From Ghosts to Key Species: Restoring Sea Turtle Populations to Fulfill their Ecological Roles

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"*What they all overlook is the fact that they came to know Chelonia long after it had been cut down to a mere trace of its primitive abundance. They either hunt it today in the few places where schools hold out, or they take the trickle of waifs and stragglers that still faintly outline the old great feeding range of the species. The young men of today catch about as many turtles in a season as their fathers did, and so see no cause for alarm. What they do not know, though, is that the scattering of schooners and canoes that hunt Chelonia in the 1900s is picking about among the ruins of the great turtle fishery of the centuries before. But that is what it is doing. The documentation is voluminous and clear.*"
Archie Carr (1955: 241-242).

When Archie Carr (1955) wrote of the "passing of the fleet" in *The Windward Road*, he recognized the phenomenon of the "shifting baseline syndrome" four decades before Pauly (1995) introduced the phrase and before the concept was emphasized in the ecological and conservation literature (Dayton *et al.* 1998; Jackson 2001; Pauly 1995; Sheppard 1995). Referring to fisheries management, Pauly (1995) described the "shifting baseline syndrome" as the tendency of scientists to use population levels at the beginning of their careers as the baseline against which to measure population change. He stressed the importance of incorporating historical anecdotes of abundance into population models. Identifying the proper perspective, or a reliable baseline, against which to assess trends in sea turtle populations is a challenge because populations were already greatly reduced or extirpated before they were recorded or quantified. Many sea turtle populations of today are ghosts (sensu Dayton *et al*. 1998) of past populations. For sea turtle conservation to succeed, the shifting baseline syndrome must be avoided when population trends are evaluated and recovery goals are set. In this essay, we discuss a framework for assessing sea turtle population trends and setting recovery goals based on sea turtles fulfilling their ecological roles (Figure 1).

Upward trends in some sea turtle populations, such as Kemp's ridleys (Márquez *et al.* 1999) and green turtles nesting at Tortuguero, Costa Rica (Bjorndal *et al.* 1999), have been celebrated, and rightly so. But these increases must be viewed in perspective—they must be evaluated with the proper baselines. For Kemp's ridleys, the 40,000 nesting females estimated from a film made on 18 June 1947 at Rancho Nuevo, México, has been used as a baseline. We should all be grateful to the persistence of Andrés Herrera in making the film and to Henry Hildebrand for rediscovering it (Hildebrand 1963). But Hildebrand (1963) reported intense commercial exploitation of eggs from the colony in 1961. What was the extent of this egg exploitation before the 1947 film, and what were the population levels of Kemp's ridleys before exploitation by humans began? These pre-exploitation population levels might have been even higher than the 1947 population, requiring a higher baseline, and further influencing how the current upward population trend is perceived.

What baseline should we use for the Tortuguero population? We know that the Tortuguero rookery has been heavily exploited since at least the 1500's (Parsons 1962). In the 1830's Cayman turtlers went to Miskito Cays (the major foraging grounds for the Tortuguero rookery), having destroyed the green turtle populations in the Cayman Islands by 1790 and in the waters of south Cuba by 1830 (Lewis 1940; Smith 2000; Williams 1970). By 1890, concerns were expressed over growing scarcity of turtles in the Miskito Cays (Hirst 1910). Duerden, in his 1901 review of the marine resources of the British West Indies, called for artificial hatching and rearing of green turtles and hawksbills under the supervision of the Government of Jamaica (the Caymans were part of the territory of Jamaica) because of "the diminution in the supply which is now being felt" in the Miskito Cays (Duerden 1901). In 1889, a formal complaint from the Governor of Jamaica was forwarded to the Government of Costa Rica protesting the indiscriminate slaughter (for calipee) of green turtles nesting at Tortuguero because of its effect on the turtle populations in the Miskito Cays (Hirst 1910). The current green turtle population in the Caribbean is estimated to represent 3-7% of the pre-human green turtle populations (Jackson *et al.* 2001). Of course, not all of those green turtles nested at Tortuguero, but undoubtedly the Tortuguero population was affected by the massive decline over the past centuries. Could Tortuguero Beach support a nesting population 20 times greater than that of today? Research now underway on density-dependent effects and carrying capacity of Tortuguero Beach for green turtles may provide an answer (Tiwari, Bjorndal & Bolten, unpubl. data) and may put the recent upward population trend in a different perspective. Both the Kemp's ridley and green turtle examples illustrate the importance of establishing appropriate baselines for evaluation of population trends.

The World Conservation Union (IUCN) has set 10 years or three generations before present (whichever is longer) as the baseline against which to assess population trends in evaluating the status of species for their Red List (Hilton-Taylor 2000; IUCN 2001). This arbitrary assignment of three generations for sea turtles exemplifies the trap of the shifting baseline syndrome. In the recent status assessment of green turtles conducted by the Marine Turtle Specialist Group at the request of IUCN (Seminoff 2002), the range of generation times for green turtles in the Atlantic was estimated as 35.5 to 45.5 years. Three generations would range from 106.5 to 136.5 years. Atlantic green turtle populations in 1865 to 1895 would therefore be the assigned baseline under IUCN guidelines. Clearly, by 1865-1895, Atlantic green turtle populations had already suffered catastrophic declines. In addition to the over-exploitation of the Tortuguero green turtle rookery (documented in the previous paragraph), green turtle nesting populations had disappeared from a number of sites including

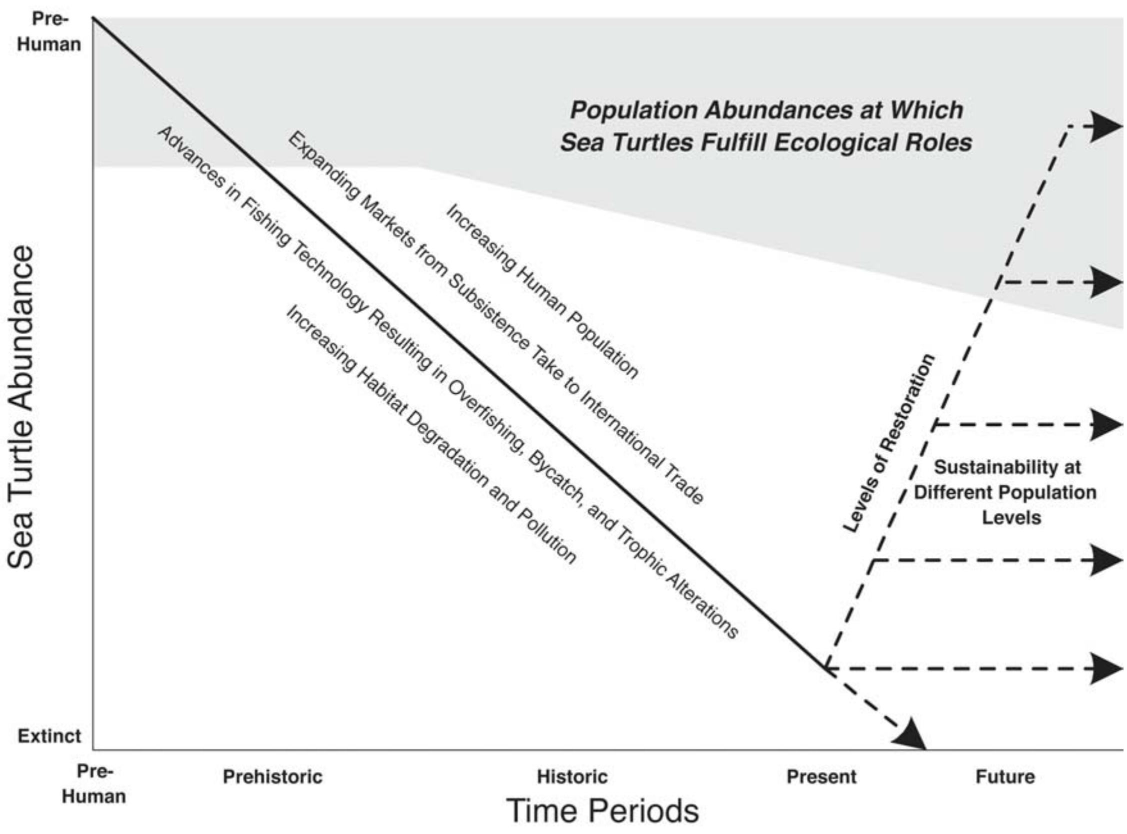

Figure 1. Diagram of the decline in sea turtle abundance from pre-human times to the present with potential trajectories for the future. Some of the causes for sea turtle declines are presented along the downward slope. The population declines are represented by a straight line although the declines for different species certainly followed different trajectories. This schematic illustrates 3 scenarios for the future: (1) if nothing is done to sustain the present levels of abundance, the populations will go extinct; (2) populations can be sustained at their present state (for many, ghosts of past populations); and (3) populations can be restored and sustained at various population levels. We propose that the goal should be to restore sea turtle populations to levels at which they fulfill their ecological roles (shaded area), a goal that would promote ecosystem recovery as well. The shaded area increases with time because, with habitat degradation, the number of sea turtles required to fulfill ecological roles may decrease. This schematic was inspired by those of Pitcher & Pauly (1998) and Pitcher (2001).

Bermuda and Cayman Islands (Parsons 1962), the Isle of Savona off the coast of Hispaniola, as well as on the west coast of mainland Hispaniola (Esquemeling 1684), and St. Helena (Ashmole & Ashmole 1997). In a recent review of coastal marine ecosystems in seven countries in the western Atlantic (Bahamas, Belize, Bermuda, Cayman Islands, Jamaica, Panama [Caribbean coast], and Virgin Islands), green turtles were described as depleted, rare, or ecologically extinct at all seven areas by 1865-1895 (Pandolfi *et al.*, in review). The 3-generation baseline of IUCN is equally inappropriate for green turtles in other geographic regions and for other sea turtle species.

The appropriate baselines against which to assess population trends are the earliest estimates of past sea turtle populations that can be derived with a reasonable degree of confidence. In many cases these estimates would significantly predate the 3-generation limit set by IUCN. Prehistoric and historic evidence can help reconstruct the abundances of pre-exploitation sea turtle populations. Prehistoric evidence-such as evaluation of middens left by prehistoric peoples (Frazier 2003; Steadman & Stokes 2002; Wing 2001)-has demonstrated that sea turtle populations came under substantial levels of exploitation and some rookeries may have been lost as a result (Carlson 1999; O'Day 2001). Thus, when Columbus first arrived in the Caribbean in 1492, sea turtle populations had already been depleted to an extent often not realized by sea turtle biologists today. Historic accounts even more clearly record the over-exploitation and rapid decline of sea turtle populations (King 1982; Parsons 1962, 1972; Ross 1982) as human populations grew and technological advances increased the efficiency of exploitation of marine resources and degradation of marine habitats. Traditional environmental knowledge and local environmental knowledge may also contribute valuable information for the reconstruction of historic sea turtle populations. In addition to reconstructions based on prehistoric and historic evidence, models of ecosystem function and estimates of carrying capacity can be used to generate baseline estimates of past abundance.

The population levels set as baselines for assessing population trends, however, may be inappropriate recovery goals. The degraded marine habitats and altered food webs of today may be unable to sustain sea turtle populations at pre-human levels. For example, the reduction in area of healthy coral reef habitats (Hughes 1994; Jackson 2001; Jackson *et al.* 2001) unfortunately means that fewer hawksbills are now needed to fulfill their roles as major predators and arbitrators in the competition for space on coral reefs (León & Bjorndal 2002). This decrease in the number of sea turtles required to fulfill their ecological roles is illustrated by the decline over time of the lower boundary of the shaded area in Fig. 1. So, if the natural, pre-human-exploitation levels of sea turtle populations cannot be sustained today, how should recovery goals be selected?

We believe that all individuals concerned with the status of sea turtles would agree that sustainable sea turtle populations are the goal of conservation and management efforts, with sustainability defined as "a characteristic of a process or state that can be maintained indefinitely" (IUCN/UNEP/WWF 1991). The debate over management of sea turtles centers on the level at which sea turtle populations should be sustained-or the recovery goal-and the probability that populations can be sustained "indefinitely" at those various levels of abundance. Recovery goals may range from attempting to sustain the current levels of depleted sea turtle populations, which in some cases would be sustaining ghosts of past populations, to restoring and then sustaining sea turtle populations at some earlier level of abundance (Fig. 1).

Recovery goals should be set to population abundances at which sea turtles can *fulfill ecological roles* unless the remaining habitat is so reduced or degraded that this population level would not be large enough to ensure sufficient genetic diversity to respond to changing selective pressures. An approach for identifying population levels that fulfill ecological roles is reconstruction of past marine ecosystems and quantification of the roles that sea turtles played in those ecosystems. These reconstructions would allow estimation of the abundance of sea turtles necessary to fulfill their ecological roles in the marine ecosystems of today. As stated above, these population levels may be below pre-human levels because of the loss of habitat. (Under certain conditions, such as dramatic trophic shifts to jellyfish-dominated food webs, sea turtle abundance required to fulfill ecological roles could be above pre-human levels.) However, the estimates of pre-human sea turtle population levels generated from prehistoric and historic evidence are essential to provide the proper perspective for evaluating the ecological roles of sea turtles. Because the declines in sea turtle populations were so massive and occurred so long ago, it would be nearly impossible for modern biologists to imagine, and thus assess, the influence of past sea turtle populations on the structure and function of marine ecosystems without the historical perspective. For example, without knowledge of the massive reduction of green turtles in the Caribbean, how could marine biologists realize that the Caribbean *Thalassia* pastures of today, characterized by long blades, extensive epibionts, and detrital-based nutrient cycles, represent a drastically altered state from the short-bladed, low-epibiont pastures of the past, in which grazing by green turtles dominated nutrient cycling?

A great advantage of using *fulfilling ecological roles* as recovery goals is that the focus of management efforts are shifted away from single-species recovery strategies to strategies that recognize the need to restore ecosystem function. Recent collapses of marine ecosystems, resulting in unstable and altered ecosystem states characterized by dramatic shifts in food webs and trophic cascades (Jackson 2001; Pauly *et al.* 1998), are not only the result of recent events, but were initiated hundreds to thousands of years ago, soon after humans began to exploit marine resources (Jackson 1997, 2001; Jackson *et al.* 2001; Pitcher 2001; Pitcher & Pauly 1998). Sea turtles (both carnivores and herbivores) were once key species in marine ecosystems. We use the concept of "key species" in the sense of "species that are important to ecosystem structure and function in whatever form (e.g., biomass, abundance, productivity, or functional role), driving ecosystem process or energy flows" (Piraino *et al.* 2002). The decline in abundance of sea turtles and other megavertebrates initiated the collapse of marine ecosystems in which they lived (Jackson *et al.* 2001; Pandolfi *et al*., in review). Today, the degradation of marine ecosystems has accelerated as a result of continued overfishing, pollution, habitat destruction, and climate change with the result that higher trophic levels have been lost and microbial processes dominate an increasing array of marine habitats (Jackson 2001; Jackson *et al.* 2001; Pauly *et al.* 1998; Pitcher 2001). Just as healthy sea turtle populations require healthy ecosystems, the reverse is also true. Only when ecosystems are restored, can the ecological services and economic benefits that marine ecosystems provide to humans be fully realized (Costanza *et al.* 1997).

Establishing recovery goals on the basis of *fulfilling ecological roles* is achievable. The Marine Turtle Specialist Group has adopted this approach as reflected in its mission statement: "The IUCN/SSC Marine Turtle Specialist Group exists to develop, support, and implement programs which promote the restoration and survival of healthy marine turtle populations that fulfill their ecological roles" (Marine Turtle Specialist Group 1995). Of course, much research is needed before the ecological roles of sea turtles can be defined (Bjorndal in press; Bjorndal & Jackson 2003), but much has already been accomplished and with focused research, much can be accomplished in the near future. We suggest an approach for building models of ecological roles (Bjorndal in press). The basic model is organized on three scales: individual, population, and ecosystem. The interactions among and within these scales may take many forms, but the most common currencies are energy and nutrients. Interactions may be quantified-and the ecological roles of sea turtles defined-by tracing flow of energy and cycling of nutrients within and among the three scales. The model can be expanded to illustrate the major processes occurring at each scale. At the individual level, digestive processing (intake of food, passage of digesta, digestion, and gut morphology) and individual productivity (somatic growth and reproduction) must be quantified. At the population level, population growth is the process of greatest interest, requiring a knowledge of the associated parameters of birth rate and probabilities of survival, immigration and emigration, as well as the effects of density-dependence and intraspecific competition. The complexity of the model increases greatly at the ecosystem level. Here, all interspecific interactions (e.g., predator-prey, competition, parasitism) come into play as well as interactions with the environment. This model is discussed in greater detail and applied to loggerheads in Bjorndal (in press).

Defining the ecological roles of sea turtles would be greatly facilitated by collaborating with programs now underway to reconstruct marine ecosystems. These programs (e.g., see Pitcher 2001) employ a diversity of tools including archaeological and historical data, traditional environmental knowledge, local environmental knowledge, and ecosystem models such as balance-mass models (Ecopath, Ecosim and Ecospace) which are compatible with our modeling approach described above.

We endorse the goal of the Marine Turtle Specialist Group to restore sea turtle populations to levels at which they fulfill their ecological roles (shaded area in Fig. 1) and then to sustain those levels. We believe that these recovery levels have the greatest probability, if not the only chance, of being sustained "indefinitely."

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Hawksbill sea turtle (*Eretmochelys imbricata*) at Layang Layang Atoll, Sabah, Malaysia. © Doug Perrine/seapics.com