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Chapter 3

Offshore Oasis: Ecology of Sea Turtles at Oceanic Islands of the Eastern Pacific

Patricia Zárate

Summary

Islands are oases of marine life and terrestrial biodiversity, and their isolation has resulted in unique flora and plant life with a more limited number of anthropogenic threats than found in mainland areas. Thus, it should be no surprise that sea turtles are attracted to these characteristics of marine areas around islands. The green turtle is the most common and abundant sea turtle species associated with islands of the eastern Pacific (EP). The Galapagos, Revillagigedos, and Tres Marías archipelagos, among others, host green turtle nesting and foraging, whereas Cocos Island, Easter Island, Malpelo Island, and Gorgona are suitable places just for feeding. Olive ridley turtles nest on Gorgona, and some leatherback nesting takes place on Coiba. Sea turtle nesting has disappeared from Clipperton Island. Most islands of the EP have relatively low human influence, and anthropo- genic threats at nesting beaches are minimal, while introduced species have perhaps the greatest impact on nesting turtles, eggs, and hatchlings. In the marine realm, artisanal and industrial fishing fleets are ubiquitous in the re- gion, and waters adjacent to these islands are no exception.

Several impor- tant international conservation efforts are under way in the region, but fur- ther implementation and integration among these are necessary to provide the appropriate protection to nesting beaches and marine habitats of the EP.

Introduction

I came to the Galápagos Islands in July 2000 on a wonderful sunny day and found myself surrounded by a spectacular nature show; turquoise waters, a great diversity of seabirds flying overhead, marine iguanas sunning themselves along rocky shores, seemingly unaware of humans, and sea lions resting along the docks near the main street of Puerto Ayora, the arrival point for most of the Archipelago's visitors on Santa Cruz Island. Visiting the place that provided inspiration for Darwin's theory of evolution by natural selection was a dream for me, as for any other biologist.

Fortunately, my dream continued when I received a position at Charles Darwin Research Station (CDRS) to study impacts of artisanal fisheries on marine resources in the Galápagos. However, prior to arriving in the Galápagos, I had attended a striking presentation months earlier by sea turtle luminary Dr. Peter Dutton, which focused on the biology of the giant leatherback sea turtle, and current threats for this and other sea turtle species. Dutton and I spoke after his presentation, and we agreed to establish a close collaboration between our institutions to study sea turtles in the Galápagos.

Two months later, Dutton and two other sea turtle specialists, Miguel Donoso from Chile and Gustavo Iturralde from Ecuador, came to Galápagos for our first sea turtle research trip – a two day trip to foraging areas around Santa Cruz island. We used the "turtle rodeo" technique to catch three long-tailed males green turtles at Caleta

Tortuga Negra along the north coast of Santa Cruz Island. I learned how to apply flipper tags for identification, to take morphological measurements, and to collect blood and tissue samples. Although I was still officially studying artisanal fisheries, this short excursion cemented my desire to switch gears and pursue sea turtle research and conservation. A few weeks later, I was given the green light to dedicate full-time work to sea turtles, on the conditions that I could raise sufficient funds to support myself and the research. With encouragement and assistance from Dutton and his NOAA team, and my boss's blessing, I restarted the program after 17 years of silence. From that point, I could think about nothing other than sea turtles in the Galápagos.

Oceanic islands and archipelagos in the eastern Pacific

The Galápagos Archipelago is certainly the most famous island group in the eastern Pacific Ocean (hereafter EP), but other island formations in the region share similar traits. These small spits of land surrounded by vast blueness are oases for marine as well as terrestrial biodiversity. Ocean currents, carrying nutrients, oxygen, heat and other ingredients necessary to create marine food webs swirl around and run into these islands – like stones being washed in a roiling river – creating concentrated areas of high productivity that support abundant marine life. Breath-taking aggregations of whales, hammerhead sharks, seabirds, and other migratory fauna bear testimony to the special conditions offered by these islands, many of which enjoy some form of national or international recognition as protected areas or UNESCO World Heritage Sites. Anthropogenic threats to marine ecosystems tend to be limited compared to threats occurring closer to

mainland areas due to the islands' relative isolation. This isolation has not only resulted in unique animal and plant life on these islands, but unique human life as well; several islands in the region are home to penal colonies or military installations. As Charles Darwin learned during his voyage on the HMS Beagle, oceanic islands act as "nature's laboratories," where animals and plants are separated from their mainland brethren, subject to natural processes in relatively isolated settings, but also can be highly susceptible to threats alien to their native environments.

Other oceanic islands in the EP include Revillagigedos, Guadalupe, and Rocas Alijos Islands (Mexico), Clipperton Island (overseas holding of France), Cocos Island (Costa Rica), and Easter Island (Chile) (plate 1). Several other islands, located not in the open ocean but on the continental shelf, function similarly to their oceanic counterparts as important habitats for unique flora and fauna; among these are Islas Tres Marías (México), Coiba Island (Panamá), Malpelo Island and Gorgona Island (Colombia), and Easter Island (Chile). Like the Galápagos, all of these sites host sea turtles, and although information from these areas is relatively scarce, they provide other examples of ocean oases, where sea turtles thrive in relatively pristine marine habitats and nesting beaches. Given the preponderance of information available from the Galápagos as compared to other island formations in the EP, this chapter focuses on current knowledge of sea turtle natural history and recent conservation efforts in the Galápagos Archipelago, but also recognizes these other oceanic and continental islands and their local sea turtle populations.

Galápagos Archipelago, Ecuador

The oceanographic conditions surrounding the Galápagos Archipelago – located along the equator roughly 500 nautical miles west of mainland Ecuador – have created extreme biogeographic isolation and the greatest level of vertebrate endemism in the entire EP. The Galápagos Archipelago, volcanic in origin, comprises 13 major islands (total area > 10 km^2), 5 of a medium size (area between 1 – 10 km^2), and 215 islets (<1 km^2) (Parque Nacional Galápagos 2006). Because of its uniqueness and incredible beauty, the Galápagos Archipelago was declared Biosphere Reserve (1984), World Heritage Site (1978; 2001), and its breathtaking Marine Reserve is considered one of the top sites in the world for diving (Sammon 1992; Scuba Diving Magazine 2010).

Sea turtle research prior to 2000.

The Galápagos Islands have been the primary island system for sea turtle research in the eastern Tropical Pacific, as several 'generations' of researchers have studies both nesting and foraging areas in the archipelago. The first scientific endeavour was the Joseph R. Slevin Expedition (California Academy's Scientific Expedition in 1905 – 1906), during which biologists sacrificed numerous green turtles, taking flipper measurements and recording stomach contents (Fritz 1981). However, it was not until 1970 that focused research targeting green turtles commenced, initially with Peter Pritchard's exploratory surveys along the coasts of most islands to determine the extent of green turtle nesting in the archipelago (Pritchard 1971; Pritchard 1972), and later with a flipper tagging program performed by Pritchard, Miguel Cifuentes, and Judy Webb to study green turtle nesting in the islands.

During the nearly seven decades of research inactivity between these expeditions, sea turtles were utilized as a food source by

sailors and island inhabitants. In fact, some of the only accounts we have of sea turtles in the Galápagos during this period come from a canning operation on the islands which relied on local green turtles, and from sailors passing through the area that landed green turtles for food (Hoff 1985, fig. 3.1). By the 1970s, commercial exploitation of sea turtles was common because they were abundant, large (over 130 kg), and easy to obtain (Pritchard 1971). However, Japanese longline fishermen had been operating in the islands for almost a decade, and their activity increased in the beginning of the 1970s, including exploitation of sea turtles. Turtles were caught by local fishermen and frozen onboard the Japanese vessels (Lundh 2004). The last official report of commercial exploitation of sea turtles at Galápagos Islands occurred in 1971 and 1972, when the Japanese vessel "Chikuzen Marou" caught 2,000 to 3,000 turtles, most of which were adult female green turtles, but also included juveniles and adult males (Green 1978; Lundh 2004).

<fig. 3.1 about here>

Historically as well as today, green turtles Chelonia mydas are the only species that nests in the Galápagos, and is by far the most common, occurring in great abundance in the marine habitats of virtually every island in the archipelago (plate 5). The Galápagos nesting population is one of two major rookeries for the species in the EP region totalling more than 1,000 nesting females per year, the other being Playa Colola, Michoacán, México (Seminoff 2004; Álvarado-Díaz and Delgado-Trejo, Chapter 11). Although green turtles in the EP are depleted relative to past levels due to the aforementioned human

consumption of eggs and meat, numbers in recent years have been stable and perhaps increasing (Seminoff 2004).

The first exhaustive nesting beach and foraging habitat assessments in the Galápagos was performed by Derek Green from 1975 to 1980. During that time, Green tagged over 2,300 green turtles and a few hawkbills at foraging areas, and tagged over 4,000 turtles at nesting sites. This research resulted in a seminal paper describing the long-distance migrations of green turtles tagged on Galápagos beaches recaptured in Central and South America, from Costa Rica to Peru, demonstrating an important linkage between the Galapagos and the rest of the region (Green 1984). Another influential paper described the growth of green turtles in foraging areas – growth so slow that Green suggested some turtles might take up to 50 years to reach maturity (Green 1993).

Green also reported an interesting dichotomy among green turtles at Galápagos foraging grounds that had been mentioned first by Joseph R. Slevin during his expedition (Slevin 1931) and later by Archie Carr (Carr 1967): the presence of a dark morph of turtle that nested and foraged locally, as well as a lighter morph known as the "yellow turtle," which was present in feeding areas but was never seen nesting. In addition to differences in coloration, these researchers described the relatively underdeveloped reproductive organs of yellow males and females compared to those of darker morph turtles of a similar size. In addition, the yellow turtle was fattier, yielding six to eight times more oil than the dark turtle. Green suggested that only 1% of green turtles in the Galápagos were of the yellow morph, which recent findings have confirmed (see below).

For several years during Green's tenure on the islands, he often worked closely with Mario Hurtado, an Ecuadorian scientist who

continued investigating the reproductive activity of green turtles (Hurtado 1984). These studies culminated in an estimated 1,400 nesting females nesting annually from 1970 to 1983 and a total of nearly 9,000 females tagged on Galápagos beaches during those years (Hurtado 1984). It was during these efforts, helped in part by Pritchard's earlier exploits, that beaches of Quinta Playa and Bahía Barahona on southern Isabela, Las Salinas on Baltra, Las Bachas on northern Santa Cruz and Espumilla on Santiago were recognized as the most important nesting sites in the Archipelago (Green 1994). However, 1983 marked the last year of this research, and not until 2000 did nesting beaches again become the focus of scientific investigation.

Recent monitoring work.

Today, the conservation status of the green turtle nesting population in the Galápagos is positive, with eggs and adults both afforded to a high level of protection and the annual number of nesting females stable. High hatching and emerging success of about 80% are obtained every season, and although feral animals such as cats, dogs and pigs, exist on some beaches, their numbers are controlled by Galápagos National Park Guard's exotic species eradication program (see below). After successfully monitoring 7 years of nesting activity at key sites beginning in 2001, more than 10,000 females have been tagged.

In addition to the nesting beach work, there also has been considerable research effort in foraging areas throughout the Archipelago. In February 2003, an expedition was launched to revisit the same sites that Green had assessed during his five years of research to provide a comparison between past and present. A research team consisting of Dutton and Jeffrey Seminoff from NOAA, USA, Nelly de Paz from Peru, the author and her teenager daughter, Mariantú, and

several very enthusiastic local and international volunteers set off on an 8-day trip to the western side of the Archipelago.

The team boarded a CDRS research vessel boat called The Beagle and travelled to Green's exact research sites, which probably had not been visited by humans for at least a decade. While approaching the first stop at Punta Espinoza, green turtles were in plain sight mating along the shoreline of the nesting beaches. At most of the sites visited, green turtles were in great abundance – some of them feeding on green algae (Ulva sp.), others resting on the bottom of lagoons or shallow ponds, or basking on sea surface – making them very easy to capture by hand. However, the most exciting event was encountering the first "yellow turtle" documented since Green's time. A juvenile of 47.4 cm in length, it had a brightly colored carapace with white, orange and brown streaks radiating from bright orange spots at the centers of each scute. The head was black with bright orange borders on facial scutes, the flippers were black with a narrow orange band along the outer and inner margins, and the plastron was uniformly light yellow (see Color Plates; Zárate 2007). Of nearly 1,000 individuals of Chelonia mydas tagged at foraging grounds in Galápagos Archipelago from 2003 to 2007, less than 10% have been of the yellow morph. While it appears that they originate from green turtle rookeries in the Indo-Pacific (Zarate et al., unpublished data), their biology, behavior, and life cycle all remain mysteries.

Green turtles nesting in the Galápagos Archipelago may represent a unique genetic stock (Zarate et al., unpublished data), but whether turtles within this stock overlap with habitats utilized by other nesting stocks was unknown until recently. Seminoff et al. (2008) tracked 12 adult female green turtles during their post-nesting movements within and away from the Galapagos Islands. The researchers

identified multiple post-nesting behavior patterns, including utilization of oceanic habitats in the southeastern Pacific, long-distance migration to neritic habitats in Central America, and residential movements of some individuals that did not leave the Archipelago. Thus, just as the Galapagos receives juvenile green turtles from multiple stocks, Galapagos nesting turtles appear to occupy multiple habitats utilized by other nesting stocks.

Besides green turtles, hawksbills Eretmochelys imbricata, olive ridleys Lepidochelys olivacea, and leatherbacks Dermochelys coriacea also have been recorded occasionally in the Galápagos Islands. Six hawksbills were captured among the nearly 1,000 green (and yellow) turtles in marine habitats from 2003 to 2007. Olive ridleys were reported several times in the past and captured by Slevin's team in 1906 (Slevin 1931), and others have been reported as victims of boat strikes and bycatch in artisanal longline gear (Murillo et al. 2004). Leatherbacks were recorded three times from 1970 to 1983 (Green 1994) and once in 2003 when an individual was incidentally captured in an artisanal longline (Murillo et al. 2004). Satellite telemetry research has demonstrated that leatherbacks migrate through and around the Galapagos Archipelago en route between nesting beaches in Mexico and Costa Rica to feeding areas in the southeastern Pacific (Eckert and Sarti 1997; Shillinger et al. 2008).

The global notoriety and history of strong conservation programs make the Galápagos Archipelago a relative safe haven for abundant green turtles and other sea turtle species, as well as countless other flora and fauna species. Although anthropogenic threats to sea turtles persist and still require conservation action (see below), the Galápagos will continue to provide a home for sea turtles in the foreseeable future.

Revillagigedos Archipelago, México

The Revillagigedos Islands are located 400 nautical miles southwest of the southern tip of Baja California, Mexico (Everett 1988). This oceanic archipelago encompasses a total area of 157.81 km² including four volcanic islands: San Benedicto, Socorro, Roca Partida y Clarión (see regional Map). Socorro and Clarión both host stations of the Mexican Navy, with a population of 250 (staff and families) in the south of Socorro and a small garrison with aproxiamtely 10 men on Clarión (Brattstrom 1982; Awbrey et al. 1984; Everett 1988). However, other than this low-density military presence, the islands are uninhabited by humans. Thus, the islands host several endemic vertebrate and plant species, important seabird rookeries and other marine megafauna. Furthering the protection of the wildlife in Revillagigedos, the Mexican Government established the islands as a Biosphere Reserve on the 1994.

As in the Galápagos, the green turtle is the only marine turtle species that nests in Revillagigedos, with relatively sparse nesting on Clarión and Socorro Islands (Brattstrom 1982; Awbrey et al. 1984; plates 1 & 5). On Clarion Island, Sulphur Beach along the southern coast is the most important nesting site for green turtles, accounting for about 70% of nesting at Revillagigedos (Awbrey et al. 1984; Everett 1988). Nesting occurs year-round but increases seasonally from July to March, with peak nesting in October and November (Juárez et al. 2003). An average of 86 nests was deposited on Sulphur beach during nesting seasons from 1999 to 2001.

Hawksbills, olive ridleys and leatherbacks are also reportedly found in coastal waters of the Revillagigedos Islands, but the only

scientific survey information available is from research by Arturo Juárez, Laura Sarti, and colleagues (Juárez et al. 2003), who most frequently observed green turtles at sea around Socorro than Clarion Islands. Green turtles captured along the coasts of the islands were predominantly adults ranging in curved carapace length from 80.0 - 108.8 cm.

As with Galápagos and other island systems, natural systems in the Revillagigedos have been impacted by introduced animals, such as sheep, cats, and pigs, which have caused declines in marine and terrestrial bird populations. It is unclear whether these invasive animals have impacted sea turtles, but known threats to sea turtles in waters around the Revillagigedos are predation by sharks and illegal fisheries.

Clipperton Island, France

Clipperton Island also known as Ile de la Passion is located in the Eastern Pacific Ocean at 510 nautical miles southeast of Socorro Island in the Revillagigedo Archipelago (Mexico) (plate 1). It is the only atoll of the North East Pacific and its basement forms a seamount rising above the sea floor at 3000 m (Glynn et al. 1996; Jost and Andrefouet 2006). Volcanic remnants is comprised by an isolated and conspicuous 29 meter-high rock, besides this the highest elevation above sea level is 4 m (Jost and Andrefouet 2006; Lorverlec et al. 2009).

The ring-shaped atoll is of approximately 9 km² and completely encloses a freshwater lagoon that was connected by two channels to the open ocean but because hurricane effects was isolated from the ocean

and became a brackish system sometime between 1839 and 1858 (Sachet 1960, Lorvelec and Pascal 2006, Lorvelec et al. 2009).

From the 1890s until 1910s human settlement took place on the island for mining activities when the introduction of coconut trees and pigs occurred with an evident impact on the island ecosystem. Reports from those days mentioned that the island was totally deserted with no vegetation cover, along with a huge abundance of crabs (Jost and Andrefouet 2006). The island is currently uninhabited but sporadically visited by crews of fishing boats and tourist. The flora and fauna in the Clipperton atoll has been characterized as low diversity (Jost and Andrefouet 2006).

The only record of sea turtles nesting on Clipperton Island comes from the notes of Benjamin Morrell (Morrel 1832) where he mentions that green turtles come to the island to lay their eggs. However, there is no indication where he saw the turtles actually nesting or found evidence such as tracks from nesting activities or eggshells or eggs on the beach. The presence of nesting activity based on Morrell's comments and the species identification as well has been questioned because of a lack of description (Lorvelec and Pascal 2006). If nesting was effectively occurring at the time of Morrel's observation it is possible that predation of eggs and adults by humans between 1893 and 1917 or the destruction of nests by the high abundance of pigs on the island during the first half of the XX century have caused the disappearance of the sea turtle population on Clipperton's Island (Lorvelec and Pasacal 2006). Inventories carried out on the island register sea turtles (Cheloniidae) as native species that have disappeared from the island that were first described on August of 1825, and with no further confirmation of reproduction on the island after that date (Lorvelec and Pascal 2009).

Lorvelec et al. (2009) visited the island on the 2004 and recorded the presence of stranding turtles at different sites along the shoreline of the island. Of the nine carcasses they found five corresponded to Lepidochelys olivacea and in the remaining four species identification was not possible because the cadavers were too decomposed or were reduced to just bones. The death of these strandings was certainly attributed to longliners fisheries and to purse seine tuna fishermen to a lesser extent.

The origin of these strandings has been speculative and based on the distribution of nesting grounds in the region (Brown and Brown 1982, Fritts et al. 1982, Lopez Castro 1999, Alava et al. 2007, Eguchi et al. 2007) and on the current information of migration undertaken by olive ridleys in the region (Parker et al. 2003) the strandings found on Ckipperton Island could come from any of the nesting ground population within the region (Lorvelec et al. 2009).

Cocos Island, Costa Rica

Cocos Island is an oceanic island of both volcanic and tectonic origin located approximately 340 nautical miles from mainland Costa Rica (plate 1). It is surrounded by deep waters and rich ocean currents that attract iconic aggregations of hammerhead sharks, rays, dolphins and other large marine species – as well as SCUBA divers. It is the only oceanic island in the eastern Pacific region topped by dense tropical forests and their characteristic flora and fauna (Sinergia 69 2000). The island was never linked to a continent, so the island is home to a high proportion of endemic species.

No information in peer-reviewed literature exists to date on sea turtles at Cocos Island. Sightings of sea turtles were first documented

during XVIII and XIX centuries (M. Montoya, personal communication), and over the past 20 years, divers visiting the island have documented (in photographs and videos) the presence of hawksbills turtles, greens, olive ridleys and leatherbacks. Sightings of sea turtles at sea are frequent around the island, but no records of nesting exist.

In recent years, the Programa Restauración de las Tortugas Marinas (PRETOMA) has led research expeditions to capture and track sea turtles and sharks around Cocos Islands. To date, satellite transmitters have been deployed on five green turtles and one hawksbill turtle, and movement patterns have demonstrated individual variability, with some turtles staying close to the Island and one making a long distance migration toward mainland Panama before the transmitter ceased to function (R. Arauz, personal communication).

Cocos Island was declared a National Park by Executive Decree in 1978, and later was designated a World Heritage Site by UNESCO in 1997. In addition, Cocos is home to a "Wetland of International Importance" as defined by the RAMSAR Convention. The only persons allowed to live on Cocos Island are Costa Rican Park Rangers. Tourists are allowed ashore only with permission of island rangers, and are not permitted to camp, stay overnight or collect any flora, fauna or minerals from the island (Montoya 2007). Threats to Cocos ecosystems include invasive rodents (Ratus ratus and Mus musculus) and feral pigs (Sus scofra), as well as illegal fishing.

Easter Island, Chile

Easter Island, or Rapa Nui in the island people’s indigenous language, is a Polynesian island of volcanic origin and one of the world's most isolated inhabited islands, located more than 2,000

nautical miles from Chile (plate 1). Famous for its monumental statues – or moai – Easter Island's palm forest was systematically deforested by native Easter Islanders in the process of erecting their statues (Hunt 2006). Chile first declared the island a National Park in 1935, and UNESCO designated it a World Heritage Site in 1996.

Little information exists regarding marine turtles around Easter Island, but leatherbacks and green turtles have been documented (M. Donoso, personal communication); green turtles have even been satellite tracked within their foraging grounds on the Easter Island (P. Dutton, unpublished data). Leatherbacks have been satellite tracked from nesting beaches in Costa Rica to waters nearby Easter Island (Shillinger et al. 2008), and they have been caught around the islands by the Chilean artisanal swordfish fleet.

Island systems on the continental shelf

Tres Marías Islands, México

The Tres Marías Islands are located just 65 nautical miles off the west coast of México (plate 1). These islands have been known since early in the history of the New World, and were first named as Las Islas de la Magdalena. The Tres Marías group comprises four islands: San Juanito, María Madre, María Magdalena, and María Cleofa. Since 1905, the Tres Marías Islands Federal Prison has been home to some of the most infamous and dangerous criminals in México.

References regarding sea turtles are very scarce, but Stejneger (1899) reported the existence of nesting around May and June by green turtles and hawksbill, and Parsons (1962) reported a large number of

hawksbills nesting on beaches of Tres Marías. Nesting activity of hawksbills on the islands has not yet been reconfirmed.

Coiba Island, Panamá

Coiba Island, the largest uninhabited tropical forested island in the Americas, is included in Coiba National Park (CNP), which is comprised of over 2,700 km^2 of islands, forests, beaches and mangroves (plate 1). The island is ringed by one of the largest coral reefs on the Pacific Coast of the Americas (Cortés 1997). The remarkable preservation of Coiba Island is largely due to its use as a penal colony since 1920; the prisoners have served as a strong deterrent to colonization by peasants and to the extraction of the island's abundant resources (Castrellón 2008). Due to the pristine nature of the island and its surrounding oceans, it was declared a National Park by the Panamanian government in 1992, and UNESCO declared the entire Coiba National Park a "World Heritage Site" in July 2005.

The Indo-Pacific current through the Gulf of Chiriquí provides a unique environment for marine life and, by extension, for recreational diving. The warm current carries tropical marine species from the other side of the Pacific, and larger animals such as humpback whales, sharks, whale sharks, orcas, among others, are also regular visitors (Aguilar et al. 1997). Regarding sea turtles, very little information exists, but olive ridleys, hawksbills, and leatherbacks have been recorded to nest on the island (Castrellón 2008).

Malpelo Island, Colombia

Malpelo Island is an oceanic island of a volcanic origin emerging from the sea bottom at about 4 km of depth, roughly 270 nautical miles

from the coast of Colombia (plate 1). It is uninhabited except for a small military post manned by the Colombian Army, which was established in 1986, and civilian visitors need a written permit from the Colombian Ministry of the Environment. It was declared a Flora and Fauna Sanctuary in 1995 and a World Heritage Site by UNESCO in 2006. Malpelo Island is a very popular diving location, as hundreds of hammerhead sharks and silky sharks are frequently seen by diving expeditions.

The marine environment is strongly influenced by the marine currents in the area, which create very productive habitats. These conditions make the island an important habitat for many migratory species, including marine mammals, schools of large pelagic fish and sharks, and sea turtles (Birkeland et al. 1975). Five species of marine turtles have been observed feeding around Malpelo Island, including hawksbills, green turtles, olive ridleys, leatherbacks, and loggerheads. However, research surveys carried out in 2006 by the Fundación Malpelo and the Centro de Investigación para el Manejo Ambiental y el Desarrollo (CIMAD) of Colombia only recorded green turtles, all of them subadults in apparently good health conditions and associated to coral reefs habitats. This first survey represented the first step in the implementation of the Sea Turtle Sighting Program at Malpelo Island (Pavía and Amorocho 2006).

Gorgona Island, Colombia

Home to a now defunct, but once notoriously harrowing prison, this island (and its smaller sister island, Gorgonilla) was christened in the 16th Century by Francisco Pizarro, who, after losing dozens of his men to venomous snake bites, likened the place to the mythical Gorgon sisters. Since the prison closed in 1984 and the Island was

named a National Park the following year, the only humans on the island are temporarily stationed Park rangers and visiting tourists.

Like other islands in the region, Gorgona is a refuge for marine and terrestrial biodiversity. The island is a popular tourist destination for whale watching, as female humpback whales pass close to shore with their newborn calves in tow every year, and its rich coral reef habitats draw divers year-round. Among the inhabitants of Gorgona's fringing reefs, relatively abundant juvenile green turtles, as well as less abundant hawksbills, have been observed during an extensive mark-recapture study conducted since 2003 by CIMAD. During this period, the research group has hand-captured nearly 500 free-swimming green turtles (<10 hawksbills and olive ridleys) during night dives around Gorgona (Amorocho 2009). In addition, low-density olive ridley nesting occurs on sandy beaches on the island (Camayo and Amorocho 2008). Like other known foraging areas for juvenile green turtles in the eastern Pacific, Gorgona appears to host a mixed stock of juvenile turtles, comprised of individuals reflecting genetic haplotypes from different rookeries from the region, as well as individuals of the yellow morph observed in Galápagos that exhibit haplotypes from western Pacific green turtle stocks (Amorocho 2009).

As consistent monitoring efforts have shown in Gorgona (and other sites), islands in the eastern Pacific often represent important feeding areas for individuals from distinct rookeries in the region, which highlights the importance of protecting these areas to ensure persistence of multiple breeding populations of green turtles in the region.

Challenges and advances in island conservation: a case study of the Galápagos Archipelago

Despite the isolation of islands from mainland areas and their associated anthropogenic effects, human-induced threats to island ecosystems certainly exist, as mentioned previously. These remote natural systems have evolved a unique and delicate balance that often differ greatly from those on the closest mainland, and thus are particularly sensitive to impacts from other environments. In particular, a common theme for island systems in the EP and elsewhere are introduced species, including plants, but also vertebrates, such as pigs, dogs, livestock, and rodents.

Among all the islands in the region, Galápagos represents the most complex system of critical biophysical, socioeconomic and cultural resources, which have a profound impact on the archipelago's natural resources and biodiversity. The number of visitors has increased 9% annually over the last 25 years, and the resident population in Galápagos more than doubled from 1990 to 2006, now topping 20,000 inhabitants. Population growth is increasing pressure on natural resources and the demand for improved public services, motor vehicles, commercial flights, fuel consumption, electricity, among others. Increased food demand for the growing Galápagos human population has been reflected in the decline of marine resources such as lobster, sea cucumber, and cod.

Major causes of concern regarding sea turtles at Galápagos Archipelago are related to the increasing tourism activity, artisanal fisheries within the Galápagos Marine Reserve (GMR) and the National Park, and introduced mammal predators. Intensive marine traffic and illegal fishery practices in the GMR has been linked to observations of dead and injured sea turtles. Additionally, feral pigs are voracious predators of sea turtle eggs and hatchlings.

Despite the challenges and problems the Archipelago is facing, Galápagos is the only oceanic archipelago with 95% of its original biodiversity still intact, which is due to a strong legal framework for conservation and the achievements of the conservation institutions in Galápagos (CDF, GNP and INGALA. 2008). However, a strong commitment among all Galápagos stakeholders is necessary to ensure sustainable co-habitation between humans and nature. In recent years, management entities of the Galápagos have implemented several measures to address these threats, which might serve as models for other island systems in the region facing similar threats.

Coastal zonation scheme implementation

In 2000, a coastal zonation scheme was established to regulate the human exploitation of natural resources within the GMR, to avoid conflicts between stakeholders, and to protect high biodiversity sites. In some areas, fishing and other activities are permitted, in other areas fishing is prohibited but tourism is allowed, and in others only research and management activities are permitted. The CDF's marine research team is carrying out systematic biological surveys to provide a baseline for future evaluation (Watkins et al. 2008). Zonation is an extremely important management tool, but has been very difficult to implement due to stakeholder resistance; e.g. fishermen were very reluctant to accept the idea of "no-take areas." The zonation scheme is to be re-evaluated in terms of both socioeconomic impacts and preliminary ecological impacts, but many of the benefits of no-take areas will only become apparent with time (Novy 2000; Heylings et al 2002; WWF-USAID 2006).

Longlining banned within the Galápagos Marine Reserve

Cold, hot and warm marine currents come together in the waters of the GMR generating a wide diversity of animal life especially around submarine volcanoes whose peaks nearly reach the surface. These areas are important for both fishermen and tourism because they host a wide variety of commercial fishes as well as sharks, sea lions, sea turtles and dolphins, among others (Oviedo 1999; Banks 2002). Although industrial fishing is forbidden within the GMR, local fishermen have used these areas for targeting tunas and swordfish using longline gear (Zárate 2002; Murillo et al. 2004; Galápagos National Park, unpublished data). Considering the high bycatch associated with this fishing gear, the CDF did a study in 2003 to determine if small-scale longlining of yellowfin tuna and swordfish should be permitted in the reserve. The researchers found that most of the catch was composed by non-target species, mostly sharks but also the four sea turtle species recorded in the Archipelago (Murillo et al. 2004). As a result, longlining was banned in Galápagos waters in 2005 (Registro Oficial 2006).

Quarantine and inspection system, eradication programs implemented

Since the New World discovery of the Galápagos Archipelago by Bishop Tomás de Berlanga, humans have introduced exotic (i.e., non-native) species to the islands, some intentionally, including goats, pigs, cats, and both ornamental and food plants (vegetables and fruits), and some accidentally, including rodents, insects, and weedy plants (Watkins et al. 2008). Herbivores, like goats, compete for the little available food with tortoises and land iguanas making it so there is not enough food to support the native creatures, while

introduced plants compete with the native plants for scarce nutrients in depauperate Galápagos soil. Pigs and goats destroy nests and eat bird and reptile hatchlings and eggs.

Immigration and tourism in recent decades to the Galápagos has increased the risk of introduced species entry through various pathways such as cargo boats and airplanes. To prevent the entry and spread of potentially threatening exotic species, the Galápagos inspection and quarantine system (SICGAL) was established in 2000 (Zapata 2008). Trained SICGAL inspectors now search incoming cargo shipments from boats and planes, as well as luggage carried by tourists and residents (Zapata 2008). It is much more cost-effective to prevent the arrival of introduced species as the costs of implementing mitigating activities after their arrival can be high and continuous.

Although the quarantine and inspection programs can prevent new biological invasions, eradication programs have been established by the Galápagos National Park to address alien species already present in the Archipelago. Successful eradication programs include: a program to eradicate feral cats (Felis catus) from the island of Baltra (Phillips et al. 2005); the largest removal of an insular goat population using ground-based methods, from Pinta island (Campbell et al. 2004); and the multi-year, multi-million dollar Isabela Project, which resulted in complete eradication of goats and donkeys from Santiago and most of Isabela islands (Carrion et al. 2006).

Most important for sea turtles, feral pigs (Sus scrofa) on Santiago Island have been responsible for a near zero recruitment rate of giant tortoises and green turtles (Calvopiña 1985; Green 1979). Like the goat eradication efforts, the eradication of pigs from Baltra island is considered the largest insular pig removal to date: Over 18,000 pigs were removed during a 30-year eradication campaign (Cruz et

al. 2005). As of 2007, several islands and islets in the Archipelago are now free of cats, goats, pigeons, donkeys, and pigs. Introduced species are more abundant and have a greater incidence on the inhabited islands, all of which are considered high priority for control and eradication efforts in the coming years.

International conservation efforts for island systems in the EP

Oceanic and continental shelf islands play an important role as developmental refugia for sea turtles – especially green turtles – in the EP region. They act as juvenile nursery and foraging areas where individuals from multiple genetic stocks mix, and provide reproduction sites for adult turtles. Because these island systems not only share function for sea turtle life cycles and natural history, but also share individual turtles and turtle populations, international conservation strategies have begun to address islands as a network of important habitats. An important framework for sea turtle conservation in the Eastern Tropical Pacific is the Marine Corridor (CMAR) Initiative, which is a voluntary multilateral agreement among the governments of Costa Rica, Panamá, Colombia, and Ecuador to work towards integrated, sustainable use and conservation of marine resources in these countries' waters. A related program, the Eastern Tropical Pacific Seascape (ETPS) Initiative managed by Conservation International, supports inter-institutional, cooperative scientific research and marine management among the same four countries. The Comisión Permanente del Pacífico del Sur (CPPS, or the Lima Convention), has developed an Action Plan for Sea Turtles in the Southeast Pacific among signatory countries Panamá, Colombia, Ecuador, Perú, and Chile (Seminoff and Zarate 2008). The Inter-American Tropical Tuna Commission

(IATTC) and its bycatch reduction efforts are globally recognized to be among the world's finest for regional fisheries management organizations. The Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC) is another policy instrument designed to decrease impacts on sea turtles from fisheries and other human impacts. Clearly, the region benefits from having several strong, complementary conservation instruments and organizational structures in place to promote and enhance sustainable resource use and biodiversity protection.

Nonetheless, sea turtle conservation in the EP requires successful implementation and greater integration among the region's international instruments and accords. New legislation and enforcement of existing laws that curb unsustainable exploitation of sea turtle products in the region's coastal communities is also necessary. Hopefully, coordinated management efforts will provide habitat protection that extends from nesting beaches to marine habitats for sea turtles and other species within and among the island oases of the EP.

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