CHAPTER

17

Sea Turtles and the Problem of Hybridization

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Introduction

There are seven, perhaps eight, species (and five genera) of sea turtles in the oceans of the world representing a lineage that goes back to the late Jurassic, 140 million years ago. With the exception of the Australian flatback, *Chelonia depressa*, which occurs only in northern Australia, all are faced with a variety of serious threats to their continued existence. The other species are generally circumglobal in distribution; they include the green turtle, *Chelonia mydas*, which occurs primarily in tropical waters although individuals may occur in temperate waters; the loggerhead, *Caretta caretta*, which regularly occurs in subtropical and temperate waters and occasionally in the tropics; Kemp's ridley, *Lepidochelys kempii*, the most endangered of all sea turtles, occurring only in the Gulf of Mexico and along the east coast of North America; the olive ridley, *Lepidochelys olivacea*, which occurs in tropical waters except in the northern Caribbean; hawksbill, *Eretmochelys imbricata*, a tropical species; and the leatherback, *Dermochelys coriacea*, the largest sea turtle, which nests in the tropics but regularly migrates to far northern and southern latitudes to feed. Some sea turtle biologists recognize an eighth species, the black turtle, *Chelonia agassizii*, which occurs off the west coast of North, Central, and South America, as distinct from *C. mydas* (A. Carr, Jr.; P.C.H. Pritchard, personal communications). Reviews of the biology, distribution, and threats to these species have been summarized in the many papers in Bjorndal (1982) and by Frazier (1980).

In 1979, biologists from around the world met in Washington, D.C., to review the status and biology of sea turtles and to make conservation and management recommendations to ensure their survival while allowing controlled exploitation for future generations. A conservation strategy plan was adopted (World Conference on Sea Turtle Conservation, 1979). The conference not only revealed a worldwide sense of obligation and need to initiate conservation activities, but also demonstrated that state-of-the-art turtle management is very elementary compared with bird and mammal game management. When asked how to reinforce a depleted or declining sea turtle population, most biologists would answer with a single recommendation: protect it.

Such a response is in most cases too vague. A manager concerned about the turtles within his area of authority would immediately respond: protect it how? Also, a simplistic response of "protect it" is really a passive response to the critical condition of many populations and may lead to a false sense of security once statutes for protection are in force.

In addition to statutory protection, a number of management options are available, including establishing egg hatcheries, moving nests to new locations on natural beaches (but not within a well-defined hatchery), massive relocation of eggs and/or hatchlings to new beaches in an attempt to supplement declining populations or reestablish extirpated ones, head-starting, captive breeding, predator control, farming and ranching, and many more. While it is beyond the scope of this chapter to discuss these options, the papers of Pritchard (1979, 1980), Ehrenfeld (1982), and Shabica (1982) provide thoughtful discussions and criticisms of them. In general, many of these options must be considered experimental. They are of limited use as conservation methods because there is no proof that they work. In some cases, it may turn out that they have been of negative value because they inadvertently diminished populations. For instance, for years hatcheries have been using Styrofoam boxes, which ensured a protected nesting environment but kept incubation temperatures perhaps lower than on beaches. With the discovery that temperature controls sex determination in sea turtles, it may be that males have been predominantly released for years in some operations (Mrosovsky and Yntema, 1980; Morreale et al., 1982). Experimental conservation procedures may also introduce the potential for hybridization between species or, more important, between demes. Hybridization, as we use it in this chapter, refers to the production of offspring between members of different populations brought together

through human action, not that resulting from genetic exchange in natural populations due to immigration.

Management techniques such as head-starting and moving eggs or hatchlings to new beaches are thus still unproven, are in many cases cost-prohibitive, and require much experimental testing, some of which is underway. At present, it seems more biologically acceptable to emphasize measures designed to eliminate poaching, prevent predation by feral and domestic animals, eliminate commercial markets, ensure the protection of nesting, feeding, migratory, and developmental habitat, and promote the use of the turtle-excluder device developed by the U.S. National Marine Fisheries Service for shrimp trawls. These techniques are known to be effective and, in most cases, the most cost-effective methods for limited budgets.

The Problem with Sea Turtle Biology

One might ask why there are seemingly few proven management options available. One principle reason is that sea turtles are marine and, as such, are out of sight most of the time. We simply do not know much about their biological requirements and life histories. For instance, such important features as sex ratio, developmental habitats of hatchlings, age at first reproduction, growth rates, longevity, and recruitment into the adult population are virtually unknown for any species. Other features such as migratory routes and internesting movement patterns are poorly known. Turtle biologists spend much of their time piecing together life cycles from the results of mark-and-recapture programs. At best, as in the cases of the relatively well-studied loggerhead (*Caretta caretta*) and green turtle (*Chelonia mydas*), mark-and-recapture results are dependent upon the chance recovery of a few individuals in a tagged fraction of one sex of an adult population that happened to nest where researchers can get to them (Carr, 1980).

The hawksbill turtle (*Eretmochelys imbricata*) presents still another problem. Its nesting is diffuse; there is little tendency to aggregate (Carr et al., 1966). The biologist is thus denied the statistical advantage of substantial numbers of animals to tag on a single beach. Another species, Kemp's ridley (*Lepidochelys kempii*), is now almost extinct. Despite knowledge of where nesting occurs, there are so few Kemp's ridleys left that research on adults is badly frustrated. On a few stretches of shore, the giant leatherback turtle (*Dermochelys coriacea*) nests in large numbers, but leatherbacks are rarely recaptured away from the nesting beaches. Therefore, the mark-and-recapture procedure is of limited use (Carr, 1980).

Difficult research logistics and our lack of understanding of basic sea turtle life histories are thus obstacles to effective sea turtle management. Another obstacle is the inadequacy of our knowledge of their systematics (Smith et al., 1978). This weakness encumbers the fundamental decision on where or to which population to apply limited available resources in order to advance the most elementary phase of management—that is, protection. Without a clearer understanding of the geographical ranges of breeding populations within species, zoologists are hard-pressed to help wildlife managers organize specific protection priorities. The solution, then, is to attempt to protect every breeding aggregation.

In fact, our admittedly limited knowledge of the population genetics of sea turtles would indicate that this is the most justified strategy for conserving these species. Although karyological and chromosomal banding studies have not proved helpful in understanding population structure and limits (Bickham et al., 1980), electrophoresis may prove very valuable. In a preliminary study of 13 loci of green and loggerhead hatchlings, Smith et al. (1978) demonstrated that, while loggerheads had much less heterozygosity than greens, loci were polymorphic between populations such that populations were readily identifiable. Thus, they suggested that, for management purposes, populations be treated as functional units independent from one another. Hendrickson (1979) has also demonstrated genetic differences between species and individual populations of sea turtles in the amino acid composition of their keratins, although large amounts of variation within ratios and overlapping ranges between different categories at present preclude use in simple discrimination tests.

As spotty as management data may be, much research is being conducted around the world on many aspects of sea turtle biology. In time, management opportunities will be more diverse. However, as we continue to attempt to unravel the great mysteries surrounding sea turtle biology while attempting to secure the future of their populations and habitat, we must be careful to avoid management errors, such as inducing hybridization of wild stocks.

Our weakness in understanding sea turtle systematics is central to any consideration of hybridization. What are the genetic groupings and reproductive limits in sea turtles? Below the generic level the answer is in almost every case unclear. New sea turtle beaches are still being discovered, and there is evidence that the turtles at each nesting beach represent a more or less complete, separate breeding colony.

Studies of electrophoretic variation (Smith et al., 1978), keratin structure (Hendrickson, 1979), distribution of heavy metals in eggs (Stoneburner et al., 1980), and population movements of several species (for instance, Carr et al., 1978) all tend to confirm that each nesting colony is a separate deme, and the more colonies that are discovered, the more "kinds" of sea turtles we are compelled to recognize. If we interpret the amended U.S. Endangered Species Act of 1973 (16 U.S. Code 1531–1543) as a statute designed to preserve genetic diversity, demes would require protection and management, and we are obliged to prevent human actions that might jeopardize or weaken the genetic integrity of populations through hybridization, especially since we know so little of the effects of hybridization on fitness.

There are two principal management practices that might lead to hybridization of sea turtle populations. These can be expressed in general terms as follows (Bacon, 1975):

1. The stocking of turtle "farms" or ranches with turtles from disjunct breeding populations, followed by the deliberate or accidental release of these or their progeny.
2. Transfer of eggs or hatchlings from a productive beach to a second beach, with the aim of establishing or restoring a breeding colony.

In both cases, hybridization between populations within a species is thought to be more of a problem than interspecific hybridization, unless what is presently recognized as one species, such as *Chelonia mydas*, is actually a composite of sibling species. Interspecific hybrids of sea turtles are definitely known only from an *Eretmochelys* × *Chelonia* cross from a nest deposited in Surinam whose progeny were hatched and raised at Cayman Turtle Farm (Wood et al., *in press*).

Farming and Ranching

Sea turtle farming and ranching is attractive to commercial investors, since products such as shell, meat, and calipee are readily marketable and many wild populations are at least nominally protected from exploitation through national laws or international agreement. Farming (raising sea turtles in a closed cycle operation without relying on wild populations except to occasionally add heterozygosity to the breeding herd) and ranching (obtaining eggs from natural beaches and raising the hatchlings in controlled conditions for market) are represented by proponents as not just commercial enterprises, but as ones that contribute toward sea turtle conservation (Brongersma, 1980). According to this view, turtle farms and ranches can save wild populations by underselling illegal collectors and driving them out of business while at the same time producing a surplus of animals, some of which may be returned to the wild to repopulate depleted areas.

For a combination of economic and biological reasons, such arguments are considered questionable by the Sea Turtle Specialist Group of the International Union for the Conservation of Nature and Natural Resources

(IUCN) and many other biologists; the alleged conservation benefits do not bear up under close scrutiny (Ehrenfeld, 1974, 1980; Dodd, 1982) and have been deemed by United States courts as insufficient cause to allow the sale of farmed products in United States markets (Anon., 1979, 1982). Nevertheless, the appeal of farming and ranching turtles has found support in the Cayman Islands, Surinam, Reunion and Seychelles in the Indian Ocean, and islands in the Pacific (IUCN, 1971; Dodd, 1982).

We must point out that the potential for increasing hybridization of sea turtle demes has never been a major objection to sea turtle aquaculture. The main objection is that farming and ranching will in all likelihood increase the market for sea turtle products and thus encourage poaching, the exact opposite of what is claimed. Other objections are that it has not been demonstrated that farms can be made independent of wild stocks (Ehrenfeld, 1974), and that compensation for eggs removed from natural nesting grounds through the release of some hatchlings might be an empty gesture owing to mortality of the released animals and their inability to function or eventually breed due to lack of imprinting on their natal beach. Indeed, ranches make no pretense about relying on wild stocks.

Hybridization of farm turtles with turtles in surrounding waters is a distinct possibility from two sources: intentional and unintentional release. The prospect of unintentional release is aggravated by the fact that all turtle farms and ranches fall within the typhoon and hurricane belts of the world where accidental release could occur during these violent storms. Carr (1956) noted that the sea turtles in holding pens of soup-processing plants routinely escaped during hurricanes in the Caribbean. Deliberate release of farmed turtles into Caymanian waters has been allowed by Cayman Turtle Farms (Wood, 1982); since turtles at the Farm were obtained from various localities in the western Atlantic, the potential for hybridization with any remnant green turtle stocks in Cayman, or with migrants in the area, and the effects of such hybridization, is unknown.

Egg or Hatchling Transfer

Hybridization between populations of sea turtles that normally do not interbreed could result from another technique that has been used as a conservation device. This is the practice of transporting eggs or hatchlings from a productive nesting beach, such as at Tortuguero, Costa Rica, to a second beach where turtles once nested or where nesting is presently reduced. Based on the theory that hatchlings would somehow imprint to the new beach and return to nest when they reached sexual maturity, the hope is that the new beach would be recolonized. Such was the premise behind Operation Green Turtle in the 1960s, when thousands of eggs and hatchlings of green turtles were sent to beaches throughout the Caribbean (Carr, 1979).

Under certain circumstances, this procedure appears justifiable as an experimental tool, the best example being that of the United States and Mexican governments' attempts to establish a second nesting population of Kemp's ridley at Padre Island, Texas (Anon., 1978). Under other circumstances, such as Operation Green Turtle, however, such movements and their resulting success could lead to interbreeding between populations, perhaps in the long run to the detriment of the population in need of conservation. Admittedly, it is possible that there would be no detrimental impact from human-induced hybridization, but the potential would indicate that such schemes should be thoroughly evaluated for genetic consequences and other options explored.

Owing to the urgent need for sound turtle management procedures, it is perhaps unwise to disregard translocation of turtles as a recovery technique without a closer examination of the risk associated with it. Defining the risk as the probability of interbreeding by genetically distinct groups of turtles, what biological factors bear on that probability?

1. *Behavior of the wild-caught sea turtles released far from their point of capture.* Owing to the strong homing instinct of these animals and the navigational acuity they appear to show (Carr et al., 1978), it is possible that a released wild-caught turtle would leave the area of its release and return to its home waters, thus nullifying the risk of interbreeding with local animals. However, the possibility needs testing. Are the drive and ability to navigate affected by distance and by factors that the turtles are subjected to in captivity? What are the age-specific and sex-specific characteristics of navigation? Would, for example, the aggressive breeding behavior of male turtles override their homing drive if they were released among local females during the breeding season?

2. *Behavior of captive-bred turtles released to the wild.* The uncertainties surrounding this subject are manifold. There are indications that hatchling turtles may be imprinted by conditions at the native shore and that the imprints are crucial to later migratory success (Frick, 1976). In the absence of such cues, how will captive-bred turtles respond upon being released? Theory suggests one scenario. Owing to the absence of imprinted information, mortality in released captive-bred animals may be higher than that in released wild-caught turtles. If the captive-bred turtles are progeny of parents from separate demes, then heritable survival information may be lacking as well, and this would put the released animals at still more of a disadvantage. Thus, hybridization may not be a serious factor to be contended with, since these turtles may have a much decreased chance

of surviving and breeding successfully. However, captive-raised turtles at Cayman Turtle Farm appear to mate successfully, although at low rates of fertility, and it is unlikely that captive-bred turtles would not attempt to mate with wild turtles should the opportunity arise; hybridization with local populations remains a possibility with unknown consequences.

3. *Population ecology of sea turtles.* A reasonable understanding of sea turtle population ecology would greatly facilitate evaluation of the risk of hybridization. The subject is still in early stages of development, owing in large part to the overwhelming logistical problems the marine turtle student must face. In spite of the lack of much population ecology data, however, data from life history studies suggest that the effects of hybridization may be lessened on a population-wide scale. Specifically, sea turtles have low survivorship to maturity, perhaps 1% or less (Hirth and Schaffer, 1974), and maturation rates may be exceedingly slow. Thus, deleterious effects of hybridization, if they occur in a relatively large population, may have little influence owing to the normal small chance of survival of a particular hatchling coupled with any selective disadvantages caused by the hybridization.

4. *The behavior of hatchlings from transplanted eggs.* The above topics may be most germane to the situation in which turtles are released from farms or ranches. If done with great care, the hatching rate of transplanted eggs has been shown to be quite high. There is no known biological reason why the young animals produced by this method should not successfully recolonize the intended habitat, provided imprinting is a reality and provided enough eggs can be transplanted to overcome the high natural mortality rate of the hatchlings. Accordingly, there seems to be a high probability that transplants will eventually interbreed with whatever endemic turtles might occur in the transplanted habitat.

Despite our incomplete knowledge of sea turtle biology, it is obvious that there are certain circumstances under which hybridization would not attend translocation. One is the case in which the local population of the species is known to be extinct, such as the green turtle colony of Bermuda. Another is illustrated by the joint Mexico–United States translocation and head-starting program for the critically endangered Kemp's ridley (Anon., 1978). As late as 1947, 40,000 ridleys nested at one time on the Rancho Nuevo beach on the Gulf coast of Mexico. Today, only about 450 females come onshore in an entire season. The population crash is attributed to decades of relentless local killing and egg taking, combined with mortality in shrimp trawls in the Gulf of Mexico where shrimping has boomed since the 1940s. In the interagency Rancho Nuevo project an effort is being made to establish a colony on a beach on Padre Island, Texas. Because there is only one breeding population of the Kemp's ridley, even if the Texas transplants mature and breed with the Rancho Nuevo colony there is no genetic risk; they are obviously of the same genetic population.

Management and Hybridization Potential

Of equal importance to sound biological bases for carrying out or not carrying out particular wildlife management projects is a clear rationale for the particular management option decided upon. In choosing options, there are at least three reasons why programs that may increase the chances of hybridization of local wild populations of sea turtles should be avoided.

First, we know that natural selection through time produces individuals that are adapted for the habitat and local conditions in which they are found. In ways that may be very subtle, hybrid turtles might be at a biological disadvantage, since they possess traits from parents who came from other environmental conditions. In other words, the hybrids may have reduced fitness. Two examples might illustrate this.

In green turtles, one population that shows phenotypic and behavioral differences from most mainland colonies is the nesting assemblage at Ascension Island in the central equatorial Atlantic. A tag-and-recapture program there has revealed that the animals nesting on the tiny island come entirely from feeding grounds off the coast of Brazil, 1600 km away (Koch et al., 1968). The Ascension Island turtles are very large. Weights of over 225 kg are common in nesting adults, whereas females of 112.5 to 135 kg are more characteristic of other Atlantic colonies of greens. One possible reason for this difference is that the greater energy requirements for the 3200-km round-trip breeding migration explain the great bulk of the island turtle's population. Perhaps the advantage of this is that large size provides a favorable relation between drag and fuel storage space for the long migratory journey. If this characteristic is genetically determined, then hybridization of the Ascension turtles with any other green turtle deme would likely produce smaller progeny, and thus reduce capacity to use Ascension Island as a nesting site. Hybridization would tend to undo the work of natural selection, reducing the survival capacity of the progeny.

Another example involves hatchlings. When young turtles hatch, they characteristically move quickly down the beach and swim rapidly out to sea for a period of days in what is termed a swimming frenzy on their way to wherever baby turtles go during the "lost year." Presumably the amount of yolk to sustain the swimming and its duration are genetically determined. If populations of turtles are then adapted to the particular environmental conditions off their natal beaches such that they may reach appropriate developmental habitat, hybridization between demes with different environmental conditions offshore could produce hatchlings unable to reach appropriate habitat. Thus, hybrids might not swim long enough or have enough yolk to sustain them, or they might swim too far and eventually be caught in currents that take them far from the area.

A second objection to hybridization is an intellectual one. As we have pointed out, much remains to be learned about the biology of sea turtles. If widespread hybridization occurred, their systematic relationships and perhaps other aspects of their biology would be hopelessly confused. Similar systematic confusion has already resulted during studies of the biology of certain salamander and fish species due to introductions by fishermen who use them as bait.

A final category of objection involves ethical considerations. Ethical and moral arguments involve nonutilitarian reasons for saving species and prevention of excessive exploitation and habitat destruction. These arguments state that species, including demes in the context of the present discussion, have a right to exist and continue to evolve, and that mankind does not have the right to destroy them through hybridization or any other means.

Admittedly, the ethical arguments are tested when the threatened species is not an easily defined and differentiated one, but consists instead of a number of disjunct but biologically unique populations found throughout the world. They are tested again when the effect of the hybridization is not the immediate disappearance of the species or deme but an alteration of its genome. Even in this case, however, the original biologic entity is lost, and if humans are responsible for the loss, then, morally, humanity has erred and lost a wonderful treasure. Unfortunately, there is no space here for an exhaustive analysis of this ethic, and no doubt it is seen differently by different people. Excellent discussions on this topic can be found in Ehrenfeld (1976) and Ehrlich and Ehrlich (1981).

Conclusion

Because of the threats imposed by hybridization, translocation of eggs or hatchlings to effect sea turtle recovery can be recommended only *in extremis* where the species or population is locally extinct or so reduced as to make the risk of adverse effects of genetic contamination seem justifiable after careful weighing of all other options. Fortunately, very few turtle populations are so depleted as to invite translocations. Owing to a wide variety of arguments, including hybridization threats, farming or ranching cannot be justified as management options in sea turtle conservation. The most appropriate and biologically sound course for their conservation remains to close existing markets and prevent new markets from becoming established, to protect nesting, feeding, migratory, and developmental habitat, and to promote the use of trawls that will exclude turtles.

While interspecific hybridization appears rare in sea turtles, the localized breeding patterns, nest site fixity, and population movements of a number of species indicate that most populations are organized into discrete reproductive units or demes. Preliminary electrophoretic data tend to confirm this assumption. Therefore, wildlife managers are faced with a complicated task, which requires protection of each individual breeding population. A wide variety of management options are available, most of which are sound biologically and will not promote hybridization between adjacent demes.

Intraspecific hybridization is considered much more of a threat than interspecific hybridization to these endangered species. Management options should be thoroughly reviewed to determine their potential for promoting hybridization, and those programs in which it might occur should be eliminated or considered only as last-resort projects.

The two most common management practices that might promote intraspecific hybridization are the setting up of sea turtle farms or ranches, ostensibly to reduce commercial pressure on wild populations, and the translocation of eggs or hatchlings to beaches where populations are much depleted or extirpated, ostensibly to restore the viability of the populations. Hybridization with local stocks could result from the accidental or deliberate release of hatchlings from farms or ranches, as well as the interbreeding of translocated individuals with local turtles.

Threats from hybridization would tend to be minimized by the tendency of suddenly released captives to home or by the captive-raised individuals' inability to complete fertilization with wild turtles in a natural environment. Even if successful breeding and hatching occurred, the probable low survival rate of the hatchlings would further tend to minimize deleterious effects on the population as a whole, at least in large populations.

On the other hand, if carried out on a widespread scale, interspecific hybridization could disrupt local gene pools, producing offspring ill-adapted to survive in a particular developmental habitat, and thus further stress a declining population. Objections to schemes that might promote hybridization also involve scientific arguments that it may lessen capability to understand the biology and systematics of various populations, and ethical arguments concerning whether it is right or wrong to artificially disrupt a functioning, adapted gene pool. Our lack of understanding of sea turtle natural history and population genetics makes it difficult to predict what the results of hybridization will be.

It is recommended, however, that sea turtle farming or ranching not be viewed as a viable management option and that translocation, at least partly because of hybridization potential, be considered only after all other management options have been carefully considered.

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