GREEN SEA TURTLE
(*CHELONIA MYDAS*)

5-YEAR REVIEW:
SUMMARY AND EVALUATION

NATIONAL MARINE FISHERIES SERVICE
OFFICE OF PROTECTED RESOURCES
SILVER SPRING, MARYLAND
AND
U.S. FISH AND WILDLIFE SERVICE
SOUTHEAST REGION
JACKSONVILLE ECOLOGICAL SERVICES FIELD OFFICE
JACKSONVILLE, FLORIDA

AUGUST 2007

U.S. Department of Commerce
National Oceanic and Atmospheric Administration

NATIONAL MARINE FISHERIES SERVICE

U.S. Department of the Interior

U.S. FISH AND WILDLIFE SERVICE

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Green Sea Turtle/*Chelonia mydas*

1.0 GENERAL INFORMATION

1.1 Reviewers

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1.2. Methodology Used to Complete the Review

Dr. Jeffrey Seminoff of the National Marine Fisheries Service gathered and synthesized information regarding the status of the green sea turtle (Section 2.3). This review was subsequently compiled by a team of biologists from the National Marine Fisheries Service's (NMFS) Office of Protected Resources and the U.S. Fish and Wildlife Service's (FWS) Southeast Regional Office and the Jacksonville Ecological Services Field Office. Our sources include the final rule listing this species under the Act; the recovery plans; peer reviewed scientific publications; unpublished field observations by the Services, State, and other experienced biologists; unpublished survey reports; and notes and communications from other qualified biologists. The draft 5-year review was sent out for peer review to six academic professionals with expertise on the species and its habitats. Peer reviewers were provided guidance to follow during the review process. Comments received from peer reviewers were incorporated into the 5-year review document (see Appendix). The public notice for this review was published on April 21, 2005, with a 90 day comment period (70 FR 20734). A few comments were received and incorporated as appropriate into the 5-year review.

1.3 Background

1.3.1 FR notice citation announcing initiation of this review

April 21, 2005 (70 FR 20734)

1.3.2 Listing history

Original Listing
FR notice: 43 FR 32800
Date listed: July 28, 1978
Entity listed: Two populations
Endangered Population - breeding colony populations in Florida and on Pacific coast of Mexico

Threatened Population - wherever found except where listed as endangered
Classification: Endangered and Threatened

1.3.3 Associated rulemakings

Regulations Consolidation Final Rule: 64 FR 14052, March 23, 1999. The purpose of this rule was to make the regulations regarding implementation of the Endangered Species Act of 1973 (ESA) by NMFS for marine species more concise, better organized, and therefore easier for the public to use.

Critical Habitat Designation: 63 FR 46693, September 2, 1998. The purpose of this rule was to designate marine critical habitat for the green turtle as follows: Culebra Island, Puerto Rico – Waters surrounding the island of Culebra from the mean high water line seaward to 3 nautical miles (5.6 km). These waters include Culebra's outlying Keys including Cayo Norte, Cayo Ballena, Cayos Geniquí, Isla Culebrita, Arrecife Culebrita, Cayo de Luis PeZa, Las Hermanas, El Mono, Cayo Lobo, Cayo Lobito, Cayo Botijuela, Alcarraza, Los Gemelos, and Piedra Steven.

1.3.4 Review history

Plotkin, P.T. (Editor). 1995. National Marine Fisheries Service and U.S. Fish and Wildlife Service Status Reviews for Sea Turtles Listed under the Endangered Species Act of 1973. National Marine Fisheries Service, Silver Spring, Maryland. 139 pages.
Conclusion: The review was conducted on the East Pacific Green Turtle only, and the conclusion was to retain the listing as endangered throughout its range.

Mager, A.M., Jr. 1985. Five-year status reviews of sea turtles listed under the Endangered Species Act of 1973. U.S. Department of Commerce, NOAA, National Marine Fisheries Service, St. Petersburg, Florida. 90 pages.
Conclusion: Retain the listing as endangered in Florida and on the Pacific coast of Mexico and threatened in the rest of its range.

FWS also conducted 5-year reviews for the green turtle in 1983 (48 FR 55100) and in 1991 (56 FR 56882). In these reviews, the status of many species was simultaneously evaluated with no in-depth assessment of the five factors or threats as they pertain to the individual species. The notices stated that FWS was seeking any new or additional information reflecting the necessity of a change in the status of the species under review. The notices indicated that if significant data were available warranting a change in a species' classification, the Service would propose a rule to modify the species' status. No change in the green turtle's listing classification was recommended from these 5-year reviews.

1.3.5 Species' recovery priority number at start of review

National Marine Fisheries Service = 5 (this represents a moderate magnitude of threat, a high recovery potential, and the presence of conflict with economic activities).

U.S. Fish and Wildlife Service (48 FR 43098) = 1C (this represents a monotypic genus with a high degree of threat, a high recovery potential, and the potential for conflict with construction or other development projects or other forms of economic activity).

1.3.6 Recovery plans

Name of plan: Recovery Plan for U.S. Population of Atlantic Green Turtle (*Chelonia mydas*)
Date issued: October 29, 1991

Name of plan: Recovery Plan for U.S. Pacific Populations of the Green Turtle (*Chelonia mydas*)
Date issued: January 12, 1998

Name of plan: Recovery Plan for U.S. Pacific Populations of the East Pacific Green Turtle (*Chelonia mydas*)
Date issued: January 12, 1998

Dates of previous plans: Original plan date - September 19, 1984

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate?

Yes.

2.1.2 Is the species under review listed as a DPS?

No. It is listed as two populations (listed before November 1978 when DPS language was added to the ESA).

2.1.3 Is there relevant new information for this species regarding the application of the DPS policy?

Yes. Although at this time, based on the best available information, the Services believe the current population listing is valid, we have information that indicates an analysis and review of the species should be conducted in the future to determine the application of the DPS policy to the green turtle. See Section 2.3 for new information since the last 5-year review and Section 4.0 for additional information.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

No. The "Recovery Plan for U.S. Population of Atlantic Green Turtle (*Chelonia mydas*)" was signed in 1991, the "Recovery Plan for U.S. Pacific Populations of the Green Turtle (*Chelonia mydas*)" was signed in 1998, and the "Recovery Plan for U.S. Pacific Populations of the East Pacific Green Turtle (*Chelonia mydas*)" was signed in 1998. While not all of the recovery criteria strictly adhere to all elements of the 2004 NMFS Interim Recovery Planning Guidance, they are still a useful measure of the species status. See Section 4.0 for additional information.

The recovery criteria for the three active recovery plans are identified below, along with several key accomplishments:

1991 Recovery Plan for U.S. Population of Atlantic Green Turtle (Chelonia mydas):

The U.S. population of green turtles can be considered for delisting if, over a period of 25 years, the following conditions are met:

1. The level of nesting in Florida has increased to an average of 5,000 nests per year for at least 6 years.
   - Green turtle nesting in Florida over the past 6 years has been documented as follows: 2001 - 581 nests, 2002 - 9,201 nests, 2003 - 2,262 nests, 2004 - 3,577 nests, 2005 - 9,644 nests, and 2006 - 4,970 nests. This averages to 5,039 nests annually over the past 6 years.

2. At least 25 percent (105 km) of all available nesting beaches (420 km) is in public ownership and encompasses greater than 50 percent of the nesting activity.
   - Efforts are underway to determine the extent of green turtle nesting beaches within conservation lands in public (federal, state, or local government) ownership and privately owned conservation lands (e.g., non-profit conservation foundations).
   - The Archie Carr National Wildlife Refuge, located in Brevard and Indian River Counties, Florida, was established in 1991 and protects important nesting habitat. Currently 9 km (60%) of the 15.0 km of beach targeted for protection have been acquired by FWS and its partners. With the addition of the previously established Sebastian Inlet State Park (5 km), a total of 14 km of oceanfront habitat is protected within the 33-km stretch. A total of 6 km is needed to complete acquisition of the Archie Carr NWR.

3. A reduction in stage class mortality is reflected in higher counts of individuals on foraging grounds.
   - The Sea Turtle Stranding and Salvage Network (STSSN) is ongoing in the Atlantic and Gulf of Mexico to document sea turtle mortality. Strandings are used as an index of at-sea mortality and provide valuable biological information on food habits and reproductive condition. Analysis of stranding data has been important in assessing regulations designed to protect sea turtles from fishery-related mortality.
   - Vital population assessment work has been conducted under the STSSN, including genetic sampling and analysis of age classes.

- Population identification has been conducted on turtles caught as bycatch in fisheries, foraging turtles, and stranded turtles using DNA analysis, flipper tagging, and satellite telemetry.
- U.S. longline fishery observer programs have been established to monitor, report, and estimate green turtle bycatch.
- Fishing gear technologies, including improvements to turtle excluder devices (TEDs) and modifications to scallop dredges and pound net leaders, have been developed and tested to reduce sea turtle bycatch.
- Prohibitions on the use of large-mesh gillnets have been enacted to reduce entanglement and mortality.

4. All priority one tasks have been successfully implemented.
   - The Florida Index Nesting Beach Survey program was established in 1989 to monitor trends in nesting activity (task 211).
   - Nest success is evaluated and nest protection measures are implemented on national wildlife refuges throughout the Southeast U.S. and U.S. Caribbean (task 212).
   - In-water population studies in the Atlantic and Caribbean are underway to provide indices of turtle abundance (task 2211).
   - Regulations requiring year-round use of TEDs by most shrimp trawlers operating in southeastern U.S. waters were required after December 1992 and modifications to improve turtle exclusion have been codified (task 2221).
   - Long-term monitoring and research of potential causes of and threats posed by fibropapillomatosis is underway. Fibropapillomatosis is a disease that is characterized by the presence of internal and/or external tumors (fibropapillomas) that may grow large enough to hamper swimming, vision, feeding, and potential escape from predators (task 227).

1998 Recovery Plan for U.S. Pacific Populations of the Green Turtle (Chelonia mydas):

To consider de-listing, all of the following criteria must be met:

1. All regional stocks that use U.S. waters have been identified to source beaches based on reasonable geographic parameters.
   - Stock structure of nesting turtles has been identified using DNA analysis, flipper tagging, and satellite telemetry.
   - Population identification has been conducted on turtles caught as bycatch in fisheries, foraging turtles, and stranded turtles using DNA analysis, flipper tagging, and satellite telemetry.
   - A sea turtle data collection and skin sampling (for subsequent DNA analysis) project has been supported in the Marshall Islands.

2. Each stock must average 5,000 (or a biologically reasonable estimate based on the goal of maintaining a stable population in perpetuity) females estimated to nest annually (FENA) over six years.
   - From 2002-2006, an average of 400 nesting females were documented annually in the French Frigate Shoals in the Northwestern Hawaiian Islands.

3. Nesting populations at "source beaches" are either stable or increasing over a 25-year monitoring period.
   - Long-term nesting beach monitoring in the French Frigate Shoals in the Northwestern Hawaiian Islands has been ongoing since 1973.
   - Green turtle population trends have been evaluated and conservation strategies have been designed and evaluated via stochastic simulation models.
   - A dramatic increase in annual nesting turtle abundance over a 32-year period (1973-2005) in the French Frigate Shoals has been documented. The increase in nesting abundance was determined to be approximately 5.7% per year.
   - Capacity building in American Samoa, Guam, and Palau for nesting beach monitoring has been supported.
   - Nesting beach monitoring in the Commonwealth of the Northern Mariana Islands has been conducted.
   - Nesting beach monitoring and tagging of nesting females on the outer islands of Yap State, Federated States of Micronesia has been supported.

4. Existing foraging areas are maintained as healthy environments.
   - Efforts to attain this goal are ongoing.

5. Foraging populations are exhibiting statistically significant increases at several key foraging grounds within each stock region.
   - Increases in foraging populations have been documented, consistent with increased nesting trends.
   - Long-term, spatially extensive, capture-mark-recapture programs have been conducted at six sites throughout the Hawaiian archipelago.
   - Capacity building in American Samoa and Palau for in-water monitoring has been supported.
   - In-water monitoring in the Commonwealth of the Northern Mariana Islands has been conducted.

6. All priority #1 tasks have been implemented.
   - Efforts are ongoing to reduce directed take through public education and information (tasks 1.1.1.1 and 2.1.1.1).
   - Law enforcement activities to prevent illegal exploitation and harassment are ongoing (tasks 1.1.1.2 and 2.1.1.2).
   - Long-term monitoring and research of potential causes of and threats posed by fibropapillomatosis has been conducted (task 2.1.6.1).
   - U.S. fishery observer programs have been conducted to monitor, report, and estimate green turtle bycatch (task 2.1.4).
   - Support has been given to the Marshall Islands to build sea turtle conservation and management capacity, including training of observers in sea turtle-fishery interaction mitigation techniques (task 2.1.4).
   - Hawaii-based longline fishery participants have been educated about sea turtle mitigation requirements, including safe handling, gear removal, and release of turtles caught incidental to the fishery (task 2.1.4).
   - Fishery mitigation experiments have been conducted in Hawaiian longline and shoreline fisheries (task 2.1.4).

7. A management plan to maintain sustained populations of turtles is in place.
   - Not yet completed.

8. International agreements are in place to protect shared stocks.
   - The U.S. is a party to the South Pacific Regional Environment Program, which has goals to promote cooperation in the Pacific Islands region and to provide assistance to ensure sustainable development for present and future generations. Sea turtles are among the focal animal groups within this program.

1998 Recovery Plan for U.S. Pacific Populations of the East Pacific Green Turtle (Chelonia mydas):

To consider de-listing, all of the following criteria must be met:

1. All regional stocks that use U.S. waters have been identified to source beaches based on reasonable geographic parameters.
   - Stock structure of nesting turtles has been identified using DNA analysis, flipper tagging, and satellite telemetry.
   - Population identification has been conducted on turtles caught as bycatch in fisheries, foraging turtles, and stranded turtles using DNA analysis, flipper tagging, and satellite telemetry.

2. Each stock must average 5,000 (or a biologically reasonable estimate based on the goal of maintaining a stable population in perpetuity) females estimated to nest annually (FENA) over six years.
   - A mean of roughly 6,050 nests has been deposited each year in Pacific Mexico (see Table 4 for additional information). The long-term (25-year) trend in nesting activity for Colola, the largest nesting concentration in Pacific Mexico, has increased since the population's low point in the mid 1980s to mid 1990s.

3. Nesting populations at "source beaches" are either stable or increasing over a 25-year monitoring period.
   - Aerial surveys of nesting areas in Mexico have been supported.
   - Monitoring and protection efforts of nesting beaches in Mexico, Galapagos Islands, and Costa Rica have been supported.
   - The only long-term trend data available are for Colola, the largest nesting concentration in Pacific Mexico, where nesting beach monitoring has been ongoing every year since the 1981-1982 nesting season. Based on the 25-year trend line, it is clear that green turtle nesting has increased since the population's low point in the mid 1980s to mid 1990s.

4. Existing foraging areas are maintained as healthy environments.
   - Efforts to attain this goal are ongoing.

5. Foraging populations are exhibiting statistically significant increases at several key foraging grounds within each stock region.
   - Resident green turtles in south San Diego Bay, California; Galapagos Islands; Chile, Peru; and Pacific Mexico have been monitored and tracked.

- Monitoring efforts on index areas in Baja California, Mexico, to obtain information on abundance, mortality, and biology, have been supported.
- Aerial surveys of foraging areas in Mexico have been supported.

6. All priority #1 tasks have been implemented.
   - An observer program in Peru to document the threat of shark and mahi mahi longline fisheries on green turtles has been supported (task 2.1.4).
   - An observer program in the Chilean swordfish-directed longline fishery has been supported and provided circle hooks and technical support for experimental testing of modified gear (task 2.1.4).
   - Fishery mitigation experiments in longline fisheries in Costa Rica, Brazil, and Guatemala have been conducted (task 2.1.4).
   - Turtle excluder device outreach and training efforts with various foreign governments have been conducted (task 2.1.4).

7. A management plan to maintain sustained populations of turtles is in place.
   - Not yet completed.

8. International agreements are in place to protect shared stocks.
   - The U.S. is a party to the Inter-American Convention for the Protection and Conservation of Sea Turtles.

2.3 Updated Information and Current Species Status

The green sea turtle was once abundant in tropical and subtropical regions throughout the world. Over the last century, this species has declined in most areas and stands at only a fraction of its historical abundance. These declines resulted in the listing of green turtles on the U.S. Endangered Species Act as threatened globally, except for the Florida and Pacific coast of Mexico breeding populations, which are listed as endangered (43 FR 32800). In accordance with these separate listings, this ESA review is divided into three subsections: A) threatened breeding populations distributed globally, B) the endangered breeding population in Florida, and C) the endangered breeding population in Pacific Mexico. These subsections are not intended to be exhaustive reviews of all new information pertaining to green turtles in each area, but instead focus on new information that is relevant for determining if a change in ESA status is warranted.

SUBSECTION A: THREATENED BREEDING POPULATIONS

A.2.3.1 Biology and Habitat

A.2.3.1.1 New information on the species' biology and life history:

Green turtles are highly mobile and they undertake complex movements through geographically disparate habitats during their lifetimes (Musick and Limpus 1997, Plotkin 2003). The periodic migration between nesting sites and foraging areas by adults is a prominent feature of their life history. Early flipper tagging studies demonstrated that female green turtles are philopatric to specific nesting beaches, returning to the same beach in subsequent nesting seasons (Carr *et al*. 1978). Genetic techniques clarified that these are also their natal beaches (Meylan *et al*. 1990). Thus, after departing as hatchlings and residing in a variety of marine habitats for up to 40 or more years (Limpus and Chaloupka 1997), green turtles make their way back to the same beach from which they originated. The timing of females' return trips for nesting, both within a season and between seasons, and their nesting biology have been the focus of extensive research for many years. Through examining green turtle nesting in the context of oceanography, it is clear that environmental periodicity is a major determinant in the timing of green turtle reproduction (Limpus and Nichols 1988, Chaloupka 2001, Solow *et al*. 2002). It is also apparent that during years of heavy nesting activity, density dependent factors (e.g., beach crowding, digging up of eggs by nesting females) may impact nesting activity and hatchling production (Tiwari *et al*. 2005, 2006), which in turn can affect a population's growth rate and recovery potential (Mazaris and Matsinos 2006). While substantial research continues to describe nesting biology, one of the most notable advances in sea turtle research has been the expansion of efforts to study turtles in the marine environment. As a result we are gaining a better understanding of the biology of all life phases.

Research on green turtles in marine habitats has addressed a variety of questions. Areas of particular advance include information on green turtle growth (Bresette and Gorham 2001, Bjorndal *et al*. 2000, Seminoff *et al*. 2002c, Balazs and Chaloupka 2004b, Chaloupka *et al*. 2004b) and age-to-maturity (Seminoff *et al*. 2002c, Zug *et al*. 2002, Balazs and Chaloupka 2004b, Chaloupka *et al*. 2004a). Coupled with the recent studies of demography and survivorship (see Subsection A.2.3.1.2.3), these data are paramount for developing accurate population models. We have also learned more about post-nesting migrations (Luschi *et al*. 1998, Cheng 2000, Godley *et al*. 2002, Craig *et al*. 2004, Kennett *et al*. 2004, Troëng *et al*. 2005), which has illuminated migratory corridors as well as their foraging area destinations. We now know that green turtles often return to the same foraging areas following subsequent nesting migrations (Godley *et al*. 2002; Broderick *et al*. 2006a; P. Dutton, NMFS, unpublished data; B. Schroeder, NMFS, personal communication, 2007), and once there, they move within specific areas, or home ranges, where they routinely visit specific localities for foraging and resting (Seminoff *et al*. 2002a, Godley *et al*. 2003, Makowski *et al*. 2006, Seminoff and Jones 2006, Taquet *et al*. 2006). However, it is also apparent that some green turtles remain in open ocean habitats for extended periods; perhaps never recruiting to coastal foraging sites (Pelletier *et al*. 2003; Seminoff *et al*. in review; J. Alfaro-Shigueto, Asociacion Pro Delphinus Peru, unpublished data). While offshore, and sometimes while in coastal habitats, green turtles are not obligate herbivores as widely believed, and instead consume invertebrates such as jellyfish, sponges, sea pens, and pelagic prey (i.e., prey that occupy the water column) (Godley *et al*. 1998, Heithaus *et al*. 2002, Seminoff *et al*. 2002b, Hatase *et al*. 2006, Parker and Balazs in press). Additional facets of green turtle biology that have been the subject of recent studies include their ecological roles (Moran and Bjorndal 2005, Aragones *et al*. 2006), diving behavior (Hochscheid *et al*. 1999; Hays *et al*. 2000, 2001, 2002; Southwood *et al*. 2003; Seminoff *et al*. 2006), and endocrine biology (Jessop *et al*. 1999, Hamann *et al*. 2000, Jessop and Hamann 2004).

Despite these advances, there are numerous gaps in our understanding of green turtle biology. We still lack sufficient information on basic demographic aspects such as growth and age-to-maturity for the vast majority of global subpopulations. Information on annual reproductive output is similarly scant for many of these sites. In the marine environment, the oceanic phase of juveniles (i.e., the "lost years") remains one of the most poorly understood aspects of green turtle life history, both in terms of where turtles occur and how long they remain oceanic. At-sea mortality in fisheries is also an area for which few data are available. The paucity of information regarding these aspects continues to inhibit effective modeling of populations and prevents a full understanding of which nesting concentrations are most at risk.

Recent efforts to characterize the status of green turtles have underscored the need to address many of these information deficiencies (Seminoff 2004, Chaloupka *et al*. 2004b). However, to achieve this understanding will require a concerted effort from biologists, modelers, and wildlife managers throughout the world. There is a major need for additional demographic information, which will require rigorous tagging programs coupled with studies using molecular tools such as genetics and stable isotopes. Achieving recovery of depleted green turtle populations will require international partnerships and information exchange, as well as protection strategies that encompass all life history phases.

A.2.3.1.2 Abundance, trends, demography, and demographic trends:

A.2.3.1.2.1. Abundance and trends

Current nesting abundance is provided for 46 threatened and endangered nesting concentrations among 11 ocean regions around the world (Figure 1). Current nesting abundance trends were determined for 23 of the threatened populations. These include both large and small rookeries and are believed to be representative of the overall trends for their respective regions. Although the smaller sites may not contribute substantially to the overall number of turtles nesting, they represent genetic diversity within each region and their status is therefore highly relevant to this evaluation. The ocean regions include: Western-, Central-, and Eastern Atlantic Ocean, Mediterranean Sea, Western-, Northern, and Eastern Indian Ocean, Southeast Asia, and Western-, Central-, and Eastern Pacific Ocean.

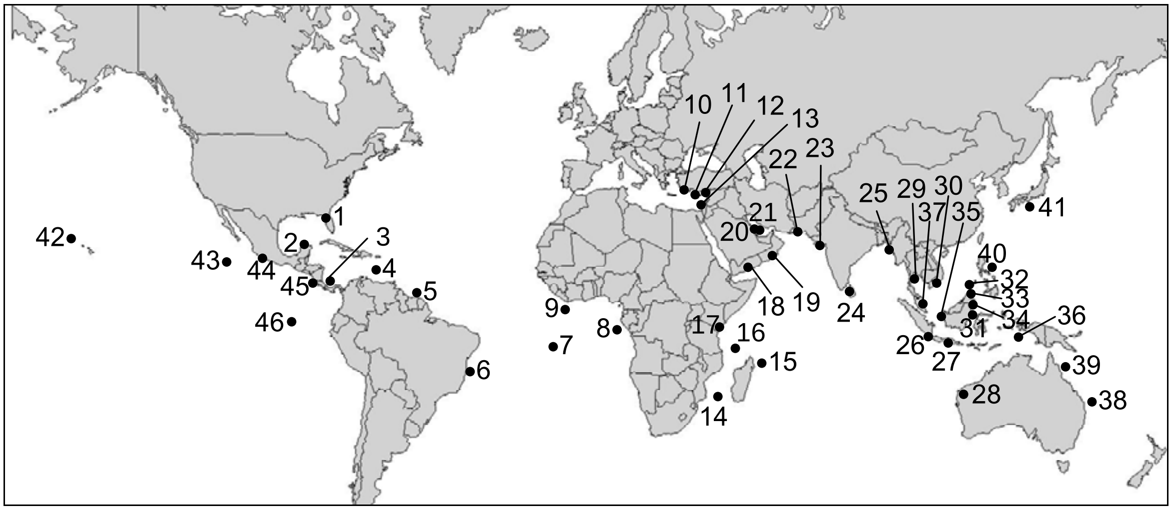

Figure 1. Map showing the location of the 46 green turtle nesting concentrations that were focused on for this evaluation. See Table 1 for site names and current annual nesting levels. Sites 1, 43, and 44 are listed as endangered (see Subsections B and C).

Estimates of current abundance are largely based on annual numbers of nesting females or deposited nests at each site. In some cases, abundance is based on egg production or egg harvest rates. Annual reproductive effort (in females, nests, or eggs) is determined during beach monitoring programs during which reproductive effort is quantified on a fixed length of beach over the course of a nesting season (Schroeder and Murphy 1999). In the few cases where egg production or egg harvest data are provided, this information was reported to state agencies by egg collectors and vendors. Because green turtle nesting activity at a given beach is often highly variable from year to year (Miller 1997), estimates of abundance are based on mean nesting activity over the course of multiple nesting seasons (at least five seasons if possible). In some cases, empirical data for single seasons are presented; however, these are not used to assess current nesting trends, even if they are suggestive of a specific population trajectory when compared to historic data.

In addition to the current abundance at each site, the total combined annual reproductive effort (number of nesting females) for all sites is presented. To estimate number of females from nest and egg counts, conversions are based on published values for eggs/female/season or nests/female/season for the site in question. If no data are available, then calculations are based on a mean of 100 eggs/nest and 3 nests/season (Hirth 1997). The application of these conversion factors are based on the assumptions that the mean number of eggs/nest and nests/female/season differ insignificantly through time, and that efforts to monitor nesting female activity and egg production are consistent through time. When using egg harvest data, we also assumed that harvest effort was consistent during all years for which data are available.

As with any assessment based on long term data, there is a level of uncertainty relating to the final results of this report. It should be noted that a major caveat of using the annual number of nesting females to assess population trends is that this data type provides information for the proportion of the adult females that nest in any given year, not the total adult female population. This limitation is heightened by the high inter-annual variability in magnitude of nesting by green turtles, and the potential that the proportion of a population's adult female cohort nesting each year oscillates over decadal or longer time frames (Limpus and Nichols 1988, Miller 1997).

To characterize the quality of data used to estimate current abundance, this report uses a letter grading system (A, B, C; Table 1). An 'A' is given to those data sources that are either in peer-reviewed published literature or are based on unpublished data collected by highly dependable experts; a 'B' is given when data are from gray literature, and a 'C' is used when data come from personal communications for which the data precision is not fully verifiable, or when the estimate is imprecise. It should be noted that the grade given for confidence in data is independent of the time duration for which the estimate is based. In other words, a letter grade of 'A' is given for peer-reviewed data, even if it represents only a single nesting season.

In addition to mean annual reproductive effort among these sites, we calculate the change in reproductive effort based on published values of former versus current nesting levels. To this extent, this report does not present robust modeling exercises, but rather provides a summary of the empirical data available for each nesting concentration. It is implicitly acknowledged that most green turtle populations are depleted relative to their historic abundance; however, this evaluation focuses on current abundance and population trends, irrespective of how nesting numbers compare to historic data. Population trends are determined by comparing the current nesting abundance with that from some earlier period, preferably ≥ 20 years in the past. A summary of these trends is given in Table 1, where the symbols ▲, ▼, and ▬ are used to indicate if a population is increasing, declining, or stable, respectively. The symbol '?' is used when data are insufficient to make a trend determination or the 'most recent' values are not current (15 years or older).

Table 1. Estimates of current abundance for green turtle nesting rookeries with data confidence grades (G) and current trend statuses (T). See Figure 1 for location of rookeries, see previous text for description of confidence grades. Units of abundance include: AF = annual nesting females; AN = annual nests; EP = annual egg production; EH = annual egg harvest. ▲ = increasing population; ▼= decreasing population; ▬ = stable population; ? = unknown trend. Sites 1, 43, and 44 are listed as endangered (see Subsections B and C).

Location	Units	Years	Abundance	G	T	Reference
WESTERN ATLANTIC OCEAN						
1. Florida USA	AN	2001-2005	5,055	A	▲	Meylan *et al*. 2006
2. Cuyo and Holbox, Yucatan Peninsula, Mexico	AN	2000s	1,500	C	▲	I.N. Pesca, unpublished data
3. Tortuguero, Costa Rica	AF	1999-2003	17,402-37,290	A	▲	Troëng and Rankin 2005
4. Aves Island, Venezuela	AF	2005-2006	335-443	B	▬	Vera 2007
5. Galibi Reserve, Suriname	AF	1995	1,803	A	▲	Weijerman *et al*. 1998
6. Isla Trindade, Brazil	AF	1990s	1,500-2,000	B	▬	Moreira and Bjorndal 2006
CENTRAL ATLANTIC OCEAN						
7. Ascension Island, UK	AF	1999-2004	3,500	A	▲	Broderick *et al*. 2006b
EASTERN ATLANTIC OCEAN						
8. Bijagos Archipelago, Guinea-Bissau	AN	2000	6,299-8,273	A	?	Catry *et al*. 2002
9. Bioko Island, Equatorial Guinea	AN	1996-1998	1,255-1,681	A	?	Tomas *et al*. 1999
MEDITERRANEAN SEA						
10. Turkey	AF	1990-2001	214-231	A	?	Broderick *et al*. 2002
11. Cyprus	AF	1995-2000	121-127	A	?	Broderick *et al*. 2002
12. Israel / Palestine	AF	1993-1998	1-3	B	?	Kuller 1999
13. Syria	AN	2004	100	B	?	Rees *et al*. 2005
WESTERN INDIAN OCEAN						
14. Eparces Islands (Tromelin and Europa)	AF	mid 1980s	2,000-11,000	B	?	Le Gall *et al*. 1986
15. Comoros Islands	AF	late 1990s	5,000	C	▲	S. Ahamada, pers. comm. 2001
16. Seychelles Islands (Aldabra and Assumption)	AF	1990s	3,535-4,755	A	▲	J. Mortimer, pers. comm. 2002
17. Kenya	AF	1999-2004	200-300	B	?	Okemwa and Wamukota 2006
NORTHERN INDIAN OCEAN						
18. Ras al Hadd, Oman	AN	2005	44,000	C	?	S. Al-Saady, pers. comm. 2007
19. Sharma, Peoples Dem. Republic of Yemen	NF	1999	15	B	?	Saad 1999
20. Karan Island, Saudi Arabia	AF	1991-1992	408-559	A	▬	Pilcher 2000
21. Jana and Juraid Islands, Saudi Arabia	AN	1991	643	A	?	Pilcher 2000
22. Hawkes Bay and Sandspit, Pakistan	AN	1994-1997	600	A	▼	Asrar 1999
23. Gujarat, India	AN	2000	461	A	?	Sunderraj *et al*. 2006
24. Sri Lanka	AF	1996-2000	184	A	▬	Kapurisinghe 2006
EASTERN INDIAN OCEAN						
25. Thamihla Kyun, Myanmar	EH	1999	<250,000	B	?	Thorbjarnarson *et al*. 2000
26. Pangumbahan, Indonesia	EH	mid 1980s	400,000	B	?	Schulz 1987
27. Suka Made, Indonesia	AN	1991-1995	395	C	▼	C. Limpus, pers. comm. 2002
28. Western Australia	AN	2001	3,000-30,000	C	?	R. Prince, pers. comm. 2001
SOUTHEAST ASIA						
29. Gulf of Thailand	AN	1992-2001	250	C	▼	Charuchinda, pers. comm. 2001
30. Vietnam	AF	1995-2003	239	B	▼	Hamann *et al*. 2006a
31. Berau Islands, Indonesia	AF	early 1980s	4,000-5,000	B	?	Schulz 1984
32. Turtle Islands, Philippines	EP	1998-1999	1.4 million	B	▬	Cruz 2002
33. Sabah Turtle Islands, Malaysia	AN	1991-2000	8,000	A	▲	Chan 2006
34. Sipadan, Malaysia	AN	1995-1999	800	A	?	Chan 2006
35. Sarawak, Malaysia	AN	1970s-1990s	2,000	A	▬	Liew 2002
36. Enu Island (Aru Islands)	AF	1997	540	C	?	Dethmers, in preparation
37. Terengganu, Malaysia	AN	1984-2000	2,200	A	▬	Chan 2006
WESTERN PACIFIC OCEAN						
38. Heron Island, southern GBR, Australia	AF	1993-1998	560	A	▲	Limpus *et al*. 2002
39. Raine Island, northern GBR, Australia	AF	1990s-2000s	25,000	C	?	Limpus *et al*. 2003
40. Guam	AF	1995-2002	45	B	▬	Cummings 2002
41. Ogasawara Islands, Japan	AF	2000-2005	500	A	▲	Chaloupka *et al*. in review
CENTRAL PACIFIC OCEAN						
42. French Frigate Shoals, Hawaii, USA	AF	2002-2006	400	A	▲	Balazs and Chaloupka 2006

Table 1 (continued).

EASTERN PACIFIC OCEAN						
43. Revillagigedos Islands, Mexico	AN	1999-2002	90	B	▬	Juarez-Ceron *et al*. 2003
44. Michoacan, Mexico	AF	2000-2006	1,395	A*	▲	C. Delgado, pers. comm. 2006
45. Central American Coast	AN	late 1990s	184-344	B	?	Lopez and Arauz 2003
46. Galapagos Islands, Ecuador	AF	2001-2006	1,650	B	▬	Zárate *et al*. 2006

* an A is used for the C. Delgado personal communication due to the fact that the authors of this report recognize this value as being highly reliable.

Based on the mean annual reproductive effort, 108,761 to 150,521 females nest each year among the 46 sites included in this evaluation. This is a crude estimate of total reproductive output because not all sites are covered and some data are for single years; however, it does provide a starting point for estimating the annual global nesting effort because most of the major nesting concentrations are included in this analysis.

It is important to note that green turtles nest in areas other than those highlighted in this report; however, these sites are not believed to contain nesting levels high enough to change their overall status and are therefore not covered here. Overall, of the 23 threatened population sites for which data enable an assessment of current trends, 10 nesting populations are increasing, 9 are stable, and 4 are decreasing. Long-term continuous datasets ≥20 years are available for 9 sites, all of which are either increasing or stable. These include Ascension Island, Hawaii, Heron Island, Ogasawara Islands, Philippine Turtle Islands, Sabah Turtle Islands, Sarawak, Terengganu, and Tortuguero. Despite the apparent global increase in numbers, the positive overall trend should be viewed cautiously because trend data are available for just over half of all sites examined. Further, the need for caution is underscored by the fact that none of the data sets spans a full green turtle generation (age to maturity + ½ reproductive longevity), which may be up to 50 years (Seminoff 2004). This suggests that impacts occurring over four decades ago that caused a change in juvenile recruitment rates may have yet to be manifested as a change in nesting abundance.

With respect to regional trends it is clear that among the 'index sites' examined in this evaluation, some regions seem to be doing better than others based on available trend data. Nesting populations are doing relatively well (# increasing sites > # decreasing sites) in the Pacific, Western Atlantic, and Central Atlantic Ocean. In contrast, populations are doing relatively poorly in Southeast Asia, Eastern Indian Ocean, and perhaps the Mediterranean. Trend analyses specifically for the threatened populations are described below, summarized by region.

Western Atlantic Ocean

For the threatened breeding populations, there are five nesting concentrations of particular interest in the Western Atlantic/Caribbean, all of which are stable or increasing. These include Yucatan Peninsula

(Mexico), Tortuguero (Costa Rica), Aves Island (Venezuela), Galibi Reserve (Suriname), and Isla Trindade (Brazil).

Along the Yucatan Peninsula, daily nesting beach reconnaissance efforts suggest that nesting has increased over the last two decades. In the early 1980s, about 875 nests/year were deposited, but by 2000 this had increased to over 1,500 nests/year (Instituto Nacional de Pesca, unpublished data).

By far the most important nesting concentration for green turtles in the western Atlantic is in Tortuguero, Costa Rica. Nesting has increased markedly since the early 1970s. From 1971-1975, there were approximately 41,250 emergences per year and from 1992-1996 there were approximately 72,200 emergences per year (based on the following equation: nesting on the entire Tortuguero beach = 1.65*nesting effort along the northern 18-km section of Tortuguero beach, where 1.65 represents the ratio of total nesting emergences on the entire Tortuguero beach to nesting emergences in the northern 18-km section; Bjorndal *et al*. 1999). Although these data are given in emergences (which include nesting and non-nesting events), they are nonetheless suggestive of a dramatic increase in green turtle abundance at Tortuguero. Based on a recent account from Troëng and Rankin (2005), this population is still on the rise: from 1999-2003, a total of about 104,411 nests/year was deposited, which corresponds to approximately 17,402-37,290 nesting females each year. This increase has occurred despite the fact that there have been substantial human impacts to this population, both at the nesting beach and at foraging areas (Troëng 1998, Troëng and Rankin González 2000, Campbell and Lagueux 2005). In Nicaragua, the primary foraging area for this nesting stock, Campbell and Lagueux (2005) report large juvenile and adult survivorship at 0.55, likely due to the ongoing directed take of green turtles in this area.

At Aves Island, Venezuela, the population appears stable to slightly increasing. From 1984-1987, 700-900 nests (about 230-300 females) per season were counted; in 1997, a total of 267 females nested (V. Vera, Dirección General de Fauna, personal communication to K. Eckert, WIDECAST, 2001); and in 2005 and 2006, a total of 335 and 443 females nested, respectively (Vera and Montilla 2006, Vera 2007).

The nesting concentration at Galibi Reserve in Suriname is stable. From 1975-1979, 1,657 females were counted (Schulz 1982), a number that increased to a mean of 1,740 females from 1983-1987 (Mohadin in Ogren 1989), and to 1,803 females in 1995 (Weijerman *et al*. 1998).

The southernmost nesting concentration in the Western Atlantic is at Isla Trindade, Brazil. This nesting population has been stable with a mean of about 1,500-2,000 females nesting per year since the early 1980s (Moreira *et al*. 1995, Moreira and Bjorndal 2006).

Central Atlantic Ocean

The only nesting concentration in the central Atlantic is at Ascension Island (United Kingdom). This population has increased substantially over the last three decades (Broderick *et al*. 2006b). Mortimer and Carr (1987) counted 5,257 nests in 1977 (about 1,500 females), and 10,764 nests in 1978 (about 3,000 females) whereas from 1999-2004, a total of about 3,500 females nested each year (Broderick *et al*. 2006b). These data are suggestive of an increase, although historic data from additional years are needed to fully substantiate this trend.

Eastern Atlantic Ocean

There are two areas of interest in the eastern Atlantic Ocean: Bioko Island (Equatorial Guinea) and the Bijagos Archipelago (Guinea-Bissau). Nesting at Bioko Island appears to have decreased, whereas nesting in the Bijagos Archipelago may be stable; however, the lack of long-term and/or multiple year data sets precludes meaningful trend assessment for both sites. At Bioko, the number of nightly emergences during the peak of the nesting season declined from 200-300 females per night during the 1940s (Eisentraut 1964) to 50-100 females per night in the 1980s (Tomas *et al*. 1999; J. Tomas, University of Valencia-Spain, personal communication, 2001). During the 1996-1997 and 1997-1998 nesting seasons, a mean of 1,468 nests were deposited (approximately 500 females; Tomas *et al*. 1999). In the Bijagos Archipelago, Parris and Agardy (1993, cited in Fretey 2001) reported approximately 2,000 females per season from 1990-1992, and Catry *et al*. (2002) reported approximately 2,500 females nesting during the 2000 season.

Mediterranean Sea

There are four nesting concentrations in the Mediterranean from which data are available, including those in Turkey, Cyprus, Israel, and Syria. Currently, approximately 300-400 females nest each year - about two-thirds of which nest in Turkey and one-third in Cyprus. Although this population is depleted from historic levels (Kasparek *et al*. 2001), nesting data gathered since the early 1990s in Turkey, Cyprus, and Israel show no apparent trend in any direction. However, a declining trend is apparent along the coast of Palestine/Israel, where 300-350 nests were deposited each year in the 1950s (Sella 1982) compared to a mean of 6 nests per year from 1993-2004 (Kuller 1999; Y. Levy, Israeli Sea Turtle Rescue Center, unpublished data.).

A recent discovery of green turtle nesting in Syria adds roughly 100 nests per year to green turtle nesting activity in the Mediterranean (Rees *et al*. 2005). That such a major nesting concentration could have gone unnoticed until recently (the Syria coast was surveyed in 1991, but nesting activity was attributed to loggerheads (*Caretta caretta*)) bodes well for the ongoing speculation that the unsurveyed coast of Libya may also host substantial nesting.

Western Indian Ocean

Green turtle nesting concentrations in this region include Eparces Islands (Tromelin, Europa, and Glorieuses), the Comoros Islands, the Seychelles Islands (Aldabra and Assumption), and Kenya. In the Eparces Islands, nesting is increasing at Glorieuses, and decreasing at Europa and Tromelin (M. Taquet, Institut National Agronomique de Paris-Grignon, France, personal communication, 2002). However, published data are needed to corroborate these trends, since only very wide ranges have been reported so far, and only for Europa and Tromelin Islands (see below).

At Europa and Tromelin, the annual number of nesting females was reported at 4,000-5,000 in the early 1970s by Hughes (1970), and 9,000-18,000 in the late 1970s by Lebeau *et al*. (1983). Further, Le Gall *et al*. (1986) give an estimate of 2,000-11,000 females per year for the mid 1970s to mid 1980s. With such wide ranging estimates, it is not currently possible to determine the current nesting trend at these islands.

In the Comoros Islands, there were approximately 1,850 females per year in the early 1970s (Frazier 1985), and about 5,000 females in 2000 (S. Ahamada, AIDEnvironment-Comoros, personal communication, 2001). However since the more recent datum is unverified, this trend should be viewed with caution.

At the Seychelles Islands, green turtles are currently increasing in number, although the population remains depleted relative to historic levels (Mortimer *et al*. 2006). The annual number of nesting females at Aldabra and Assumption during the early 1900s was approximately 12,000 females based on information collected during the organized exploitation of the species for calipee production (Mortimer 1985), and by the onset of protective measures in 1968 that number had dropped to approximately 1,700 females (Mortimer 1984). Since then, however, the number of females nesting in the Seychelles has increased. For example, at Aldabra the nesting activity increased from about 1,700 nests/year during 1981-1984 to about 4,500 nests/year from 1995-2002 (Mortimer *et al*. 2006).

In Kenya, approximately 200-300 females nested each year from 1999 to 2004 (Okemwa and Wamukota 2006); however, there are not sufficient data to determine the current population trend.

Northern Indian Ocean

Seven rookeries are examined in the Northern Indian Ocean: Hawkes Bay and Sandspit (Pakistan), Gujarat (India), Karan Island (Saudi Arabia), Ras al Hadd (Oman), and Sharma (Peoples Democratic Republic of Yemen), Jana and Juraid Islands (Saudi Arabia), and Sri Lanka. Declines are evident at Hawkes Bay and Sandspit where a mean of approximately 1,300 nests were deposited annually from 1981-1985 (Groombridge and Luxmoore 1989) and a mean of approximately 600 nests were laid from 1994-1997 (Asrar 1999). At Gujarat, 866 nests were deposited in 1981 (Bhaskar 1984) and 461 nests in 2000 (Sunderraj *et al*. 2006). However, since these two data points are for single years it is not possible to determine a trend. At Sharma, counts of nightly nesters during peak nesting season in 1966 and 1972 (30-40 females; Hirth 1968, Hirth and Hollingworth 1973) versus the same index during the peak of the 1999 nesting season (15 females; Saad 1999) are suggestive of a decline. However, the lack of multiple-year data sets for both Sharma and Gujarat preclude trend assessment. This is particularly true since Saad (1999) only worked at one beach predominantly, while estimates from Hirth (1968) and Hirth and Hollingsworth (1973) represented a greater area (N. Pilcher, Marine Research Foundation, personal communication, 2007).

Nesting may be stable at beaches in Karan Island and Ras Al Hadd, although updated nesting numbers are urgently needed. At Karan Island (Saudi Arabia), 500-1,000 females nested annually during the 1970s (Basson *et al*. 1977), and during the 1991 and 1992 seasons, 559 and 408 females nested, respectively (Pilcher 2000). At Ras al Hadd (Oman), Ross and Barwani (1982) reported about 6,000 females nesting each year for the period 1977-1979, and Ross (in Groombridge and Luxmoore 1989) described the same number for the late 1980s. Although annual nesting totals have not been published since the 1980s, monitoring in the mid-to-late 1990s and early 2000s by park rangers indicate that nesting during peak periods ranges from 200-400 females/night (AlKindi *et al*. 2003), and approximately 44,000 nests were recorded in 2005 for Ras al Hadd and Ras al Jinz nesting beaches (S. Al-Saady, Ministry of Regional Municipalities, Environment and Water Resources, personal communication, 2007), thus confirming that Oman remains one of the most important nesting concentrations of green turtles in the Indian Ocean, if not the entire world.

In Saudi Arabia, data are available for two seasons from Karan Island (1991 and 1992) and only a single season from both Jana and Juraid Islands (1991), indicating that approximately 600 nests are deposited each year between these sites (Pilcher 2000). However, the fact that so few years of nesting data are available suggests that this figure should be used cautiously if attempting to derive an annual mean. At Sri Lanka, a mean of 184 females nested each year from 1996-2000 (Kapurisinghe 2006), but as with other short term data sets, no trend can be established.

Eastern Indian Ocean

The current status is described for four nesting concentrations in the Eastern Indian Ocean: Suka Made (Indonesia), Pangumbahan (Indonesia), Thamihla Kyun (Myanmar), and western Australia. Relative to the neighboring regions of the Northern Indian Ocean and Southeast Asia, populations in the Eastern Indian Ocean appear substantially depleted. Information for Suka Made (Meru Betiri National Park, East Java, Indonesia) suggests that nesting has declined since the early 1970s. Schulz (1987) reports a mean of approximately 1,500 nests from 1970-1974, which is substantially greater than the mean of 395 nests per year from 1991-1995 as reported by Arrinal (unpublished data via C. Limpus, Queensland Parks and Wildlife Service, personal communication, 2002). At Pahgumbahan (West Java, Indonesia), the mean annual egg harvest was 2.5 million eggs in the 1950s and 400,000 eggs in the 1980s (Schulz 1987). This apparent decline should be interpreted cautiously since it could be reflective of a decline in collection efforts rather than a decline in egg production. At Thamihla Kyun, Maxwell (1911, cited in Groombridge and Luxmoore 1989) reported a mean annual egg harvest of about 1.74 million eggs from 1883-1898. In 1999, less than 250,000 eggs were harvested (Thorbjarnarson *et al*. 2000). Yet, despite the apparent declines at Pahgumbahan and Thamihla Kyun, the lack of recent and/or multiple year datasets prevents an assessment of the current trends at these sites. For western Australia, there are four primary nesting concentrations, located at North West Cape, and on the islands of Lacepede, Scott Reef, and Ashmore Reef. Few data are available, although it has been estimated that the mean annual number of nests is somewhere between 3,000 and 30,000 (R.I.T. Prince, Australia Wildlife Research Centre, personal communication, 2001). Although data are not sufficient to draw any conclusions regarding long-term trends in western Australia, these sites together may constitute the most important green turtle nesting concentration in the Indian Ocean.

Southeast Asia

Population trends are described for nine nesting concentrations in the Southeast Asia region. These include Gulf of Thailand, Vietnam, Berau Islands and Enu Island (Indonesia), Philippine Turtle Islands, Sabah Turtle Islands, Sipadan, Sarawak, and Terengganu (all in Malaysia). Data suggest that populations are currently stable at all but Thailand, Vietnam, and perhaps Berau Island, although updated information is needed for this site.

Annual nesting in the Gulf of Thailand has decreased from a mean of approximately 405 nests per year between 1975-1983 to a mean of approximately 250 nests per year from 1992-2001 (Charuchinda and Monanunsap 1998; M. Charuchinda, Marine Fisheries Division Mannai Island, Thailand, personal communication, 2002).

In Vietnam, the only site for which monitoring has occurred for an appreciable period is Con Dao National Park, monitored since 1995. Here, annual nesting of green turtles has remained relatively stable, with an annual mean from 1995-2003 of 239 females (World Wildlife Fund, unpublished data, and Nguyen Thi Dao 1999, cited in Hamman *et al*. 2006a). Outside of Con Dao, there appear to have been substantial decreases. For example, prior to the 1960s, approximately 500 females nested each year along the mainland beaches and near-shore islands of south-central Vietnam and approximately 100 females nested each year on islands in the Gulf of Tonkin (Hamann *et al*. 2006a). However, aside from Con Dao, breeding populations of green turtles in Vietnam have declined significantly and probably number approximately 10 nests per year in both the Gulf of Tonkin and south-central Vietnam mainland coast (Hamann *et al*. 2006a).

In the Aru Islands, nesting beach monitoring has been ongoing sporadically at Enu Island since the late 1970s (K. Dethmers, University of Canberra, personal communication, 2007). Although there appears to have been a decline during the ensuing years, the lack of continuous monitoring prevents an assessment of the current trend at this site. Nevertheless, data collected in 1997 (540 nesting females) suggest that this site is an important nesting area for green turtles in Southeast Asia (Dethmers 2000; K. Dethmers, University of Canberra, Australia, unpublished data).

In the Berau Islands (northeast Kalimantan, Indonesia), green turtle nesting has substantially decreased over the last 60 years. Schulz (1984) estimated that approximately 36,000 females nested each season in the 1940s, with roughly 200 females/night during the peak of the nesting seasons. In the mid 1980s, approximately 4,000-5,000 females nested each season, with about 25 females/night during the peak nesting periods (Schulz 1984). However, the data for the 1940s has not been verified and may be reflective of number of nests rather than females (N. Pilcher, Marine Research Foundation, personal communication, 2007). This potential coupled with the lack of more recent data precludes trend analysis for this site.

At the Philippine and Sabah (Malaysia) Turtle Islands, both considered to be part of the same nesting population in the Sulu Sea (Moritz *et al*. 2002), information based on annual egg production and egg harvest indicates that nesting has increased at the Sabah Islands and remained stable at the Philippine Islands. At Sabah, a mean of approximately 550,000 eggs were harvested annually from 1965-1968 (de Silva 1982); this number dropped to approximately 250,000 in the early 1980s (Groombridge and Luxmoore 1989), but had increased to nearly 1 million eggs by the late 1990s (E. Chan, Institute of Oceanography, Kolej Universeti Sains dan Teknogli, Malaysia, personal communication, 2002). It should be noted, however, that from 1965-

1968 data represent eggs harvested, whereas during subsequent years data represent eggs incubated or protected, which is not reflective of total production, and Pilcher (2000) suggested that effort and data accuracy were dependable only after 1985. However, this potential underestimation for the later years adds further support to the increasing trend for Sabah green turtles. In the Philippine Turtle Islands, egg production remained fairly stable from 1984-2000, with an annual mean of about 1.4 million eggs per year (Cruz 2002).

At the Sipadan (Malaysia) rookery, Chan (2006) reports that nesting levels have been fairly consistent each year from 1995 to 1999, numbering about 800 nests/year, with relatively little inter-annual variation in abundance.

In Sarawak and Terengganu (Malaysia), it appears that nesting abundance has been stable for 20 years or more. At Sarawak, approximately 2,000 nests were deposited per year from 1970-2001, and at Terengganu, about 2,200 nests per year were laid from 1984-2000 (Liew 2002, Chan 2006). It should be noted, however, that data since 1927 (Banks 1937) suggests that the current population, although stable, is dramatically reduced from historical levels.

Western Pacific

Trends are presented for four sites in the Western Pacific: Heron Island (southern Great Barrier Reef (sGBR), Australia), Raine Island (northern Great Barrier Reef (nGBR), Australia), Guam (USA territory), and Ogasawara Islands (Japan). Three sites have shown an increase in abundance, while a fourth (Guam) appears stable.

At Heron Island (sGBR), Chaloupka and Limpus (2001) found an increase in annual nesting abundance of approximately 3% per year from 1974-1998. The mean annual abundance from 1993-1998 was about 560 females (Limpus *et al*. 2002). More recently, based on data through 2002, Chaloupka *et al*. (in review) reported a mean annual growth rate of 3.8% for the Heron Island rookery. The increase in annual nesting at Heron Island is concurrent with an observed increase of 8% per year from 1985-1992 for the green turtle population in southern Great Barrier Reef waters (Chaloupka and Limpus 2001).

At Raine Island (nGBR), the population has apparently increased based on a positive change in the number of turtles observed during nightly tally counts (Limpus *et al*. 2003). For example, mean nesting levels increased from 2,361 females/night during 1974-1979 to 3,680 females/night during 1995-2000. However, since the mid 1990s there has been a leveling off of the rate of increase (Chaloupka *et al*. in review) and there are concerns about the long-term health of this nesting population (Limpus *et al*. 2003). First, there have been recent recruitment failures due to flooding of nests by rising ground waters, which threaten the long-term viability of this rookery (Limpus *et al*. 2003). Second, although green turtles still nest in large numbers, there has been a progressive decrease in the mean nesting size of females (Limpus *et al*. 2003). Although this decrease is only a few centimeters or less, it may be a response to a reduction in the proportion of older turtles to the population (probably due to mortality in Southeast Asia) (Limpus *et al*. 2002) and a warning that the Raine Island nesting population may be in the early stages of decline. Another trend indicative of decline is that in recent years there has been an increase in the mean remigration interval of turtles nesting at Raine Island (Limpus *et al*. 2002). Given that the remigration interval of females returning for only their second season is longer than that for turtles that have nested during multiple prior seasons (i.e., older turtles), the observed increase in mean remigration interval further supports the notion that fewer large turtles are present in the population (Limpus *et al*. 2002). However, that these trends could also be interpreted as good signs indicating a preponderance of new recruits to the population, or a decrease in forage quality at the foraging sites for Raine Island nesters.

Despite the status of Raine Island as the largest nesting concentration worldwide, there are still no reliable estimates of mean annual female abundance. This is largely because no surveys have been done over the course of the entire nesting season, and also a result of the sheer numbers of turtles that may nest on any given night, which makes accurate counting very difficult. However, based on a quasi mark-recapture study in which females were painted during nightly tally counts followed by the counting of marked and unmarked turtles in internesting habitats, Limpus *et al*. (2003) stated that "…for mean tally counts of 4,000 females per walk of the beach… there is an estimated internesting population adjacent to the Raine Island Rookery of approximately 25,000 breeding female *C. mydas*." This value, although a rough estimate, suggests that during some years, Raine Island may not be the largest nesting colony in the world as widely believed. However, in particularly dense years upwards of 80,000 females can be present in the internesting habitat (Limpus *et al*. 2003).

At Guam, nesting was stable from 1990-2001 with the annual number of nesting females fluctuating between 2 and 60 females (Cummings 2002). This trend also appears to be ongoing in the marine environment, where aerial surveys during 1994-2002 show a fairly constant near shore abundance of 150-250 turtles (Cummings 2002).

The Ogasawara nesting population (Chichi-jima Island) is one of the major green turtle nesting concentrations in Japan and has the longest continuous record of harvest for anywhere in the world (Horikoshi *et al*. 1994). Relative to the late 1800s/early 1900s, there has been a substantial decline in annual harvest rates for green turtles in this region, which is suggestive of a long-term decline in the population. However, since nesting abundance data were first collected in the late 1970s, there has been an increase in the annual nesting abundance. The population has increased from a mean of approximately 100 females/year in the late 1970s/early 1980s to a mean of approximately 500 per year since 2000. Chaloupka *et al*. (in review) reports an estimated annual population growth rate of 6.8% per year for the Chichi-jima rookery.

Central Pacific

The green turtle nesting concentration at East Island in the French Frigate Shoals (Hawaii, USA) is the largest in the Central Pacific. Since the initial nesting surveys in 1973, there has been a marked increase in annual green turtle nesting at East Island (Balazs and Chaloupka 2004a, 2006). During the first 5 years of monitoring (1973-1977), the mean annual nesting abundance was 83 females, and during the most recent 5 years of monitoring (2002-2006), the mean annual nesting abundance was 400 females (Balazs and Chaloupka 2006; G. Balazs, NMFS, unpublished data). This increase over the last 30+ years corresponds to an underlying near-linear increase of about 5.7% per year (Balazs and Chaloupka 2006).

Information on in-water abundance trends is consistent with the increase in nesting (Balazs 1996, 2000; Balazs *et al*. 2005). This linkage is to be expected since, based on genetics, satellite telemetry, and direct observation, green turtles from the nesting beaches in the French Frigate Shoals rookery remain resident to foraging pastures throughout the archipelago (with the possible exception of the oceanic juvenile phase - for which there are no available data and which genetic sampling has yet to reveal) and are the exclusive nesting population present in these areas (Balazs 1976, 1994; Bennett *et al*. 2002; Dutton and Balazs in review). A significant increase in catch per unit effort of green turtles was seen from 1982-1999 during bull-pen fishing conducted at Palaau, Molokai (Balazs 2000). The number of immature green turtles residing in foraging areas of the eight main Hawaiian Islands has increased (Balazs 1996). In addition, although the causes are not totally clear, there has been a dramatic increase in the number of basking turtles in the Hawaiian Islands over the last two decades, both in the southern foraging areas of the main islands (Balazs 1996) as well as at northern foraging areas at Midway Atoll (Balazs *et al*. 2005). Although it is not possible to unequivocally tie this increase in basking to an increase in in-water abundance, it nonetheless provides a compelling example of abundance change for the Hawaiian green turtle population.

Eastern Pacific

Green turtles in the eastern Pacific Ocean have been considered among the most depleted of green turtle populations worldwide. However, recent evidence suggests that may not be the case. This section will discuss the situation for green turtles in the Galapagos and along the Pacific coast of Central America. For a discussion of current population trends of green turtles in Michoacan and the Revillagigedos Islands, see Subsection C on the Endangered Pacific Mexico Breeding Population.

In the Galapagos Islands (Ecuador), nesting at the four primary nesting sites (Quinta Playa and Barahona - Isabela Island, Las Bachas - Santa Cruz Island, and Las Salinas - Baltras Island) has been stable to slightly increasing since the late 1970s. Mean annual nesting abundance at these sites was 1,283 females from 1979-1980 to 1982-1983 (Green and Ortiz-Crespo 1982; M. Hurtado, unpublished data). From 2001-2002 to 2005-2006, a mean of 1,648 females nested each year (Zárate *et al*. 2006). Based on these data, it is apparent that the Galapagos nesting concentration is currently the largest for green turtles in the eastern Pacific Ocean, followed by Michoacan, which has had a mean of 1,395 nesters per year since 2000 (C. Delgado-Trejo, Universidad Michoacana, personal communication, 2006). Historically, however, with upwards of 25,000 females per year, the Michoacan site was the largest (Cliffton *et al*. 1982).

Green turtles nest sporadically along much of the Pacific coast of Central America, and although long-term trends are available for only one site, it is clear that a substantial number of green turtles nest along this coast each year. At Playa Naranjo (Costa Rica), 326 confirmed green turtle nests were laid during the 1971-1972 nesting season, compared to 102 nests in 1996-1997, 11 nests in 1998-1999 (Behm *et al*. 2002), and about 200 nesting emergences in 2006-2007 (A. Gaos, PRETOMA, Costa Rica, unpublished data). Additional sites in Costa Rica include Caña Blanca, where 50-100 nests/year were reported from 1998-2000, and Punta Banco, where 73-233 nests were deposited annually from 1996-2001 (López and Arauz 2003). Green turtles have also been reported to nest at El Hawaii, Guatemala, where approximately 20 nests were deposited per night in the late 1970s (Cornelius 1982), and at Jiquilisco, El Salvador (Marquez 1990).

A.2.3.1.2.2. Demography

The primary demographic features of green turtles that are relevant for interpreting population abundance and long term trends include age-to-maturity (often via growth studies), reproductive longevity, reproductive output (i.e., egg production, clutch frequency, internesting interval), and annual survivorship. A brief description of these features is given below.

Most green turtles exhibit particularly slow growth rates, which has been described as a consequence of their largely herbivorous (i.e., low net energy) diet (Bjorndal 1982). Growth rates of juveniles vary substantially among populations, ranging from <1 cm/year (Green 1993) to >5 cm/year (McDonald-Dutton and Dutton 1998), likely due to differences in diet quality, duration of foraging season (Chaloupka *et al*. 2004b), and density of turtles in foraging areas (Bjorndal *et al*. 2000, Seminoff *et al*. 2002c, Balazs and Chaloupka 2004b). In general, there is a tendency for green turtles to exhibit monotonic growth (declining growth rate with size) in the Atlantic and non-monotonic growth (growth spurt in mid size classes) in the Pacific, although this is not always the case (Chaloupka and Musick 1997, Seminoff *et al*. 2002c, Balazs and Chaloupka 2004b).

Consistent with slow growth, age-to-maturity for the green turtles appears to be the longest of any sea turtle species (Chaloupka and Musick 1997, Hirth 1997). Estimates based on skeletochronology and mark recapture studies indicate that age-to-maturity ranges from perhaps less than 20 years to 40 years or more (Limpus and Chaloupka 1997, Zug and Glor 1998, Seminoff *et al*. 2002c, Zug *et al*. 2002, Chaloupka *et al*. 2004b).

Estimates of reproductive longevity range from 17-23 years (Carr *et al*. 1978, Fitzsimmons *et al*. 1995, Chaloupka *et al*. 2004b). Considering that mean remigration intervals range from 2 to 5 years (see Hirth 1997 for review), these reproductive longevity estimates suggest that a female may nest 3 to 11 seasons over the course of her life. Based on the reasonable means of 3 nests/season and 100 eggs/nest (Hirth 1997), a female may deposit 9 to 33 clutches, or about 900-3,300 eggs, during her lifetime. These are very approximate estimates, but they nonetheless provide a basis for characterizing reproductive effort in green turtles.

Survivorship has been quantified for green turtles resident to foraging areas as well as for adult females at nesting beaches. In general, survivorship tends to be lower for juveniles and subadults than for adults. In the southern Great Barrier Reef, Chaloupka and Limpus (2005) provided estimates for mean annual adult survival (0.95) that was significantly higher than survival for either subadults or juveniles (0.85 and 0.88, respectively). Seminoff *et al*. (2003) reported mean annual survival of adults and juveniles as 0.97 and 0.58, respectively, in the Gulf of California. At a Bahamas foraging habitat, juvenile green turtle survivorship was considerably higher at 0.89, although this value dropped to 0.76 once turtles emigrated from this protected site (Bjorndal *et al*. 2003). Low survivorship as a result of human impacts has also been reported for a Caribbean Nicaraguan foraging area where Campbell and Lagueux (2005) found low survival (0.55) among large juveniles and adults; they also report annual survival of adults nesting at Tortuguero of 0.82, which is close to the value of 0.85 reported by Troëng and Chaloupka (2007) for the same rookery. Therefore, it is apparent that the survivorship at any particular site will be influenced by the level of human impacts, with the more pristine green turtle stocks tending to represent more 'natural' survivorship values (e.g., Great Barrier Reef) and others with survivorship values largely influenced by anthropogenic impacts (e.g., Nicaragua).

A.2.3.1.2.3. Demographic trends

One aspect relating to green turtle demography that seems to be a growing problem is the increasing female bias in the sex ratio of green turtle hatchlings, likely related to two primary factors: global climate change and imperfect egg hatchery strategies (Tiwol and Cabanban 2000, Hays *et al.* 2003, Baker *et al*. 2006). Global warming is unequivocal (IPCC 2007a) and may result in significant changes in hatchling sex ratios. The fact that green turtles exhibit temperature-dependent sex determination (Mrosovsky 1994) suggests that there may be a skewing of future green turtle cohorts toward strong female bias (because warmer temperatures produce more female embryos). At least one site - Ascension Island - has had an increase of mean sand temperature in recent years (Hays *et al*. 2003). A similar, although more localized, problem is that of high incubation temperatures in poorly located egg hatcheries of nesting beach conservation programs. For example, artificially high incubation temperatures are resulting in nearly 100% female sex among hatchlings at the Sabah Turtle Island hatcheries (Tiwol and Cabanban 2000).

A.2.3.1.3 Genetics and genetic variation:

The genetic substructure of the green turtle regional subpopulations shows distinctive mitochondrial DNA properties for each nesting rookery (Bowen *et al*. 1992, FitzSimmons *et al*. 2006). Mitochondrial DNA data suggest that the global matriarchal phylogeny of green turtles has been shaped by ocean basin separations (Bowen *et al*. 1992, Encalada *et al*. 1996) and by natal homing behavior (Meylan *et al*. 1990). Studies examining microsatellites (nuclear DNA) confirm that, like females, male turtles demonstrate regional philopatry (FitzSimmons *et al*. 1997a), although male-mediated gene flow among populations has also been reported, and may act as a mechanism for the genetic exchange that occurs among beaches (Roberts *et al*. 2004, FitzSimmons *et al*. 1997b). However, comparatively few data are available on male green turtle demography, and the strength of male philopatry to nesting beaches. The importance of male mediated gene flow is also unknown for the vast majority of nesting sites.

The fact that sea turtles exhibit fidelity to their natal beaches suggests that if populations become extirpated they may not be replenished by the recruitment of turtles from other nesting rookeries over ecological time frames. Moreover, because each nesting population is genetically discrete, the loss of even one rookery represents a decline in genetic diversity and resilience of the species (Bowen 1995). If, however, an exploited population is able to withstand total extirpation, genetic diversity may not be appreciably reduced (Encalada 1994, Chassin-Norria *et al*. 2004). Therefore, it can be argued that any population, no matter how small, will continue to contribute to the overall genetic diversity of green turtles. While this is correct at a genetic level, it is important to note that the probabilities of and opportunities for depleted populations contributing to a geographically-wider gene pool will be reduced.

Over the last decade, there have been substantial efforts to determine the nesting population origins of green turtles assembled in foraging grounds. Genetic research has shown that green turtles from multiple nesting beach origins commonly mix in these areas (Bass *et al*. 1998, 2006; Lahanas *et al*. 1998; Bass and Witzell 2000; D'Aloia and Al Ghais 2000; Formia 2002; Nichols 2003a; Luke *et al*. 2004; Dethmers *et al*. 2006; Naro-Maciel *et al*. 2007; Bolker et al. 2007; P. Dutton, NMFS, unpublished data). However, such mixing occurs at extremely low levels in Hawaiian foraging areas and this central Pacific population stands out as perhaps the most isolated of all green turtle populations worldwide (Dutton and Balazs in review). There is one main mitochondrial DNA haplotype with no difference in mitochondrial DNA haplotype frequencies between foraging ground populations and females nesting at the East Island rookery (LeRoux *et al*. 2003, Dutton and Balazs in review). Although green turtles from the east Pacific population have been rarely recorded in Hawaiian waters (LeRoux *et al*. 2003, Dutton and Balazs in review), the low frequency of these occurrences suggests that they are not ecologically significant.

A.2.3.1.4 Taxonomic classification:

The taxonomic classification for the green turtle has not changed since the species was listed. It remains as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Reptilia
Order: Testudines
Family: Cheloniidae
Genus: *Chelonia*
Species: *mydas*
Common name: Green sea turtle

A.2.3.1.5 Spatial distribution and change in distribution within the historic range:

A.2.3.1.5.1. Spatial distribution

The green turtle has a circumglobal distribution, occurring throughout tropical, subtropical waters, and, to a lesser extent, temperate waters. Their movements within the marine environment are not fully understood, but it is believed that green turtles inhabit coastal waters of over 140 countries (Groombridge and Luxmoore 1989).

Nesting occurs in more than 80 countries worldwide (Hirth 1997). The primary nesting rookeries (i.e., sites with ≥ 500 nesting females per year) are located at Ascension Island, Australia, Brazil (Trindade Island), Comoros Islands, Costa Rica (Tortuguero), Ecuador (Galapagos Archipelago), Guinea-Bissau (Bijagos Archipelago), Eparces Islands, Indonesia, Malaysia, Oman, Philippines, Saudi Arabia, Seychelles Islands, Suriname, and United States (Hawaii) (see Subsection A.2.3.1.2 and Seminoff 2004 for citations). Lesser nesting areas are located in Agalega, Angola, Aru Islands, Bangladesh, Bikar Atoll, Brazil (Atoll da Rocas), Chagos Archipelago, China, Costa Rica (Pacific coast), Cuba, Cyprus, Democratic Republic of Yemen, Dominican Republic, d'Entrecasteaux Reef, Equatorial Guinea (Bioko Island), French Guiana, French West Indies, Ghana, Gulf of Carpentaria coast of Australia, Guyana, India, Iran, Japan, Kenya, Madagascar, Maldives Islands, Mayotte Archipelago, Mexico (Yucatan Peninsula, Revillagigedos Islands), Micronesia, Myanmar, Natuna Islands, New Caledonia, Nicaragua, Pakistan, Palmerston Atoll, Papua New Guinea, Primieras Islands, Sao Tome é Principe, Scilly Atoll, Sierra Leone, Solomon Islands, Somalia, Sri Lanka, Taiwan, Tanzania, Thailand, Turkey, Venezuela, and Vietnam (for a complete listing of country citations see Seminoff 2004). Sporadic nesting occurs in at least 30 additional countries (Groombridge and Luxmoore 1989).

A.2.3.1.5.2. Change in distribution of the species within its historic range

The present distribution of the breeding sites has been largely affected by historical patterns of human exploitation. Most of the substantial breeding colonies left today are those that have not been permanently inhabited by humans or have not been heavily exploited until recently (Groombridge and Luxmoore 1989, Seminoff 2004). Although not the case for all rookeries, this demographic trend is corroborated by the fact that several islands that formerly held large breeding colonies are known to have lost them once becoming inhabited by humans (e.g., Bermuda, King 1982; Mauritius, Hughes 1982; Reunion, Bertrand *et al*. 1986; Cape Verde Islands, Parsons 1962). In addition, the Cayman Island rookery, formerly one of the largest green turtle rookeries in the world, was nearly if not totally extirpated after human colonization and the onset of an organized turtle fishery at these islands (Parsons 1962). Although green turtles continue to nest at extremely low levels at the Cayman Islands (Aiken *et al*. 2001), it is unknown whether they are a relict nesting subpopulation or the result of recolonization by turtles from adjacent nesting rookeries in the western Atlantic or headstarted turtles from the Cayman Turtle Farm (Wood and Wood 1993).

A.2.3.1.6 Habitat or ecosystem conditions:

Green turtles spend the majority of their lives in coastal foraging grounds. These areas include both open coastline and protected bays and lagoons. While in these areas, green turtles rely on marine algae and seagrass as their primary diet constituents, although some populations also forage heavily on invertebrates. These marine habitats are often highly dynamic and in areas with annual fluctuation in seawater and air temperatures, which can cause the distribution and abundance of potential green turtle food items to vary substantially between seasons and years (Carballo *et al*. 2002). Many prey species that are abundant during winter and spring periods become patchy during warm summer periods. Some species may altogether vanish during extreme temperatures, such as those that occur during El Niño Southern Oscillation events (Carballo *et al*. 2002).

Conditions at coastal foraging areas have been shown to impact the timing of green turtle reproduction (Limpus and Nicholls 1987, Solow *et al*. 2002). Therefore, despite the fact that foraging areas are usually separated from nesting areas by hundreds to thousands of kilometers, they have a profound influence on population dynamics of green turtles. Annual and decadal oscillations likely play a large role; however, a better understanding is needed concerning how environmental variability triggers or limits green turtle migration and reproduction. In addition, red tide episodes at foraging areas may lead to mortality of juvenile and adult green turtles, thereby impacting a population's present and future reproductive status (Redlow *et al*. 2002; J. Seminoff, NMFS, personal observation; L. Sarti, CONANP, personal communication, 2007).

In addition to coastal foraging areas, oceanic habitats are used by oceanic-stage juveniles, migrating adults, and, on some occasions, by green turtles that reside in the oceanic zone for foraging. Despite these uses of the oceanic zone by green turtles, much remains to be learned about how oceanography affects juvenile survival, adult migration, and prey availability.

At nesting beaches, green turtles rely on safe and healthy beaches with intact dune structures, native vegetation, and normal beach temperatures for nesting (Ackerman 1997). Coastal areas denuded of vegetation or with coastal construction can impact thermal regimes on beaches and thus affect the incubation and resulting sex ratio of hatchling turtles. Further, climate change may impact these beaches through sea level rise (Baker *et al*. 2006, IPCC 2007a) and eventually, lethal incubation temperatures on nesting beaches (Glen and Mrosovsky 2004).

A.2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

The determination to list a species under the ESA is based on the best scientific and commercial data regarding five listing factors (see below). Subsequent 5-year reviews must also make determinations about the listing status based, in part, on these same factors.

A.2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

There are increasing impacts to the nesting and marine environment that affect green turtles. Structural impacts to nesting habitat include the construction of buildings and pilings, beach armoring and renourishment, and sand extraction (Lutcavage *et al*. 1997, Bouchard *et al*. 1998). These factors may directly, through loss of beach habitat, or indirectly, through changing thermal profiles and increasing erosion, serve to decrease the amount of nesting area available to nesting females, and may evoke a change in the natural behaviors of adults and hatchlings (Ackerman 1997; Witherington *et al*. 2003, 2007). In addition, coastal development is usually accompanied by artificial lighting. The presence of lights on or adjacent to nesting beaches alters the behavior of nesting adults (Witherington 1992) and is often fatal to emerging hatchlings as they are attracted to light sources and drawn away from the water (Witherington and Bjorndal 1991). In many countries, coastal development and artificial lighting are responsible for substantial hatchling mortality. Although legislation controlling these impacts does exist (Lutcavage *et al*. 1997), a majority of countries do not have regulations in place.

Considering that coastal development and beach armoring is detrimental to green turtle nesting behavior (Lutcavage *et al*. 1997), the pending human population expansion is reason for major concern. This concern is underscored by the fact that over the next few decades the human population is expected to grow by more than 3 billion people (about 50%). By the year 2025, the United Nations Educational, Scientific and Cultural Organization (UNESCO) (2001) forecasts that population growth and migration will result in a situation in which 75% of the world human population will live within 60 km of the sea. Such a migration undoubtedly will change a coastal landscape that, in many areas, is already suffering from human impacts. The problems associated with development in these zones will progressively become a greater challenge for conservation efforts, particularly in the developing world where wildlife conservation is often secondary to other national needs.

In addition to impacting the terrestrial zone, anthropogenic disturbances also threaten coastal marine habitats, particularly areas rich in seagrass and marine algae. These impacts include contamination from herbicides, pesticides, oil spills, and other chemicals, as well as structural degradation from excessive boat anchoring and dredging (Francour *et al*. 1999, Lee Long *et al*. 2000, Waycott *et al*. 2005). Overall, seagrass habitats are perhaps the most susceptible of all coastal marine habitats since the areas where they occur (sheltered coast with good water quality) are often targets for port development, and commonly are at the downstream end of drainages from human settlements (Waycott *et al*. 2005). Compounding the problem is that these habitats show low resiliency to human disturbance, and once damaged, often take years if not decades to fully regenerate (Francour *et al*. 1999). Further, the introduction of alien algae species threatens the stability of some coastal ecosystems and may lead to the elimination of preferred dietary species of green turtles (De Wreede 1996). Although some alien algae species are consumed by green turtles (Russell and Balazs 1994), others may prove toxic to green turtles, or at the very least, their promulgation may negatively impact the availability of native green turtle benthic foods (i.e., on the sea floor).

The vast depletion of green turtles in coastal foraging areas has likely resulted in widespread habitat modifications as a result of the associated loss of ecological function, which has negative implications for the maintenance of both marine and terrestrial ecosystems. As large herbivores, green turtles impact seagrass productivity and abundance (Bjorndal 1982, Zieman *et al*. 1984) and continue to represent an essential trophic pathway over expansive coastal marine habitats (Thayer *et al*. 1982, 1984; Valentine and Heck 1999). Through egg deposition on beaches, sea turtles act as biological transporters of nutrients and energy from marine to terrestrial ecosystems (Bouchard and Bjorndal 2000). Thus, with most green turtle populations substantially depleted relative to historic levels, it is likely that today's coastal marine and terrestrial systems are dramatically modified (Jackson 1997, Jackson *et al*. 2001). The fact that the total adult green turtle population for the entire pre-Columbian Caribbean population ranged from somewhere between 16 to 660 million turtles (combined estimates from Jackson 1997, Bjorndal *et al*. 2000) and were regulated by the availability of turtlegrass (*Thalassia testudinum*) underscores just how much the current green turtle population, and coastal habitat, has changed.

A.2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Green turtles, like all sea turtle species, are vulnerable to anthropogenic impacts during all life-stages: from eggs to adults. Three of the greatest threats to green turtles result from intentional killing for commercial and subsistence use. These include take of eggs, killing of females on nesting beaches, and directed hunting of green turtles in foraging areas. Fisheries bycatch is also a major issue, and is described in a later section.

Take of Eggs

One of the most detrimental human threats to green turtles is the intentional take of eggs from nesting beaches. As each nesting season passes and populations continue to suffer from egg removal, they will progressively lose the juvenile cohorts that would have recruited from the post-hatchling phase (Mortimer 1995). Present nesting populations may appear hardy, but without recruitment into the juvenile population and a well-balanced distribution of turtles among all cohorts, populations are more vulnerable to decline (Crouse *et al*. 1987, Frazer 1992).

Egg removal has impacted green turtle populations throughout the world. It is an ongoing major problem in Comoros Island, Costa Rica, Gambia, Equatorial Guinea, Guinea-Bissau, India, Indonesia, Ivory Coast, Malaysia, Maldives, Mexico, Panama, Philippines, Sao Tome é Principe, Saudi Arabia, Senegal, Sri Lanka, Thailand, and Vietnam (summarized in Seminoff 2004).

Killing of Nesting Females

Killing of nesting females continues to threaten the stability of green turtle subpopulations in many areas. These losses affect nesting populations both by reducing adult abundance and through reducing the population's potential for annual egg production. Areas with ongoing intentional killing of nesting adults include Australia, Bioko Island, Costa Rica, Guinea-Bissau, India, Japan, Mexico, Seychelles, and Yemen (Seminoff 2004). For example, from 1997 to 1999 a mean of 9.8% of nests near the township of Tortuguero, Costa Rica, were poached (S. Troëng, The Ocean Conservancy, personal communication, 2002) and, over the entire nesting beach, a mean of 600 adults were killed annually with a peak of 1,720 nesting adults poached in 1997 (Troëng 1998, Troëng and Rankin González 2000). Although there are likely more countries where such intentional take continues, it is apparent that, based on the preceding list, the killing of nesting females remains a problem in many areas throughout the world.

Hunting of Turtles in Foraging Habitats

The large-scale in-water movements of green turtles often cross jurisdictional boundaries and traverse areas where protection is absent. While adult mortality results in more quickly observable changes at the nesting beach, it is the mortality of immature turtles in marine habitats that may be a greater threat to the stability of green turtle populations. This life-stage is the most valuable in terms of recovery and stabilization of sea turtle populations due to the fact that not only have large juveniles already survived many mortality factors thus having a high reproductive value, but also there are typically more juveniles than adults in a population (Crouse *et al*. 1987, Ogren 1989). Therefore, relatively small changes in the survival rate of this life-stage class impact a large segment of the population (Crouse 1999). As with the delayed feedback from egg harvest, green turtles' slow maturation delays the observable effects of juvenile harvests, and they may not manifest as a decline in nesting females for decades. However, once there is a crash in the adult nesting population as a result of such impacts, the nesting population may be substantially more difficult to recover compared to a population with a thriving sub-adult population (Mortimer 1991).

Areas of particularly heavy exploitation of green turtles include the Caribbean Sea, Southeast Asia, Eastern Pacific, and Western Indian Ocean. Along the Caribbean coast of Nicaragua, approximately 11,000 adult and juvenile green turtles were killed annually in the 1990s; according to preliminary analyses, current exploitation levels appear to have decreased. At the Miskito Cays along the Caribbean coast of Nicaragua, an area considered to be the primary foraging habitat for turtles originating from Tortuguero, a mean of 9,357 turtles were killed per year from 1994-1996 (Lagueux 1998). This large-scale directed fishery continues today, although the autonomous regional governments and the Ministry of the Environment and Natural Resources (MARENA) are initiating discussions that may lead to a lessening of the take (C. Lagueux, Wildlife Conservation Society, personal communication, 2007). In Southeast Asia, tens of thousands, perhaps more than 100,000 juvenile and adult green turtles, were hunted annually as recently as the late 1990s (Limpus *et al*. 2002). In the eastern Pacific, up to 10,000 green turtles were harvested annually as recently as 2001 (Nichols *et al*. 2002). Directed hunting continues to be a problem in this region, although there are signs that this has started to decline (Seminoff *et al*. 2003). In the western Indian Ocean, one of the areas of greatest concern is in Madagascar. First reported in the 1990s (Rakotonirina and Cooke 1994, Mbindo 1996), this fishery currently lands thousands of green turtles each year (A. Cooke, Marine and Coastal Environment Programme, National Environment Office, Madagascar, personal communication to J. Mortimer, Seychelles Island Conservation Society, 2001). When combined with incidental captures, green turtle mortality in the Madagascar region is believed to be at least 10,000 individuals each year (J. Mortimer, Seychelles Island Conservation Society, personal communication, 2001). A similar situation has been described in Oman, where, in 1990 for example, a combined 4,280 green turtles were taken through direct harvest and incidental capture in demersal trawl fisheries (Hare 1991).

Intentional capture of green turtles also occurs in many other countries, including Australia, Bahamas, British Virgin Islands, Cameroon, Cayman Islands, Comoros Islands, Costa Rica, Cuba, Egypt, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea-Bissau, India, Indonesia, Ivory Coast, Liberia, Mayotte Archipelago, New Caledonia, Pakistan, Papua New Guinea, Sao Tome é Principe, Seychelles, Sierra Leone, Solomon

Islands, Togo, Turks and Caicos, Vanuatu, and Vietnam (Seminoff 2004). Despite substantial declines in green turtle subpopulation size, intentional killing remains legal in several of these countries (Humphrey and Salm 1996, Fleming 2001, Fretey 2001).

A.2.3.2.3 Disease or predation:

Diseases threaten a large number of existing subpopulations. The most commonly identified disease in green turtles is fibropapillomatosis (FP). This disease is characterized by the presence of internal and/or external tumors (fibropapillomas) that may grow large enough to hamper swimming, vision, feeding, and potential escape from predators (Herbst 1994). Fibropapillomas have been reported in all sea turtle species. For unknown reasons, the frequency of FP is much higher in green turtles than in other species.

Although FP has been the subject of extensive research, the particular cause of this condition remains unknown. Outbreaks of the disease may be linked to a predominant viral variant that is endemic in that habitat (Ene *et al*. 2005), and there is speculation that the prevalence of this disease has reached epidemic proportions due to immunosuppression in green turtles brought about by human-related habitat degradation (George 1997). However, immunosuppression may not be a prerequisite for development of FP in all cases (Work *et al*. 2001). Other potential causes that have received attention include the ingestion of toxic algae such as *Prorocentrum* spp. (Holloway-Adkins 2001, Anderson 2002) and *Lyngbya majuscula* (Arthur *et al*. 2006). The widespread incidence of FP should be taken into consideration when determining the ESA listing status of green turtles.

The population-level impacts of this disease to green turtles are not yet understood. Extremely high incidence has been reported in Florida, where the affliction rate reaches 62% in some areas (Schroeder *et al*. 1998), and Hawaii, where affliction rates peaked at 47% to 69% in some foraging areas (Murakawa *et al*. 2000). The fact that 22% of the 6,027 green turtles stranded in Florida from 1980-2005 had external FP tumors suggests serious consequences for population stability (FFWCC 2007, Singel *et al*. 2003). However, it should also be noted that photographic evidence from Hawaii and Florida shows that the tumors on some green turtles go into recession (Bennett *et al*. 2000, Hirama 2001) and in some cases the presence of FP may not hinder an individual's growth (Chaloupka and Balazs 2005). The implications of these studies are still not fully understood, although it is indicative that FP is not always lethal. To better explain the physical impact of tumor presence, additional comprehensive studies are needed (Work *et al*. 2004).

This disease has also been reported for green turtle subpopulations of Australia, Bahamas, Barbados, Brazil, British Virgin Islands, Cameroon, Cayman Islands, Costa Rica, Cuba, Equatorial Guinea, Federated States of Micronesia, Gabon, Gambia, Indonesia, Japan, Kenya, Mexico, Nicaragua, Philippines, Puerto Rico, Sao Tome and Senegal, Seychelles, U.S. Virgin Islands, and Venezuela (summarized in Seminoff 2004).

A.2.3.2.4 Inadequacy of existing regulatory mechanisms:

The conservation and recovery of sea turtles, and green turtles particularly, is facilitated by a number of regulatory instruments at international, regional, national, and local levels. As a result of these designations and agreements, many of the intentional impacts directed at sea turtles have been lessened: harvest of eggs and adults has been slowed at several nesting areas through nesting beach conservation efforts and an increasing number of community-based initiatives are in place to slow the take of turtles in foraging areas. Moreover, there is now an increased international effort to reduce sea turtle interactions and mortality in artisanal and industrial fishing practices.

Despite these advances, human impacts continue throughout the world. The lack of comprehensive and effective monitoring and bycatch reduction efforts in many pelagic and near-shore fisheries operations still allows substantial direct and indirect mortality, and the uncontrolled development of coastal and marine habitats threatens to destroy the supporting ecosystems of long-lived green turtles. Although several international agreements provide legal protection for sea turtles, additional multi-lateral efforts are needed to ensure they are sufficiently implemented and/or strengthened, and key non-signatory parties need to be encouraged to accede.

Considering the worldwide distribution of green turtles, virtually every legal instrument that targets or impacts sea turtles is almost certain to cover green turtles. A summary of the main regulatory instruments from throughout the world that relate to green turtle management is provided below. The pros and cons of many of these were recently evaluated by Hykle (2002) and Tiwari (2002), and a summary of these findings is given when appropriate.

United States Magnuson-Stevens Fishery Conservation and Management Act

The recently-amended U.S. Magnuson-Stevens Fishery Conservation and Management Act (MSA), implemented by NMFS, mandates environmentally responsible fishing practices within U.S. fisheries. Section 301 of the MSA establishes National Standards to be addressed in management plans. Any regulations promulgated to implement such plans, including conservation and management measures, shall, to the extent practicable, (A) minimize bycatch and (B) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch. Section 301 by itself does not require specific measures. However, mandatory bycatch reduction measures can be incorporated into management plans for specific fisheries, as has happened with the U.S. pelagic longline fisheries in the Atlantic and Pacific oceans. Section 316 requires the establishment of a bycatch reduction engineering program to develop "technological devices and other conservation engineering changes designed to minimize bycatch, seabird interactions, bycatch mortality, and post-release mortality in Federally managed fisheries."

FAO Technical Consultation on Sea Turtle-Fishery Interactions

While not a true international instrument for conservation, the Food and Agriculture Organization of the United Nations' (FAO) technical consultation on sea turtle-fishery interactions was groundbreaking in that it solidified the commitment of this international body to reduce sea turtle bycatch in marine fisheries operations. Recommendations from the technical consultation were endorsed by the FAO Committee on Fisheries (COFI) and called for the immediate implementation by member nations and Regional Fishery Management Organizations (RFMOs) of guidelines to reduce sea turtle mortality in fishing operations, developed as part of the technical consultation. Compliance with these guidelines is voluntary.

Indian Ocean – South-East Asian Marine Turtle Memorandum of Understanding (IOSEA)

This MOU puts in place a framework through which States of the Indian Ocean and South-East Asian region, as well as other concerned States, can work together to conserve and replenish depleted marine turtle populations for which they share responsibility. This collaboration is achieved through the collective implementation of an associated Conservation and Management Plan. Currently, there are 26 signatory states. The United States became a signatory in 2001. Numerous accomplishments have been made under the auspices of this MOU (for detailed information, visit the IOSEA website at http://www.ioseaturtles.org).

Memorandum of Understanding on ASEAN Sea Turtle Conservation and Protection

The objectives of this MOU, initiated by the Association of South East Asian Nations (ASEAN), are to promote the protection, conservation, replenishing, and recovery of sea turtles and their habitats based on the best available scientific evidence, taking into account the environmental, socio-economic and cultural characteristics of the Parties. It currently has nine signatory states in the South East Asian Region. Additional information is available at http://www.aseansec.org/6185.htm.

Memorandum of Agreement between the Government of the Republic of the Philippines and the Government of Malaysia on the Establishment of the Turtle Islands Heritage Protected Area

Signed in 1996, this bilateral MOA paved the way for the Turtle Islands Heritage Protected Area (TIHPA), which protects one of the most important green turtle nesting concentrations in the world and is also the site of substantial foraging activity in coastal waters. Additional information is available at http://www.oneocean.org/ambassadors/track_a_turtle/tihpa/index.html.

Memorandum of Understanding Concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa.

This MOU was concluded under the auspices of the Convention on the Conservation of Migratory Species of Wild Animals (CMS) and became effective in 1999. It aims at safeguarding six marine turtle species - including the green turtle - that are estimated to have rapidly declined in numbers during recent years due to excessive exploitation (both direct and incidental) and the degradation of essential habitats. However, despite this agreement, killing of adult turtles and harvesting of eggs remains rampant in many areas along the Atlantic African coast. Additional information is available at http://www.cms.int/species/africa_turtle/AFRICAturtle_bkgd.htm.

Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC)

This Convention is one of only a handful of international treaties dedicated exclusively to sea turtles, setting standards for the conservation of these endangered animals and their habitats with a large emphasis on bycatch reduction. It is the only binding multi-national agreement for sea turtles and is open to all countries in North, Central, and South America, and the Caribbean. It currently has 12 signatory countries, with the United States being a signatory in 1999. Additional information is available at http://www.iacseaturtle.org.

Convention on the Conservation of Migratory Species of Wild Animals

This Convention, also known as the Bonn Convention or CMS, is an international treaty that focuses on the conservation of migratory species and their habitats. As of January 2007, the Convention had 101 member states, including parties from Africa, Central and South America, Asia, Europe, and Oceania. While the Convention has successfully brought together about half the countries of the world with a direct interest in sea turtles, it has yet to realize its full potential (Hykle 2002). Its membership does not include a number of key countries, including Brazil, Canada, China, Indonesia, Japan, Mexico, Oman, and the United States. Additional information is available at http://www.cms.int.

Convention on Biological Diversity (CBD)

The primary objectives of this international treaty are 1) the conservation of biological diversity, 2) the sustainable use of its components, and 3) the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. This Convention has been in force since 1993 and currently has 190 Parties. While the Convention provides a framework within which broad conservation objectives may be pursued, it does not specifically address sea turtle conservation (Hykle 2002). Additional information is available at http://www.cbd.int.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

Known as CITES, this Convention was designed to regulate international trade in a wide range of wild animals and plants. CITES was implemented in 1975 and currently includes 169 Parties. Although CITES has been effective at minimizing the international trade of sea turtle products, it does not limit legal and illegal harvest within countries, nor does it regulate intra-country commerce of sea turtle products (Hykle 2002). Additional information is available at http://www.cites.org.

Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean

This Protocol is under the auspices of the Barcelona Convention for the Protection of the Mediterranean Sea against Pollution. It has been in force since 1999 and includes general provisions to protect sea turtles and their habitats within the Mediterranean Sea. The Protocol requires Parties to protect, preserve, and manage threatened or endangered species, establish protected areas, and coordinate bilateral or multilateral conservation efforts (Hykle 2002). In the framework of this Convention, to which all Mediterranean countries are parties, the Action Plan for the Conservation of Mediterranean Marine Turtles has been in effect since 1989. Additional information is available at http://www.rac-spa.org.

Convention on the Conservation of European Wildlife and Natural Habitats

Also known as the Bern Convention, the goals of this instrument are to conserve wild flora and fauna and their natural habitats, especially those species and habitats whose conservation requires the cooperation of several States, and to promote such co-operation. The Convention was enacted in 1982 and currently includes 45 European and African States and the European Union. According to Hykle (2002), while the Convention's "innovative approach to holding States to account for their implementation of the Convention is laudable, and has certainly drawn attention to issues of species and habitat protection, its efficacy in relation to particular marine turtle cases that have been deliberated for many years is debatable." Additional information is available at http://www.coe.int/t/e/cultural_co-operation/ environment/nature_and_biological_diversity/Nature_protection.

Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region

Also called the Cartagena Convention, this instrument has been in place since 1986 and currently has 21 signatory states. Under this Convention, the component that may relate to green turtles is the Protocol Concerning Specially Protected Areas and Wildlife (SPAW) that has been in place since 2000. The goals of this protocol are to encourage Parties "to take all appropriate measures to protect and preserve rare or fragile ecosystems, as well as the habitat of depleted, threatened or endangered species, in the Convention area." All six sea turtle species in the Wider Caribbean are listed in Annex II of the protocol, which prohibits (a) the taking, possession or killing (including, to the extent possible, the incidental taking, possession or killing) or commercial trade in such species, their eggs, parts or products, and (b) to the extent possible, the disturbance of such species, particularly during breeding, incubation, estivation, migration, and other periods of biological stress. Hykle (2002) believes that in view of the limited participation of Caribbean States in the aforementioned Convention on the Conservation of Migratory Species of Wild Animals, the provisions of the SPAW Protocol provide the legal support for domestic conservation measures that might otherwise not have been afforded. Additional information is available at http://www.cep.unep.org/law/cartnut.html.

Convention for the Protection of the Natural Resources and Environment of the South Pacific Region

This Convention has been in force since 1990 and currently includes 12 Parties. The purpose of the Convention is to protect the marine environment and coastal zones of the South-East Pacific within the 200-mile area of maritime sovereignty and jurisdiction of the Parties, and beyond that area, the high seas up to a distance within which pollution of the high seas may affect that area. Additional information is available at http://ekh.unep.org/?q=node/684.

Pacific Regional Environment Programme (SPREP)

SPREP is a regional organization based in Samoa established by the governments and administrations of the Pacific region (21 Pacific island member countries and four countries with direct interests in the region). The goals of SPREP are to promote cooperation in the Pacific islands region and to provide assistance to ensure sustainable development for present and future generations. Sea turtles are among the focal animal groups within SPREP. Additional information is available at http://www.sprep.org.

A.2.3.2.5 Other natural or manmade factors affecting its continued existence:

There are several other manmade factors that affect green turtles in foraging areas and on nesting beaches. Two of these are truly global phenomena: climate change and fisheries bycatch.

Impacts from climate change, especially due to global warming, are likely to become more apparent in future years (IPCC 2007a). The global mean temperature has risen 0.76ºC over the last 150 years, and the linear trend over the last 50 years is nearly twice that for the last 100 years (IPCC 2007a). There is a high confidence, based on substantial new evidence, that observed changes in marine systems are associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels, and circulation. These changes include shifts in ranges and changes in algal, plankton, and fish abundance (IPCC 2007b), which could affect primary food resources of green turtles.

As global temperatures continue to increase, so will sand temperatures, which in turn will alter the thermal regime of incubating nests and alter natural sex ratios within hatchling cohorts (e.g., Glen and Mrosovsky 2004). The effects of global warming are difficult to predict, but may be exacerbated on developed nesting beaches where shoreline armoring and construction has denuded natural vegetation. Sea level rise from global warming (IPCC 2007a) is also a potential problem , particularly for areas with low-lying beaches where sand depth is a limiting factor, as the sea may inundate nesting sites and decrease available nesting habitat (Daniels *et al*. 1993, Fish *et al*. 2005, Baker *et al*. 2006). The loss of habitat as a result of climate change could be accelerated due to a combination of other environmental and oceanographic changes such as increase in the frequency of storms and/or changes in prevailing currents, both of which could lead to increased beach loss via erosion (Antonelis *et al*. 2006, Baker *et al*. 2006).

Fisheries bycatch in artisanal and industrial fishing gear is also a major impact. Although other species such as leatherback turtles and loggerhead turtles have received most of the attention relative to sea turtle bycatch, green turtles are also susceptible, particularly in nearshore artisanal fisheries gear. These fisheries practices include drift-netting, long-lining, set-netting, pound netting, and trawl fisheries, and their adverse impacts on sea turtles have been documented in marine environments throughout the world (National Research Council 1990, Lutcavage *et al*. 1997, Epperly 2003).

In addition, there are numerous localized impacts to green turtles. Increasing incidence of exposure to heavy metals and other contaminants in the marine environment is of concern. Contaminants such as PCBs, mercury, copper, and other metals are present in tissues of green turtles from numerous areas (Presti *et al*. 1999, Miao *et al*. 2001, Al Rawahy *et al*. 2006, Lewis 2006). Although their explicit effects on sea turtles have yet to be determined, such exposure may lead to immunosuppression or other hormonal imbalances (J. Keller, National Institute of Standards and Technology, personal communication, 2006). Many of these agents also diminish the health of coastal marine ecosystems, which may, in turn, adversely affect green turtles. The interaction from oils spills is an episodic problem that can also impact turtles worldwide (Yender and Mearns 2003), and this may lead to immunosuppression and other chronic health issues (Sindermann *et al*. 1982).

Additional manmade factors affecting green turtles, albeit perhaps not as globally impacting as those mentioned above, include impacts of boat traffic on turtles and coastal habitats, ingestion and entanglement in marine debris, and intake of turtles into cooling systems of coastal powerplants. Boat strikes have been shown to be a major mortality source in Florida (Singel *et al*. 2003), and it is quite likely that this is a chronic, albeit unreported, problem near developed coastlines in other areas as well (e.g., Oros *et al*. 2005). Boat traffice has been shown to exclude green turtles from preferred coastal foraging pastures (Seminoff *et al*. 2002a), which may negatively affect their nutritional intake. In addition, the ingestion of and entanglement in marine debris can reduce food intake and digestive capacity (Bjorndal *et al*. 1994, Sako and Horikoshi 2002), and entanglement has been shown to cause mortality of sea turtles (Bugoni *et al*. 2001). The impacts of marine debris continue to be an emerging issue and, although data are lacking from open ocean areas, it is quite likely that green turtles as well as other species are substantially impacted in these regions (e.g., J. Seminoff, NMFS, unpublished data). Along developed shores, intake into the cooling systems of some coastal power plants has resulted in forced submergence and mortality of sea turtles, particularly green and loggerhead turtles (Florida Power and Light and Quantum Resources Inc. 2005; Christina Fahy, NMFS, personal communication, 2007).

Finally, there is the issue of unregulated and illegal fisheries which target green turtles throughout Southeast Asia for the curio trade. Over the past decade, several reports of boats captured with hundreds and hundreds of dead green turtles suggest this is a dire regional threat (N. Pilcher, Marine Research Foundation, personal communication, 2007).

In addition to climate change and sea-level rise, natural impacts on green turtles may include the effects of aperiodic hurricanes and catastrophic environmental events such as tsunamis. In general, these events are episodic and, although they may affect green turtle hatchling production, the results are generally localized to a small area (but see Hamann *et al*. 2006b) and they rarely result in whole-scale losses over multiple nesting seasons (Hamann *et al.* 2006b). The negative effects of hurricanes on low-lying and/or developed shorelines may be longer-lasting and a greater threat overall.

SUBSECTION B: ENDANGERED FLORIDA BREEDING POPULATION

While the ESA listing focuses on the Florida breeding population, it is important to note that Florida also hosts numerous foraging populations of green turtles along a major portion of the state's coastline (Figure 2). Because some of these turtles also nest in Florida, examining the state's foraging population is also necessary for this evaluation.

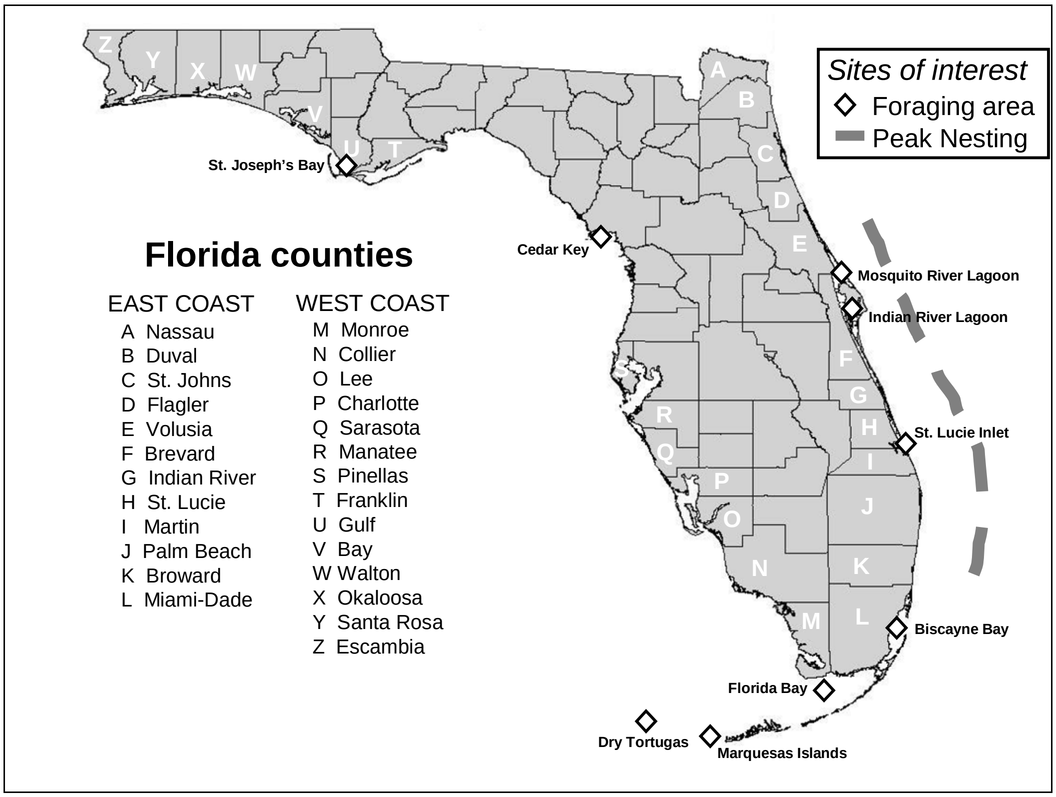

Figure 2. Map of areas of interest for green turtles in Florida.

B.2.3.1 Biology and Habitat

B.2.3.1.1 New information on the species' biology and life history:

Florida green turtles undertake complex movements and migrations through geographically disparate habitats during their lifetimes. Upon leaving the nesting beach, hatchlings begin an oceanic phase, perhaps floating passively in major current systems (gyres) that serve as open-ocean developmental grounds. This early oceanic phase remains one of the most poorly understood aspects of green turtle life history (oceanic refers to the vast open ocean environment from the surface to the sea floor where water depths are greater than 200 meters). However, growth studies using skeletochronology indicate that green turtles in the western

Atlantic shift from this oceanic phase and recruit to neritic developmental areas predominantly as 5- to 6-year-olds (neritic refers to the inshore marine environment from the surface to the sea floor where water depths do not exceed 200 meters) (Zug and Glor 1998). These new arrivals recruit to protected lagoons and open coastal areas rich in sea grass and marine algae (Bresette *et al*. 2006) and this 'first stop' in their developmental migration may last for up to 6 years, after which time turtles may shift to other sites as larger juveniles/subadults (Musick and Limpus 1997, Zug and Glor 1998). While in coastal habitats, green turtles exhibit site fidelity to specific areas or home ranges (Bresette *et al*. 1998, Makowski *et al*. 2006), and it is clear that they can home in on these sites if displaced (e.g., from cold-stunning, McMichael *et al*. 2003). The size class structure and seasonality of green turtles in Florida's foraging areas have been increasingly monitored (Bresette *et al*. 1998, Bagley 2003, Kubis *et al*. 2003, McMichael *et al*. 2006).

As adults, green turtles commence breeding migrations between foraging grounds and nesting areas that are undertaken every few years (Plotkin 2003). Reproductive migrations of Florida green turtles have been identified through flipper tagging and satellite telemetry. Based on these studies, the majority of adult female Florida green turtles are believed to reside in nearshore foraging areas throughout the Florida Keys from Key Largo to the Dry Tortugas and in the waters southwest of Cape Sable, Florida and some post-nesting Florida green turtles also reside in Bahamian waters (B. Schroeder, NMFS, personal communication, 2007).

Green turtle nesting ecology in Florida has been the focus of research for several decades. Annual reproductive effort, hatching success, and spatial nesting patterns of green turtles in Florida have also been the subject of several new studies (Weishampel *et al*. 2003, 2006; Antworth *et al*. 2006). In addition, the effects of environmental factors on reproductive periodicity have been examined recently (Weishampel *et al*. 2003).

B.2.3.1.2 Abundance, trends, and demography:

B.2.3.1.2.1. Abundance and trends

Green turtle nesting abundance in the state of Florida has been monitored for nearly three decades and has been the focus of numerous reports (Dodd 1982, Conley and Hoffman 1987, Meylan *et al*. 1995, Ehrhart and Bagley 1999, Witherington and Koeppel 2000, Ehrhart *et al*. 2003, Meylan *et al*. 2006, Chaloupka *et al*. in review). Like several of the more recent reports, data presented in this evaluation were gathered as part of two initiatives within the state: the Statewide Nesting Beach Survey (SNBS) and Index Nesting Beach Survey (INBS) programs. The purpose of the SNBS, initiated in 1979, is to document total distribution, seasonality, and abundance of sea turtle nesting in Florida. The INBS program was started in 1989 in an effort to determine nesting trends at a set number of beaches. Of the 190 SNBS sites, 33 participate in the INBS program, and the nesting trend in Florida since 1989 is derived from these 33 index beaches. Data in this evaluation are based on the number of nests deposited annually at each of these sites. Species identifications and determinations of nesting or non-nesting emergences are based on evaluations of features of tracks and nests (FFWCC 2007). We have high confidence in the results from both surveys, but there are several caveats and limitations of using nest counts as an indicator of population trends (see Subsection A.2.3.1.2.1).

In addition to the overall nesting trend as determined by the INBS, this report provides a measure of current annual nesting activity. This value is based on data collected as part of the SNBS and is based on the mean nesting abundance from 2000-2006 throughout the state.

Nesting data collected during the SNBS (2000-2006) show that a mean of approximately 5,600 nests are laid each year in Florida (Table 2). Nesting occurs in 26 counties with a peak along the east coast, from Volusia through Broward Counties (Figure 2). During this period, the counties with the greatest level of nesting activity were Brevard County, with a mean of 2,582 nests/year, and Palm Beach County, with a mean of 1,407 nests/year (FFWCC 2007).

The green turtle nesting population of Florida appears to be increasing based on 18 years (1989-2006) of nesting data from throughout the state (Figure 3). Indeed, quantitative analysis by Chaloupka *et al.* (in review) for the Melbourne Beach area provides unequivocal evidence of an increase over more than two decades. In viewing the trend graph, it is important to note in the last four years there are three 'low' years. However, considering that nearby nesting populations in Tortuguero (Troëng and Rankin 2005) displayed a similar annual nesting pattern in recent years, this observed decrease may be related to lesser reproductive effort due to environmental variability at foraging grounds rather than a decrease in number of nesting females.

The increase in nesting in Florida is likely a result of several factors, including: (1) a Florida statute enacted in the early 1970s that prohibited the killing of green turtles; (2) the ESA listing in 1973, affording complete protection to eggs, juveniles, and adults in all U.S. waters; (3) the passage of Florida's constitutional net ban amendment in 1994 and its subsequent enactment, making it illegal to use any gillnets or other entangling nets in state waters; (4) the likelihood that the majority of Florida adult green turtles reside within Florida waters where they are fully protected; (5) the protections afforded Florida green turtles while they inhabit the waters of other nations that have enacted strong sea turtle conservation measures (e.g., Bermuda); and (6) the listing of the species on Appendix I of CITES, which stopped international trade and reduced incentives for illegal trade from the U.S.

Green turtles hatched on Florida beaches are migratory and occupy foraging and developmental habitats within the state as well as in coastal regions throughout the wider Caribbean. Although there are several research projects in Florida that involve the observation and capture of juvenile green turtles, few have a time series that would lend sufficient power to a trends analysis of abundance indices (sightings/captures as a function of effort). No Florida in-water project has had abundance indices incorporated into a rigorous analysis or a published trends assessment. Similarly, we are unable to make any conclusions regarding trends among in-water populations outside of Florida.

Table 2. Mean annual nesting abundance (2000-2006) for 26 counties that participated in Florida's Statewide Nesting Beach Survey program (data courtesy of Florida Fish and Wildlife Conservation Commission 2007). *Nesting data for Bay County were collected only during the 1999 and 2002 nesting seasons.

EAST COAST			WEST COAST		
County	Mean	Range	County	Mean	Range
Nassau	2	(0-5)	Monroe	44	(0-108)
Duval	1	(0-3)	Collier	2	(0-9)
St. Johns	13	(0-23)	Lee	5	(0-7)
Flagler	28	(0-47)	Charlotte	6	(0-39)
Volusia	200	(1-392)	Sarasota	7	(0-11)
Brevard	2582	(116-4878)	Manatee	0	(0-1)
Indian River	413	(14-633)	Pinellas	0	(0-1)
St. Lucie	254	(14-420)	Franklin	2	(0-4)
Martin	465	(48-808)	Gulf	3	(0-9)
Palm Beach	1407	(81-2339)	Bay*	0.5	(0-1)
Broward	156	(11-255)	Walton	3	(0-5)
Miami Dade	6	(0-64)	Okaloosa	8	(0-29)
TOTAL ANNUAL MEAN: 5527 nests			Santa Rosa	1	(0-2)
			Escambia	2	(0-6)
			TOTAL ANNUAL MEAN: 83.5 nests		

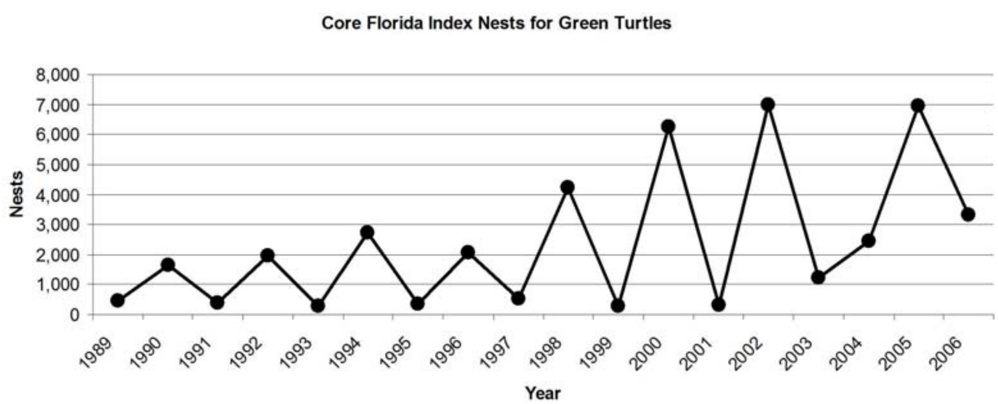

Figure 3. Annual nest production for green turtles in Florida (1989-2006) based on Florida's Index Nesting Beach Survey program (Florida Fish and Wildlife Conservation Commission, unpublished data).

B.2.3.1.2.2. Demography

The primary demographic features of green turtles relevant for interpreting population abundance and long term trends include age-to-maturity (often via growth studies), reproductive longevity, reproductive output (i.e., egg production, clutch frequency, internesting interval), and annual survivorship. While these have been the subject of considerable research worldwide, there are comparatively few such advances for green turtles in Florida. A brief description of these aspects follows. For a broader discussion on green turtle demography, including information on survivorship and age-to-maturity, go to Subsection A.2.3.1.2.2.

Green turtles exhibit variable growth rates in different neritic habitats in Florida. So far, studies using capture-mark-recapture techniques as well as skeletochronology have concluded that growth may vary depending on the study location and size range of turtles. Along the east coast of Florida - in Mosquito Lagoon and open coast near St. Lucie Inlet - juvenile green turtles exhibit non-monotonic growth, with annual increases ranging from 2-5 cm per year (Zug and Glor 1998, Bresette and Gorham 2001). In St. Joseph's Bay along the Florida panhandle, juvenile growth is also non-monotonic, ranging from 2-8 cm per year (McMichael *et al*. 2006).

Although no estimates of reproductive longevity are available for Florida, data from Tortuguero (Carr *et al*. 1978) and Aves Island (Vera 2007) suggest that green turtles in the Wider Caribbean may remain reproductive for up to 23 years. Considering that the mean remigration intervals for Florida nesters is 2 years (Bjorndal *et al*. 1983, Witherington and Ehrhart 1989), a reproductive life span of this duration would result in a female nesting during 11-12 seasons over the course of her life. Florida green turtles nest 3-4 times per season (Johnson 1994) and deposit a mean of 136 eggs per nest (Witherington and Ehrhart 1989). Thus, a female may make 33-48 nests, or about 4,500-6,500 eggs, during her lifetime. These crude calculations suggest that Florida green turtles are among the most fecund nesting populations worldwide (for comparison see Hirth 1997).

B.2.3.1.3 Genetics and genetic variation:

The genetic substructure of the green turtle regional subpopulations shows distinctive genetic properties for each nesting rookery (Bowen *et al*. 1992, FitzSimmons *et al*. 2006). See Subsection A.2.3.1.3 for a discussion of the regional genetic patterns for green turtles, as well as the implications of the decrease at, and loss of, nesting concentrations.

In addition to studies examining the global genetic structure for green turtles, there have been recent efforts to determine the nesting population origins of green turtles assembled in Florida foraging areas.

Mitochondrial DNA analyses show numerous haplotypes for green turtles in Florida developmental habitats, and indicate that the juveniles assembled in these areas originate from Barbados, Costa Rica, Florida, Mexico, Venezuela, and Suriname (Bass and Witzell 2000, Bagley *et al*. 2000, Bolker *et al*. 2007). Studies from other areas within the Wider Caribbean similarly show that green turtles originating from Florida nesting beaches are present, as juveniles, in foraging grounds throughout the Wider Caribbean, including the Bahamas, Cuba, southeastern U.S., Barbados, and Venezuela (Lahanas *et al*. 1998, Luke *et al*. 2004, Bass *et al*. 2006, Moncada *et al*. 2006, Bolker *et al*. 2007).

B.2.3.1.4 Taxonomic classification:

The taxonomic classification for the green turtle has not changed since the species was listed. It remains as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Reptilia
Order: Testudines
Family: Cheloniidae
Genus: *Chelonia*
Species: *mydas*
Common name: Green sea turtle

B.2.3.1.5 Spatial distribution:

Nesting occurs in all coastal counties except those in the Big Bend area of Florida (Table 2, Figure 2). The highest nesting densities are located along the southeast coast from Brevard to Palm Beach Counties (FFWCC 2007). Green turtles nesting in Florida depart to foraging areas located throughout the Florida Keys and, to a lesser extent, the Bahamas (see Subsection B.2.3.1.1).

In addition to nesting beaches, green turtles are found in coastal waters throughout the state (Witherington *et al*. 2006). Several neritic habitats along the east coast of Florida have been identified as important areas for green turtles, including Mosquito and Indian River Lagoons (Bresette *et al*. 2002, Bagley 2003, Kubis *et al*. 2003), Port Canaveral (Schmid 1995, Redfoot and Ehrhart 2000), St. Lucie Inlet (Bresette *et al*. 2002), and Biscayne Bay (Cantillo *et al*. 2000). Juveniles also reside at shallow coastal reefs adjacent to the high energy coastline of eastern Florida; their presence has been documented from Brevard to Broward Counties (Schmid 1995, Bresette *et al*. 1998, Broadstone *et al*. 2003, Holloway-Adkins 2006, Holloway-Adkins *et al*. 2006, Makowski *et al*. 2006). Along the shores of southwestern Florida, green turtles have been documented in the Florida Keys (Witherington *et al*. 2006), Florida Bay (Schroeder *et al*. 1998), the Marquesas (M. Bresette, Quantum Resources, Inc., personal communication, 2007), the Dry Tortugas

(Reardon and Mansfield 2002), and the western Everglades (Witzell and Schmid 2004). Along Florida's Gulf of Mexico (west) coast, green turtles have been documented at places such as the Everglades and St. Joseph's Bay (Schmid 1998, McMichael *et al*. 2006).

Because of the migratory nature of green turtles, individuals from the Florida nesting population also move to areas outside Florida. These sites within the Wider Caribbean include, but are not necessarily limited to the Bahamas, Barbados, Cuba, Puerto Rico, southeastern U.S., and Venezuela (Lahanas *et al*. 1998, Luke *et al*. 2004, Bass *et al*. 2006, Moncada *et al*. 2006, Bolker *et al*. 2007, Diez and van Dam 2007). Again, it is likely that additional areas are visited by green turtles, although to date the lack of flipper tagging recoveries and/or genetic analysis of green turtles assembled in these distant foraging areas have resulted in a lack of information for most areas.

B.2.3.1.6 Habitat or ecosystem conditions:

See Subsection A.2.3.1.6.

B.2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

The determination to list a species under the ESA is based on the best scientific and commercial data regarding five listing factors (see below). Subsequent 5-year reviews must also make determinations about the listing status based, in part, on these same factors.

B.2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

In Florida, there are increasing impacts to the nesting and marine environments that affect green turtles throughout the state. Structural impacts to nesting habitat include the construction of buildings and pilings, beach armoring and renourishment, and sand extraction (Lutcavage *et al*. 1997, Bouchard *et al*. 1998, Mosier 1998, Mosier and Witherington 2002, Leong *et al*. 2003, Roberts and Ehrhart 2003). These factors may directly, through loss of beach habitat, or indirectly, through changing thermal profiles and increasing erosion, serve to decrease the amount of nesting area available to nesting females, and may evoke a change in the natural behaviors of adults and hatchlings (Ackerman 1997, Schroeder and Mosier 2000). In addition, coastal development is usually accompanied by artificial lighting. The presence of lights on or adjacent to nesting beaches alters the behavior of nesting adults (Witherington 1992) and is often fatal to emerging hatchlings as they are attracted to light sources and drawn away from the water (Witherington and Bjorndal 1991, Nelson-Sella *et al*. 2006). These threats have been well documented along the coastal stretches of Florida, and although comparatively few data are available for outlying regions, it is likely that they are also impacting Florida green turtles in areas outside the state. See Subsection A.2.3.2.1 for more information. Anthropogenic disturbances also threaten coastal marine habitats, particularly areas rich in seagrass and marine algae, key forage species for Florida green turtles (see Subsection A.2.3.2.1 for further discussion).

B.2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

As in other areas worldwide, green turtles originating from Florida nesting beaches are vulnerable from anthropogenic impacts during all life-stages: from eggs to adults. These include egg harvest, the killing of females on nesting beaches, and directed hunting of green turtles in foraging areas. While these threats have been largely eliminated in Florida due to successful conservation measures, the hunting of juvenile and adult turtles continues both legally and illegally in many foraging areas where green turtles originating from Florida are known to occur (Fleming 2001, Chacon 2002). However, the mortality caused by direct hunting is difficult to quantify and therefore it is not possible to characterize how detrimental this threat is to the Florida population.

B.2.3.2.3 Disease or predation:

While green turtles in Florida have demonstrated encouraging signs of recovery after more than 20 years of protection efforts, the high incidence of fibropapillomatosis among foraging populations threatens to curb these improvements. This disease is a condition for which the particular causes remain unknown, although within specific locations, an FP outbreak can be linked to a predominant viral variant that is endemic in that habitat (Ene *et al*. 2005). This disease is characterized by the presence of internal and external tumors (fibropapillomas) that may grow large enough to hamper swimming, vision, feeding, and potential escape from predators (Herbst 1994).

The population-level impacts to Florida green turtles are not fully understood. However, the fact that 22% of the 6,027 green turtles stranded in Florida from 1980-2005 had external FP tumors suggests that this disease is of serious consequence for population stability (FFWCC 2007, Singel *et al*. 2003). FP continues to be a major problem in the Indian River Lagoon system (28-72% affliction) and along the nearshore reefs of central eastern Florida (8-21%). Interestingly, however, FP remains absent at Port Canaveral, a site relatively close to these aforementioned sites (Hirama and Ehrhart 2003). A comparison of FP rates at two sites near St. Lucie County found a similar pattern of presence/absence, with the intake canal of St. Lucie power plant showing low incidence (3.2 and 2.9% in 1999 and 2000, respectively) versus high incidence in the nearby Indian River Lagoon (59.4 and 70.2% in 1999 and 2000, respectively) (Bresette *et al*. 2005). Between

1980 and 1998, all green turtle strandings with signs of FP were found in southern Florida where over 20% of all green turtles exhibited FP (Foley *et al*. 2005). Since 1998, some green turtles with FP have stranded in northeast and northwest Florida (A. Foley, Florida Fish and Wildlife Conservation Commission, personal communication, 2007). Photographic evidence from Hawaii shows that the tumors on some green turtles go into recession (Bennett *et al*. 2000). The implications of tumor recession are still not fully understood, although it is indicative that FP may not be lethal in all cases. Clearly there remains much to be learned about FP, and it is clear that future research should address aspects such as the physical impact of tumor presence, the rates of regression, and the spatiotemporal change in affliction rate at the sites where FP is known to occur (Work *et al*. 2004).

Although FP can be considered a natural disease, there is speculation that the prevalence of this disease has reached epidemic proportions due to immunosuppression in green turtles brought about by human-related habitat degradation (George 1997). Other potential causes that have received attention in Florida include the ingestion of the toxic alga *Prorocentrum* spp. (Holloway-Adkins 2001, Anderson 2002), as well as a variety of environmental factors (Foley *et al*. 2005). However, no definite cause has been determined. The widespread incidence of FP should be taken into consideration when determining the ESA listing status of Florida green turtles.

With respect to predation, green turtles are heavily impacted in some areas by sharks (e.g., Heithaus 2001), but terrestrial predators such as ants and terrestrial vertebrates appear to be a much larger problem for green turtle survival. Fire ants have been shown to cause high hatchling mortality (Allen *et al*. 2001), and the presence of vertebrate predators such as dogs and raccoons also impact hatchlings as well as unhatched eggs (Engeman *et al*. 2005). While these threats have been mitigated in some areas such as Florida (Engeman *et al*. 2005), they are very problematic in some areas and have led to catastrophic hatchling mortality in some cases.

B.2.3.2.4 Inadequacy of existing regulatory mechanisms:

Conservation and recovery of sea turtles, and green turtles particularly, is facilitated by a number of regulatory instruments at international, regional, national, and local levels. Considering the distribution of Florida green turtles throughout the Wider Caribbean, virtually every instrument that targets or impacts sea turtles in the region is almost certain to cover green turtles. A list of the main regulatory instruments in this region follows. Please see Subsection A.2.3.2.4 for a description of each instrument.

- *United States Magnuson-Stevens Conservation and Management Act*
- *Inter-American Convention for the Protection and Conservation of Sea Turtles*
- *Convention on the Conservation of Migratory Species of Wild Animals*
- *Convention on Biological Diversity*
- *Convention on International Trade in Endangered Species of Wild Fauna and Flora*
- *Convention for the Protection and Development of the Marine - Environment of the Wider Caribbean Region*

B.2.3.2.5 Other natural or manmade factors affecting its continued existence:

There are several other manmade factors that affect green turtles from the Florida nesting population. These threats occur on Florida's nesting beaches as well as in foraging areas within the state, in other areas of the U.S., and in the Wider Caribbean. Because of the dispersal of green turtles nesting in Florida to areas throughout the Wider Caribbean and Gulf of Mexico, human threats outside of Florida may also have profound impacts on the local breeding population (e.g., directed killing, fisheries bycatch; see Subsection A.2.3.2.5). Standing out as one of the major threats to green turtles in Florida waters - which is a byproduct of the burgeoning human population - is the impact of boat strikes. Boat strikes were the most common injury among the 4,542 green turtles stranded along the coast of Florida from 1980-2001 (Singel *et al*. 2003).

For discussion of the impacts of directed hunting on green turtles originating from Florida, see Subsection B.2.3.2.2. For information on other natural and manmade factors such as debris ingestion and entanglement, intake in coastal power plants, the effects from petroleum spills, and the impacts from catastrophic storms, see Subsection A.2.3.2.5.

SUBSECTION C: ENDANGERED PACIFIC MEXICO BREEDING POPULATION

C.2.3.1 Biology and Habitat

C.2.3.1.1 New information on the species' biology and life history:

Also called black turtles, green turtles nesting along the Pacific mainland coast and offshore islands of Mexico inhabit numerous habitats over the course of their lives. Upon leaving the nesting beaches along the mainland coast of Michoacan and offshore Revillagigedos Islands (Figure 4), hatchlings begin an oceanic phase, perhaps floating passively in major current systems (gyres) that serve as open-ocean developmental grounds. This early oceanic phase remains one of the most poorly understood aspects of green turtle life history, although opportunistic sightings in the eastern Pacific have increased our understanding of where these areas are (Nichols *et al*. 2001). Once settling into coastal habitats, developing green turtles reside in protected lagoons as well as open coastal areas rich in sea grass and marine algae (Figure 4; Seminoff *et al*. 2002a, 2006; Lopez-Mendilaharsu *et al*. 2005). Green turtles in the eastern Pacific Ocean - particularly those in foraging habitats of northwestern Mexico - are more omnivorous than green turtles in other areas of the world (Bjorndal 1997).

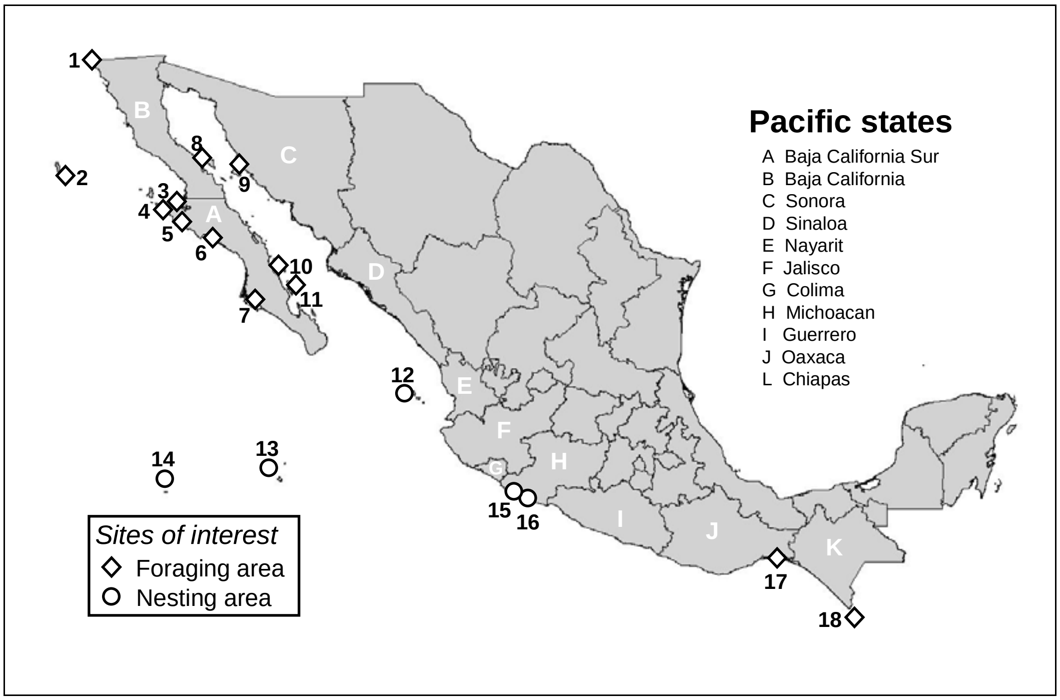

Figure 4. Map of Mexico showing foraging and nesting areas of interest for the east Pacific green turtle. See Table 3 for identification of sites.

Table 3. Summary of sites of interest for green turtles along the Pacific coast of Mexico.

1. San Diego Bay (USA)	10. Loreto Bay National Park
2. Isla Guadalupe	11. Canal de San Jose
3. Laguna Ojo de Liebre	12. Tres Marias Islands
4. Bahia Tortugas	13. Socorro Island, Revillagigedos
5. Estero Coyote	14. Clarion Island, Revillagigedos
6. Laguna San Ignacio	15. Colola Beach, Michoacan
7. Bahia Magdalena	16. Maruata Beach, Michoacan
8. Bahia de los Angeles	17. Laguna Mar Muerta
9. Canal del Infiernillo	18. Poza de Nance (Guatemala)

Considerable research has focused on the biology of green turtles assembled in foraging areas north of Michoacan. In these 'northern' foraging areas, there is greater information on population size structure (Gardner and Nichols 2001, Seminoff *et al*. 2003, Koch *et al*. 2006), growth (Seminoff *et al*. 2002c), foraging ecology (Seminoff *et al*. 2002b; Lopez-Mendilaharsu *et al*. 2003, 2005), daily movements and home range and habitat use (Seminoff 2000, Nichols *et al*. 2001, Seminoff *et al*. 2002a, Seminoff and Jones 2006), diving behavior (Seminoff *et al*. 2006), energetics (Jones *et al*. 2005), and health (Presti *et al*. 1999, Gardner 2003). Comparatively less is known about the ecology of green turtles in foraging areas south of Michoacan. Aside from population size structure and seasonality at the Poza de Nance lagoon in northern Guatemala (Figure 4; C. Alfaro, Universidad de San Carlos, Guatemala, unpublished data), virtually no data are available for the 'southern' foraging areas. Furthermore, few data are available from oceanic foraging habitats, although data from neritic sites at the Revillagigedo Islands have demonstrated the seasonality and sizes of foraging turtles (Juarez-Ceron *et al*. 2003).

There are several satellite telemetry studies that have demonstrated the migratory corridors used by green turtles as they move between nesting beaches and foraging grounds. Green turtles nesting in Michoacan follow a coastal migratory corridor, usually remaining within 100 km of the mainland coast as they depart to the north and south (Nichols 2003a; J. Nichols, The Ocean Conservancy, unpublished data; J. Seminoff, NMFS, unpublished data). Green turtles nesting in the Revillagigedos traverse oceanic regions as they move to coastal foraging areas along mainland Mexico and the Baja California Peninsula, and turtles moving north of the border to San Diego Bay, USA, follow a coastal trajectory as soon as they reach the Baja Peninsula (P. Dutton, NMFS, unpublished data).

In addition to in-water ecology at foraging areas, a number of recent studies have examined the nesting biology and demography of green turtles in Pacific Mexico. This research has focused on clutch frequency (Alvarado-Diaz *et al*. 2003), hatching success (Juarez-Ceron *et al*. 2003), hatchling sex ratio (Hernandez-Molina and Alvarado-Diaz 2005), as well as the impact of El Niño on reproductive output (Fuentes *et al*. 2000).

C.2.3.1.2 Abundance, trends, and demography:

C.2.3.1.2.1. Abundance and trends

There is one primary nesting concentration (Colola - Michoacan) and three lesser nesting sites (Maruata, Michoacan; Clarion Island, Revillagigedos Archipelago; and Socorro Island, Revillagigedos Archipelago) in Pacific Mexico. Recent nesting abundance is provided for these four sites based on the mean number of nests deposited annually over the course of multiple nesting seasons (since 2000 when possible) (Table 4). Annual reproductive effort has been monitored continuously since the 1981-1982 nesting season at Colola and from 1981-1995 and 2003-2006 at Maruata. These efforts have been carried out by biologists from the Universidad Michoacana de San Nicholas Hidalgo. Nesting on the Revillagigedos Islands has been monitored by biologists from the Universidad Autonoma de Mexico (Mexico City) as well as by federal biologists from the Mexican fisheries management agency Secretary of the Environment and Natural Resources (SEMARNAT).

Table 4. Annual number of nests deposited at four key sites in Pacific Mexico.

Site	Years (interval)	Annual mean (range)	Reference
Colola, Michoacan	2000-2005 (5 years)	4,326 nests (3,068-6,501 nests)	J. Alvarado, University of Michoacan, unpubl. data.
Maruata, Michoacan	2003-06 (4 years)	1,600 nests	C. Delgado, University of Michoacan, personal communication, 2007).
Clarion Island, Revillagigedos	1999-2001 (3 years)	79 nests (65-105 nests)	Juarez-Ceron *et al*. 2003
Socorro Island, Revillagigedos	1999-2001 (3 years)	47 nests (49-92 nests)	Juarez-Ceron *et al*. 2003

Based on these nesting beach monitoring efforts, it is apparent that a mean of roughly 6,050 nests are deposited each year in Pacific Mexico. However, the estimate for Maruata is based on a single season, which suggests that this contribution to the overall mean should be viewed with caution.

In addition to the current abundance at each site, the long-term trend in nesting activity is provided for Colola, the largest nesting concentration in Pacific Mexico. See Subsection A.2.3.1.2.1 for a summary of the assumptions, caveats, and limitations of using annual reproductive effort to determine population trends. Based on the 25-year trend line (Figure 5), green turtle nesting has increased since the population's low point in the mid 1980s to mid 1990s. This observed increase may have resulted from the onset of nesting beach protection in 1979 - as is suggested by the similarity in timing between the onset of beach conservation and the age-to-maturity for green turtles in Pacific Mexico. The initial upward turn in annual nesting was seen in 1996, about 17 years after the initiation of a nesting beach protection program (Cliffton *et al*. 1982, Alvarado *et al*. 2001), and growth data from the Gulf of California suggest that green turtles mature at about 15-25 years (modified from Seminoff *et al*. 2002c). Although not a clear cause of the increasing nesting trend, the consistency in timing is nonetheless compelling. The presidential decree protecting all sea turtles of Mexico (Diario Oficial de la Federacion 1990) certainly helped the situation, but this occurred much later than the start of nesting beach conservation. It is more likely that this national legislation has had its greatest positive impact at the foraging areas, where green turtle hunting was once rampant.

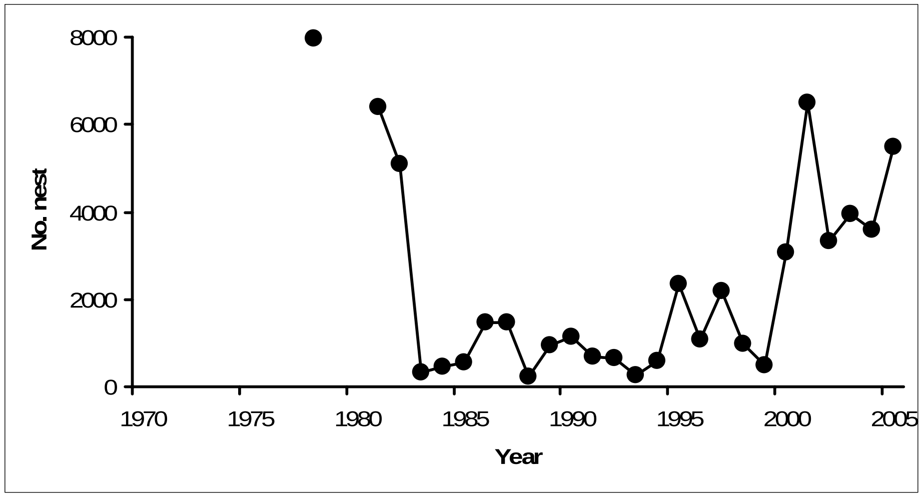

Figure 5. Annual number of nests at Colola, Michoacan, Mexico. Colola is the most important green turtle nesting concentration in Pacific Mexico. Data courtesy of J. Alvarado and C. Delgado Trejo, Universidad Michoacana de San Nicholas Hidalgo.

In addition to the preceding discussion of nesting abundance and long-term trends, the status of green turtles is described below for five regions in Mexico. These include Northwestern Mexico, Michoacan, Revillagigedos Islands, Tres Marias Islands, and Remainder of Coast (including all nesting areas not covered in the other four categories).

Northwestern Mexico

The coastal waters of northwestern Mexico are an incredibly important foraging region for turtles originating from mainland Mexico, as well as from the Revillagigedos Islands (Seminoff 2000; Nichols 2003a; P. Dutton *et al*., NMFS, unpublished data). It is difficult to quantify long-term population trends among foraging populations in this area because scientific studies of turtles in marine habitats have only been ongoing since the early 1990s. However, based on comparisons of historic fisheries data with more recent capture program data, it is apparent that green turtles are at a fraction of their former abundance. The tremendous declines are illustrated by the fact that nearly 500 turtles were captured in only three weeks in 1961 at Bahia de los Angeles - a major foraging area in the Gulf of California - whereas slightly more than 300 turtles were captured at the same site using the same methods, although slightly less effort, during a 10-year study (1995-2004; Seminoff *et al*. 2003; J. Seminoff, NMFS, unpublished data.). Although the population remains depleted relative to historic levels, anecdotal information suggests that juvenile green turtles have become more common in northwest Mexican foraging areas since the 1990 ban on turtle use (Diario Oficial de la Federacion 1990).

Michoacan

The highest nesting densities for the state of Michoacan are at Colola and Maruata. Colola Beach is the main nesting beach and accounts for ~ 74.4% of green turtle nesting in the State of Michoacan; Maruata contains 24.1% of the nesting within the state (Delgado and Alvarado 2006; C. Delgado, Universidad Michoacana, personal communication, 2007). In addition, nesting in Michoacan occurs at the smaller beaches of Xicuaza, La llorona, paso de Noria, Cachan, Ximapa, Motin del oro, Arenas blancas, Cuilala, Chocola, La placita, and la Tikla; however, nesting data for these been collected by the local fisheries commission and multiple year data sets are currently unavailable. The longest-term data available are for Colola, where nesting beach monitoring has been ongoing every year since the 1981-1982 nesting season (Figure 5). An estimate by Cliffton *et al*. (1982) places annual nesting for all of Michoacan in the early 1970s at approximately 25,000 females. However, this nesting population was likely already depleted by the time of Cliffton's estimate, as major green turtle harvests along the Pacific coast of Mexico had been ongoing for at least 60 years by that point (Craig 1926).

Revillagigedos Islands

Despite its importance as a key nesting area for green turtles in Pacific Mexico - both in terms of nesting numbers and genetic uniqueness - few data are available. The three primary nesting sites are Academy Bay and Playas Blancas on Clarion Island (Brattstrom 1982, Awbrey *et al*. 1984), and Sulfur Bay on Socorro Island (Marquez 1990). From 1999-2001, a mean of 47 nests were deposited each year at Socorro Island, and a mean of 79 nests were deposited each year at Clarion Island (Juarez-Ceron *et al*. 2003). Nesting activity at Clarion may be stable based on the fact that Awbrey *et al*. (1984) counted 80 body pits in October 1976, and believed these represented the entire nesting activity for that season. However, as with all single year data sets, especially those based on counts of body pits, the data should be viewed with extreme caution.

Tres Marias Islands

Tres Marias Islands is a small archipelago located around 90 km west of the state of Nayarit, Mexico (Figure 4). Although little is known about current nesting or in-water populations, we do know that these islands were a favorite site to catch and store great quantities of sea turtles during buccaneer days. The diaries of Edward Cooke and Woodes Rogers provide testimony that these islands were an important breeding ground for green turtles, as they both reported taking approximately 100 females in a night as provisions for the following weeks (Cooke 1712 (1969)). As recently as the late 1950s, green turtles were observed at nesting beaches in the islands (Zweifel 1960). Virtually nothing is known about the current status of green turtles at the Tres Marias Islands, due largely to the fact that they are the site of a prison colony and gaining legal access is nearly impossible (J. Seminoff, NMFS, personal observation).

Remainder of Coast (Baja California Sur, Sinaloa, Nayarit, Jalisco, Colima, Guerrero, Oaxaca, Chiapas)

Solitary nesting by green turtles occurs throughout these areas (Seminoff 1994, NMFS and USFWS 1998b). Among the more important of these areas for green turtle nesting are Barra de la Cruz (Oaxaca) and the coast of Colima (Seminoff 1994). At Barra de la Cruz, < 20 nests were documented during the 1992-1993 season (Seminoff 1994). On the coast of Colima, approximately 30 nests were reported for Cuyatlan during the 1993-1994 season (J. Seminoff, NMFS, unpublished data).

C.2.3.1.2.2. Demography

The primary demographic features of green turtles that are relevant for interpreting population abundance and long term trends include age-to-maturity (often via growth studies), reproductive longevity, reproductive output (i.e., egg production, clutch frequency, internesting interval), and annual survivorship. There have been several advances in our knowledge of green turtle demography along the Pacific coast of Mexico, which are described below. See Subsection A.2.3.1.3 for a discussion of the regional genetic patterns for green turtles, as well as the implications of the decrease at, and loss of, nesting concentrations.

Green turtles exhibit particularly slow growth rates and age-to-maturity for the species appears to be the longest of any sea turtle (Chaloupka and Musick 1997, Hirth 1997). Growth rates vary substantially among Pacific Mexico foraging populations, ranging from 1.4 cm/year (Seminoff *et al*. 2002c) to >5 cm/year (McDonald-Dutton and Dutton 1998), likely due to both varying diet quality and duration of foraging season. Based on growth data from the Gulf of California, Seminoff *et al*. (2002c) estimate that green turtles require from 9-21 years to reach sexual maturity after settling into this neritic foraging area. However, McDonald-Dutton and Dutton (1998) found very high growth rates for green turtles inhabiting waters near the effluent of a power plant in San Diego Bay, USA, suggestive of perhaps even faster maturation rates. It is important to note that the growth rates for this site may benefit from the unnaturally warm waters caused by the powerplant's effluent (J. Seminoff, NMFS, unpublished data).

With respect to nesting activity, the lack of reliable reproductive longevity estimates precludes an examination of total reproductive output per female lifetime. However, information is available regarding many of the general demographic aspects of green turtle nesting along the Pacific coast of Mexico, and these aspects underscore the substantial differences in morphology and reproductive output between the Michoacan and Revillagigedos nesters. Females nesting in Michoacan are substantially smaller than those nesting in the Revillagigedos (82 cm versus 94 cm mean curved carapace length; Alvarado and Figueroa 1990, Juarez-Ceron *et al*. 2003). The nesting season in Michoacan runs from September through January (Alvarado and Figueroa 1990), with females nesting every 3 years (Alvarado and Figueroa 1990) and depositing a mean of 3.1 nests per season (Alvarado-Diaz *et al*. 2003) with roughly 65.1 eggs per nest (Alvarado and Figueroa 1990). In the Revillagigedos Islands, nesting occurs from March through November with a peak in April/May (Brattstrom 1982, Awbrey *et al*. 1984), and although mean clutch frequency is unknown, there are substantially more eggs per nest (mean = 95 eggs; Juarez-Ceron *et al*. 2003). Hatching success of eggs incubated *in situ* in the Revillagigedos is 90% (Juarez-Ceron *et al*. 2003) compared to 92% and 89% for eggs incubated *in situ* in Colola and Maruata, respectively (C. Delgado, Universidad Michoacana, personal communication, 2007). In contrast, the most recent data for hatching success from eggs incubated in hatcheries in Colola and Maruata are 75.6% and 59.4%, respectively (C. Delgado, Universidad Michoacana, personal communication, 2007).

Only one study has examined annual survivorship in the Pacific Mexico breeding population (Seminoff *et al*. 2003). This study found that, like other areas in the world, survivorship tends to be lower for juveniles and subadults (0.58) than for adult green turtles (0.97).

C.2.3.1.3 Genetics and genetic variation:

The genetic substructure of the green turtle regional subpopulations shows distinctive genetic properties for each nesting rookery (Bowen *et al*. 1992, FitzSimmons *et al*. 2006). See Subsection A.2.3.1.3 for a discussion of the regional genetic patterns for green turtles, as well as the implications of nesting beach loss.

Among nesting populations in Pacific Mexico, Dutton *et al*. (NMFS, unpublished data) have found substantial differences in the mitochondrial DNA haplotype frequencies between the Michoacan and Revillagigedos Islands rookeries. These differences suggest that the Revillagigedos nesting turtles are evolutionarily more closely related to nesting populations from Hawaii and the western Pacific (P. Dutton, NMFS, unpublished data), a dichotomy that is consistent with the larger size and greater reproductive output of Revillagigedos Island nesters.

Recent efforts to determine the nesting population origins of green turtles assembled in foraging areas have found that green turtles from multiple nesting beach origins commonly mix at feeding areas in the Gulf of California (Nichols 2003a; P. Dutton, NMFS, unpublished data). Along the Pacific Mexico coast and in San Diego Bay (USA), the existing haplotype frequencies of foraging turtles suggests that these sites have substantially greater input from the Revillagigedos Islands than from Michoacan, perhaps 100% of turtles coming from the Revillagigedos population at some sites (Nichols 2003a; P. Dutton *et al*., NMFS, unpublished data). In addition, green turtles with eastern Pacific origins have been found, albeit rarely, in Hawaiian waters (LeRoux *et al*. 2003, Dutton and Balazs in review) and Japanese waters (Kuroyanagi *et al*. 1999).

C.2.3.1.4 Taxonomic classification:

The taxonomic classification for the green turtle has not changed since the species was listed. It remains as follows:

Kingdom: Animalia
Phylum: Chordata
Class: Reptilia
Order: Testudines
Family: Cheloniidae
Genus: *Chelonia*
Species: *mydas*
Common names: Green sea turtle, black sea turtle

The green turtle is in the family Chelonidae and subfamily Cheloniinae (Deraniyagala 1953). The species is widely believed to be constituted by one species and subspecies, although in the eastern Pacific Ocean its species designation has been under tremendous scrutiny; some authors support full species status (e.g., Pritchard 1997, Figueroa 1989) whereas others support subspecies status (e.g., Bowen *et al*. 1992, Karl *et al*. 1992, Parham and Zug 1996). This turtle was originally described as a full species, *Chelonia agassizii*, by Bocourt (1868). Carr (1952) described it as a subspecies, *Chelonia mydas agassizii*. However, in a later treatment Carr (1961) appeared to waver toward support of full species status as he recognized the unique coloration and shape of this turtle: "I would say that a complete novice in turtle study would be able to separate 95 to 98 percent of a mixed lot of *Chelonia*." Caldwell (1962) described the northeastern Pacific green turtle and provided the apparent subspecies synonym of *Chelonia mydas carrinegra* (the name is derived from Caldwell's colleague, Archie Carr, and the turtles' dark pigmentation). Figueroa (1989) examined skull characteristics of turtles from the Michoacan nesting rookery and those from the Caribbean nesting colony at Tortuguero, Costa Rica, and concluded that the *agassizii*-type was sufficiently dissimilar to Caribbean green turtles to warrant its status as a full species. Pritchard (1997) also justified full species status, stating that "*agassizii*- and *mydas*-like forms are sympatric in several places in the Pacific, including the Galapagos Islands and New Guinea; the degree of differentiation in size, shape, and color is more extreme than that found in any other *Chelonia* population; the dark plastral pigment of *agassizii* is not environmentally derived; and there may be purely physical reasons why a 40-kg adult male *agassizii* may be unable to mate with a 200-kg female *mydas*, even if the two do come in contact." Subsequent contributions on the subject include that of Kamezaki and Matsui (1995) who examined 45 skulls from six nesting sites around the world including *agassizii* skulls from the Galapagos Islands and concluded that, though the *agassizii* form was unique, it did not warrant full species status. Similarly, genetic studies by Bowen *et al*. (1992) and Grady and Quattro (1999) found that East Pacific green turtles represented only a small subset of lineage diversity within the mitochondrial DNA gene tree for globally distributed *Chelonia*, and thus were deserving of no greater distinction than subspecies level. Studies by Karl *et al*. (1992) on nuclear DNA supported these findings.

C.2.3.1.5 Spatial distribution:

Green turtle nesting occurs sporadically along much of the Pacific coast of Mexico from the state of Sinaloa south to Chiapas (Seminoff 1994), and near the tip of the Baja California Peninsula (Tiburcios Pintos *et al*. in press). The primary nesting sites, which are discussed above, include the beaches of Colola and Maruata in Michoacan, and Clarion and Socorro Islands in the Revillagigedos Archipelago.

The primary foraging areas for this population stretch from the U.S.-Mexico border to the Guatemala-Mexico border (Figure 4), although some turtles from Michoacan have been found as far south as Colombia (Alvarado and Figueroa 1992). Coastal areas of northwest Mexico (Sonora, Baja California, and Baja California Sur) are perhaps the most important foraging sites for green turtles; the primary sites include all of the Gulf of California and the lagoons of Estero Coyote, Laguna San Ignacio, Laguna Ojo de Liebre, and Bahia Magdalena along the Pacific coast of the Baja Peninsula. In addition, Guadalupe Island - about 200 km off the coast of Baja California - has recently been found to be a major green turtle feeding area (Figure 4; J. Seminoff, NMFS, unpublished data.). South of Michoacan, there are numerous lagoons and wetland areas that serve as foraging areas, including Laguna Corralero in Guerrero, Laguna Pastoria, Bahias Huatulco, and Laguna Mar Muerta in Oaxaca, and a series of lagoons along most of the Chiapas coast (Esteros San Francisco, Sambuquero, Chocohuital, Castañi, and Huetate) (J. Seminoff, NMFS, and L. Sarti, CONANP, unpublished data).

C.2.3.1.6 Habitat or ecosystem conditions:

See Subsection A.2.3.1.6.

C.2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

The determination to list a species under the ESA is based on the best scientific and commercial data regarding five listing factors (see below). Subsequent 5-year reviews must also make determinations about the listing status based, in part, on these same factors.

C.2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

Impacts to green turtle habitat are diverse and widespread in Pacific Mexico. Several of the lesser green turtle nesting beaches in Mexico suffer from coastal development, a problem that is especially acute at Maruata, a tourist site with tourist activity and heavy foot traffic during the nesting season (Seminoff 1994). Artificial lighting is also a problem in many of these areas. Other significant impacts on nesting beach habitat include disturbances from feral and domestic animals (Figueroa *et al*. 1993, Seminoff 1994).

With respect to marine habitat degradation, coastal habitats along the Pacific coast of Mexico are relatively pristine and free from contamination, although they too are likely modified today due to the depletion of green turtles (see Subsection A.2.3.2.1). Coastal development constitutes a major threat in several areas, perhaps none more so than in northwest Mexico where the development of a large marina network (*Escallera Nautica*) is planned for at least five major foraging areas (Nichols 2003b). There are also a number of commercial algae harvesting operations throughout this region that collect this product for the production of industrial agar (Pacheco-Ruiz and Zertuche-Gonzalez 1996). Although impacts from these ongoing and proposed human activities are difficult to quantify, the recent human population increase along the Baja California Peninsula underscores the need to develop and implement management strategies that balance development and economic activities with the needs of green turtles.

C.2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Green turtles, like other sea turtle species, are particularly vulnerable to anthropogenic impacts during all life-stages: from eggs to adults. These include egg harvest, the killing of females on nesting beaches, and directed hunting of green turtles in foraging areas.

Egg Harvest

One of the most detrimental human threats to green turtles is the intentional harvest of eggs from nesting beaches. As each nesting season passes and populations continue to suffer from egg harvest, they will progressively lose the juvenile cohorts that would have recruited from the post-hatchling phase (Mortimer 1995). Present nesting populations may appear hardy, but without recruitment into the juvenile population and a well-balanced distribution of turtles among all cohorts, populations are more vulnerable to decline (Crouse *et al*. 1987, Frazer 1992).

At the largest green turtle nesting beach along the Pacific coast of Mexico, nearly all eggs were harvested for at least several decades prior to 1978 (Cliffton *et al*. 1982). In the mid 1970s, this harvest reached upwards of 70,000 eggs per night during the peak of the nesting season in Colola and 7,000-15,000 in Maruata (probably 100% of all nesters) (Cliffton *et al*. 1982). The problem persists today, albeit at substantially reduced levels (Alvarado-Diaz *et al*. 2001).

Harvest of Nesting Females

The killing of nesting females continues to threaten the stability of green turtle subpopulations. This directed take affects nesting populations both by reducing adult abundance and through reducing the population's potential for annual egg production. Ongoing harvest of nesting adults has been documented in Michoacan (Alvarado-Diaz *et al*. 2001).

Hunting of Turtles in Foraging Habitats

Mortality of turtles in foraging habitats continues to be problematic for recovery efforts in Pacific Mexico. Although subpopulations may be protected at nesting beaches, their large-scale in-water movements often take them to areas where protection is absent. Green turtles are hunted in many areas of northwest Mexico despite legal protection (Nichols *et al*. 2002; Seminoff *et al*. 2003; J. Seminoff, NMFS, personal observation). As recently as 2002, Nichols *et al*. (2002) described a black market that killed tens of thousands of green turtles each year. Although killing turtles is illegal, the consumption of turtle meat remains rampant in many social circles of Mexico and the southwest United States (Nichols and Safina 2004; J. Seminoff, NMFS, personal observation). Sustaining this culture of consumption is the tradition of eating turtle meat at fiestas, quinceaneras, and Semana Santa gatherings.

C.2.3.2.3 Disease or predation:

No fibropapillomatosis has been documented in green turtles in Mexican foraging habitats, although a variant of FP has been found in one green turtle from San Diego Bay, USA (Greenblatt *et al*. 2005) that shared DNA affinities with the Mexican green turtle population (P. Dutton, NMFS, unpublished data). In addition, a few other turtles in San Diego Bay were believed to have the precursor to FP based on eye anomalies (McDonald-Dutton and Dutton 1990).

C.2.3.2.4 Inadequacy of existing regulatory mechanisms:

The conservation and recovery of sea turtles, and green turtles particularly, is facilitated by a number of regulatory instruments at international, regional, national, and local levels. Considering the distribution of green turtles throughout Pacific Mexico, virtually every instrument that targets or impacts sea turtles in the region is almost certain to cover green turtles. A list of the main regulatory instruments in this region is provided below. Please see Subsection A.2.3.2.4 for a description of each instrument.

It should also be pointed out that in 1990 a presidential decree was proclaimed that banned the use or sale of sea turtle products throughout all of Mexico (Diario Oficial de la Federacion 1990). Signed by then-President Carlos Salinas de Gortari, this was a monumental declaration on the part of the Mexican Government to prohibit the use of all sea turtle species in Mexico. It mandated fines and jail time for individuals caught with sea turtle products. However, the continued poaching of turtle eggs throughout the country and hunting of sea turtles in foraging areas, particularly in northwest Mexico, suggests this legislation has not achieved its intended goal (Nichols and Safina 2004).

- *United States Magnuson-Stevens Conservation and Management Act*
- *FAO Technical Consultation on Sea Turtle-Fishery Interactions*
- *Inter-American Convention for the Protection and Conservation of Sea Turtles*
- *Convention on the Conservation of Migratory Species of Wild Animals*
- *Convention on Biological Diversity*
- *Convention on International Trade in Endangered Species of Wild Fauna and Flora*

C.2.3.2.5 Other natural or manmade factors affecting its continued existence:

There are several other manmade factors that affect green turtles in Pacific Mexico. Because of the dispersal of green turtles nesting in Pacific Mexico to areas throughout the Eastern Pacific Ocean, human threats outside of Mexico may have profound impacts on the local breeding population (e.g., global warming, fisheries bycatch, contamination, vessel strikes, and intake in coastal power plants). Perhaps the most detrimental of these is fisheries bycatch in artisanal and industrial fishing. These fisheries practices include drift-netting, long-lining, set-netting, pound netting, and trawl fisheries, and their adverse impacts on sea turtles have been documented in marine environments throughout the world. See Subsection A.2.3.2.5. for further discussion of these impacts.

2.4 Synthesis

THREATENED BREEDING POPULATIONS

Current nesting abundance trends were determined for 23 threatened nesting concentrations among 11 ocean regions around the world. They included both large and small rookeries and are believed to be representative of the overall trends for their respective regions. Of these 23 sites for which data enable an assessment of current trends, 10 nesting populations are increasing, 9 are stable, and 4 are decreasing. Long-term continuous datasets ≥20 years are available for 9 threatened population sites, all of which are either increasing or stable. These include Ascension Island, Hawaii, Heron Island, Ogasawara Islands, Philippine Turtle Islands, Sabah Turtle Islands, Sarawak, Terengganu, and Tortuguero. Despite the apparent global increase in numbers, the positive overall trend should be viewed cautiously because trend data are available for just over half of all sites examined. With respect to regional trends, data from index sites suggest that some regions are doing better than others based on available trend data. Nesting populations are doing relatively well (# increasing sites > # decreasing sites) in the Pacific, Western Atlantic, and Central Atlantic Ocean. In contrast, populations are doing relatively poorly in Southeast Asia, Eastern Indian Ocean, and perhaps the Mediterranean.

Threats to nesting and marine habitats continue to affect threatened green turtle populations. Continuing human population expansion into coastal areas is expected to increase the severity of existing threats and is therefore a cause for major concern. Green turtles are also highly vulnerable to anthropogenic impacts during all life-stages, and three of the biggest threats result from harvest for commercial and subsistence use (e.g., egg harvest, the harvest of females on nesting beaches, and directed hunting of green turtles in foraging areas). Diseases, particularly fibropapillomatosis, threaten a large number of existing subpopulations. Fisheries bycatch in artisanal and industrial fishing gear is also a major impact. These fisheries practices include drift-netting, long-lining, set-netting, pound netting, and trawl fisheries, and their adverse impacts on sea turtles have been documented in marine environments throughout the world. In addition, increasing incidence of exposure to heavy metals and other contaminants in the marine environment is of concern in some areas. Additional factors affecting green turtles include boat traffic and its modification of green turtle behavior in coastal areas, boat strikes as a major mortality source in some areas, the ingestion of and entanglement in marine debris that can reduce food intake and digestive capacity, and the interaction with oil spills.

ENDANGERED FLORIDA BREEDING POPULATION

The green turtle nesting population of Florida appears to be increasing based on 18 years (1989-2006) of index nesting data from throughout the state. Although in the last four years there are three 'low' years, this may be due to lesser reproductive effort as a result of environmental variability at foraging grounds rather than a decrease in the number of nesting females. The increase in nesting in Florida is likely a result of several factors, including: (1) a Florida statute enacted in the early 1970s that prohibited the killing of green turtles in Florida; (2) the species listing under the ESA in 1973, affording complete protection to eggs, juveniles, and adults in all U.S. waters; (3) the passage of Florida's constitutional net ban amendment in 1994 and its subsequent enactment, making it illegal to use any gillnets or other entangling nets in state waters; (4) the likelihood that the majority of Florida adult green turtles reside within Florida waters where they are fully protected; (5) the protections afforded Florida green turtles while they inhabit the waters of other nations that have enacted strong sea turtle conservation measures (e.g., Bermuda); and (6) the listing of the species on Appendix I of CITES, which stopped international trade and reduced incentives for illegal trade from the U.S.

While nesting has increased, impacts to nesting beaches and the marine environment have also increased. Among the most significant threats to nesting habitat in Florida are structural impacts (e.g., construction of buildings, beach armoring, and beach renourishment) and beachfront lighting. These activities result in direct habitat destruction and degradation decreasing the extent and suitability of nesting sites on Florida beaches (e.g., increased erosion, altered thermal profiles). The high incidence of fibropapillomatosis disease among some foraging populations is a serious concern. Within U.S. waters, fisheries bycatch of Florida green turtles remains a threat. Human threats (e.g., directed killing, fisheries bycatch) outside of Florida may have profound impacts on the Florida breeding population because of the dispersal of Florida green turtles to juvenile foraging areas throughout the Wider Caribbean and Gulf of Mexico. Vessel strikes are a growing concern and, as human populations increase in coastal areas, vessel strikes are likely to increase.

ENDANGERED PACIFIC MEXICO BREEDING POPULATION

There is one primary nesting concentration in Pacific Mexico (Colola, Michoacan) and three lesser nesting sites (Maruata, Michoacan; Clarion Island, Revillagigedos Archipelago; and Socorro Island, Revillagigedos Archipelago). Based on nesting beach monitoring efforts, a mean of roughly 6,050 nests are deposited each year in Pacific Mexico. The only long-term trend data available are for Colola, the largest nesting concentration in Pacific Mexico, where nesting beach monitoring has been ongoing every year since the 1981-1982 nesting season. Based on the 25-year trend line, it is clear that green turtle nesting has increased since the population's low point in the mid 1980s to mid 1990s. This observed increase may have resulted from the onset of nesting beach protection in 1979 - as is suggested by the similarity in timing between the onset of beach conservation and the age-to-maturity for green turtles in Pacific Mexico. The initial upward turn in annual nesting was seen in 1996, about 17 years after the initiation of a nesting beach protection program, and growth data from the Gulf of California suggest that green turtles mature at about 15-25 years. Although not a clear cause of the increasing nesting trend, the consistency in timing is nonetheless compelling. The 1990 presidential decree protecting all sea turtles of Mexico certainly helped the situation, but this occurred much later than the start of nesting beach conservation. It is more likely that this national legislation has had its greatest positive impact at the foraging areas, where green turtle hunting was once rampant.

Impacts to green turtle habitat are diverse and widespread in Pacific Mexico. Several of the lesser green turtle nesting beaches in Mexico suffer from coastal development, a problem that is especially acute at Maruata, a tourist site with tourist activity and heavy foot traffic during the nesting season. Artificial lighting is also a problem in many of these areas. Other significant impacts on nesting beach habitat include disturbances from feral and domestic animals. Coastal development also constitutes a major threat to marine habitats in several areas, perhaps none more so than in northwest Mexico where the development of a large marina network is planned for at least five major foraging areas. Green turtles are also highly vulnerable to anthropogenic impacts during all life-stages, and three of the biggest threats result from harvest for commercial and subsistence use (e.g., egg harvest, the harvest of females on nesting beaches, and directed hunting of green turtles in foraging areas). Because of the dispersal of green turtles nesting in Pacific Mexico to areas throughout the Eastern Pacific Ocean, human threats (e.g., global warming, fisheries bycatch, contamination) outside of Mexico may have profound impacts on the local breeding population.

3.0 RESULTS

3.1 Recommended Classification:

3.1.1 Endangered population

Based on the best available information, we do not believe the breeding colony populations in Florida and on the Pacific coast of Mexico should be delisted or reclassified. However, for the current population listings for the green turtle (both Endangered and Threatened), we have information that indicates an analysis and review of the species should be conducted in the future to determine the application of the DPS policy to the green turtle. See Section 4.0 for additional information.

3.1.2 Threatened population

Based on the best available information, we do not believe the threatened green turtle populations should be delisted or reclassified. However, for the current population listings for the green turtle (both Endangered and Threatened), we have information that indicates an analysis and review of the species should be conducted in the future to determine the application of the DPS policy to the green turtle. See Section 4.0 for additional information.

3.2 New Recovery Priority Number: No change.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

We have preliminary information that indicates an analysis and review of the species should be conducted in the future to determine the application of the DPS policy to the green turtle. Since the species' listing, a substantial amount of information has become available on population structure (through genetic studies) and distribution (through telemetry, tagging, and genetic studies). The Services have not yet fully assembled or analyzed this new information; however, at a minimum, these data appear to indicate a possible separation of populations by ocean basins. To determine the application of the DPS policy to the green turtle, the Services intend to fully assemble and analyze this new information in accordance with the DPS policy. See Section 2.3 for new information since the last 5-year review.

The current "Recovery Plan for U.S. Population of Atlantic Green Turtle (*Chelonia mydas*)" was completed in 1991, the "Recovery Plan for U.S. Pacific Populations of the Green Turtle (*Chelonia mydas*)" was completed in 1998, and the "Recovery Plan for U.S. Pacific Populations of the East Pacific Green Turtle (*Chelonia mydas*)" was completed in 1998. The recovery criteria contained in the plans, while not strictly adhering to all elements of the 2004

NMFS Interim Recovery Planning Guidance, are a viable measure of the species status. The species biology, demographic trends, and population status information can be updated where appropriate; however, the recovery actions identified in the plans are appropriate and properly prioritized. While some additional recovery actions can no doubt be identified, the Services believe that the current plans remain valid conservation planning tools. The recovery plans should be re-examined over the next 5-10 year horizon, particularly if the DPS analysis results in restructuring of the current listing, to update the plans to conform to the 2004 NMFS Interim Recovery Planning Guidance. In the near-term, additional information and data are particularly needed on genetic relationships among nesting populations, impacts of coastal and pelagic fisheries, foraging areas and identification of threats at foraging areas, and long-term population trends.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of *Green Sea Turtle*

Current Classification: Endangered and Threatened

Endangered Population - breeding colony populations in Florida and on Pacific coast of Mexico
Threatened Population - wherever found except where listed as endangered

Recommendation resulting from the 5-Year Review: No change

Review Conducted By:

Jeffrey Seminoff, Barbara Schroeder (National Marine Fisheries Service)
Sandy MacPherson, Earl Possardt, Kelly Bibb (U.S. Fish and Wildlife Service)

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve ______________ Date 8/7/07
David L. Hankla

REGIONAL OFFICE APPROVAL:

for **Lead Regional Director, Fish and Wildlife Service**

Approve ______________ Date 8/17/07

Cooperating Regional Director, Fish and Wildlife Service

X Concur ____ Do Not Concur

______________ Date 8/22/07

NATIONAL MARINE FISHERIES SERVICE
5-YEAR REVIEW of *Green Sea Turtle*

Current Classification: Endangered and Threatened

Endangered Population - breeding colony populations in Florida and on Pacific coast of Mexico
Threatened Population - wherever found except where listed as endangered

Recommendation resulting from the 5-Year Review: No change

Review Conducted By:

Jeffrey Seminoff, Barbara Schroeder (National Marine Fisheries Service)
Sandy MacPherson, Earl Possardt, Kelly Bibb (U.S. Fish and Wildlife Service)

REGIONAL OFFICE APPROVAL: The draft document was reviewed by the appropriate Regional Offices and Science Centers.

HEADQUARTERS APPROVAL:
Director, Office of Protected Resources, NOAA Fisheries

Approve: James H Lecky Date: AUG 10 2007
James H. Lecky

Assistant Administrator, NOAA Fisheries

✓ Concur _____ Do Not Concur

Signature_______________ Date 8/22/07
Samuel D. Rauch, III
Deputy Assistant Administrator
for Regulatory Programs

APPENDIX

Summary of peer review for the 5-year review of *Green Sea Turtle* (*Chelonia mydas*)

A. Peer Review Method: See B. below.

B. Peer Review Charge: On April 20, 2007, the following letter and Guidance for Peer Reviewers of Five-Year Status Reviews were sent via e-mail to potential reviewers requesting comments on the 5-year review. Requests were sent to Dr. Karen Bjorndal (University of Florida), Dr. Carlos Delgado (Universidad Michoacana de San Nicolás de Hidalgo, Mexico), Carlos Diez (Puerto Rico Department of Natural and Environmental Resources), Dr. Colin Limpus (Queensland Parks and Wildlife Service), Dr. Nicolas Pilcher (Marine Research Foundation, Malaysia), and Dr. Blair Witherington (Florida Fish and Wildlife Conservation Commission).

We request your assistance in serving as a peer reviewer of the U.S. Fish and Wildlife Service and National Marine Fisheries Service's (Services) 5-year status review of the green sea turtle (Chelonia mydas). The 5-year review is required by section 4(c)(2) of the United States Endangered Species Act of 1973, as amended (Act). A 5-year review is a periodic process conducted to ensure the listing classification of a species as threatened or endangered on the Federal List of Endangered and Threatened Wildlife and Plants is accurate. The initiation of the 5-year review for the green turtle was announced in the Federal Register on April 21, 2005, and the public comment period closed on July 20, 2005. Public comments have been incorporated into the status review.

The enclosed draft of the status review has been prepared by the Services pursuant to the Act. In keeping with directives for maintaining a high level of scientific integrity in the official documents our agencies produce, we are seeking your assistance as a peer reviewer for this draft. Guidance for peer reviewers is enclosed with this letter. If you are able to assist us, we request your comments be received on or before May 18, 2007. Please send your comments to Sandy MacPherson at the address on this letter. You may fax your comments to Sandy MacPherson at 904-232-2404 or send comments by e-mail to Sandy_MacPherson@fws.gov.

We appreciate your assistance in helping to ensure our decisions continue to be based on the best available science. If you have any questions or need additional information, please contact Sandy MacPherson at 904-232-2580, extension 110. Thank you for your assistance.

Sincerely yours,

David L. Hankla
Field Supervisor
Jacksonville Ecological Services Field Office

Enclosures

Guidance for Peer Reviewers of Five-Year Status Reviews

U.S. Fish and Wildlife Service, North Florida Ecological Services Office

February 7, 2007

As a peer reviewer, you are asked to adhere to the following guidance to ensure your review complies with Service policy.

Peer reviewers should:

1. Review all materials provided by the Service.

2. Identify, review, and provide other relevant data that appears not to have been used by the Service.

3. Not provide recommendations on the Endangered Species Act classification (e.g., Endangered, Threatened) of the species.

4. Provide written comments on:

- *Validity of any models, data, or analyses used or relied on in the review.*
- *Adequacy of the data (e.g., are the data sufficient to support the biological conclusions reached). If data are inadequate, identify additional data or studies that are needed to adequately justify biological conclusions.*
- *Oversights, omissions, and inconsistencies.*
- *Reasonableness of judgments made from the scientific evidence.*
- *Scientific uncertainties by ensuring that they are clearly identified and characterized, and that potential implications of uncertainties for the technical conclusions drawn are clear.*
- *Strengths and limitation of the overall product.*

5. Keep in mind the requirement that we must use the best available scientific data in determining the species' status. This does not mean we must have statistically significant data on population trends or data from all known populations.

All peer reviews and comments will be public documents, and portions may be incorporated verbatim into our final decision document with appropriate credit given to the author of the review.

Questions regarding this guidance, the peer review process, or other aspects of the Service's recovery planning process should be referred to Sandy MacPherson, National Sea Turtle Coordinator, U.S. Fish and Wildlife Service, at 904-232-2580, extension 110, email: Sandy_MacPherson@fws.gov.

C. Summary of Peer Review Comments/Report:

A summary of peer review comments from the four respondents is provided below. The complete set of comments is available at the Jacksonville Ecological Services Field Office, U.S. Fish and Wildlife Service, 6620 Southpoint Drive South, Suite 310, Jacksonville, Florida, 32216.

Dr. Carlos Delgado, Universidad Michoacana de San Nicolás de Hidalgo, Michoacán, Mexico: Dr. Delgado provided information to update Subsection C for the endangered green turtle breeding colony population on the Pacific coast of Mexico. He gave the most recent demographic information for the nesting stock in Michoacan and gave suggestions on how to best characterize the green turtles nesting in Colola and Maruata, Mexico.

Carlos Diez, Puerto Rico Department of Natural and Environmental Resources, San Juan, Puerto Rico: Mr. Diez commented that the assessment focused specifically on nesting beaches and though he did not provide specific comments on the document, he did provide important information regarding the presence of green turtles in foraging habitats of Puerto Rico that had originated from Florida and other areas of the Caribbean.

Dr. Nicolas Pilcher, Marine Research Foundation, Sabah, Malaysia: Dr. Pilcher provided very substantive comments relating to the data presented in Subsection A. He commented that while the overall assessment was very accurate, there were a few data sources that were questionable and he went on to provide additional data and contacts for people in the field from whom the most up to date data were available. Dr. Pilcher also recommended that the evaluation make very clear that most current populations are likely at a mere fraction of their historic abundance, regardless of the current trend. Information regarding sea-level rise was also provided, and there were numerous minor edits suggested throughout the document.

Dr. Blair Witherington, Florida Fish and Wildlife Conservation Commission, Melbourne, FL, USA: Dr. Witherington suggested that we use published information as much as possible to define either increasing or decreasing trends, and that published trends assessments should take precedence over the 5-year review author's determinations. He also suggested that all data in Table 1 be converted to the same units (e.g., annual number of nesting females) so as to not confuse the reader. He also suggested that we frame the data sets' time series in terms of green turtle generation time. For the Florida nesting population, he asked for further clarification regarding the differences between the Florida nesting population and the foraging population. More information was asked for regarding the impacts of global climate change, debris ingestion, and oil spills on green turtles. Numerous minor edits were suggested.

D. Response to Peer Review:

Dr. Carlos Delgado, Universidad Michoacana de San Nicolás de Hidalgo, Michoacán, Mexico: All comments by Dr. Delgado were incorporated.

Carlos Diez, Puerto Rico Department of Natural and Environmental Resources, San Juan, Puerto Rico: The information on foraging green turtles was added.

Dr. Nicolas Pilcher, Marine Research Foundation, Sabah, Malaysia: All suggested edits and new data suggested by Dr. Pilcher were incorporated. We attempted to contact two individuals for more recent data, but received no reply. We also added substantial text throughout the document to highlight the fact that most populations, even if currently increasing, stand at a small fraction of their historic abundance.

Dr. Blair Witherington, Florida Fish and Wildlife Conservation Commission, Melbourne, FL, USA: All suggested minor edits were incorporated. We elected to keep the current use of published and unpublished information in the evaluation. While true that in many cases unpublished data are unverifiable, we believe that the unpublished data included in the review are highly reliable. We did not change the units in Table 1 and instead adopted the second option suggested by Dr. Witherington, which was to make a specific field in the Table that clearly describes what units are used for each nesting site. We also provided more context about green turtle generation times in light of the trends presented in the evaluation. We added text describing the differences between the nesting and foraging populations in Florida. We added text providing context to global climate change, as well as more information on debris ingestion and the impacts from oil spills.