as “awareness,” “understanding,” and “training/application.”

Awareness

Awareness simply alerts the target population to the existence of species, their needs, and their conservation problems. Such instruction is crucial for laying the groundwork toward a pro-conservation attitude. A variety of techniques can be used to create awareness including T-shirts, posters, and bumper stickers bearing depictions of turtles and/or conservation slogans. Mass media approaches (e.g., radio and television programs) can also be effective in acquainting the public about turtles and their conservation problems. In particular, early education through books or classroom lessons and projects should be promoted. The earlier that such attitudes can be instilled in humans the better, but it is never too late to try.

In general, children seem to possess an affinity for turtles, and thus lessons involving turtle diversity, value, and problems are likely to be popular and useful in developing an appreciation of biodiversity and in creating a general conservation ethic. In the United States, preschool children are often introduced to turtles through cleverly written children’s stories such as Yertle the Turtle (Seuss, 1958) and Timothy Turtle (Graham, 1946).

As the children grow older, somewhat more advanced books are available that provide biological information along with conservation messages. As one example, the juvenile level book, Look Out For Turtles by Berger (1992) notes that some people kill turtles for food, make ornaments from their shells, destroy their homes, and dump poisons into their water. It concludes by telling the readers that they have an important job to do for turtles and lists several things that they can do including: removing turtles from roads; helping to protect and clean the areas where turtles live; and asking for laws that will prevent sea turtles from being caught in fishing nets. Turtles by Baskin-Salzberg and Salzberg (1996) was written for children in the 7- to 12-year range. This attractive little book, which is liberally laced with excellent glossy photographs, introduces children to the fossil history of turtles, the present-day forms, and the conservation problems of the group. It also concludes with several things that everyone can do to help turtles including: leave them in the wild, don’t buy them as pets, and do not buy products made from turtles. Addresses of organizations that can provide further information are at the end. A turtle classic beyond, From Mississippi to Louisiana. Along the way the natural history, rivers, boats, danger, and how to color it.

For older children and adults, awareness, and to solicit information by conservation organizations, there is a wealth of books created by Indranil Das. Each book is a drawing of a particular turtle in the United States, postcards of reptiles (including Michigan). Posters can be especially useful in areas with a high percentage of illiteracy. For that purpose, posters and/or turtles specifically geared toward awareness. A sampling of popular works includes: Pritchard (1967, 1979), Obst (1995, 1996). An updated version is now also available on CD-ROM.

organizations that can provide more information about helping turtles are listed at the end. A turtle classic best suited for the junior high level student and beyond, *Minn of the Mississippi* (Holling, 1951) traces the adventures of a three-legged snapping turtle from the cold waters of Minnesota to the bayous of Louisiana. Along the way the reader is treated to a wealth of information on natural history, rivers, boats, and rivermen.

An additional child-oriented approach is to prepare special coloring books promoting conservation themes. An excellent example of this approach is a coloring book created by Indraneil Das (1996) for children in India. On one page of the book is a drawing of a particular Indian turtle for coloring, and on the facing page is a short account of how to recognize the turtle, where it is found, why it is in danger, and how to color it.

For older children and adults, posters are another popular device to promote awareness, and to solicit information from the public concerning threatened species by conservation organizations (fig. 7.12). Some countries have posters depicting their turtles and tortoises (e.g., India and Thailand) and within the United States, posters of reptiles (including turtles) exist for several states (e.g., Illinois, Michigan). Posters can be especially effective in developing countries that have a high percentage of illiteracy. For the literate, field guides and popular books on reptiles and/or turtles specifically, have been very influential in creating public awareness. A sampling of popular turtle books with world-wide coverage include Pritchard (1967, 1979), Obst (1986), Ernst and Barbour (1989), and Rogner (1995, 1996). An updated version of Ernst and Barbour's *Turtles of the World* is now also available on CD-ROM (Ernst et al., 1998).

Regarding specific countries, more books have been written about the U.S. chelonian fauna than any other. The first, *Turtles of the United States and Canada*, published in 1939 by Clifford Pope was succeeded by *Handbook of Turtles* by Archie Carr (1952) which stood as the authority for the next two decades. In 1972, Carl Ernst and Roger Barbour took over with the publication of *Turtles of the United States*. The most recent book, *Turtles of the United States and Canada* (1994) by Ernst, Lovich, and Barbour has come full circle, being titled the same as Pope's original. Not only does this book create an awareness of the species and their habits but it also calls attention to specific conservation problems to a greater extent than its predecessors. *The Year of the Turtle* by Carroll (1991), a beautifully written and illustrated depiction of life of the spotted turtle (*Clemmys guttata*) and other northeastern U.S. aquatic turtles, exemplifies another form of educational turtle literature available to the public. Few countries other than the United States also have popular guides to their chelonian fauna. *The Turtles of Canada* (Froom, 1976), *Australian Freshwater Turtles* (Cann, 1998), *Turtles of Thailand* (Nuttapaph, 1979), *The Turtles of Venezuela* (Pritchard & Trebbau, 1984), *The South African Tortoise Book* (Boycott & Bourquin, 1988, 2000), *Colour Guide to the Turtles and Tortoises of the Indian Subcontinent* and *Turtles and Tortoises of India* (Das, 1991, 1995), and *Tortues Continentales de Gayane Francaise* (Mettrailler & Le Gratiet, 1996) are examples.
WANTED
Reports on Sightings of the
ALLIGATOR SNAPING TURTLE

The ALLIGATOR SNAPING TURTLE is the world's larg-
est fresh water turtle (record size is 219 lbs.). They average
between 60-110 lbs. Missouri is the northern limit of the species
range. Habitat loss and over-harvesting have caused a population
decline of this species. The ALLIGATOR SNAPING TUR-
TLE is now listed as RARE in Missouri.

Anyone seeing an ALLIGATOR SNAPING TURTLE in
southern or southeastern Missouri is asked to contact their
local Conservation Agent or the person listed below.

The common snapping turtle may be confused with the
ALLIGATOR SNAPING TURTLE. See illustrations and
descriptions below.

Common Snapping Turtles
- average 16-35 lbs.
- Head is
- portrayed with no pronounced
- hooked beak.
- Upper shell without 3 prominent ridges
- and no "extra" scales.

ALLIGATOR SNAPING TURTLES average 60-110 lbs.
- Head is large and "chubby" with a pronounced hooked
- beak.
- Upper shell has 3 prominent ridges and a row of "extra" scales along each
- side of shell.

For reporting sightings of ALLIGATOR SNAPING
TURTLES, contact:
Tom R. Johnson, Herpetologist
Missouri Department of Conservation
P.O. Box 180
Jefferson City, Missouri 65102

Figure 7.12
A poster issued by the Missouri Department of Conservation to solicit information from
the public concerning encounters with the alligator snapping turtle (Macrolemys
temminckii).

More specific to conservation efforts, Groombridge (1996–2001) that
the threatened amphibians and reptiles (Klemens, 2000b) provides a con-
ceptual framework for conservation action.

Understanding
Understanding is the next step beyond awareness or that they are threatened, or even declin-
ing. In the United States, raising understanding begins in early grades. Students learn that some species are extinct because the rainforest is being cut, and the consequence is to the forest. Relative to river turtles, raising awareness could be related to raising awareness of people happening to rivers of the world having relationships with the river.

Information in the scientific literature is abstract for the general public to understand.words are needed to serve as intermediate steps. Innovative techniques are required to translate conservation biology into forms that can be understood. Jeanne Mortimer (1995) noted that attending to a species is such a long delay from when a species is listed until it is declared extinct. The population dynamics involved are complex, and the information through words or mathematical formulaic representation of these concepts is important.

Still another way to promote understanding is through word imagery. Frazer’s (1992) analogy,”meridianology,” with the concept of treating threats to species is interesting. This analogy, which tends to headstarting and captive breeding, can be applied to the public not only to understand but also to act. It is associated with these ex-situ techniques that are needed in the race to educate the public about river river turtles.

Implementation Education
Implementation education represents the next step in the process, instructing how to apply the new knowledge. Workshops and training courses may be needed in the race to inform conservation are useful in this regard.
More specific to conservation are the Red Lists of the IUCN (e.g., Baillie & Groombridge, 1996–2001) that publicize the threatened animals of the world, or more specifically lists for individual countries such as the four-volume Chinese Red Data Book of Endangered Animals. In this series, Volume 3 by Zhao (1998) concerns the threatened amphibians and reptiles. The recently published Turtle Conservation (Klemens, 2000b) provides a comprehensive overview of conservation issues and recommended conservation action for all the major chelonian groups.

Understanding

Understanding is the next step beyond just being aware of the existence of species or that they are threatened, or endangered. It is to comprehend why species are declining. In the United States, rain forest units are becoming commonplace in the early grades. Students learn that many species of animals and plants are becoming extinct because the rainforest is being destroyed. They are taught why rainforests are being cut, and the consequences that the cutting will have to all of life in the forest. Relative to river turtles, similar units could be designed around what is happening to rivers of the world and how this in turn affects organisms associated with the river.

Information in the scientific literature is frequently too complicated and abstract for the general public to understand or retain. This is where good teachers are needed to serve as intermediaries between the scientists and the general public. Innovative techniques are required to put the knowledge being accumulated by the conservation biologists into forms that allow general understanding. For example, Jeanne Mortimer (1995a) noted the difficulty of explaining to the public why there is such a long delay from when adult turtles and their eggs are removed from the populations until population declines are actually observed. She found that while the population dynamics involved were too difficult for the general public to grasp through words or mathematical formulas alone, they were receptive to diagrammatic representation of these concepts.

Still another way to promote public understanding is through analogy and word imagery. Frazer’s (1992) association of the catchy term, “half-way technology,” with the concept of treating symptoms rather than causes of a disease creates the sort of analogy that tends to stick in the human mind. Then, his labeling of headstarting and captive breeding as forms of half-way technology allows the public not only to understand but also to remember the conservation problems associated with these ex-situ techniques. More approaches such as these are badly needed in the race to educate the public to the conservation problems of river turtles.

Implementation Education

Implementation education represents the cumulative stage of the educational process, instructing how to apply the methods of conservation biology to the problem. Workshops and training courses made available by organizations concerned with conservation are useful in this regard. An excellent example of this type of program
is the University of Michigan’s innovative GREEN (Global Rivers Environmental Education Network) project (Stapp et al., 1995). In this program, teachers worldwide take their students to a local river and teach them techniques of studying water quality, watershed usage, and identifying socioeconomic factors leading to the deterioration of river quality. The students share their findings with local officials and with student groups in other countries. GREEN not only provides students with the opportunity to gain an in-depth understanding of their local environmental problems, but also encourages them to act on their findings and to share their information with other cultures on a global scale.

An example more specific to turtles is the recent Turtle and Tortoise Conservation Project in India, a three-year joint Indo-U.S. undertaking between the Wildlife Institute of India and the U.S. Fish and Wildlife Service (Bhupathy et al., 1994; Choudhury et al., 1997). Objectives of this multifaceted project were:

1. To determine the conservation status of tortoises and freshwater turtles in India.
2. To identify viable turtle populations and suitable habitats to establish protected areas.
3. To set up captive breeding units for endangered chelonians aimed at reintroduction.
4. To acquaint local wildlife officials with conservation problems of turtles in their region and train them in conservation methods suitable to solve these problems.

To satisfy the latter objective, at the end of three years of fact-finding involving field work, museum surveys, and sending out questionnaires to zoos and wildlife officers, a large workshop was held at the National Chambal Gharial Sanctuary in Madhya Pradesh. Federal and state wildlife officers, along with interested biologists from the U.S., were invited to the four-day workshop to disseminate the information collected during the study. Turtle conservation problems and how to deal with them were the main topics of discussion.

Recovery plans and action plans are publications that fall into the category of implementation education. Recovery plans include aspects of all three of the aforementioned levels. Such plans are required by the Endangered Species Acts of the United States and Australia and are also being prepared for species in other countries. Recovery plans typically contain three sections. The first usually provides information on the ecology of the species, the causes of its decline, and criteria to be met before downlisting a species from the endangered category. The second section outlines the actions proposed to achieve recovery. The last section details the implementation schedule and estimates the costs involved. Recovery plans are available for several river turtles including the river terrapin (E. Moll, 1984a), ringed map turtle (USFWS, 1988), Alabama red-bellied turtle, (USFWS, 1989), flattened musk turtle (USFWS, 1990), and yellow-blotched map turtle (USFWS, 1993).

Action plans typically concern groups of species and thus operate at a different scale from the species-specific recovery plans. The IUCN’s Species Survival Commission Specialist Groups (1998) have concluded that no one species in the group based on information from the consultation action, and there organized action plans are included in the Action Plan for the Conservation of Freshwater Specialist Group (1996) for the Conservation of Turtles and Tortoises. The action plans provide some of the guidelines for their management on the global scale.

**Conclusions**

There is not a single approach to the management of every species or every region. The following steps may be used. It is the task of conservationists to select these tools with others to fit the particular situation (2000a) and by Seigl and Dadd (1990). Conservation action. That which necessarily be successful for developing countries with both intrinsic factors such as the status of the species, as well as extrinsic factors such as local politics, and state of the economy.

Ideally, conservationists tend to emphasize the protection of a declining species rather than the eradication of the species. It is an important part of the conservation of a threatened species. For example, it may be necessary to allow some portions of the population in order to protect them. Similarly, if species is at an extreme (e.g., the Chinese three-toed box turtle), populations in a region is safe even if the population from neighboring countries may be the only source.

Again, every situation is different and a program fits all approaches. Long-lived vertebrates and success depend on how well the premises that can serve as guidelines serve for such turtles.

1. Education: the people involved should be informed why the turtles will benefit them now or in the future. They should be given integral roles in the...
RIVER TURTLES

GREEN (Global Rivers Environmental Network). In this program, teachers worldwide are taught techniques of studying socioeconomic factors leading to river health and biodiversity and share their findings with local communities. GREEN not only provides a depth understanding of their local ecosystems but the global scale.

The recent Turtle and Tortoise Conservation Indo-U.S. undertaking between the IUCN/SSC Turtle Specialist Group and Wildlife Service (Bhupathy et al., 2000) described the multifaceted project were: tortoises and freshwater turtles in suitable habitats to establish a network of 109 sites.

Conservation problems of turtles in different habitats with methods suitable to solve these problems.

Years of fact-finding involving field biologists, including Chambal Ghariah Sanctuary in India, and divers, along with interested biologists, at the annual workshop to disseminate the conservation problems and how to solve them.

Species that fall into the category of threatened species of all three of the aforementioned Endangered Species Acts of the U.S., prepared for species in other countries. The first usually provides protection of its decline, and criteria to list species at the endangered category. The second requires recovery. The last section details costs involved. Recovery plans are needed for the river terrapin (E. Moll, 1984a), red-bellied turtle (USFWS, 1989), low-blotched map turtle (USFWS, 1989), and two species and thus operate at a different levels. The IUCN's Species Survival Commission Specialist Groups have been instrumental in preparing Action Plans for a wide diversity of taxa. Typically, each Action Plan evaluates the status of species in the group based on input from the volunteer specialists, reviews current conservation action, and then outlines needed conservation projects. River turtles are included in the Action Plan prepared by the IUCN/SSC Tortoise and Freshwater Specialist Group (1989), and the more recent “A Global Action Plan for the Conservation of Tortoises and Freshwater Turtles: Strategy and Funding Prospectus for 2002–2007” by the Turtle Conservation Fund (2002). These two action plans provide some of the best overviews of the status of river turtles and their management on the global scale.

Conclusions

There is not single approach to the conservation of river turtles that can be applied to every species or every region. We have listed a number of the available tools which can be used. It is the task of the conservation biologist to mix and match these tools with others to fit each unique situation as suggested by Klemens (2000a) and by Seigel and Dodd (2000) with their “gradient” approach to designing conservation action. That which works in developed countries will not necessarily be successful for developing countries. The approach chosen will depend on intrinsic factors such as the status of the population and the biology of the species as well as extrinsic factors such as the predominant religion/culture of the region, local politics, and state of the economy.

Ideally, conservationists tend to favor in-situ approaches that provide complete protection of a declining species, its community, and its habitat. However, if the species is an important part of the local economy and/or part of a long-standing tradition (e.g., the traditional, Central American river turtle Easter dinner in Belize), it may be necessary to allow some exploitation while moving to protect significant portions of the population in order to marsh support from the local human population. Similarly, if species become so much in demand and their price so extreme (e.g., the Chinese three-striped box turtle [Cuora trifasciata]) that no wild population in a region is safe even in protected areas (such as the current exploitation of turtles from neighboring countries by the Chinese), then captive breeding of populations may be the only short-term approach available for saving them.

Again, every situation is different and it is impossible to provide a “one conservation program fits all” approach. Nevertheless, based on what we know about long-lived vertebrates and successful conservation programs, there are several basic premises that can serve as guidelines in considering conservation action for river turtles:

1. Education: the people involved or affected by the conservation program should be informed why the action is necessary and if or how this program will benefit them now or in the future. If possible, the local people should be given integral roles in the conservation program.
2. Ideally, all life history stages of a declining river turtle population should receive protection, but if this is not possible then adults and older juveniles should receive precedence.

3. In-situ techniques should be utilized where practical, but where ex-situ methods are warranted they should be adopted as temporary measures and affiliated with in-situ methods such as habitat acquisition, improvement, and maintenance.

We are cautiously optimistic that river turtles find themselves in today's waters of their home rivers initially, but optimism is false, and believe that which we can build upon to attain, if we are aware of the main problem are rapidly coming to grips with them. We certainly do not minimize in implementing effective conservation planning are the necessary first steps.

The idea of turtle biologist particularly new concept, Symposia held in conjunction with the (e.g., at Williamsburg, Virginia Dick Vogt and the late Jack McCormick, the enclaves at the namesake) has continued at several-year intervals, mainly concerned with chelonian, often raised also. As awareness of the world's turtle populations began, turtle biologists was to seek to identify problems. The 1993 conference (Abbema, 1997) focused attention on a year a new chelonian society was