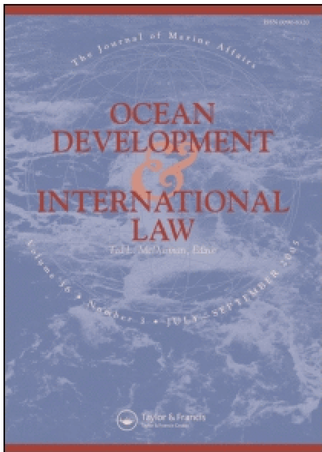

Ocean Development & International Law

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713774325

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Online Publication Date: 01 April 2008

To cite this Article: Dutton, Peter H. and Squires, Dale (2008) 'Reconciling Biodiversity with Fishing: A Holistic Strategy for Pacific Sea Turtle Recovery', Ocean Development & International Law, 39:2, 200 — 222

To link to this article: DOI: 10.1080/00908320802013685
URL: http://dx.doi.org/10.1080/00908320802013685

Ocean Development & International Law, 39:200–222, 2008

ISSN: 0090-8320 print / 1521-0642 online
DOI: 10.1080/00908320802013685

Reconciling Biodiversity with Fishing: A Holistic Strategy for Pacific Sea Turtle Recovery

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Recovery of sea turtle populations requires addressing: multiple sources of mortality; nonmarket, diffuse benefits with costs localized on the poor; and a transboundary resource with incomplete jurisprudence, markets, and institutions. Holistic recovery strategies include: beach conservation protecting nesting females, their eggs, and critical breeding habitat to maximize hatchling production; enhanced at-sea survival of turtles on the high seas and in commercial coastal fisheries; and reduced artisanal coastal fisheries mortality of turtles. The traditional approach of focusing long-term sustained conservation efforts on the nesting beaches has by itself led to increases in several sea turtle populations. However, current conservation is inadequate to reverse declines in other cases such as the critically endangered leatherback populations in the Pacific. This article discusses policy instruments comprising a holistic recovery strategy that reconciles fishing with biodiversity conservation.

Keywords holistic recovery strategy, responsible fishing, sea turtles

Introduction

Nesting beach protection has been the most cost-effective approach in sea turtle conservation over the past three decades and, in many cases, despite the complex life histories of these animals, this approach by itself appears to have stimulated long-term increases in depleted sea turtle populations (Balazs and Chaloupka 2004; Chaloupka et al. 2007; D. L. Dutton et al. 2005; Troëng and Rankin 2004). However, in some cases, this single conservation approach has failed to recover endangered sea turtle populations that also face anthropogenic threats at sea, including: fisheries, illegal harvest, and pollution. Population recovery in these cases is likely to be delayed at best, or even reversed, by a policy that addresses only one of these multifaceted threats and that fails to take a holistic approach by tackling multiple sources of mortality.

Lack of information on population status, biology, and impacts of different threats hinders evaluating management options in a rigorous scientific manner. The decision on which approach to adopt should be evaluated on a case-by-case basis. Given this uncertainty,

Received 12 April 2006; accepted 8 August 2006.
The results presented are not necessarily those of NOAA Fisheries. The authors are grateful for the comments of an anonymous referee.
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there is a need to integrate a broad suite of approaches into a holistic strategy that can be tailored as necessary. In the short run, such a holistic strategy will prevent extinction of populations that are clearly in crisis and, in the long run, will accelerate recovery compared to adopting just a single type of intervention.

Three broad threads woven together lead to this holistic recovery strategy. First, the recovery strategy should address users and sources of anthropogenic mortality where possible over the entire life cycle, migration range, and habitat in the Pacific commons. Second, multilateral cooperative and coordinated conservation efforts among nations and other parties will be required for this transnational resource. Third, a comprehensive conservation framework will be necessary that mixes biological, economic, technological, political, and legal conservation measures.

This article discusses an integrated, multilateral recovery strategy that addresses multiple sources of sea turtle mortality at different life stages in the face of continued fishing by large-scale, small-scale, and artisanal fleets and mortality at the turtle nesting sites themselves. The discussion explores a variety of policy instruments that address the sources of mortality at different life history stages. Also discussed are the roles played by harvesters and consumers of seafood and the creation of economic incentives through market-based and other policy instruments, where practicable, to facilitate recovery, as opposed to command-and-control regulations, laws, and adverse incentives. Positive economic incentives help contribute toward a self-enforcing recovery strategy in a multilateral framework emphasizing cooperation and coordination among players.

This article is organized as follows. The first section discusses the different issues involved, including: sources of mortality, migration and jurisdiction, distribution of costs and benefits, incentives for conservation, fisheries-related conservation, a holistic approach to recovery, and the Kemp's ridley as a case study in bilateral conservation. The second section discusses potential policy instruments. The third section offers concluding remarks.

Issues

Sources of Mortality

There is a triad of primary sources of anthropogenic sea turtle mortality, those centered on nesting grounds, large-scale commercial fishing fleets operating wholly or in part on the high seas, and small-scale and artisanal fishing operating in coastal waters.

Sea turtles and their eggs have been prized worldwide for human consumption. Their oils are used for lubricants and ingredients in cosmetics, and their shells for jewelry and eyeglass frames. Nonetheless, the high mortality of turtles and plunder of their nests by both humans and animals have been and remain a prime cause of population declines (Chaloupka 2003; National Research Council 1990). Encroachment of human populations into coastal habitats further contributes to population declines by degrading nesting beaches. Harvesting of turtles for subsistence or commercial purposes and incidental mortality in commercial and artisanal fishing also diminish sea turtle populations. Considerable uncertainty remains over the status of key stocks and the extent to which bycatch in various fisheries has contributed and continues to contribute to declines in Pacific sea turtles (FAO 2004; Lewison, Freeman, and Crowder 2004). The relative importance of fisheries-related mortality can vary over time. In one of the only comprehensive studies evaluating competing risk factors for sea turtles, Chaloupka (2003) showed that, despite fisheries-related mortality of loggerheads in the southwest Pacific, it was fox predation of eggs on the nesting beaches in the 1960s and 1970s that was the primary cause of decline in the western Australia loggerhead nesting populations. While that threat has been eliminated, fisheries-related mortality is now posing a greater threat to this population. This dynamic approach to risk assessment is made possible by a scientifically rigorous long-term dataset available for this loggerhead stock (Chaloupka 2003). The gaps in information for Pacific populations of leatherbacks introduce a large level of uncertainty into similar efforts to model competing risk factors (i.e., Kaplan 2005).

In general, impacts on nesting beaches tend to threaten all the species in similar ways. Egg harvesting, predation, and nesting habitat destruction have been important sources of mortality for all species of Pacific sea turtles (NMFS and USFWS 1998a–d). Fisheries tend to affect different species of sea turtles to varying degrees as a result of different life histories. Hawksbills appear to be rarely caught in either pelagic fisheries (McCracken 2000; Wetherall et al. 1993) or coastal fisheries (Alfaro-Shigueto et al. 2003; Poiner and Harris 1996; Robins 1995). The main hazard for hawksbills in the marine environment has been commercial harvesting for "bekko" or tortoiseshell (Meylan and Donnelly 1999). Olive ridleys have also been subjected to direct commercial harvest for leather in the Pacific coastal waters of Mexico. This species, however, is also present in pelagic waters and therefore is caught in both pelagic net and longline fisheries and coastal net, line, and trawl fisheries. Green turtles tend to inhabit coastal waters and embayments, so that they are more commonly caught in fisheries that operate in these habitats, and are not typically taken in pelagic longline fisheries. Loggerheads and leatherbacks are the species that pelagic net and longline fisheries most commonly interact with on the high seas, although both these species also occur in coastal waters. This article focuses on the commercial high seas fisheries and therefore is primarily of relevance to conservation of leatherbacks, loggerheads, and olive ridleys in the Pacific. However, also warranting further consideration are the small-scale coastal fisheries that are an important and intractable source of mortality for these and the other species of sea turtles in the Pacific.

Leatherbacks

The catastrophic population decline has been well documented in the Malaysian leatherback population that nested in Terengganu, once one of the largest rookeries in the Pacific, that now is all but extinct (Chan and Liew 1996). For almost 50 years, every egg laid at this beach was harvested and, in the late 1970s, there was a dramatic decline in the number of nesters from several thousand to just two or three annually since the 1990s and only one in 2005. There were attempts to reverse this decline through protection measures (harvest quotas, beach hatcheries), but these measures seem to have been too little, too late. In addition, habitat degradation on the nesting beaches appears to have contributed to the inability of these measures to be effective at increasing hatchling production. The extent that impacts at sea contributed to the Malaysian population collapse is unknown, but clearly the demographic erosion caused by the total harvest of eggs over at least one leatherback generation (9 to 20+ years) would have meant that any take of adults had a relatively larger impact than if there had been a large pool of younger generations to sustain this population.

This may be a pattern that is repeating itself for leatherbacks in the eastern Pacific, although this is not as well documented. The nesting populations in Mexico and Costa Rica have recently collapsed, most likely as a result of a convergence of several factors: mortality caused by the high seas driftnet fisheries of the 1980s; coastal artisanal gillnet fisheries in South America into the 1990s; a long history of intensive egg harvest beginning in the 1970s; killing of females on nesting beaches; and possibly environmental factors that are not yet understood, such as effects of long-term cycles of climate variation (Saba et al. 2007). The taking of eggs has been significantly reduced in Costa Rica and Mexico but, with the breeding population reduced to critically low numbers, the take of any leatherbacks from this breeding stock will have a relatively large negative impact on recovery.

The largest leatherback population that remains in the Pacific occurs in Papua in the western Pacific (P. H. Dutton et al. 2007; FAO 2004). While there is uncertainty over the historic status of this population, data from recent surveys do not indicate that the Papua population has collapsed in the way that the Malaysian and eastern Pacific populations have (Hitipeuw et al. 2007). There is also not as long a history of whole-scale commercial harvest of eggs. There is, however, directed taking of reproductive adults on foraging grounds around Indonesia (Hitipeuw 2006; Suarez and Starbird 1996), feral pig predation, beach erosion, and human subsistence harvest of eggs. Evidence suggests that leatherbacks from these western Pacific stocks migrate to foraging and developmental areas across the North Pacific and off the west coast of North America (Benson et al. in press), and it is these turtles that are caught incidentally in high seas longline and coastal driftnet fisheries (P. H. Dutton et al. 2000, unpublished data). Historic curtailment of large-scale egg harvest and relatively large numbers of nesters create a better opportunity for population recovery and for effective beach conservation (Hitipeuw et al. in press).

Olive Ridleys

The eastern Pacific olive ridley "arribada" populations increased dramatically in the past decade, since closure of the nearshore fishery for olive ridleys in 1990 (M. R. Márquez, Carrasco, and Jiménez 2002). An "arribada" is a mass nesting of turtles that is a characteristic of the ridley species. Prior to that closure, large-scale commercial harvest of eggs and directed commercial take of juveniles and adults for leather were the primary sources of mortality that led to a decline in the nesting populations. The large-scale commercial harvest of turtles occurred entirely in the Mexican exclusive economic zone (EEZ) and appears to have dwarfed other sources of mortality. This fishery appears to have targeted subadults, effectively removing animals from the population before they could breed. The dramatic and rapid recovery of this population following cessation of this mortality probably occurred because there were sufficient hatchlings and juveniles recruiting into the population to allow recovery once this pressure point on a crucial life stage was removed. Illegal harvest of eggs and incidental take in pelagic longline, coastal gillnet, and trawl fisheries throughout Central and South America are the primary sources of mortality. Legal harvest of eggs in Costa Rica at Playa Ostional, carried out by the local community, has been acclaimed as a rare example of biologically rational use.

Loggerheads

In the North Pacific, loggerheads, that nest almost exclusively in Japan, have declined greatly (FAO 2004). Sources of mortality include: human encroachment and egg harvest on nesting beaches; incidental take in coastal fisheries (which take larger juveniles and adults), incidental capture in high seas fisheries all across the North Pacific (longline, driftnet, gillnet), and incidental and directed take in artisanal and small-scale commercial fisheries operating in areas where juvenile feeding aggregations occur off Baja California, Mexico.[1] In the southern hemisphere, the primary nesting beaches occur on the southern Great Barrier Reef, Australia, and this stock has declined greatly over the past 30 years (Chaloupka and Limpus 2001). Sources of mortality include: drowning in Australian otter trawl fisheries, feral fox predation of eggs in the 1960s and 1970s, and incidental capture in longline fisheries operating in the South Pacific (Chaloupka 2003), including in the southeast Pacific (Alfaro-Shigueto et al. 2004; Donoso and Dutton 2006).

Migration and Jurisdiction

Sea turtles are migratory, weaving their way in and out of EEZs of different nations and through the high seas. Their breeding habitat[2] can lie in one nation and their developing and foraging habitat in another nation's waters or in the high seas where this is little or no governance. This creates a transboundary resource and jurisdictional problems because there is no central authority to organize and enforce conservation. Property rights are absent or insufficiently well developed in EEZs and the high seas for this Pacific common resource.[3] As a result of the transboundary and migratory nature of sea turtles, conservation strategies are required to tackle the transboundary issue and avert this Pacific "Tragedy of the Commons." Conservation and recovery limited to unilateral measures by individual nations are likely to fall short of the required conservation level, which instead requires cooperative and multilateral conservation, involving the efforts of multiple nations acting in tandem. Because there is no central authority to organize and enforce conservation in these situations, self-enforcing and voluntary agreements are required (Barrett 2003).

Distribution of Costs and Benefits: Incentives for Conservation

The distribution and nature of costs and benefits of sea turtle conservation contributes to a misalignment of incentives for conservation and recovery. Benefits are largely enjoyed by populations in high-income, developed countries or high-income groups in developing countries. These benefits are predominately non-market economic values, notably existence value and, to a lesser extent, indirect use value.[4] As economic values without markets, the question arises of how to create markets or other mechanisms to express consumer demand for indirect use and nonuse value associated with public goods and common resources.[5] The costs, in contrast, largely fall on lower-income local communities, largely in developing countries, many of which are marginal to their societies and can ill afford to adopt costly conservation measures. These costs are also immediate and tangible through lost incomes and consumption of turtles, turtle eggs, fish, shrimp, and other marine-related resources associated with turtles (i.e., these costs are largely opportunity costs of direct use values forgone).

A potential "free rider" problem also arises with conservation and recovery efforts for this Pacific common resource.[6] Incentives arise to free ride because people cannot be excluded from enjoyment of continued existence even though they do not pay their appropriate fair share. These free rider issues largely arise in the high-income, developed countries or high-income groups in developing countries because existence value increases with income. These free rider problems can be overcome by collective action; by increasing participation in cooperative, multilateral conservation; and by actual compensation from the gainers to the losers or those bearing the costs in the form of side payments for the conservation measures.

Fisheries-Related Conservation

Some attempts have been made to conserve Pacific sea turtles through fisheries management by unilaterally shutting down commercial, large-scale fisheries that typically fish wholly or partly on the high seas. But, with transboundary turtles migrating across EEZs and through the high seas, fish formerly caught in the fishery are likely to be caught by other nations and imported back into the nation with the closed fishery—creating what are called "production and trade leakages"—resulting in little or no net conservation gain for sea turtles. Vessels might also reflag or shift their operations to other fisheries that remain open (also a form of production leakage) and export their fish or shrimp to the market that remains open (a trade leakage). Shutting down all or most longline and gillnet fisheries in the Pacific plugs these production and trade leakages, but this may not come to pass or may require considerable time—time that vulnerable sea turtle populations simply do not have.[7] In this instance, fishing and sea turtle mortality will continue, which then begs the question of the best conservation and recovery approach to take in a world of continued fishing.

In the scenario of continued fishing, the bycatch and mortality of sea turtles in commercial, large-scale fisheries would be reduced as much as possible by adopting appropriate fishing practices and gear technology standards that have been shown to reduce sea turtle mortality, such as the replacement of J-hooks and squid bait by circle hooks and mackerel-type bait in longline swordfish fisheries (FAO 2004; Watson et al. 2003, 2005) and using turtle excluder devices (TEDs) in shrimp fisheries (FAO 2004). Nonetheless, even reduced mortality from commercial, large-scale fishing may be insufficient to induce the recovery of sea turtle populations because there are other important sources of mortality.

The artisanal and small-scale commercial longline and gillnet fisheries of the Pacific remain an important source of mortality at sea for turtles. Many of these fisheries operate close to nesting grounds, foraging areas, or in the migration paths of sea turtles. The extent of sea turtle mortality from these fisheries remains unknown, but the critical role of these fisheries and complexity of this issue are becoming increasingly evident. In some cases, there are opportunities for tangible gains. For example, in Peru, coastal artisanal gillnets are responsible for most of the mortality of leatherbacks in that country and the fishery responsible is confined to one area in the north of Peru, even though there are similar gillnet fisheries along the entire coast (Alfaro-Shigeto et al. 2007). Targeting conservation efforts on this northern fishing community alone would significantly reduce leatherback mortality in the eastern Pacific. In general, however, reducing mortality in these fisheries is likely to prove more complex than in large-scale fisheries or nesting site protection for a number of reasons, including having participants who are frequently among the most disenfranchised and poor in their societies, are geographically dispersed, are often in isolated areas, and are large in numbers. These countries are lower income and developing, and financial resources in many instances are simply unavailable or limited to address this important source of sea turtle mortality. In one rare attempt to address this pressing issue, the Inter-American Tropical Tuna Commission (IATTC) is spearheading changes in technology standards and operating procedures in small-scale commercial longline fisheries in the eastern Pacific Ocean (Hall 2006).

Opportunities for a More Holistic Approach to Recovery

In contrast to the conservation challenges of many marine mammals, such as dolphins or whales, sea turtles offer a unique opportunity to increase population levels through a broad-based recovery strategy that directly addresses mortality on nesting grounds. Rather than a defensive strategy focusing primarily on reducing at-sea mortality from commercial fishery interactions, a recovery strategy can become proactive. The recovery strategy can widen its approach to include measures that directly increase the population and address all sources of mortality throughout all stages of the life cycle in a holistic manner.

The unique life history makes sea turtle populations vulnerable to several sources of mortality at critical stages in their life, which is aggravated by the several decades required to reach sexual maturity for many species. Yet, this unique life history also creates opportunities for conservation that simply do not exist for other marine species, such as whales and dolphins.

Saving the Kemp's Ridley: A Bilateral Case Study

One example of a more comprehensive recovery strategy occurred in the Atlantic with the Kemp's ridley, once the most endangered sea turtle on the planet, which now appears to be on the road to recovery. The Kemp's ridley is unique in that almost all the critical life history stages occur within the territories of two countries, Mexico and the United States; and, hence, the transboundary issues were able to be addressed under a bilateral framework. Nevertheless, there are important lessons from this case given the remarkable rate of recovery that has occurred once a broad suite of measures were put in place.

Mexico and the United States have engaged in a joint program for the recovery of the Kemp's ridley. Mexico initiated conservation efforts in 1966 at Rancho Nuevo, Tamaulipas, the species' primary nesting area; however, the population continued to decline for the next two decades.[8] The bilateral program was established in 1978 and by the late 1980s the decline of the stocks stabilized. Since then, the population has been increasing steadily. It now appears that this early intervention pioneered by scientists at Mexico's Instituto Nacional de Investigaciones Biologicos Pesqueras (INP) was important in preventing the imminent extinction of the Kemp's ridley. However, the recent signs of recovery are generally acknowledged to be the result of the expanded bilateral effort that provided additional resources and a forum to craft and implement a broader recovery strategy. The bilateral conservation programs have focused on the nesting process and have included: beach and nest protection, establishment of additional nesting areas to extend the range and reduce risks, head-starting programs, and implementation of measures to reduce fishing mortality. Much of this collaborative work has been done under a formal bilateral cooperative agreement between the United States' National Marine Fisheries Service (NMFS) and INP, known as MEXUS-Golfo.

The Kemp's ridley program is a success story that has served as a model for sea turtle conservation, providing the framework for a similar approach currently under way with the Pacific leatherback under the MEXUS-Pacifico Cooperative Agreement between NMFS and INP. However, unlike the Kemp's ridley, the leatherback is pelagic and highly migratory and its nesting and foraging habitat encompass the entire ocean basin.[9] The bilateral approach that succeeded for Kemp's ridley may be inadequate to address recovery of the severely depleted leatherback nesting populations in Pacific Mexico.

The leatherback population continues to decline even though mortality of eggs and adult female leatherbacks has been reduced as a result of U.S.-Mexico conservation efforts since 1995. Although progress has been made on protection of nesting populations, current efforts in the Pacific are limited by insufficient financial resources and competing economic interests from land development. In Mexico, people from private and governmental institutions protect nesting leatherbacks and their eggs (Sarti et al. 2007). However, this work is logistically challenging and there is insufficient money to implement a completely effective program, so that at best 45%–50% of the nests are protected each year. In addition, critical nesting habitat suffers encroachment by land development. For instance, in Costa Rica, one of the most important leatherback nesting areas comprises three beaches in Guanacaste. A national park was recently established (Las Baulas) to protect most of this nesting area, but the land (high dune area inland) adjoining the nesting beaches is not protected and the habitat is encroached by development of luxury homes. The Costa Rican government, which is interested in an ambitious program to purchase land, has insufficient funds for implementation. With the eastern Pacific leatherback populations at such critically low numbers, it is unlikely that the present level of beach protection will be sufficient to reverse the population decline.

Economic Incentives and Market-Based Policy Instruments

Economic-based approaches to environmental protection are premised on the idea that it is possible to confront firms, consumers, and governments with the same kinds of incentives they face in markets. Economic incentives guide them to address all costs and benefits from consumption and production, even if not presently captured by market values. Policy decisions can then be viewed as strategic choices that restructure economic incentives to more closely align decentralized private behavior with social goals and, in the international arena, restructure relations among international parties to help shift noncooperative behavior toward the cooperative behavior required for multilateral conservation. Every substantive choice can affect incentives and, thereby, the behavior of the remaining participants.

Market-based approaches replace the adverse incentives currently threatening turtle populations with positive incentives—carrots—that foster conservation and population recovery or negative incentives—sticks—that penalize adverse behavior. The rationale for market-based approaches is to put the powerful and decentralized forces of markets and market-based policy instruments to work in the service to the environment. When markets for biodiversity conservation emerge, a venue develops for increased and direct participation by civil society, such as conservation groups, and a willingness to pay for existence value is realized. Market-based approaches also potentially lower regulatory costs by allowing individual generators of turtle mortality to more closely equate the marginal costs of abatement or conservation among themselves, creating cost-effectiveness. Market-based policy instruments and economic incentives have a critical role to play in both developing and developed countries.

A multilateral agreement on sea turtle conservation should produce for its parties a favorable benefit-cost ratio or else it may either never enter into law or collapse (Barrett 1998). Reducing sea turtle mortality in general, or even achieving a prescribed overall level of mortality, that is cost-effective raises the benefit-cost ratio.

At-Sea Measures: Performance and Technology Standards for Responsible Fishing

Performance standards directly address sea turtle mortality through limiting the incidental take and mortality of sea turtles in fisheries. Prominent international examples of performance standards include limits on dolphin mortality used in the 1998 Agreement on the International Dolphin Conservation Program,[10] caps on emissions of greenhouse gases under the 1997 Kyoto Protocol,[11] and limits on ozone-depleting chemicals under the 1987 Montreal Protocol.[12]

There are two performance standards in international instruments of turtle conservation in the Pacific. The Inter-American Convention for the Conservation and Protection of Sea Turtles prohibits the intentional capture or killing of sea turtles (with exceptions of subsistence takes under specific conditions) (Gibbons-Fly 1999).[13] The Memorandum of Understanding on the Conservation and Management of Marine Turtles and Their Habitats of the Indian Ocean and South-East Asia (IOSEA-MOU) Conservation and

Management Plan includes a provision to "Mitigate Threats and Bycatch," by reducing "the incidental capture and mortality of marine turtles in the course of fishing activities to ensure that any incidental take is sustainable through regulation of fisheries and through development and implementation of measures such as turtle excluder devices (TEDs) and seasonal or spatial closure of waters."[14] The IOSEA-MOU similarly lists a program to "[r]educe to the greatest extent practicable the incidental capture and mortality of marine turtles in the course of fishing activities."[15] The degree of enforcement and compliance ultimately determines the effectiveness of these performance standards.

Performance standards can potentially have compliance requirements through monitoring, verification, and enforcement, both to punish noncompliance and to deter nonparticipation. A free rider problem can arise without effective compliance.

Technology standards refer to mandatory design and equipment requirements, and include operating standards. Important examples of technology standards aimed at reducing the incidental take of sea turtles include TEDs with shrimp trawling and the replacement of J-hooks and squid bait by circle hooks and mackerel-type bait in longline fisheries.

Performance standards with transboundary issues tend to require cooperation among nations, rather than simply coordination of activities (Barrett 2003, 2006). The use of dolphin mortality limits, a performance standard and use right, is implemented through a formal international environmental agreement, the International Dolphin Conservation Program.[16] Technology standards, in contrast, tend to require coordination rather than the more demanding cooperation among nations (Barrett 2003, 2006). Technology standards are thus often easier to implement and obtain compliance than performance standards. For example, with TEDs, a technology standard, nations do not have to actually formally cooperate, particularly through formal and binding multilateral agreements and commissions. Instead, nations can simply adopt TEDs and coordinate their technical designs; in effect, working side-by-side in parallel. Up to some point, a technology standard may induce a positive feedback or strategic complement on either the benefit or cost side so that, as one country does more, another country does more (Barrett 2003).Compliance is often easier to verify because the technology standard can be checked on a routine basis in port, whereas performance standards require ongoing monitoring, perhaps by at-sea observers. International environmental agreements based on performance standards tend to be comparatively narrow but deep and, in contrast, international agreements built on technology standards can be broader but shallower and easier to involve the cooperation of comparatively more nations. With technology standards, a limited group of like-minded nations can start coordination and then expand from this initial grouping. Technology standards can also be more rapidly implemented than formal performance standards.

Mitigation Measures and Conservation Investments

Mitigation measures and conservation investments can make an important contribution to a holistic approach to recovery of turtle populations.[17] This approach is well established in the international arena. The Kyoto Protocol provides allowances for "sinks"—credits for the absorption of carbon dioxide by forests, cropland management, and revegetation (Barrett 2003).The Clean Development Mechanism for the Kyoto Protocol allows an Annex I country to mitigate its emissions by undertaking abatement within a non-Annex I country (Barrett 2003).

The U.S. Endangered Species Act allows for mitigation to counter environmental degradation. For example, timber companies in the southern United States are allowed to purchase timber lands with sufficiently high densities of nesting sites for a listed woodpecker (red-cockaded woodpecker) to satisfy the Endangered Species Act requirements (i.e.. to serve as a mitigation measure, which allows harvests of timber from other lands with lower densities of woodpecker nesting sites) (Heal 2000). The U.S. wetlands mitigation banking (WMB) curtails wetlands loss and encourages protection and rehabilitation of wetlands as a precondition for developing other areas.

Sea turtles provide a unique opportunity for mitigation and conservation investments because they return to nesting sites to lay eggs, thereby providing a focal point for conservation. Conservation investments to protect the turtles, sites, eggs, and hatchlings can serve to actively increase the turtle population beyond that which would otherwise occur in the absence of such conservation policies (Balazs and Chaloupka 2004; D. L. Dutton et al. 2005; P. H. Dutton et al. 2002; Troëng and Rankin 2004). In short depending on the program design, conservation investments, as part of a population recovery program addressing all sources of sea turtle mortality, can aim to create a net increase in turtles even after explicitly accounting for uncertainty.[18]

Conservation investments can be directly established between developing and developed countries, and in fact are critical given the disconnected localized costs in developing countries and fishers and nonmarket benefits concentrated in developed countries. Benefiting those in developing nations, who may bear much of the conservation burden from resource use forgone, is critical (Giordano 2002). Economic incentives for conservation and compensation to communities and subsistence users of sea turtles and their eggs are thus important elements and must not be overlooked.[19]

Conservation investments can stimulate the emergence of environmental entrepreneurs (mitigation bankers) who coordinate and implement these investments (Bishop 2003). Some environmental groups are emerging to fulfill this valuable function. For example, Conservation International is working with The Nature Conservancy and communities in the Solomon Islands to invest in conservation in Solomon Islands sea turtle nesting sites (Gjertsen and Stevenson 2005). These intermediaries may provide higher quality mitigation at lower cost due to economies of scale and specialization. Similarly, regulatory agencies, fishing fleets, and governments may find it easier to oversee fewer contracts and interactions than numerous, separate mitigation projects on isolated nesting grounds. Mitigation measures and conservation banking may help generate significant funds from generators of sea turtle mortality, their governments, or consumers of biodiversity in general and sea turtles in particular.

A number of specific conservation investments for leatherback and loggerhead turtles in the Pacific can yield a net increase in turtles (Polovina and Dutton 2003). These investments for leatherbacks include: hiring villagers to protect nests from predation by feral pigs in Papua (Irian Jaya), Indonesia at Wermon Beach; working with villagers to reduce and eliminate the harpooning of adult females in coastal foraging grounds around the Kei Islands in Papua (Irian Jaya), Indonesia; and eliminating loss of eggs due to dog predation, human harvest, and beach erosion at Papua New Guinea nesting beaches. Further measures for loggerhead turtles include mortality reduction workshops with fishers and placing observers on local boats to ensure that all the live loggerheads caught in halibut gillnets are returned to the ocean in Baja California, Mexico, and nest relocation to improve hatch success at two nesting beaches in Japan (Polovina and Dutton 2003).

Conservation Funds

An endowed conservation trust fund for sea turtles would be analogous to the Multilateral Fund, the Global Conservation Fund sponsored by the Moore Foundation, Clean Development Administration, or the Global Environmental Facility. Such a fund could be financed by contributions from large-scale commercial fishing fleets, their governments, environmental groups, foundations, and other parties interested in biodiversity conservation in general and sea turtles in particular. Such a fund could finance conservation investments or adoption of technology standards in developing countries.

Taxes or Fees Levied on Producers and Consumers

Taxes, fees, or charges can be levied on swordfish or shrimp landings, on the basis of sea turtle mortality, or on consumption of swordfish or shrimp. These Pigovian taxes or fees can be levied either unilaterally on domestic producers or consumers or multilaterally through an existing or future international agreement.

Taxes or fees levied on the swordfish or shrimp landings of producers or on consumers of these catches, when these seafood products are caught with sea turtle interactions, can potentially yield several dividends. The first dividend is the reduction in sea turtle mortality. The second dividend is the revenue raised to finance sea turtle conservation investments and population recovery.[20] There is an equity argument in favor of fees in that the users of the globe's resources—the producers who initially exploit the resources and environment and the consumers who consume the final products—should bear the costs and compensate the public for their use. As a market-based policy instrument, Pigovian taxes provide economic incentives for conservation and have the potential to be cost-effective because those producers paying the tax are able to balance their costs of compliance at the margin (the equimarginal principle). Equity and effectiveness of conservation are both enhanced by taxes or fees established in a multilateral framework that recognizes the transboundary nature of sea turtles and the ability and willingness to pay from developed and developing countries.

In principle, a tax or fee can be levied on the number of sea turtle interactions or on sea turtle mortality (i.e., on a measure of the external cost). Ideally, the tax or fee sums up to the economic value of the expected mortality from the accumulation of sea turtle mortality of adults and subadults. Vessels that can reduce their sea turtle interactions inexpensively will invest in doing so because each interaction reduced or reductions in turtle mortality is that much less paid in taxes or fees. Vessels that find it expensive to reduce their sea turtle interactions will continue to interact and pay the taxes. A similar tax was levied on the production of chlorofluorocarbons (CFCs) during the mandatory phaseout under the Montreal Protocol, creating a hybrid system under which a phased decline in CFC production was augmented by a pollution tax (Portney 2003).

Such a tax on at-sea takes or mortality of sea turtles would be difficult to implement without direct observer coverage. Instead, a tax on swordfish or shrimp landings is a more practical way to incorporate the full external costs of swordfish and shrimp production from sea turtle mortality into the seafood price. This tax could be determined from the estimated take and mortality rates of sea turtles given the reported amount of target species catch. An analogous situation occurred with the transferable permit system that accomplished the U.S. phaseout of leaded gasoline. Stavins (1998, p. 487) observes, "The currency of that system was not lead oxide emission from motor vehicles, but the lead content of gasoline." The turtle currency would be shrimp or swordfish landings.

Fees Versus Subsidies

A direct subsidy or tax break to swordfish or shrimp producers can also lower interaction rates with, and mortality of, sea turtles (an external cost) by subsidizing adoption of a technology standard. A technology standard or new technology can generate external benefits, justifying a subsidy, since reduced turtle mortality makes available more nonmarket benefits available to all. Such a "good" subsidy can be effective in adopting new technology or altering fishing practices. Payments can even be made to harvesters to stop catching swordfish or shrimp (i.e., through vessel buybacks or switching to longline tuna through deeper sets). However, a subsidy from the public sector to producers for an external cost of sea turtle mortality raises the issue of whether the "polluter" or the damaged party pays. The Coase theorem states that it does not matter in principle, but in practice establishing the property rights among the parties involved can be critical. Another potential problem with subsidies for adoption of a technology standard is that they can unintentionally counter reductions in sea turtle mortality or perhaps even increase mortality by lowering the costs of fishing (creating a "moral hazard" problem). However, in developing countries, poverty in coastal communities and lack of government resources for enforcement may override such a concern (Alfaro-Shigueto et al. 2004).

The research required to develop a new technology standard can be considered a public good. Research to develop a new technology, such as a technology standard that lowers turtle mortality (TEDs or circle hooks with mackerel-type bait) can legitimately be considered a public good and therefore financed by the public sector since the benefits accrue to all. Without subsidies for research or finance by the public sector, there are often insufficient incentives for individuals to conduct this research because the investors do not capture the full benefits of their investment and there are substantial incentives for free riding. Public finance or subsidization of research for a new technology standard that reduces sea turtle mortality is also a way to capture the intangible benefits the public enjoys from the existence of sea turtles, which otherwise do not have a means of expression through markets.

Transferable Turtle Mortality Limits as a Use or Property Right

Performance standards can be strengthened to form use or property rights. Strengthening the characteristics of use or property rights, most notably exclusive use, but also transferability, duration, and divisibility, leads to a stronger property or use right. These rights can be private or held collectively. Dolphin mortality limits, established through the International Dolphin Conservation Agreement, are a form of private use right for individual vessels since they allow individual vessels exclusive use for a single year, are not transferable, and ownership is retained by the IATTC.[21] Marketable emission permits, such as those in the Kyoto Protocol, are a private property right since they contain the stronger characteristics of ownership by individuals or groups, exclusive use, transferability, divisibility into smaller or larger units, and long duration. Transferability allows a market for biodiversity conservation to emerge and opens the possibility of purchase by conservationists, where the market price would now include non-market existence value. Rights-based at-sea conservation of sea turtles may be hampered by the paucity of international agreements and observers providing a legal basis with a transboundary resource and monitoring, enforcement, and compliance. Most critically, a "turtle mortality limit" (TML) that is individually held as a use right faces the problem that turtle interactions are often rare events and the overall TML for a depleted population may easily be insufficient in numbers to assign even one right to take a turtle to each vessel (Segerson 2006). Under these circumstances, group use rights may be preferred.

Voluntary Agreements Within EEZs

Because protective measures can be costly, fishers interacting with sea turtles may not undertake them unilaterally or voluntarily, particularly under conditions of open access. However, a growing literature in the field of environmental economics suggests that voluntary approaches to environmental protection can be effective under certain conditions even when protective measures are costly (Segerson and Miceli 1998). Incentives for voluntary protection can exist, for example, when governments threaten to impose more costly command-and-control regulatory actions or protective measures if voluntary approaches are not successful in meeting protection targets.

Vessel owners, for example, can voluntarily enact time and area closures for shallow-set longline fishing. The Hawaiian pelagic longline fishery for swordfish, which is currently regulated by separate overall caps on loggerhead and leatherback takes and mortality, faces a race to catch swordfish by individual vessels before the caps are reached and the fishery shut down. Such a race to fish creates adverse incentives that do not lead to the optimum combination of times and areas to catch swordfish while also conserving turtles. A voluntary agreement among vessels in the fishery would effectively create a common use right with effective management for the group and allow fishers to coordinate fishing and even allow payments from some vessels to others less effective at avoiding sea turtle interactions for their right to catch swordfish and implicitly their right to interact with turtles. The use of voluntary agreements would also help address the problem of rare events for turtle interactions and the insufficient number of turtles for a rights-based approach based on TMLs. Voluntary agreements can even be enforced by binding contracts among participating fishers and the use of at-sea observers.

Ecolabeling and Environmental Product Certification

Ecolabeling or environmental product certification offers a way to provide economic incentives to adopt technology or even production standards. At a minimum, they certify turtle friendly standards defined as adoption of technology standards such as mortality reduction measures, or more strongly, participation in verifiable observation of the entire fleet. Such certification also guides consumers to make ecologically responsible decisions on seafood and thereby help convey consumer preferences to markets and from there to the fishing and processing sector.

Direct and Indirect Conservation Payments

Direct conservation payments to communities can potentially provide a critical contribution to turtle conservation. Direct payments can target nest protection, land purchases, leases, easements, and financial incentives such as performance payments. Sellers deliver conservation outcomes in exchange for a negotiated payment in cash or kind. Payments are conditional on conservation outcomes (Rice 2000). These payments can be crafted as multiyear conservation agreements in the form of contracts to local communities encompassing nesting site and critical habitat in general.

Indirect conservation payments are also suitable in some circumstances and provide conservation incentives. They find income-generating activities that are not only environmentally benign, but actually promote conservation. Ecotourism is a well-known possibility (Gjertsen and Stevenson 2005). Alternatively, community members may receive wages as patrollers on nesting beaches, thereby generating a tangible economic benefit from turtle protection, as in Jamursba Medi, Papua, Indonesia in a World Wildlife Fund project (Hitipeuw 2005). These direct and indirect conservation payments can be coupled with performance and technology standards and other conservation methods in a holistic conservation strategy. Direct or indirect conservation payments can occur as side payments from developed to developing nations in the context of an international environmental agreement or through voluntary, but collective, mitigation programs.

One example of direct payments for leatherback turtle conservation occurs in Rendova, Solomon Islands (Gjertsen and Stevenson 2005). The participating villages each have a turtle monitor, a villager chosen by the project manager. An incentive program induces villagers to bring the turtle monitor to a nesting leatherback with the incentive being payments to both individuals and the community. Additional funds are paid if the nest successfully hatches. Such direct conservation payments helps to close the gap between external benefits enjoyed by society and the otherwise lower private benefits realized by private players.

International Agreements

The holistic strategy for recovery of sea turtles faces the transboundary nature of sea turtles and their encounter with a gauntlet of transnational fisheries in the EEZs of multiple countries and on the high seas. That is, the holistic strategy must address the transnational externality arising with shared resources in which the outcome that any one country can realize depends not only on its own actions, but also on what others do (Barrett 2003, 2005).

Traditional concepts of international law did not require states to cooperate to conserve marine resources. The principle of the freedom of the high seas has long been a basic tenet of international law. While the 1982 United Nations Convention on the Law of the Sea (UNCLOS) continues to recognize the right of all states for their vessels to exploit resources on the high seas, this is subject to qualification of the duty of conservation. All states must take or cooperate with other states in taking conservation measures for their respective nationals as may be necessary for the conservation of living marine resources of the high seas.[22] The 1995 United Nations Fish Stocks Agreement has gone further requiring states to cooperate through regional fisheries management organizations. Free riding is nonetheless a very real possibility when states benefit from the cooperation of others that conserves living marine resources, but themselves do not undertake conservation measures.

In some instances, unilateral policies may suffice for population recovery. In other instances, where the locus of turtle conservation resides within the EEZ or EEZs of the one or two parties, bilateral agreements or coordinated policies between two nations are sufficient to ensure recovery of a sea turtle population. Bilateral agreements are easier to develop than multilateral agreements due to lower numbers and the necessity that participation by both is needed to sustain a mutually satisfying outcome and nonparticipation by one country is far easier to deter (Barrett 2003).In many instances, however, population recovery may require, or be accelerated by, cooperation among multiple nations in a self-enforcing multilateral agreement, such as the Inter-American Convention for the Conservation and Protection of Sea Turtles.[23] Such a binding multilateral agreement needs to be self-enforcing because there is no third party to enforce agreements due to the constraint imposed by national sovereignty, even though the agreement is binding under international law (Barrett 2003, 2005). Success is dependent on the political will of the parties involved.

In some instances, nonbinding agreements may be all that is possible, including coordination among nations in a memorandum of understanding (MOU), such as the IOSEA-MOU[24] or the MOU under negotiation for the South Pacific. In other situations, informal coordinated or harmonic behavior is more appropriate, such as the development and use of circle hooks for pelagic longline fishing between the United States and Japan, where interests align or the coordinated efforts between the IATTC and Latin American nations where there is more direct and coordinated behavior.

Coordinated or harmonic behavior can be very effective with technology standards, as discussed above. Because it is nonbinding and does not require ratification by member parties to enter into force, behavior can be quickly organized, which is critical for endangered populations. Coordinated behavior can also more easily be narrowed to those parties with a genuine interest, helping to sidestep the potential problem of "broad but shallow" agreements that can arise with larger numbers of participants, especially in formal multilateral cooperative agreements (Barrett 2003; Victor 2006).[25] Nonbinding agreements (such as MOUs) that coordinate behavior also allow inclusion of a broad swathe of states into loosely coordinated behavior and norms. Nonbinding agreements may also outperform binding agreements, and can be more flexible and less prone to raise concerns about noncompliance, thereby allowing governments to adopt ambitious targets and far-ranging commitments (Victor 2006). Binding cooperative agreements can always build off of coordinated or even harmonic behavior and "soft law" since the nonbinding instruments allow for a process through which governments commit to more ambitious courses of action as they learn what works (Skærseth, Stokke, and Wettestad 2006; Victor 2006).

Success requires that a self-enforcing treaty ensure that every party is better off with the program than without it but, to succeed, the program also needs to ensure that each party would lose by not participating (Barrett 2003, 2005).[26] That is, free riding through nonparticipation in a self-enforcing treaty must be addressed by some credible means, through a negative incentive such as a credible trade measure, as discussed below, or a positive incentive that creates an aggregate gain by participation for all parties and an individual gain for each party. As discussed below, such a gain may require side payments, or transfers from one party to another, which help create a sense of fairness and hence legitimacy.

In sum, evidenced by the now defunct North Pacific Fur Seal Treaty (Barrett 2003), a self-enforcing international agreement needs to: (1) create an aggregate gain, so that all parties involved have a reason to participate; (2) distribute this gain so that all parties would prefer that the agreement succeed; (3) ensure that each party would lose by not participating, given that all the other parties agreed to participate; (4) provide incentives for all the parties to comply with the buyback; and (5) deter entry by third parties.[27]

Trade Restrictions

Trade restrictions achieve two objectives: They can be used to punish countries that do not cooperate and to correct for a loss in competitiveness of the countries that do cooperate (Barrett 2003). A trade restriction, to be effective, needs to be sufficiently severe (so that, when imposed, behavior will be changed) and credible (meaning that, given that a country chooses not to participate or not to comply, the cooperating countries are better off for imposing the restrictions) (Barrett 2003).

Trade restrictions restructure incentives by providing positive economic incentives to countries that participate in, and comply with, an international agreement or technology standard, such as with the use of TEDs or circle hooks and mackerel-type bait. Trade restrictions also provide negative incentives by punishing those countries that fail to participate in, and comply with, agreements or standards. Trade restrictions also plug production and trade leakages. Trade restrictions impose a cost on member nations of an international sea turtle agreement by forgoing the gains from trade, which reduces the credibility of trade restrictions. Trade restrictions, however, face legal issues under the

World Trade Organization regarding, among other things, discriminating application and protectionist motivations and, therefore, must be crafted with care.

A licensing system for imports of "turtle safe" shrimp and swordfish provides one means of implementing a trade restriction. A licensing system and other steps would reduce black market trade in shrimp and swordfish that is not "turtle safe." Again, concerns may arise regarding the consistency of such measures with obligations under the World Trade Organization.

Side Payments

Side payments, or transfers between and among parties, have both distributive and strategic functions (Barrett 2005).Side payments can be implemented through technology transfers, payment of incremental costs to adopt technology standards by developing country fleets (such as circle hooks for longlines); for direct or indirect conservation; for nesting site protection; and for access to otherwise restricted markets for shrimp and swordfish. Side payments help increase participation and make agreements fair. Side payments, by which gainers of a policy can compensate those who bear the burdens, help ensure that nations that would otherwise lose by participating instead gain.[28] Side payments also acknowledge the "common but differentiated" responsibilities to biodiversity conservation of developing and developed countries, as explicitly recognized by the London Amendment to the Montreal Protocol in 1994[29] and the establishment of the Global Environmental Facility.[30] Side payments can occur bilaterally from one group or nation to another, informally through conservation brokers such as nongovernmental organizations (NGOs), or multilaterally through international commissions or conservation trust funds for sea turtles or biodiversity in general.

Conclusion

Reconciling sea turtle recovery in the Pacific with continued fishing is essential for recovery of critically endangered sea turtle populations, such as eastern Pacific leatherbacks, because fishing will continue under any likely policy scenario. From a broader perspective, turtle recovery coupled with fishing can be viewed as reconciling biodiversity conservation with continued commercial use of marine resources. A holistic approach that extends beyond merely reducing fishery bycatch mortality of sea turtles is required if the turtle populations are to recover or stabilize in the long run.

This holistic approach includes: (1) effective beach conservation to protect nesting females, their eggs, and critical breeding habitat in order to maximize hatchling production; (2) enhancement of at-sea survival of juveniles and adults at critical foraging areas and as they move into different developmental habitats by dealing with large-scale, commercial fishing fleets; and (3) reduction of subsistence, small-scale, and artisanal coastal fishers' takes of turtles, perhaps the most intractable component. The current level of conservation effort is inadequate to reverse the decline of leatherback turtles in the Pacific. If fishing is to continue, these efforts must be greatly enhanced by integrating fishery management into a holistic sea turtle recovery strategy.

Important building blocks of a holistic recovery strategy include mitigation measures and conservation investments, such as: nesting site and other habitat protection; community involvement in conservation; and adoption of technology standards to reduce bycatch of sea turtles by swordfish, tuna, and shrimp fishing fleets. Additional ingredients include side payments to increase participation and compliance, to equitably distribute the burdens, and to finance mitigation and adoption of technology standards in developing nations. Additionally, taxes and fees, including in-kind contributions, deserve consideration as a "double dividend" means of raising revenues to fund mitigation measures and side payments while helping producers and consumers to bear some of the external costs generated by their activities. Performance standards, such as turtle mortality limits, or some form of individual or group use or property right, are also potential components of a broad-based strategy. Direct conservation payments, especially to local communities for nesting site and habitat preservation and coastal small-scale and artisanal fishers for adoption of technology standards and perhaps not fishing during nesting seasons, may well make a surprisingly effective, but currently underappreciated, contribution to sea turtle population recovery. Direct conservation payments of this kind would address two of the three anthropogenic sources of sea turtle mortality.

There are opportunities to immediately implement these holistic recovery measures under existing international sea turtle and fisheries treaties. Moreover, existing agreements might be augmented through additional formal or informal bilateral or multilateral agreements. There could also be coordinated actions by individual nations, nongovernmental and industry organizations, and others acting in tandem that are not formal cooperative agreements, but which are nonetheless effective and quicker to establish. National action plans can also play a role. The window of opportunity to effectively implement conservation measures may soon close as some species in the Pacific teeter on the brink of extinction. Integrating fisheries management into a holistic recovery strategy in the short run may help tip the balance in favor of recovery for loggerheads and leatherbacks, and in the long run help reconcile fishing with biodiversity conservation.

Notes

1. See NOAA-NMFS 2004 BiOp for details of loggerhead take and kills in Pacific.

2. Habitat, as defined by the 2004 Revised Memorandum of Understanding for the Conservation and Management of Sea Turtles and Their Habitats of the Indian Ocean and South-East Asia, "means all those aquatic and terrestrial environments which marine turtles use at any stage of their life cycle." For information on the MOU on the Indian Ocean and South-East Asia Conservation of Sea Turtles, see http://www.ioseaturtles.org/.

3. A common resource is rival (depletable), but not excludable (one individual or group exploiting the resource cannot exclude another from exploitation).

4. Indirect use value derives from services (less tangible qualities) that influence production processes by firms or households. Existence value arises from knowledge that environmental service exists and is linked to altruism.

5. A public good is one that can be consumed by all without depleting the good (i.e., a good which is nonexcludable and nonrival).

6. A free rider is a party or person who receives the benefit of a good or service, but avoids paying for it.

7. The Pacific high seas drift gillnet fishery was shut down by the United Nations in the late 1980s. However, only a handful of nations were involved and it is questionable whether the extensive longline fleets of the entire Pacific can all be effectively shut down. Moreover, high seas driftnet fishing is reputably continuing under vessels reflagged to states, such as Georgia, that are not signatories to the agreement. A more likely scenario for high seas longlining is termination of some fleets and continued, and perhaps even expanded, longlining by the remaining fleets, which leads to production and trade leakages and continued sea turtle mortality. Moreover, there still remains the source of sea turtle mortality from shrimp trawling and coastal drift gillnetting, longlining, purse seining, and groundfish trawling, particularly in developing countries during nesting season.

8. Based on an amateur film by Andrés Herrera taken in 1947, Hildebrand (1963) and Carr (1963) guessed that 40,000 turtles nested at Rancho Nuevo (R. Márquez et al. 1999). No data were available until 1965, at which point the biggest arribada numbered less than 5,000 turtles. In 1973, the largest arribada contained only 200 individuals. Despite beach protection, this number continued to drop for the next 20 years, by which time total nestings for the season only numbered in the hundreds. Surveys conducted between 1978 and 1988 indicated an average of about 800 nests per year, declining at about 14 nests per year, to an all-time low in the late 1980s (R. Marquez et al. 1999). The total number of nesting females may have been as low as 350 on beaches where tens of thousands of Kemp's ridley used to nest.

This initial failure to respond to protection indicates that recruitment was jeopardized by prolonged near-total harvest of eggs and shrimp trawling in the Gulf of Mexico, the primary juvenile and subadult habitat and the only habitat of adults. In 1990, the mortality from shrimp trawling was estimated to lie between 500 and 5,000. Collectively, other trawl fisheries, passive gear fisheries, and entanglement fisheries were estimated in 1990 to yield between 50 and 500 deaths a year. Deaths due to dredging and collisions with boats were estimated in 1990 to lead to a further 5–50 deaths per year. Additional sources of anthropogenic mortality were estimated in 1990 to come from: oil rig removal; intentional harvests; entrainment by electric power plants; ingestion of plastics and debris; and from accumulation of toxic substances, especially from ingested petroleum residues. Mortality also occurs from human and nonhuman predation of eggs in nests and predation of hatchlings and juveniles by crabs, birds, fish, and mammals. The nesting population reached a low in the mid-1980s and in the past few years has begun to modestly and steadily increase (See NMFS-USFWS 2007 Five-Year Status Review at www.nmfs.noaa.gov/pr/pdfs/species/kempsridley_5yearreview.pdf.)

9. Recent studies using satellite telemetry and molecular genetics have shown that leatherbacks migrate from their nesting beaches in Papua, Indonesia, to foraging areas found across the North Pacific as far as waters off the west coast of the United States (Benson et al. 2007; P. H. Dutton et al. 2000). In the eastern Pacific, adult females migrate from nesting beaches in Mexico and Costa Rica to the southeast Pacific to forage off the coasts of Peru and Chile.

10. See information at http://www.iattc.org/1DCPENG.htm.

11. See information at unfccc.int/Kyoto_protocol/items/2830.php.

12. See information at ozone.unep.org.

13. With respect to the Inter-American Sea Turtles Convention, see information at http://www.seaturtle.org/iac. The Convention provides a general prohibition on the taking of sea turtles and their eggs in the territories of the parties and in waters under their respective jurisdictions, but allows subsistence take to satisfy the needs of traditional communities under certain circumstances. The Convention requires that the take be reported to the other parties. The Convention also provides that countries with subsistence takes agree to take into account the relevant recommendations of the Consultative Committee and to ensure that such take does not undermine the overall objectives of the Convention.

14. Programme 1.4, p. 1, of the 2004 Revised Conservation and Management Plan of the Memorandum of Understanding for the Conservation and Management of Sea Turtles and Their Habitats of the Indian Ocean and South-East Asia.

15. See supra note 2.

16. See supra note 10.

17. Theoretical literature on the potential for transferable development rights or biodiversity mitigation include Cervigni (1999) and Panayotou (1994).

18. One issue with mitigation measures is the "moral hazard" problem that vessels taking sea turtles as incidental catches will have less reason to avoid interactions. Moral hazard refers to a problem of asymmetric information whereby the actions of one party to a transaction are unobservable.

19. Gjertsen and Stevenson (2005) provide a case study. Payments to collected eggs for hatcheries with further payments conditional on the rate of hatching success is another example. Payments for beach patrols to protect against anthropogenic and animal predation of in situ nests, hatching rate success from in situ nests, and movement of in situ nests to areas above the high-tide line are other examples.

20. See Bovenberg and Goulder (1999) for a general discussion. In addition, comparable charges are used in Europe and Japan to address water and, to a lesser extent, air pollution (Tietenberg 1990). France and the Netherlands use charges designed to raise revenues to fund activities that improve water quality. Moreover, taxes intended to raise revenue in competitive markets distort resource allocation and create economic inefficiency through what is called a dead weight loss. However, when there is a preexisting market failure and inefficiency due to an external cost (such as sea turtle mortality from fishing), a tax or fee both raises revenue for conservation and recovery and addresses the market failure, thereby inducing efficiency. Dead weight loss, therefore, is not an issue when there is preexisting market failure and a corresponding Pigovian tax.

21. See supra note 10.

22. See UNCLOS, arts. 116–119 of the Law of the Sea.

23. See supra note 13.

24. See supra note 2.

25. Costs with broad participation include: the complexity of negotiating package deals among countries whose interests are highly diverse, rapidly rising saturation for leverage over the problem as numbers rise, increased variation in starting points, values of payoffs to the individual parties, temptations to deviate from the international agreement, and other factors (Barrett 2003; Victor 2006).

26. Barrett (2003) observes that self-enforcing agreements are: individually rational (each player derives benefits from cooperation at least equal to what it would derive from noncooperation), collectively rational (Pareto optimality or no player can be made better off without making another worse off), and fair. Moreover, the benefits of full cooperation require that it is not enough that each individual player receives a payoff at least as great as it would under noncooperation, but that no subcoalition would be better off standing on its own and refusing to cooperate with the remaining players (Munro, Van Houtte, and Willman 2004). When the players form a single coalition or grand coalition, the full benefits of cooperation can be realized. Side payments may be necessary to ensure that these conditions are satisfied so that the core is not empty.

27. Ostrom et al. (1999, p. 279) observe that managing common property resources involves two distinct elements: restricting access and creating incentives (usually by assigning individual rights to, or shares of, the resource for users) to invest in the resource instead of overexploiting it. Limiting access alone can fail if the resource users compete for shares, and the resource can become depleted unless incentives or regulations prevent overexploitation. The individual rights can be extended to common or group rights (Baland and Platteau 1996). Participation is an additional issue in transnational common resources (with their rivalry or depletion or subtractability).

28. Side payments redistribute the additional gain from cooperation and help guarantee that all parties are at least as well off as before cooperation, thereby insuring a Pareto improvement and perhaps a Pareto optimum (and, hence, individual rationality as noted by Barrett 2003).

29. See supra note 12.

30. See information at www.gefweb.org.

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