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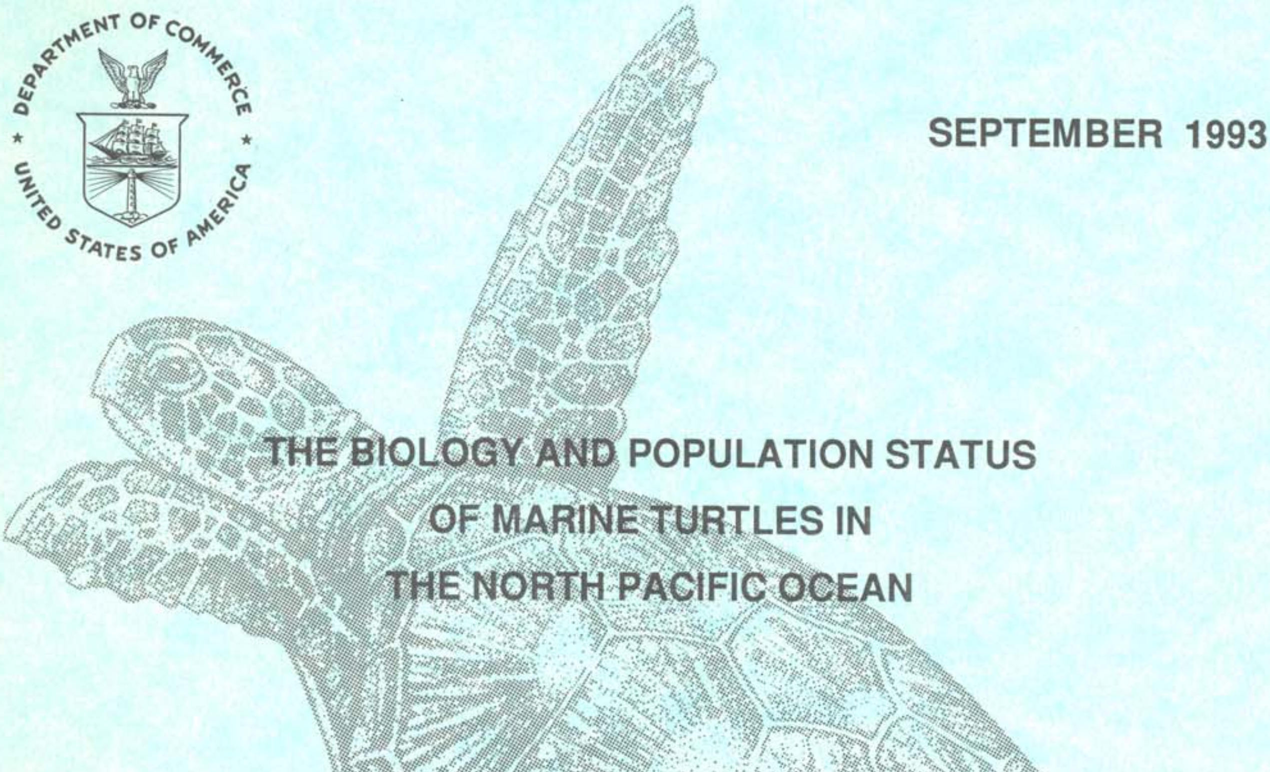

THE BIOLOGY AND POPULATION STATUS OF MARINE TURTLES IN THE NORTH PACIFIC OCEAN

Karen L. Eckert

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U.S. DEPARTMENT OF COMMERCE
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PREFACE

In recent years considerable international attention has been directed toward high-seas driftnet fisheries in the North Pacific Transition Zone and their impacts on living marine resources. Among the many species affected are marine turtles whose populations are sufficiently depleted to warrant listing as protected species under U.S. and international laws. To provide a foundation for assessing impacts of the driftnet fisheries on marine turtles, the Honolulu Laboratory commissioned this study to review available background information. The aim was to assemble and summarize current data on the biology and conservation status of turtles in the North Pacific, and to cover a wide spectrum of sources, including unpublished reports and personal accounts.

Soon after the completion of this study, the countries involved in high-seas driftnet fishing agreed to a moratorium on the use of large-scale driftnets sponsored by the United Nations. Nevertheless, this compendium remains a valuable source of information. It will be particular value to programs to assess other sources of risk to turtle populations in the North Pacific, develop recovery plans, and monitor population recovery.

Opinions expressed in this paper are those of the author and are not necessarily shared by the National Marine Fisheries Service.

Jerry A. Wetherall
George H. Balazs
20 July 1993

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LIST OF ABBREVIATIONS

BCS	Baja California Sur
CCL	Curved carapace length
CITES	Convention on International Trade in Endangered Species
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DAWR	Division of Aquatic and Wildlife Resources, Government of Guam
EEZ	Exclusive Economic Zone
ESA	U. S. Endangered Species Act of 1973, as amended
ETP	Eastern Tropical Pacific
FSM	Federated States of Micronesia
FWS	U. S. Fish and Wildlife Service
GAC/BEECS	Genetic Analysis Core, Biotechnologies for the Ecological, Evolutionary and Conservation Sciences (University of Florida)
GBR	Great Barrier Reef, Australia
HSWRI	Hubbs-Sea World Research Institute
IUCN	World Conservation Union
MMDC	Micronesian Mariculture Demonstration Center, Palau
mtDNA	mitochondrial DNA
NMFS	U. S. National Marine Fisheries Service
NPWS	National Parks and Wildlife Service, Government of Australia
NWMMSN	Northwest Marine Mammal Stranding Network
SCL	Straight-line carapace length
SPREP	South Pacific Regional Environment Programme
TAMU	Texas A&M University

TED	Turtle excluder device
UNAM	Universidad Nacional Autónoma de México
UNEP	United Nations Environment Programme
WWF	World Wildlife Fund
WWII	World War II

OBJECTIVES AND SCOPE OF WORK

The objective of this report is to provide a comprehensive review of the biology and population status of sea turtles potentially subject to entanglement in North Pacific high-seas driftnet fisheries. The report will assist National Marine Fisheries Service efforts to assess the impacts of the driftnet fisheries on threatened and endangered sea turtle populations. The species of concern are the green sea turtle complex (*Chelonia mydas*), loggerhead sea turtle (*Caretta caretta*), olive ridley sea turtle (*Lepidochelys olivacea*), hawksbill sea turtle *Eretmochelys imbricata*), and leatherback sea turtle (*Dermochelys coriacea*). Within each of these species, the populations of interest include those whose members may be encountered in the epipelagic waters of the North Pacific. The document presents information on a broad range of topics germane to sea turtle taxonomy, life history, distribution, and exploitation. Relevant national and international conservation legislation is also summarized.

The scope of work is defined as north of the equator and encompassing the following countries (Figure 1): Canada, USA (including the continental west coast, Hawaii, Guam, Palau, and the Northern Mariana Islands), Mexico, Japan, Korea, China, Taiwan, Viet Nam, Kampuchea, Thailand, Malaysia (including Sarawak and Sabah), Philippines, Federated States of Micronesia, Republic of the Marshall Islands, and Kiribati. The unincorporated U. S. territories (Howland, Baker, Wake, and Jarvis Islands, Johnston and Palmyra Atolls, Kingman Reef, Midway) are also included (in particular, see Biological Review: *Chelonia mydas*). The report was compiled after a comprehensive review of the scientific literature on this region, including government documents and material assembled by conservation organizations. To the extent possible, government agencies, government and non-government scientists, fishing industry representatives, lay persons, and other knowledgeable sources throughout the region were consulted to provide current information on the status of turtle populations, research, monitoring, exploitation, protection and recovery measures, and other relevant topics. The general organization of the country sections is to proceed from north to south in the eastern Pacific (Canada, USA, Mexico) and likewise in the western Pacific (Japan, Korea, China, etc.).

Despite efforts to be thorough, it is inevitable in any endeavor of this magnitude that some pertinent information will be missed. Comparatively little research in this region has been published in peer-reviewed journals or other easily accessible periodicals. Language barriers also pose challenges. Nevertheless, it is clear from the data reviewed herein that all species of sea turtle are declining throughout the North Pacific region, though admittedly some species in some regions far more rapidly than others. The factors most frequently implicated in the demise of populations are the relentless harvest of turtles and eggs, loss of beachfront habitat to commercial development, incidental catch by the region's fisheries, degradation of offshore coral reefs and sea grass beds, marine pollution, and general harassment. In several government regions the legal framework for the conservation of remaining stocks is antiquated, allowing, for example, the take of breeding-age adults. Even in countries with adequate protective legislation, enforcement is generally inadequate.

Five major topics are reviewed: (1) the importance of sea turtles to human populations, including exploitation, trade, and cultural traditions, (2) the national laws pertaining to sea turtles throughout the region, as well as selected international agreements potentially useful in the transnational conservation of sea turtles, (3) a biological review of the five species of sea turtle inhabiting the North Pacific (summarized in Table 1), (4) factors important to assessing the impact of high-seas driftnet fisheries, and (5) research and monitoring needs required for improved assessment of the impact of high-seas driftnet fisheries on North Pacific sea turtle populations. It is noteworthy that while there are a wide variety of fishing industries, both coastal and high-seas, which are known or suspected to ensnare and drown threatened and endangered species of sea turtle in the region, only high-seas driftnets will be considered for the purposes of this report.

IMPORTANCE OF NORTH PACIFIC SEA TURTLES TO HUMAN POPULATIONS: EXPLOITATION, TRADE, USE, CULTURAL VALUES AND TRADITIONS

Several comprehensive regional and subregional literature surveys have been published, especially on the subjects of exploitation, trade, and use of sea turtles for domestic and export markets. It is not the intention of this report to duplicate these efforts. In many cases I have drawn liberally from information summarized in Bjorndal (1982) and Groombridge and Luxmoore (1989).

Canada

Only the leatherback and the green turtle have been recorded in Pacific Canadian waters. The latter is known from a single specimen stranded in 1954 and deemed to be "off course" (Gregory and Campbell 1984). Rare records of east Pacific green turtles from Alaska confirm that the species only occasionally strays into far northern waters (Hodge 1981). Leatherbacks had been reported in the waters of British Columbia "about ten times in the last 47 years" at the time of Gregory and Campbell's book. Several records were earlier summarized by MacAskie and Forrester (1962). The leatherback does not permanently reside or breed in Canada, but probably feeds in Canadian waters. Sea turtles have never been taken commercially, and the few brought ashore have been curiosities, often entangled in nets and drowned (Francis Cook, Canadian Museum of Nature, *in litt.*, 4 September 1991). The extent of incidental catch is unquantified. No nesting occurs in Canada, hence there is no opportunity for egg collection. Canada is a Party to CITES and there is no international trade in sea turtles or their products.

United States of America

With the exception of import, transshipment, and cannery industries based in San Diego during the late nineteenth and early twentieth centuries, there is no indication that sea turtles were ever an important component of local economy or culture on the western seaboard of the USA. Stinson (1984) explained that during the latter half of the nineteenth century, whaling vessels and vessels of the Pacific Mail Steamship Company "frequently entered San Diego Bay with shipments of sea turtles from the lagoons of southern Baja California [Mexico]." The turtles were intended for both the local market and for subsequent transport to the San Francisco and London wharves (Smith 1894; Nelson 1921; Parsons 1962). Turtles were also shipped directly to San Francisco by steamer from Magdalena Bay in Baja California (Townsend 1916). Shipments during this time involved so many turtles that fishermen, market owners, and vessel captains tried repeatedly to establish a steady market for sea turtle products. A 3 March 1887 classified ad in the San Diego Herald read, "Turtle soup for the whole county at Connor's Market. Go and see the big sea turtles." (Stinson 1984). Local hotels occasionally displayed sea turtles and included them on the menu whenever possible.

In 1919, a cannery was built in San Diego to process turtles imported from Mexico. Based on the account of Bell and MacKenzie (1923), Stinson (1984) reported that 15,000 cases of sea turtle were processed at the cannery in 1919. To supply the cannery and other turtle industries, 255,000 pounds of sea turtle were imported into California in 1919 and 77,000 pounds in 1920. In March 1922, the Mexican government issued an edict regulating the fishing of sea turtles in Mexican waters. Turtle imports to California declined drastically. By the mid-1930s, San Diego's turtle industry ended. In addition to Stinson's (1984) discussion of the economic importance of sea turtles to San Diego, there are several informative accounts (e.g., Ingle and Smith 1949; Parsons 1962; Rebel 1974; Cato et al. 1978) of the much larger turtle industries in Florida and other mainland southeastern states outside the scope of this report.

In the island state of Hawaii, a rich folk lore surrounds the sea turtle (e.g., Handy and Handy 1972). Early inhabitants are known to have sought out hawksbills for laminae, which were used both for medicinal purposes and to fashion fish hooks and other implements (Balazs 1978). The more abundant green turtles, however, were the favored catch. Referencing a wide variety of sources, Balazs (1980) provided the following historical overview. The exploitation of green turtles for food was part of the native culture when Captain James Cook arrived in the Hawaiian Islands in 1778. This traditional usage undoubtedly started as early as A.D. 600 with the occupation of Hawaii by Polynesians from other Pacific areas. Under the strictly enforced Hawaiian *kapu* system that remained in effect until 1819, turtles could only be eaten by men who were nobility or priests. Turtles were captured principally by hand while diving underwater, with spears or harpoons from shore, and with nets made of cord from the bark of native plants. Another method involved the use of two 7-cm hooks lashed to a flat stone that was attached to a long line. This was apparently used to hook turtles both from shore and while diving in areas where resting turtles could be found.

The traditional controlled exploitation of sea turtles by Hawaiians gradually disappeared with the abolition of the *kapu* system, the influx of foreigners, and the discovery of the unexploited and uninhabited northwestern segment of the archipelago. Both the commercial and noncommercial exploitation of green turtles in the main islands proceeded with virtually no controls from 1819 until the adoption of protective legislation by the State in 1974. During this period, hunting techniques increased in both efficiency and sophistication, and the hunting range expanded to nearly all coastal areas. This was due principally to the availability of outboard motors, motor vehicles, firearms, spear guns, inexpensive machine-made nets and, later, SCUBA equipment. Further, the commercial demand for turtle meat and other Hawaiian seafoods increased considerably with the advent of large-scale tourism following statehood in 1959. According to Hawaii State Division of Fish and Game records, the total reported turtle catch from 1948-1973 was 90,803 kg. Lacking any system of verification, this is surely an underestimate (Balazs 1980).

Today a low level of poaching is reported in Hawaii and there is an undetermined level of incidental catch in Hawaiian and continental U. S. waters. There is no legal exploitation or commercial use. All sea turtles are fully protected by the Endangered Species Act of 1973, as amended.

United States Outlying Territories in the North Pacific

The U. S. outlying territories in the North Pacific Ocean are comprised of the Republic of Palau, Guam, the Northern Mariana Islands, and the unincorporated territories of Howland, Baker, Wake, and Jarvis Islands, Johnston and Palmyra Atolls, Kingman Reef, and Midway. The unincorporated island territories are largely uninhabited at the present time and no historical information could be located to indicate the extent to which sea turtles were important to indigenous or itinerant peoples. American Samoa, situated south of the equator, is not included in the present report.

In the Republic of Palau, both hawksbills and green turtles have historically been heavily exploited for meat, shell and eggs. The following text, with references, is based largely on Johannes (1986). The Palauans enjoy a reputation for being "the best fishermen in Micronesia" and catch turtles using nets, hand-capture (generally while turtles are resting or mating), spearguns, and spears, the latter sometimes coupled with a 'rodeo' technique where men jump into the water from a boat to retrieve the speared turtle. In an early account, Kramer (1929) remarked that turtle meat was very popular with the chiefs, described the culinary preparation of turtle, and explained some of the relevant taboos. Anon. (1961) discussed the distribution of meat within the village and noted that the meat was sometimes used in treating illness. Turtle meat was also important in religious ceremony. Green turtle meat has always been especially popular among Palauans. Hawksbill meat is consumed more today than in the past, however, since cooking innovations have eliminated the foul smell and traditional taboos have been discarded. There are no estimates of the annual harvest of either species, but the breakdown of traditional beliefs and management practices, coupled with increased human populations and more efficient transport, fishing methods and equipment, have put increasing pressure on turtle populations (Groombridge and Luxmoore 1989).

The "gradual but steady decline in [hawksbill] abundance" observed by Robert Owen (Conservation Officer for Micronesia 1949-1978, cited in Pritchard 1982a) appears to be largely a result of the shell trade. Tortoiseshell (hawksbill shell, or bekko) has traditionally provided many products. The local business of making shell implements and adornments once constituted "a regular industry such as can be found in no other oceanic group" (Kramer 1929). According to Force (1976), an object made of turtle shell was appreciated for its size, the beauty and thickness of the shell, the quality of the artisans's skill in producing the object, and for its age. Today accomplished craftsmen are few in number. By 1971 only two men were acknowledged artisans, producing mostly for the tourist market (Force 1976). At the time of Pritchard's (1978) report, hawksbill shells were commonly sold as souvenirs in Palau at $60-$70 each; one in five Japanese and other tourists departed with one, some elaborately engraved. Virtually all shell items are sold domestically. Export is negligible (Groombridge and Luxmoore 1989), although Johannes (1986) reported that during the mid-1800s, Palau turtle shell possessed a high foreign trade value. Recent reports confirm that the illegal killing of hawksbills for "the jewelry and handicraft trade" continues today (Becky Madraisau, MMDC, pers. comm. *in* Maragos 1991).

The collection of eggs is prohibited in Palau, both by the U. S. Endangered Species Act (which still applies to Palau) and the Trust Territory Code. However, despite both the illegality of the harvest and recent conservation measures designed to curb it, the collection of eggs appears to be very high. Pritchard (1978, 1982a) estimated that 80% of the eggs laid are taken for human consumption. Similarly, Groombridge and Luxmoore (1989) concluded from various sources that egg harvest within the Ngerukeuid Islands Preserve and on the Seventy Islands approached 80%, despite protection of these areas as sanctuaries. With regard to hawksbills in the Rock Islands, Maragos (1991) concluded that "chronic egg poaching destroys over 75% of the nests" (59-86% per year, 1982-1990); interviewees reported that nesting activity had "declined substantially over the last decade."

The persistent harvest of marine turtles for meat and eggs clearly has been detrimental to local stocks. Older Palauan fishermen seem unanimous in their opinion that turtles are far less abundant today than they were 10-20 years ago, with a decrease in the numbers of large green turtles especially noticeable (Johannes 1986). Past conservation efforts seem to have failed (see Helfman 1968; Johannes and Black 1981; Johannes 1986). Present levels of take are unknown, but green turtles (one of the few sources of fresh red meat) are still widely eaten by the Southwest Islanders. Based on a June 1992 survey of the Southwest Islands, Suzanne Geermans (SPREP, unpubl. ms) reports that gravid females are routinely caught when they crawl ashore to nest and both male and female turtles are caught while feeding on the reef. The adults are targeted because "the big males and females are the tastiest to eat". This despite Johannes' (1986) contention that turtle meat and eggs no longer constitute an important item in the local diet. Direct harvest is not the only threat. Hawksbills nesting in the Rock Islands are harassed by tourists and picnickers, buildings and shelters are constructed on or near nesting beaches (primarily for tourists), and lights (lanterns, fires) disturb females attempting to nest (Becky Madraisau, MMDC, pers. comm. *in* Maragos 1991).

With the exception of the trade statistics, which were taken from Groombridge and Luxmoore (1989), the information cited below for Guam was furnished by Gerald Davis, Acting Chief, DAWR (*in litt.*, 22 August 1991). In Guam, federal and local laws restricting the harvest and transport of any marine turtle or turtle product are enforced by local conservation officers who are also deputized U. S. Fish and Wildlife Service Agents. Recent encounters with poachers have all been with boaters hoping to spear turtles; the officers monitor these areas during peak turtle poaching times. Turtles are also taken while nesting, but it is not possible for officers to be present in all areas in order to apprehend offenders. When poachers are convicted, all gear and vehicles (cars, boats) are confiscated and fines and/or penalties are levied. This is a deterrent, but not a solution to the illegal harvest. A serious challenge is posed by immigrants who are unfamiliar both with local regulations and the English language. Foreign vessels also capture turtles within the Exclusive Economic Zone (EEZ) around Guam, but enforcement at sea is problematic because only one U. S. Coast Guard vessel is available for Guam.

Historically the harvest of sea turtles was more common prior to WWII, but the take continued legally until 1978 when the green turtle was listed as Threatened under the provisions of U. S. Endangered Species Act. One local fisherman caught 80 turtles over 18 months (1967-1968), with the largest estimated at 450 lbs. Local residents traditionally served turtle meat at *fiestas* (weddings, funerals, christenings) and there are several present day reports that this custom continues clandestinely in southern villages. Conservation officers recently arrested poachers from the southern part of Guam with five green turtles that they intended to sell for *fiestas*. Strong native beliefs render sea turtle protection difficult. For example, DAWR occasionally receives calls requesting turtle meat for a pregnant Chamorro woman who believes her baby might be lost if the meat is unavailable. The majority of turtles taken are juvenile greens (avg. 60 lb), as they are the predominate species in surrounding waters; mature adults are rarely encountered. Hawksbills are also present, leatherbacks are rarely sighted, and there are no records of loggerheads.

Despite the problems posed by direct harvest, it appears that habitat destruction is the most serious threat to sea turtles in Guam. Habitat destruction occurs mainly due to construction and development. In 1990, Guam received more than 740,000 tourists. With that number expected to rise, the number of hotels and other beachfront developments will perpetuate the degradation of potential nesting grounds. On the north coast of the island a military base indirectly protects important habitat since there has been limited access to this area. However, now several landowners around Uruno are trying to develop their land. This will place some of the last nesting sites in danger, and may have a major impact on remaining sea turtle populations. Another effect of coastal development is sedimentation which has damaged coral reefs, potentially jeopardizing food sources for some turtle species. Incidental catch also occurs (e.g., there is a large amount of longline fishing for tuna just outside Guam's EEZ). Finally, harvest continues in adjacent areas, such as the Philippines and the Republic of Palau, which share turtle stocks with Guam.

While there is some evidence that sea turtles pass in and out of Guam on foreign vessels, there appears to be no import or export per se of sea turtles or their products. A 212-foot purse seiner, docked at the Commercial Port on its way to Taiwan, was seized in October 1989 when U. S. Department of Commerce officials discovered three small (35-45 cm) live hawksbills aboard the vessel. A fine of US$ 35,000 was deposited in the Wildlife Conservation Fund as a precondition for release of the vessel (Government of Guam 1990). Import and export of sea turtles and derived products is prohibited in Guam by virtue of the USA ratification of CITES. Japanese Customs statistics record the import of 21 kg and 43 kg of hawksbill shell from Guam in 1952 and 1953 (none since then) and the export of small quantities of worked tortoiseshell to Guam from 1971-1977. Fijian Customs statistics show the export of F$344- and F$4-worth of worked tortoiseshell to Guam in 1970 and 1973, respectively, and the Philippines reported exporting worked "shell" to Guam in 1979 and 1980 (summarized by Groombridge and Luxmoore 1989).

The Northern Mariana Islands consist of the inhabited islands of Saipan, Tinian, Rota, Alamagan, Pagan and Agrihan, and uninhabited islands of Farallon de Medinilla, Anatahan, Sarigan, Guguan, Aquijan, Amagan, Asuncion, Maug and Farallon de Pajaros. There is very little published information on the historical exploitation and use of sea turtles in these islands, largely because our knowledge of the traditional culture of the original Chamorro people is scarce since Spaniards virtually eliminated the indigenous inhabitants during colonial rule (Johannes 1986). Johannes (1986) quoted an early account by de la Corte (1870) which stated that tortoiseshell was not produced in the Marianas. Pritchard (1982a) noted that stuffed turtles (hawksbills, olive ridleys, green turtles) were for sale at several locations in Saipan and were reportedly caught locally. He concluded with the observation that turtles were being captured in increasing numbers in the northern islands (a diver could "easily" catch 4-5 turtles a day), mostly by divers for sale to hotels and gift shops. Thus, while the historical contributions of sea turtles to custom and diet may never be known, illegal exploitation is certainly occurring at the present time (Scott Eckert, HSWRI, pers. comm., 1992).

Mexico

The people of Mexico have a long history of subsistence and commercial exploitation of sea turtles. Only a brief summary of usage along the Pacific coast can be presented here. For a detailed discussion of the historical and contemporary harvest, trade, use, and cultural value of sea turtles in Mexico, the reader is referred to Parsons (1962), Caldwell (1963), Márquez (1965, 1976a), Pritchard (1969a), Smith (1974), Felger et al. (1976), Cliffton et al. (1982), Felger and Moser (1987), Groombridge and Luxmoore (1989), and Alvarado and Figueroa (1991). In the Pacific, the species involved were (and are, despite recent protection) predominantly the east Pacific green turtle (=black turtle), the leatherback, and the olive ridley, all of which once nested in huge numbers along the coast. Commodities included meat, eggs, skin (leather), oil, and shell. In some areas, sea turtles provided important sources of protein and were consumed for purported medicinal and aphrodisiac qualities. Historically, sea turtle shells were sometimes used structurally in housing and flipper integument was employed as footwear by the Seri Indians (Caldwell 1963). Use extends to pre-Columbian times when turtle oil was valued as a treatment for chest ailments, especially tuberculosis, and leprosy (Dawson 1944; Giral and Cascajares 1948).

In modern times turtles have been harvested by harpooning, netting, direct capture while swimming, and "turning" on the nesting beach. In addition, there has been widespread and intensive egg collection. The result has been a well documented decline in nesting populations of black turtles and olive ridleys (Cliffton et al. 1982; Groombridge and Luxmoore 1989; Steiner and McLamb 1990; Alvarado and Figueroa 1991), as well as a deep concern that the large leatherback populations may soon collapse (Laura Sarti M., UNAM, pers. comm., 1991). According to the Instituto Nacional de Pesca, 4,618 metric tons of black turtle were landed from 1966 to 1970 (Márquez et al. 1976), representing an estimated 125,000 adult and subadult turtles. The harvest culminated in a population crash by 1977 (Cliffton et al. 1982). Black turtles hibernating in the Gulf of California have also been heavily exploited. Prior to 1970 the population was fished primarily by Seri Indians who relied on the turtles for about 25% of their animal protein. After Mexican skin-divers discovered the turtles in 1972, they were quickly depleted. Divers averaged five turtles per hour of diving time during the 1974-1975 season; five boats were capturing 80 turtles a week. By 1978, the winter dormant population was so depleted as to be endangered (Felger et al. 1976; King 1982).

Perhaps the most well-publicized story is that of the olive ridley turtle, where in modern times three of the four largest Pacific Mexico populations have collapsed from the over-exploitation of gravid females and their eggs (Cliffton et al. 1982; Ross 1982; Groombridge and Luxmoore 1989). Márquez (1976b) estimated that 20,000-50,000 females nested annually at Mismaloya, Tlacoyunque, and Chacahua, whereas as many as 100,000 females nested each year at La Escobilla in Oaxaca. Thousands of turtles were harvested commercially, primarily for meat and skins. In recent years the harvest quota of 20,000 animals per annum has been largely ignored, threatening the last of the most impressive *arribada* populations. When it became known that the annual kill was approaching 75,000 to 100,000 animals, mostly breeding-age adults, an open letter was sent to the President of Mexico urging him to respond to the crisis (Earth Island Institute 1990). The primary market has been Japan, which imported 50,611 kg of skins from 1976-1979 and 94,084 kg of leather from 1976-1986 (Milliken and Tokunaga 1987).

In May 1990, President Salinas de Gortari announced a ban on the harvest of all marine turtles and their eggs, as well as on trade in sea turtle products (Aridjis 1990). This had the immediate effect of eliminating all quotas, closing the slaughterhouses, and terminating the lucrative export of olive ridley skins. While enforcement of the ban is a challenge, especially as it pertains to subsistence take, commercial export has ended and, with vigilance, commercial domestic harvest is sure to decline in the near term.

Japan

Tortoiseshell (hawksbill shell or bekko) craftsmanship, originally introduced to Nagasaki by the Portuguese, is an important cultural tradition in Japan. A brief paper, "The making of bekko tortoiseshell ware" (anonymous and undated), was distributed at the First Japanese Sea Turtle Conference, held in Kagoshima Prefecture, Japan, 23-24 November 1990. It provided a useful overview of the industry. Carapace and plastron scutes are chosen on the basis of color and thickness. Selected scutes are warmed and softened over a burner before being clamped in a press. Forms are then engraved on the flattened pieces using a gauge and plastic stencils, whereupon the marked forms are cut out using a hand saw. Rough edges are scraped smooth and all surfaces are finely sanded (traditionally, craftsmen used a dried plant, *tokusa* or scouring rush, to achieve a perfect surface). Pieces are rinsed, joined at the edges, and held in a warm hand clamp in order to prevent slippage during the ultimate joining process. Finally, the pieces are placed between sheets of newspaper or cloth covered in cellophane and willow boards soaked in water, and further sandwiched between two hot iron boards and gripped in a vice at a pressure of about 100 kg/cm^2. The heat of the iron boards is controlled by the craftsman using only a gas burner, water, and knowledge obtained through long experience. The various methods and tools used in the joining process have been passed from generation to generation and differ among shops in Nagasaki.

The amount of time spent in the pressure vice is crucial and is determined solely by the craftsman. When the vice is released, the pieces, which have now been squashed out of shape, are restored to their original condition by submersion in boiling water for about 10 minutes. Restored pieces are shaved to achieve a desirable thickness and size, warmed and softened over a burner, and then pressed and cooled in a special wooden mold. The article so molded is then carved and finished by buffing, polishing, and waxing. Tiny holes are drilled in the surface of the item and metal fittings installed with glue. The resulting objects, which can be extremely beautiful, are highly regarded for ceremony and ornamentation. According to Jack Woody (FWS, pers. comm., 1991), there are two bekko industry centers in Japan -- Nagasaki (presumed to be the larger) and Tokyo. In 1989, there were 60 bekko "factories" in Nagasaki employing 987 workers. All or most of these are small, family owned and operated, and employ an average of 16.5 people, of which 50% or more are family members. Industry growth is slow. Products are distributed for sale as follows: Nagasaki (60%), Tokyo (10%), Osaka (10%), other areas in Japan (20%).

While relatively few persons rely on the bekko industry for their livelihood, tens of thousands of turtles have been sacrificed to the industry each year. Indeed, annual Japanese imports may exceed the total number of adult female hawksbills that breed each year on beaches around the world (estimated to be 15-25,000 by Groombridge and Luxmoore 1989). This represents an unsustainable scenario for a species that requires in excess of 30 years to reach maturity in the western Pacific (Colin Limpus, Australia NPWS, pers. comm., 1991). The seriousness of the situation has not escaped the attention of the international conservation community and the result has been extensive negative publicity toward Japan for not curtailing the time-honored tradition. As more and more countries have acceded to CITES, Japan has been accused of sponsoring a global black market, openly accepting shell from Indonesia (a CITES party since 1979) and covertly importing large quantities from other CITES parties by re-routing shipments through non-CITES nations (Canin 1991). From 1970-1990, Japan imported a documented 752,620 kg of bekko, representing some 710,000 hawksbills, in addition to 587,000 stuffed hawksbills (Canin 1991).

In addition to large imports of bekko, which are possible because Japan ratified CITES in 1980 with a reservation on hawksbill sea turtles [N.B. such a "reservation" effectively exempts a CITES party from trade restrictions otherwise imposed by the treaty on the species concerned], Japan has also been the world's largest importer of olive ridley products, mainly skins from Mexico. It has been estimated that in direct violation of an annual Mexican quota of 20,000 turtles, 100,000 or more turtles, mostly gravid females, were processed per annum to service the Japanese market (Steiner and McLamb 1990). Japan withdrew its CITES reservation on olive ridleys effective 31 January 1992 (CITES 1992), effectively closing the market to Mexican imports. Japan has also been an active participant in trade in green sea turtle products. From 1970-1987, about 400,000 stuffed green turtles were imported (Canin 1991) before Japan withdrew its CITES reservation on the green turtle in 1987 (Nichols et al. 1991). In total, since 1970, Japan has imported sea turtle products representing a minimum of 2,250,000 turtles (Canin 1991). Import statistics and other industry details are presented in Milliken and Tokunaga (1987), Groombridge and Luxmoore (1989), and Canin (1991).

While some Japanese buyers and artisans have come to depend on the enormous import of sea turtle material for their income, it is clear that the desire for sea turtle products, especially for traditional articles of ornamentation, will have to come from an increased reliance on the reuse and recycling of items already in circulation. Recent pleas to ban trade in hawksbill shell have come from foreign governments (e.g., USA: Donnelly 1991; Australia: Anon. 1991), as well as from the IUCN/SSC Marine Turtle Specialist Group (Bjorndal 1991) and other prominent conservation organizations (Donnelly 1989, 1990; Canin 1991). Japan responded by announcing its intention to drop its CITES reservation on the hawksbill (Bush 1991; TRAFFIC 1991) and cease all trade in hawksbill shell and other products by 1 January 1993. The decision was made in large part to avoid trade sanctions on the part of the USA under the auspices of the Pelly Amendment to the Fisherman's Protective Act of 1967. In preparation for dropping its CITES hawksbill reservation by July 1994, Japan imposed an import quota of 5,000 kg of bekko between August 1991 and August 1992 and 2,500 kg of bekko between August-December 1992 (Donnelly 1991).

In contrast to volumes of literature on the international bekko trade, comparatively little is available on traditional domestic sea turtle harvest and marketing. According to Uchida and Nishiwaki (1982), there is no "hawksbill or green turtle catch for profit along the coast of Japan." However, locally-occurring sea turtles, primarily green turtles and loggerheads, and their eggs are harvested by residents for food. Based largely on the accounts of Kurata (1979) and Uchida and Nishiwaki (1982), Groombridge and Luxmoore (1989) noted that turtles are hunted for meat around the Ogasawara Islands and the southern parts of the main islands; eggs are collected in the Kagoshima Prefecture. Uchida and Nishiwaki (1982) estimated the total combined catch of greens and loggerheads in the Kagoshima, Wakayama, and Kouchi Prefectures to be about 50-100 adults per annum and concluded that the harvest began only after WWII. Data from the Ogasawara Islands indicate that most of the harvest takes place off Chichijima, Hahajima, and Mukojima where the number of green turtles caught commercially from 1978-1986 was 1,093 (81 were subsequently tagged and released). Most of the turtles are caught by harpoon or are turned on the nesting beach (H. Tachikawa and H. Suganuma, *in litt.*, 19 December 1986 to Groombridge and Luxmoore 1989).

Korea

Very little information is available concerning the exploitation, trade, use, or cultural value of sea turtles in the Democratic People's Republic of Korea [North Korea] or the Republic of Korea [South Korea]. In their recent review of the global status of green turtles and hawksbills, Groombridge and Luxmoore (1989) stated, "While sea turtles may be expected to occur in the waters around Korea, no evidence has been found to confirm this, nor whether any nesting occurs." In an obscure earlier reference, Won (1971) described rare occurrences of green turtles, loggerheads and leatherbacks in Korean waters. While domestic information is scarce, some international trade is known to occur. Korea is categorized as "a major consumer of wildlife and wildlife products" by Nichols et al. (1991). Korean Customs statistics indicate that the Republic of Korea exported 62,735 kg of worked tortoiseshell to 11 countries, Hong Kong, and "others". The biggest buyer was Japan (43,785 kg), but shipments have also gone to the USA, Canada, Australia, and Europe (Groombridge and Luxmoore 1989).

Korea has not ratified CITES. The Republic of Korea imported 146,724 kg of "tortoiseshell and plates" and "claws and waste of tortoiseshell" from nine countries, in addition to Hong Kong and "others", from 1975 to 1986. By far the largest source was Indonesia, providing 97,889 kg during this time, but China and Thailand were also consistent suppliers. With the exception of India and Switzerland, source countries were in southeast Asia. Interestingly, neither Japanese nor Indonesian Customs reports confirm these levels of import and export, suggesting that the shell is not from sea turtles. However, it is difficult to imagine what other "worked tortoiseshell" products could be exported (Groombridge and Luxmoore 1989). Given the amount of raw material imported, it is conceivable that indigenous animals are not captured for use by the tortoiseshell industry. More recent trade data are not available, nor is information concerning the number of persons involved in the tortoiseshell industry or the income derived therefrom.

China

There are few easily accessible published accounts of the exploitation, trade, or cultural traditions with regard to sea turtles in China. Five species of sea turtle occur in China, including the green turtle (the most abundant species), hawksbill, loggerhead, olive ridley, and leatherback. Turtles, mainly green turtles and mainly adults and subadults, are captured in large numbers around Hainan and the Xisha Islands, both at sea using trammel nets, harpoons or other means, and on the nesting beach (Frazier et al. 1988). Captures of all five species seem to be more common during the summer months. Nearly 100 tonnes of sea turtle were landed in Qionghai, Hainan, in 1985 and the harvest appears to have been increasing since 1977 (as summarized by Groombridge and Luxmoore 1989). Fishermen from Qionghai county captured 2,034 turtles in the Xisha and Dongsha Islands in 1986 (Chu-Chien et al. 1991). Chu-Chien (1982) noted that fishermen from Hainan Island had over-fished the Xisha and Nansha Islands even though their catches are made by hand from small sailing boats. Coastal residents are accustomed to eating meat and eggs and shells are used for medicine or made into arts and crafts. Sea turtle populations are "decreasing rapidly" because of their high economic value (Chu-Chien et al. 1991). Incidental catch in fishing nets and trawls is also a problem and affects all species. In the waters of Fujian and Guangdong, incidental take may approach 1,000 turtles per annum and include a significant number of gravid females (Frazier et al. 1988).

Hawksbill shell has traditionally been used to fashion eyeglass frames, necklaces, and other ornaments, while the shell of the green turtle was used in traditional medicine (Wang Xiaoyan, *in litt*., 20 November 1986 to Groombridge and Luxmoore 1989). Today there are markets for all parts of the turtle, and shells have even been purchased to make wine (Frazier et al. 1988). Historically there was an attitude of respect and protection for sea turtles in China but as their commercial value increased, this sentiment was lost. In 59 interviews with coastal people and fishermen in the southeastern provinces of Fujian and Guangdong (including Hainan Island), Frazier et al. (1988) were told that sea turtles were once revered and respected and often released when accidentally caught, but in recent years most turtles caught were killed. Today a single turtle may sell for the equivalent of a month's wages. The interviewees were unified in their belief that sea turtles had become much less abundant over the last few decades.

Trade statistics are not available for China, but it is possible to infer imports and exports of tortoiseshell from the records of its trading partners. According to Groombridge and Luxmoore (1989), the only countries to report exports to China are Hong Kong, Singapore, and Thailand, while Hong Kong, Japan, and South Korea report importing from China. Customs data (1974-1985) record 147,279 kg tortoiseshell exported from Hong Kong to China, 6,481 kg from Singapore, and 10,750 kg from Thailand. During the same period, 816 kg were exported from China to Hong Kong, 8,439 kg to Japan, and 5,600 kg to South Korea. In addition, Italy reported exporting to China six handbags made from green sea turtle in 1983. China acceded to CITES on 8 January 1981, and has never recorded any trade in sea turtles products in its Annual Reports.

Taiwan

Mao (1971) provided a comprehensive summary of the biology and economic importance of sea turtles in Taiwan and the following text is excerpted from his account. With regard to the olive ridley, he notes that although the flesh "does not taste good" it is nevertheless eaten by Taiwanese. The species is not, however, utilized in any other way. With regard to the green turtle, Mao tells the story of a young fishermen who said that when his grandfather first came to Taiwan from the mainland, the meat of the green turtle was commonly used as food. At the time of Mao's report the species was still recognized as a delicacy by coastal peoples; plastrons were ground up as chicken food or were sold to Chinese medicine shops. Eggs were consumed. Similarly, both meat and eggs of the hawksbill were used as food. Hawksbill shell was also valued by craftsmen, and "for four hundred years, much of the best shell has been sent to Shanghai and Singapore for exportation". In China the shell was used for making eyeglass frames, necklaces, earrings, etc. Mao commented "it has been said that articles made from tortoiseshell become opaque on cloudy or rainy days, more clear and transparent on fine days." He quoted Li (1957) in describing the process whereby scutes were peeled off by applying boiled vinegar, and not by heat as was sometimes described in foreign books. Finally, leatherback turtles were captured for both meat and oil. The meat, which had "a bad taste", was sold for NT$5.00 a chin, the eggs were eaten wherever available, and the oil yielded by the skin and shell was used to varnish boats. At present, sea turtles are "commonly" captured by fishermen, sold to Buddhist temples and purchased and released by people who believe the act will bring them good luck. They are also caught, killed and displayed in fishing ports and retail shops (Keith Highley, EarthTrust, *in litt*., 18 August 1992).

Groombridge and Luxmoore (1989) summarized import and export volumes of "tortoisehell" (a mix of marine and freshwater turtle shell) from 1974 to 1985. Based on Taiwan Customs statistics, they reported that 502,345 kg was imported from ten countries, in addition to Hong Kong and "others". The most prominent sources varied among years, but were generally Hong Kong, Indonesia, Singapore, Thailand, or "others". Material "originating" in Hong Kong or Singapore had presumably been re-exported from other sources, rendering determination of the true volume or source of sea turtle shell problematic. During the same time, 113,499 kg was exported to more than 30 countries. With few exceptions, Taiwan has been an importer of raw shell and an exporter of worked shell. Much of the worked tortoiseshell exported has gone to Japan, but the USA, Australia and, recently, Saudi Arabia have featured as major destinations.

Viet Nam

Sea turtle exploitation has a long history in Viet Nam. According to Bourret (1941), both green turtles and hawksbills occurred all along the coast of the former French possessions in Indochina, which included Viet Nam, and at that time were considered to be common. Parsons (1962) cited reports from the voyages of Dampier around the end of the 17th century that there was a flourishing industry extracting oil from green turtles in the Con Son group off the Mekong Delta. Hawksbills, too, were hunted as there was once an indigenous tortoiseshell industry in Tonkin, northern Viet Nam, based on shell sent from the Cochin China region of southern Viet Nam (Bourret 1941). Groombridge and Luxmoore (1989) concluded that capture by nets, trawls, and turning on the nesting beaches (as reported for Kampuchea, Bourret 1941) were all likely to occur in Viet Nam. With the exception of Baird (1993), there are no published data regarding the extent to which sea turtles are exploited, or the degree to which they have traditional or cultural value in the society. No information is available on current population levels.

Baird (1993) surveyed retail shops selling green and hawksbill turtle products in inner Ho Chi Minh City in March 1992. Displayed inventory in 72 shops consisted of whole stuffed turtles and a variety of tortoiseshell (hawksbill shell) items, including fans, eye glass frames, bracelets, hair pins, combs, lighters, cigarette holders, boxes, purses, necklaces, and shoe horns. In addition to 99 stuffed turtles, Baird documented 21,366 tortoiseshell items for sale. Most dealers claimed they bought the merchandise from people in Ha Tien, Kien Giang Province, and Vung Tau (about 60 km from Ho Chi Minh City on the coast). Both places are "well known in southern Viet Nam for their sea turtles". Primary consumers appear to be tourists, many of whom come from east Asian countries. Ho Chi Minh City is the center of the retail sea turtle product trade, but other cities also display similar items and the duty-free shop in the Hanoi airport offers "a large selection of turtle products tax-free."

Kakidachi and Uchida (1973 *in* Groombridge and Luxmoore 1989) reported that hawksbills were caught for taxidermy in the Ha Tien area, possibly on feeding grounds among the nearby coral islands, and some proportion of these was exported to Singapore. Groombridge and Luxmoore (1989) summarized Customs data from countries which imported tortoiseshell from Viet Nam (i.e., Hong Kong, South Korea, Singapore, Taiwan), but concluded that most of the shell was from various freshwater turtles which are widely fished in Viet Nam. They mentioned that Japan had "never reported importing bekko (=hawksbill shell) from Viet Nam." However, according to Japanese Customs statistics as summarized by Milliken and Tokunaga (1987), Viet Nam supplied 1,347 kg of worked bekko to Japan from 1971 to 1977. From 1984, when small-scale trade resumed, to the end of 1986, another 27 kg were received. Milliken and Tokunaga also record a 23 kg shipment of worked green turtle shell to Japan in 1973. Japan did not import either hawksbill or green turtle material from Viet Nam in 1990 (Canin 1991); no other data are available.

Kampuchea

Very little information is available concerning the exploitation, trade, use, or cultural value of sea turtles in Kampuchea. The following brief account is excerpted from Groombridge and Luxmoore (1989) and is based on earlier writings by Bourret (1941) and Le Poulain (1941). Green turtles were hunted for meat, but hawksbills were not eaten and were considered poisonous (they were, however, hunted for their valuable shells). The eggs of both species were consumed and traded locally. Turtles usually were caught with nets about 200 m long and 3 m deep having a mesh size of 40 cm. The nets were used to encircle shallow areas and turtles then were frightened into the nets by fishermen beating the water with sticks. In deeper waters trawling was used. Turtles also were turned on the nesting beaches. The villages of Samit and Lucson were said to be centers for turtle fishing. In 1941, hawksbills were worth about 12 Piastres each for their shell, while green turtles sold for only 8 Piastres. Some international trade with Viet Nam was likely, probably to supply the tortoiseshell industry in the Tonkin region. Recent data could not be found. Groombridge and Luxmoore did not discuss the exploitation of olive ridleys, loggerheads, or leatherbacks. The flesh of all five species is eaten in adjacent Thailand (Humphrey and Bain 1990).

Thailand

Despite the fact that all five locally-occurring species of marine turtle (leatherbacks, greens, olive ridleys, hawksbills, loggerheads) are protected (Ministerial Regulations, B.E. 2525, 26 August 1982), Groombridge and Luxmoore (1989) conclude that "turtle meat is widely, but not openly, consumed when it is available. There is evidence of turtle killing in 12 provinces." Humphrey and Bain (1990) confirm this, noting that all five species are actively hunted for their eggs, meat and/or shell. They note that although the flesh of the leather-back is rarely eaten and the shell has virtually no commercial value, the large eggs bring a premium price. Prior to protective legislation, sea turtles constituted a popular source of seafood in some coastal provinces, as well as in Bangkok, even though turtle eggs normally cost four to five times more than poultry eggs in the market (Phasuk 1982). Phasuk also noted a generally decreasing trend in the avail-ability of sea turtles and their eggs after 1965. He attributed this to a lack of regulations controlling the harvest prior to 1947 (the Fisheries Act of B.E. 2490, April 1947, regulated the egg harvest and forbade killing of turtles), as well as to the rapid development of commercial trawling operations in the Gulf of Thailand and along the west coast which were started about 1963. He observed, "sea turtles migrate to shallow areas for nesting [and] are easily caught in the nets during trawling operations where they become entangled and die."

Sea turtles are still described as "widespread" in Thai waters (Humphrey and Bain 1990), but are severely threatened by over-exploitation, habitat modification by man, and accidental drowning in trawls (Lekagul and Damman 1977; Ginsberg 1981). Stuffed turtles are occasionally sold (Polunin 1975). The history of exploitation is long. Historically turtles were an important part of the subsistence of many indigenous peoples, including the "sea gypsies" who are variously known as *Moklen*, *Urak Lawoi*, and *Moken* in Burma and western peninsular Thailand (Hogan 1972). Polunin and Sumertha Nuitja (1982) note with regret that so little has been written about maritime peoples in the region, especially the sea gypsies, who have long been involved in sea turtle trade. Today, as was the case throughout much of history, turtles are caught in nets, turned on beaches, or harpooned at sea. The full extent of the subsistence and commercial catch has not been quantified. The magnitude of the take incidental to other forms of fishing, notably trawling and longlining, is unknown but could be large (Polunin and Sumertha Nuitja 1982). In the Gulf of Thailand, bamboo-stake fish traps often catch and kill turtles (Polunin 1975).

In contrast to the paucity of data on turtle take, information regarding the harvest of eggs is somewhat more accessible since the rights to collect eggs are rented out by the Government to collectors who are required to release hatchlings equivalent to a certain percentage of the eggs collected (Phasuk and Rongmuangsart 1973; Groombridge and Luxmoore 1989). Unfortunately, there appears to be less than stringent regard for the regulatory system. Polunin (1975) concluded that the harvest was so intensive that not a single nest escaped collection. Exploitation (largely illegal) was high even on the most remote beaches. He calculated the total annual harvest in Thailand to be 390,000 eggs. Eggs are generally sold in the vicinity of the beach on which they were collected, but some are transported for sale in the city markets of Bangkok. Published details on specific cultural values and traditions, such as religious customs, associated with sea turtles and their eggs are not readily available.

Sea turtle products are actively traded. The major destinations for Thai sea turtle shell have been listed as Hong Kong, Taiwan, and Singapore (Mack et al. 1982). However, contrary to the conclusion of Humphrey and Bain (1990) that "Thailand is among the world's leading exporters of raw tortoiseshell", Groombridge and Luxmoore (1989) suggested that "much of the shell exported may have been of fresh-water turtle bones and shells which are widely used in oriental medicine." According to Milliken and Tokunaga (1987), Japanese Customs record show but a single shipment (20 kg in 1970) of hawksbill shell imported from Thailand. Exports of raw green turtle shell have been considerably higher, totaling 6,330 kg from 1970-1986, and two shipments (238 kg in 1974, 204 kg in 1979) of worked green turtle shell were also recorded. Thailand acceded to CITES in 1983 and has never reported exporting any turtle products. Nevertheless, in addition to the shell trade, CITES Annual Reports of importing countries indicate a substantial tourist trade in leather goods made from turtle skins (Groombridge and Luxmoore 1989).

Malaysia

As summarized by de Silva (1982), the overexploitation of sea turtles, especially hawksbills, in Eastern Malaysia (Sabah and Sarawak) has existed since prior to WWII and "the slaughter has since accelerated catastrophically." In Sabah, millions of eggs have been harvested for several decades. On the islands of Selingaan, Bakkungan Kecil, and Gulisaan, which now constitute the Sabah Turtle Islands National Park, more than six million eggs (mostly green turtle) were harvested from 1965-1978, despite the fact that the harvest had been illegal since 1973 and the islands were declared a National Park in 1977. Apart from being considered a delicacy by a variety of ethnic groups, the eggs provided an important source of food. Harvests from rookeries close to markets also provided a source of income. Islamic residents are forbidden by religious custom to eat turtle flesh, but other ethnic groups, such as the Chinese, have regularly hunted turtles on the beach and at sea (de Silva 1982). Today sea turtles and their eggs are protected in Sabah, but the greatest threat to the conservation effort in the Turtle Islands Park is the theft of eggs from nesting beaches and sometimes even from hatcheries (Francis Liew, Sabah Parks, *in litt.*, 23 May 1991). Some residents have an exemption for the traditional subsistence harvest of eggs (Laurentius N. Ambu, Sabah Wildlife Dept., *in litt.*, 17 June 1991).

Sea turtles are declining in Sabah waters and their worsening plight is attributed to five factors: mass egg collection for more than 50 years at every rookery, frightening away turtles approaching the nesting beaches by brightly lit fishing vessels, illegal hunting by mechanized fishing vessels in Sabah waters to supply an ever-increasing demand on the mainland, increased small boat activity off nesting beaches, and the large-scale slaughter of turtles outside the territorial waters of Eastern Malaysia in the Sulu Sea, South China Sea, and Celebes Sea by Filipino and Japanese fishermen. Sand mining on the beaches, an increase in offshore trawling, fishing using explosives, and the illegal killing of turtles by Filipino fishermen within the territorial waters of Sabah present additional problems. Products and parts rendered from illegally captured sea turtles have been brought into Sandakan (Sabah) by Filipino barter traders for transshipment to Japan; such products have included carapaces, plastrons, flippers, skin, calippee, and oil. In 1971, Malaysia banned the import of turtle products (de Silva 1982).

In an historical perspective of the exploitation in neighboring Sarawak, Leh (1985) noted that the history of turtle egg collection dates probably to the 16th century when eggs were a barter trade item with China. In the 1950s, the annual number of green turtle eggs collected and sold in the local market was around two million. Leh stated that the local residents did not eat the turtles, only their eggs. Banks (1986) wrote that the mean number of eggs exported from 1900-1927 was 300,000/yr. He also summarized the annual take of green turtle eggs from 1927-1985, showing that 1-3 million eggs were collected per year until 1960, roughly 500,000 eggs were collected per year during the 1960s, and <300,000 eggs have been collected per year since. In 1989 and 1990, 185,461 and 117,701 eggs, respectively, were collected (data courtesy of the Sarawak Museum), or less than 5% of peak yields in the mid-1930s. Most of the eggs were harvested from the Talang Talang Islands. From 1971-1975, 1,194,391 eggs were collected from the three "turtle islands" at Talang Talang Besar, Talang Talang Kecil, and Pulau Satang, northwest of Sarawak (Chin 1975). As in Sabah, turtle populations are declining in Sarawak (de Silva 1982). As of 1991, there are plans for a Marine Turtle Research Center on Pulau Satang Besar and the sale of eggs to the public is forbidden (Laurentius N. Ambu, Sabah Wildlife Dept., *in litt.*, 17 June 1991).

On the mainland, variously referred to as peninsular or Western Malaysia, the situation is comparable; that is, populations have declined primarily as a result of the overexploitation of eggs. Green turtles were apparently "very common" on the west coast of the peninsula in the early 1900s (Boulenger 1912) but today nesting on the west coast is rare (Siow and Moll 1982) and east coast nesting is largely confined to selected offshore islands and beaches on the Terengganu/ Pahang border (Mortimer 1989). The nesting population of leatherback turtles has declined by a dramatic 98% over the last three decades (Aikanathan and Kavanagh 1988). At the time of Siow and Moll's (1982) report, egg yields from green and leatherback turtles were 43% and 34%, respectively, of 1956 levels. Hendrickson and Alfred (1961) estimated that about 1.66 million leatherback eggs were consumed annually in the mid-1950s. Despite declines, sea turtles continued to play an important role in the economy of the east coast, providing tourist attractions, protein, employment, and government revenue (Leong and Siow 1980). The marketing of leatherback eggs is now forbidden and egg collectors sell their harvest to government supervised hatcheries. The collection of green turtle eggs persists, but it has been suggested that this should be prohibited on Palau Redang (Mortimer 1989). As is the case in Eastern Malaysia, turtle flesh is rarely consumed because of religious beliefs.

With regard to international trade, Mack et al. (1982) reported total domestic exports of raw bekko (hawksbill shell) to be 25,443 kg from 1976-1978. In addition, imports and re-exports of bekko during this period amounted to 39,193 kg and 51,799 kg, respectively. In 1976 and 1977, the value of imported worked hawksbill shell was US$ 13,817. According to Japanese Customs data as reported in Milliken and Tokunaga (1987), 2,997 kg of bekko were exported to Japan from 1970-1986, with nearly 80% of the trade occurring from 1970-1973. In addition, Japan reported receiving 3,041 kg of raw green turtle shell in 1970 and 1971, 7 kg of worked green turtle shell in 1972, and 346 kg of worked hawksbill shell in 1973. Similar trade has not been reported since 1973. Malaysia ratified CITES in 1978.

Philippines

The Philippine archipelago consists of more than 7,000 islands and islets extending 1,850 km north to south and 1,060 km east to west. The coastline is no less than 17,462 km long, including 1,000 km of sandy beaches offering sea turtles potentially ideal nesting habitat (de Celis 1982). de Celis (1982) listed the following four sea turtle species in order of relative abundance and local importance: the green turtle, hawksbill, olive ridley, and leatherback, and noted also that there had been both a marked decline in turtle populations and a dearth of research. There is a prolonged history of exploitation and use of marine turtles, particularly green turtles, in the Philippines that predates the Spanish period (1521-1898) and continued through the American regime (1898-1946) to the present day. Domantay (1953) described the turtle fisheries of the Turtle Islands, recorded the value of turtle eggs produced annually, and explained the marketing and preserving of turtle eggs. Earlier reports detailed the economic value of tortoiseshell commerce (Seale 1917; Taylor 1921 *in* de Celis 1982).

In modern times the turtle shell industry has been especially lucrative. More than 150,000 turtles have been exported to Japan alone in the last two decades. From 1970-1985, 32,921 kg of raw hawksbill shell was exported to Japan, making the Philippines Japan's third most important source in the Asian region (Milliken and Tokunaga 1987) despite ratification of CITES by the Philippines in 1981 [N.B. Only 199 kg have been exported since 1986; data courtesy WWF-Japan]. In addition, 10,003 kg of worked hawksbill shell (1973-1980), 26,510 kg of raw green turtle shell (1970-1981), 59,771 of worked green turtle shell (1972-1983), and 44,319 kg of turtle skins (1976-1983) were exported to Japan (Milliken and Tokunaga 1987). There also has been significant trade with Taiwan and, to a lesser extent, the USA and some European countries (Mack et al. 1982). The worked hawksbill and green turtle shell consists largely of stuffed turtles. Pejabat and Siow (1977) published the following account after a visit to Cebu City, one of the two major turtle processing centers (the other is Mindoro) in the Philippines:

"Traditionally, turtle meat and eggs are eaten and scutes from the hawksbill turtle are used to make ornamental items in the Philippines. The full scale cottage industry of processing turtles by stuffing was started in 1970, and since then the export market for stuffed turtles was established resulting in big increases in the number of turtles being killed every year. [In] Cebu City, ... there are about 50 processors each processing on an average 400 hawksbill and 100 green turtles each year. This means in Cebu City alone 25,000 turtles are processed annually. Taking into account Mindoro and other small processing centres, the total number of marine turtles killed for this purpose can be put at 75,000 annually." Cebu City is still a clearinghouse for a large variety of hawksbill and green turtle products, including polished shells, jewelry, combs, and stuffed turtles. The buyers are usually tourists (Louella Dolar, Silliman Univ., pers. comm., 1993).

In addition to shell, the high demand for meat, bones (cartilage) and eggs "causes the coastal people to hunt [sea turtles] indiscriminately" (de Celis 1982). Domantay (1953) estimated an annual average egg collection of 1,401,450 in the three main Turtle Islands from 1948-1951, with daily yields on some islands (e.g., Baguan) exceeding 5,000 green turtle eggs during peak season (July, August, September). Later, interviews with collectors in the Tawi Tawi group and the Turtle Islands led Datuin (1979 *in* de Celis 1982) to conclude that during the previous five years it had been extremely difficult to capture a turtle of marketable size (>61 cm carapace length). He noted that the turtle-dependent tribes were going farther afield for their catch. Egg collection, too, had become less lucrative. He estimated that each collector was only able to gather 300 eggs, in contrast to 800-1,000 eggs per week per hunter in the early 1970s. The implied decline in egg production was corroborated by a field survey of the distribution of sea turtles which showed a marked decline in the populations of green and hawksbill turtles, as indicated by a decrease in their nest distribution (Fontanilla and de Celis 1978).

Today, despite legal protection enacted in 1982, both turtles and their eggs are harvested in the Philippines. A traditional and still popular belief is that turtle meat endows the consumer with long life (Louella Dolar, Silliman Univ., pers. comm., 1993). Polunin (1975) quoted an estimate that 5,000 large green turtles were captured annually in the Sulu Sea. Alcala (1980) concluded that "most, if not virtually all, nesting turtles in Central Visayas end up on the table and in souvenir shops. There is reason to believe that a similar situation exists throughout the Philippines." F. S. Matillano (*in litt.*, 5 January 1987 to Groombridge and Luxmoore 1989) analyzed Fisheries Statistics and calculated that 739 metric tonnes of sea turtle were harvested from Municipal Waters (within 7 km of shore and <12.8 m in depth) from 1976-1983. Turtles are captured using spears, spearguns, nets, and fish corrals. In a recent review, Groombridge and Luxmoore (1989) estimated the total egg harvest to exceed 500,000 eggs per year (>50% of all eggs laid) and repeated the findings of others that sea turtle populations in general show serious declines. The precise economic contribution of these various industries is unquantified.

Federated States of Micronesia

The Caroline Islands consist, from west to east, of the Republic of Palau and the States of Yap, Truk, Pohnpei (Ponape), and Kosrae. Palau was discussed under U. S. Outlying Territories; the remaining four entities constitute the Federated States of Micronesia (FSM). There are no more than a half dozen records of olive ridley, loggerhead, and leatherback sea turtles in the Caroline Islands and no commercial trade due to their scarcity. In contrast, hawksbill and green sea turtles are found throughout the region and nest on many of the islands; they have long been harvested for their meat, shell and eggs. Between WWII and the early 1970s, according to Cato et al. (1978), hawksbill shells were used for traditional jewelry and artifacts and were also sold to tourists. The trade was almost entirely at the retail level within the islands, although some wholesale shipments may have been made to Guam and Hawaii and unworked shell was exported to Japan prior to WWII during the Japanese administration. While the FSM has not yet ratified CITES, a sharp decline in the export of tortoiseshell items followed passage of the U. S. Endangered Species Act (1973) and Trust Territory Endangered Species Act (1975) which listed the hawksbill as "Endangered".

Again according to Cato et al. (1978), green turtles are captured for meat throughout the FSM. There was at the time of their writing no appreciable monetary trade or export in green turtle products; the turtles were usually directly consumed by the catcher or distributed in a traditional manner. Cato et al. also reported that "hundreds if not thousands" of green turtles were taken illegally every year from the remote nesting islands in Micronesia, especially Merir and Helen Islands (Republic of Palau), by foreign fishing boats. These boats operate primarily from Taiwan, although Japanese and Okinawan boats also participated. Living turtles were sold in Taiwan, Hong Kong, and Japan. Thousands of eggs were also collected. Due to the remoteness of the islands it was (and is) difficult to control this activity (Cato et al. 1978). At the present time, Palau-based government supply ships are also participating in commercial turtle-trafficking between islands. Green turtles occasionally are seen around the main islands, but most nesting occurs on small isolated islands such as Oroluk, Pikelot, East Fayu, West Fayu, Gaferut, Merir Island, and Ulithi Atoll which are away from human population centers (e.g., McCoy 1982; Pritchard 1982a; Lecky 1984).

Declines in turtle numbers have been reported from Pikelot and Oroluk, while the stocks at East and West Fayu, Gaferut, and Helen Reef appear to be stable (Lecky 1984). Based on a 1990 field survey, Naughton (1991) considered Oroluk Atoll to be perhaps the most important site for green turtles in the Eastern Caroline Islands. He noted that island residents take every turtle encountered (mostly adult females) and urged that the species be protected there. Less is known about the present status of hawksbills, which occur in much lower abundance than do green turtles (Groombridge and Luxmoore 1989). With the decline in importance of traditional tabus (see Johannes 1978) and the preference for modern boats and motors over traditional canoes, both green and hawksbill turtles face increasing harvest throughout the FSM. Population pressures, the emergence of a "money economy", and other factors have intensified the pressure on natural resources in the region (McCoy 1982). Thoughtful reviews of the status and traditional use of marine turtles, including customs and mythology, in this vast region are available in McCoy (1974, 1982), Pritchard (1982a), and Johannes (1986). Very little quantitative information is available.

Republic of the Marshall Islands

The Marshall Islands comprise a widespread District at the eastern end of Micronesia. With the exception of a few small isolated reef islands, such as Jemo, the Marshalls are comprised exclusively of atolls, most of which are made up of a few to many dozens of islets. The atolls are roughly aligned along two parallel axes, the northeastern Ratak Chain and the southwestern Ralik Chain. The human population is widely distributed with a few areas of concentration. There has not been much written on the status of sea turtles in the Marshall Islands and there are no quantitative data on the extent of the turtle harvest. Nevertheless, recent reports (e.g., Thomas 1989; Eckert 1992) make it clear that the take of sea turtles (primarily mature females) and their eggs is not only widespread but virtually unregulated. The annual harvest is "roughly estimated" at 1000 turtles (Glen Lokjohn, pers. comm. to Eckert 1992). Nesting of green turtles is concentrated on the uninhabited atolls, with Bikar Atoll likely to support the largest nesting population, probably followed by Bikini and Taongi Atolls; Ebon is reportedly the best spot for catching turtles in the water (Pritchard 1982a).

Historically a number of the more northerly atolls in the Ratak Chain were used as game reserves by the Marshallese. Periodically turtles were harvested with the chief "opening the season" on the first visit of the year (Anon. 1961 *in* Johannes 1986). Tobin (1952) described the elaborate ritual attending this event on the isolated island of Jemo. Missionaries later discouraged these customs and today the conservation afforded sea turtles from the traditional practices has been lost (Johannes 1986). Green turtles in particular (and their eggs) are harvested whenever available. According to Thomas (1989), green turtles are under "heavy hunting pressure" for their shell, meat and eggs and protective legislation is nearly impossible to enforce. Similarly, Eckert (1992) reported that the harvest and consumption of sea turtles is common throughout the Republic, with Majuro and the Southern Islands importing turtles from the Northern Islands. The fishermen concentrate their efforts on and adjacent to nesting beaches. An increasingly popular method of capture is for a snorkeler to locate a sleeping turtle at night and plant a hook in its neck. The hook is tethered to the boat with a long line which is then used to retrieve the animal (Eckert 1992).

Turtles are a popular item at Marshallese festivals. On 15 May 1992, just prior to Eckert's visit, 10 large female green turtles had been brought to Wotje Atoll from Erikup Atoll for "Liberation Day" celebrations. More than 50 turtles were expected to be eaten at Wotje during the course of this celebration and all were likely to be gravid females from the islets of Erikup. Eckert's brief May 1992 survey of three of the Erikup Atoll islets (Enego, Loj, Erikup) revealed numerous campsites and large piles of turtle bones and other turtle remains. Glen Lokjohn, a Wotje turtle fisherman interviewed by Eckert (1992), acknowledged that there are "substantially fewer" green turtles than there once were and that nesting had declined by as much as 50% over the last decade. Hawksbills are more rare and the extent to which they are taken for meat or shell is not known. There are occasional references to the use of turtle shell for ornaments (e.g., Kramer and Neverman 1938).

Johannes (1986) concluded that only in the Caroline and Marshall Islands do sea turtles still play essential roles in the lives of significant numbers of people. However, the dependence is far from universal. Sea turtles do not appear to be essential to either cultural or nutritional well-being on most high islands or district population centers. It is mainly among some of the more remote, low islands of Micronesia that turtles have remained truly important in modern times. International commerce is negligible. The Marshall Islands are not mentioned in recent papers detailing international trade in sea turtle products (e.g., Mack et al. 1982; Milliken and Tokunaga 1987). Fijian Customs reports indicated the export of worked tortoiseshell items to the Marshall Islands in 1974 (Groombridge and Luxmoore 1989).

Kiribati (formerly the Gilbert Islands)

The nation of Kiribati spans nearly 4,700 km of the equatorial Pacific. It encompasses three island assemblages formerly known as the Gilbert Islands, the Phoenix Islands, and the Line Islands. Based largely on information documented by Anon. (1979), Groombridge and Luxmoore (1989) concluded that the meat, eggs, and shells of hawksbills and green turtles are utilized in Kiribati. Hawksbill meat is eaten to a lesser extent since cases of fatal poisoning have been attributed to this species. The belief in some areas that the hawksbill is sacred is perhaps related to these deaths. The capture of foraging and nesting turtles appears to be widespread and primarily non-commercial. Both eggs and meat are important items in the diet. However, turtles are considered totem creatures and there are (or were at the time of Anon. 1979) several traditional constraints on eating them. It is difficult to estimate the extent of use, but a few details are available. For instance, the subsistence harvest in Tarawa was estimated by Anon. (1979) to be 666 turtles per year, including 576 captured by net, 48 by harpoon, 40 by diving, and two while nesting. Historical levels of exploitation may have been much higher. When Captain Cook discovered Christmas Island (now part of the Line Islands in eastern Kiribati) in 1777, 200-300 green turtles were captured during the eight days there (Beaglehole 1967 *in* Balazs 1982a).

Anon. (1979) reported that turtles were typically captured by use of nets which traditionally were made of coconut twine but today are mainly of monofilament construction. Nets are 150-220 m long, with a mesh size of 50 cm, and are usually set in the lagoons near the sea grass feeding grounds. Some 80% of the turtle caught at Tarawa are caught using nets. Harpoons are also employed, particularly at Betio (Tarawa) and Abemama, and are generally used at night. Ripe pandanus fruits are sometimes used as ground baits to attract turtles. On the steep reef-front on the ocean side of the islands, turtles are caught during the day as they rest in coral crevices. Divers descend with ropes tied to log floats, which they tie or hook into the turtles. Tarawa, Butaritari, Kuria, Aranuka, and Nikunau are five of the main areas for turtle fishing (Groombridge and Luxmoore 1989). It is not possible to determine the full extent of exploitation, trade, and use from published data. Fijian Customs statistics (q.v.) reported imports of worked tortoiseshell products from Kiribati in 1973, 1975, 1977 and 1978 (Groombridge and Luxmoore 1989).

STATUS OF NORTH PACIFIC SEA TURTLE POPULATIONS UNDER CONSERVATION AND WILDLIFE PROTECTION LAWS

National Legislation

Nations which border the North Pacific, while quite different from one another in language and socio-political custom, share a history of overexploitation of their sea turtles and hold in common the future of this depleted resource. The majority of North Pacific nations now provide some measure of protection to sea turtles which occur within their borders, and most also regulate the import and export of these species and their products. Mexico, China, the Philippines, Sarawak, Taiwan, Thailand, and the USA have all promulgated federal legislation which provides complete protection to sea turtles, although full enforcement is an unmet challenge. Some countries have made great advances in the field of sea turtle conservation in the last few years. Unfortunately, nations which continue to sanction the harvest of sea turtles are undermining the conservation efforts of their neighbors, especially when large juveniles and breeding-age adults are targeted. In Japan, for example, the Tokyo Metropolitan Government has banned the capture of turtles <75 cm curved carapace length. Similarly, several States in greater Micronesia selectively protect small size classes despite well documented evidence (e.g., Crouse et al. 1987; Frazer 1989) that taking large turtles can exert severe pressure on remaining stocks.

In the text which follows, domestic regulations which define the legal status of sea turtles are reviewed. The details have been drawn from two recent compendia, one by the CITES Secretariat and IUCN (Groombridge and Luxmoore 1989) and the other by WWF and TRAFFIC(USA) (Nichols et al. 1991). Ecuador, Colombia, and Central America, otherwise excluded from the scope of this report (see Scope of Work), are noted when appropriate as parties to international treaties and agreements discussed in a later section.

Canada

There are no federal or provincial wildlife or conservation laws which provide for the protection of marine turtles in Canada. However, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was established in 1976 by the 40th Federal-Provincial Wildlife Conference. COSEWIC has federal representatives from Fisheries and Oceans, the Canadian Wildlife Service, the Canadian Parks Service, and the Canadian Wildlife Service, as well as from the Natural Resource Departments of each of the ten provincial and two territorial governments, and from three non-governmental national wildlife organizations. In addition, there are scientific subcommittees for mammals, birds, amphibians and reptiles, fish and marine mammals, and plants (for additional detail, see Cook and Muir 1984).

COSEWIC meets annually to examine Status Reports on species that occur in Canada. A status designation for those accepted is decided by consensus confirmed by recorded vote. The leatherback sea turtle (*Dermochelys coriacea*) was designated to be "Endangered" in 1981, but the report has yet to be been published. The green turtle *(Chelonia mydas agassizii*) is on the candidate list for consideration, along with the Kemp's ridley (*Lepidochelys kempii*) and the loggerhead (*Caretta caretta*) which have been recorded in the Canadian Atlantic. COSEWIC decisions have no legislative force and it exists only to make recommendations. However, the consensus aspect mean that COSEWIC decisions carry weight with provincial and federal departments which in turn recommend legislation (Francis Cook, Canadian Museum of Nature, *in litt*., 4 September 1991).

Canada became a party to CITES effective 9 July 1975 (UNEP 1989). There is no reported international trade in sea turtles or their parts and products.

United States of America

The most prominent and comprehensive national law providing protection to sea turtles under Atlantic, Pacific, and Caribbean U. S. jurisdiction is the Endangered Species Act (28 December 1973, as amended). According to 50 CFR 17.11, the following designations apply as of the dates given [N.B. 1970 designations were made under the aegis of the Endangered Species Conservation Act of 1969, which preceded and is superseded by the Endangered Species Act of 1973]:

Endangered:

Dermochelys coriacea -- 2 June 1970 (35 FR 8495)
Lepidochelys kempii -- 2 December 1970 (35 FR 18320)
Eretmochelys imbricata -- 2 June 1970 (35 FR 8495)
Chelonia mydas -- Breeding colony populations in Florida, 28 July 1978 (43 FR 32808)
L. olivacea -- Breeding colony populations on the Pacific coast of Mexico, 28 July 1978 (43 FR 32808)

Threatened:

C. mydas -- All other populations, 28 July 1978 (43 FR 32808)
L. olivacea -- All other populations, 28 July 1978 (43 FR 32808)
Caretta caretta -- 28 July 1978 (43 FR 32808)

The Endangered Species Act (ESA) prohibits, with respect to endangered and threatened wildlife, import and export, delivery, receipt, or transport in interstate or foreign commerce, selling or offering for sale in interstate or foreign commerce, "taking" (harming, harassing, pursuing, hunting, shooting, wounding, trapping, killing, capturing, or collecting, or attempting to do so), or possessing or transporting any illegally taken wildlife parts or products. Permits to take endangered wildlife may only be granted for scientific research or to enhance the propagation or survival of the species. Permits to take threatened wildlife may be granted for these reasons and for education or exhibition.

A Memorandum of Understanding established that the National Marine Fisheries Service (Department of Commerce) has jurisdiction while turtles are in the water and the Fish and Wildlife Service (Department of Interior) has jurisdiction while turtles are on land. The two agencies often join forces to help regulate sea turtle trade. All federal agencies must ensure that actions authorized, funded, or carried out by them do not result in the destruction or adverse modification of habitat designated as Critical Habitat for marine turtles pursuant to Section 7 of the ESA. Critical Habitat has not been designated for any species of marine turtle in the U. S. Pacific. A draft proposed rule was prepared in 1980 to designate Critical Habitat for the green turtle (*Chelonia mydas)* in Hawaii, American Samoa, and the Trust Territories, but this was never approved by the U. S. Fish and Wildlife Service (C. Kenneth Dodd, FWS, pers. comm., 1991). In addition, several beaches were considered by Dodd (1978a) to be potential candidates for Critical Habitat for the hawksbill turtle (*Eretmochelys imbricata*) in the U. S. Pacific, including American Samoa (Tutuila Island, Rose Atoll, Swains Island) and the Trust Territories (portions of Palau, Truk District, Lower Mortlocks).

The Lacey Act, originally enacted in 1900, was amended in 1969 to authorize the Federal Government to enforce restrictions on wildlife which are subject to state, territorial or foreign laws. The Lacey Act makes it a federal crime to import into the United States (or transport within the U. S. across state lines) any wildlife that has been taken, transported, possessed or sold in violation of the law of a state or a foreign country (Bavin 1982). The Pelly Amendment to the Fisherman's Protective Act of 1967 (22 U.S.C. 1978) is a powerful but seldom-used law which allows the U. S. to embargo fish and/or wildlife products from nations that undermine international conservation or fishery programs for endangered species (Donnelly 1991). On 20 March 1991, the government of the U. S. formally censured Japan under the Pelly Amendment for that country's continuing trade in endangered sea turtles (for further discussion, see Japan). In 1975, CITES came into force in the United States. CITES imposes trade restrictions on certain wildlife species which are internationally traded, including sea turtles.

United States Outlying Territories in the Pacific

The U. S. outlying territories in the Pacific consist of some 2,200 islands concentrated primarily in the western Pacific. Of these, only about 96 islands are inhabited. While the total land area is only 1,800 km^2, the islands extend over 7.8 million km^2 of Pacific Ocean, or about the same area as the continental United States. The outlying territories include the political jurisdictions of the Republic of Palau, Guam, the Northern Mariana Islands, American Samoa (which lies south of the equator and is not included in the present report), and the unincorporated territories of Howland, Baker, Wake, and Jarvis Islands, Johnston and Palmyra Atolls, Kingman Reef, and Midway. The Trust Territory of the Pacific Islands, now consisting of only one government unit (Palau), was established in 1947 by the United Nations as a strategic areas trusteeship under U. S. administration. The Federated States of Micronesia and Republic of the Marshall Islands have their own constitutions but are freely associated with the U. S.

While some U. S. flag areas have separate legislation regulating or protecting wildlife and plants, the ESA has precedence over such legislation. When, in 1978, the green, loggerhead, and olive ridley sea turtles were listed under the ESA, protective regulations were promulgated along with the listing in an effort to conserve and restore sea turtle populations to their former levels of abundance. These regulations contained a provision for the continued "subsistence" taking of green turtles for personal use by residents of the Trust Territory, "... if such taking is customary, traditional, and necessary for the sustenance of such resident and his immediate family" (50 CFR 17.42(b) and 227.72(f)). The protective regulations apply to all U. S. states and possessions including those in the Caribbean, but the Trust Territory (now consisting solely of Palau) was the only area to receive an exemption for subsistence use as defined above. The rationale for this action was that many of the native inhabitants followed a traditional way of life in the villages on small remote islands that are limited in natural food resources (Balazs 1983b). Sea turtles are also protected by Palauan law (Chapter 12, 24 PNC 1201; T24-44; para 1201) (Maragos 1991), but clandestine harvest is a serious problem in some areas.

Several wildlife refuges have been designated among the U. S. flag areas in the Pacific, including Rose Atoll (14°33'S, 168°09'W) in American Samoa and the unincorporated and uninhabited island territories of Howland (0°48'N, 176°38'W), Baker (0°13'N, 176° 28'W), and Jarvis (0°23'S, 160°01'W) which were designated National Wildlife Refuges in 1974. Johnston Atoll (16°45'N, 169°31'W) is also a National Wildlife Refuge (Balazs 1982a).

The U. S. ratification of CITES (effective July 1975) included the following territories: the Republic of Palau, Guam, the Northern Mariana Islands, and American Samoa. In addition, all U. S. territories and possessions are subject to the ESA which implements CITES in the U. S.

Mexico

"Rules relating to the taking, utilization, and marketing of sea turtles" (September 1968) once regulated the commercial exploitation of sea turtles by establishing minimum sizes and closed seasons, and prohibited the exploitation of and trade in sea turtle eggs. The species involved were *Caretta caretta*, *Chelonia mydas*, *Eretmochelys imbricata*, and *Dermochelys coriacea*. The Directorate of Fisheries was empowered to modify closed seasons, to close certain areas to turtle hunting, and to limit the numbers of animals taken; turtles taken by shrimp boats were to be landed alive; the domestic trade in turtle skins and other products was regulated. Later, "Ley de Desarrollo Pesquero" (25 May 1972) authorized adoption of seasons and other regulations for the taking of sea turtles. Annual Fisheries Regulations prohibited the take of sea turtles on both coasts, with the exception of the olive ridley (*L. olivacea*) for which quotas were set (Groombridge and Luxmoore 1989). On 28 May 1990, the President of Mexico declared full protection to all species of sea turtle, including a ban on their capture and trade. This had the immediate effect of rendering all sea turtle harvest, both commercial and subsistence, obsolete, canceling all legal quotas, and closing the olive ridley slaughterhouse in Oaxaca (Aridjis 1990). Despite the significant advance in national legislation, field enforcement is a continuing problem.

Mexico joined CITES without reservations effective 30 October 1991 (WWF 1992a).

Japan

The Law for the Regulation etc., of the Transfer of Endangered Species of Wild Fauna and Flora (Law No. 58, 2 June 1987) prohibits sale or transfer within Japan of live or whole stuffed species (but not parts or derivatives) of wild animals and plants designated by Environment Agency regulation as "Rare Species". The Environment Agency has designated as "Rare Species" most taxa on Appendix I of CITES, with the exception of species for which Japan holds CITES reservations such as the hawksbill sea turtle. The law does not apply to possession. The Wildlife Protection and Hunting Law (1918) and amendments up to and including Law No. 83 of 1983 prohibits taking of wildlife other than game designated by the Director-General of the Environment Agency. This law also prohibits taking of wildlife in designated areas (Nichols et al. 1991). The Tokyo Metropolitan Government has passed legislation specifically prohibiting sea turtle fishing in June and July, banning the collection of eggs, and prohibiting the capture of turtles <75 cm curved carapace length (Tachikawa and Suganuma, *in litt.*, 19 December 1986 to Groombridge and Luxmoore 1989).

Japan became a party to CITES effective 4 November 1980, and has assigned implementation responsibilities primarily to the Ministry of International Trade and Industry (MITI) as Management Authority. Japan currently holds reservations on several Appendix I species, including the hawksbill (*Eretmochelys imbricata*). Reservations entered on the green turtle (*Chelonia mydas*) and olive ridley (*Lepidochelys olivacea*) were withdrawn in 1987 (Nichols et al. 1991) and 1992 (CITES 1992), respectively. Article XXIII(3) of CITES requires that Parties be treated as non-Parties in relation to trade in species on which they have taken reservations; thus the Party is effectively exempted from treaty requirements with respect to these species. Japan's extensive trade in sea turtles, all of which are listed on Appendix I, has been particularly damaging because it has involved enormous numbers of turtles, many illegally imported from CITES Parties such as Indonesia (Lyster 1985; Barr 1991; Canin 1991). Since 1970, Japan has imported products representing a minimum of 2,250,000 sea turtles (Canin 1991).

On 20 March 1991, the U. S. government formally censured Japan under the Pelly Amendment for continuing to trade in endangered sea turtles, setting into motion negotiations which culminated in Japan's announcing an end to its import of hawksbill turtle shell. Japan banned all such imports as of 31 December 1992 and announced the withdrawal of its CITES reservation on the hawksbill turtle as of July 1994 (Donnelly 1991; TRAFFIC 1991).

Korea

Domestic administrative responsibilities for wildlife are divided among several government bodies according to species groups. The Fisheries Administration is responsible for sea turtles, while the Environmental Administration oversees other reptiles. No species have officially been designated for protection under the Fisheries Law (No. 295, 9 September 1953; modified as Law No. 3492, 3 December 1981) and trade in taxa listed on the CITES appendices which are eligible for protection, particularly all sea turtle species and the Asian arowana (*Scleropages formosus*), goes unregulated. [N.B. Despite the fact that sea turtle species are theoretically protected from international trade by the trade laws discussed below, it is the Fisheries Law which governs domestic take and sea turtles are not protected under this law (Andrea Gaski, TRAFFIC(USA), pers. comm., 1991).]

Until recently, wildlife trade controls in the Republic of Korea [South Korea] were maintained through the Wildlife Protection and Hunting Law, No. 1931 (20 March 1967; modified as Law No. 3673, 30 December 1983) and the Environment Protection Law, No. 3078 (1977, as amended). The Environment Protection Law has now been superseded by the new Environmental Basic Policy Law, No. 4.257 (1 April 1990), effective 1 February 1991. The new Law No. 4.257 reiterates all of those elements pertaining to species conservation and wildlife trade previously found in the Environment Protection Law. Environmental Administration Notice 89-5 (1 March 1989) designated all species of Cheloniidae and *Dermochelys coriacea* fully protected [N.B. Sea turtles are protected from trade, but apparently not from domestic usage; see above.] Ministry of Trade Notice No. 89-8 (8 March 1989) reaffirmed the existence of trade controls for species listed under the Environment Protection Law, and noted that coverage applies to live and dead specimens and manufactured products (Nichols et al. 1991).

Import and export permits are issued by the governors or mayors of the 15 administrative districts. The Republic of Korea is not a party to CITES and remains a major consumer of wildlife and wildlife products. South Korean officials have stated intentions to join CITES for a number of years, but the country has yet to do so (Nichols et al. 1991).

As for the Democratic People's Republic of Korea [North Korea], no information is available concerning wildlife legislation in general or sea turtles in particular (Bjorndal 1982; Groombridge and Luxmoore 1989; Nichols et al. 1991).

China

The Law of Wild Animals Protection of the People's Republic of China became effective 1 March 1989. The Act provides that all wild animals are protected. It further provides that all "rare and endangered wild animals" are under the "key protection" of the Act, and divides rare and endangered wild animals into two categories. Category I animals are subject to "national key protection" and are under the protection of the wild animal administrative unit of the State Council, China's central government. Category II animals are subject to "local key protection" and are under the protection of provinces, autonomous regions, and municipalities. Special permits are issued for the capture of listed species for scientific study (among other things). The Act charges local wildlife authorities with the duty to designate "nature reserves" and "hunting-forbidden" zones, and prohibits import, export and trade in rare and endangered animals without permission from the appropriate authority; violations give rise to criminal liability. The five species of sea turtle which occur in China are designated Category II species; i.e., *Caretta caretta*, *Chelonia mydas*, *Eretmochelys imbricata*, *Lepidochelys olivacea*, and *Dermochelys coriacea*. The hunting and killing of these species is strictly forbidden (Nichols et al. 1991).

Groombridge and Luxmoore (1989) enumerate four pieces of legislation which specifically protect sea turtles in China. These are: (a) regulation of breeding and protection of aquatic resources, (b) detailed rules and regulations of aquatic resources reproduction and protection in Guangdong Province, (c) stipulation of the reserves of Xisha, Nansh and Zhongsha Islands in Guangdong, and (d) stipulation of the Huidong Turtle Reserve, Guangdong Province. Frazier et al. (1988) explained that the Huidong Turtle Reserve was created in 1984 about 100 km northeast of Hong Kong. Prior to 1984, turtles in this area were routinely killed by humans. Large signs now proclaim the conservation area at major points of entry and four beach wardens patrol the beach recording sea turtle nestings. The Reserve is an important green turtle breeding area (Zhou Kaiya, Nanjing Normal Univ., *in litt.*, 8 May 1991).

China became a party to CITES effective 8 April 1981. No specific legislation exists to implement CITES at the present time, although enactment of such legislation is under consideration (Nichols et al. 1991).

Taiwan

Taiwan is not eligible to become a member of the United Nations and may not join CITES, a U. N. administered treaty. Nonetheless, Taiwan has enacted wildlife legislation which attempts to comply with CITES requirements as closely as possible. The Wildlife Conservation Law, No. 1-3266 (1989) regulates both international and domestic trade in "conservation wildlife", which is the list of protected species compiled and authorized by the Council of Agriculture (COA) of the Executive Yuan. The law intends that endangered, rare and valuable species be conserved and not utilized. Schedule I, "Endangered Conservation Wildlife", incorporates all CITES Appendix I species, including all sea turtles. Except under extraordinary circumstances, conservation wildlife may not be disturbed, abused, hunted, captured, traded, killed, exchanged, or illegally owned or possessed. Listed species are additionally protected from commercial trade by a restrictive regulatory process (Nichols et al. 1991).

The Cultural Heritage Conservation Law (Executive Act of 26 May 1982) prohibits and penalizes the hunting, fishing, collecting, logging or other forms of destruction of designated rare and valuable animals and plants. Four species of sea turtle are so designated and thus protected under this law: *Chelonia mydas japonica*, *Eretmochelys imbricata squamata*, *Caretta caretta gigas*, and *Dermochelys coriacea.* In addition, the Fisheries Law (Executive Act of 11 November 1929, as amended) authorizes the regulation of marine and freshwater species. COA Announcement No. 8040406A (29 December 1989) prohibits licensed driftnet vessels operating in the North Pacific region from catching, possessing or transporting trout, salmon, or any aquatic products which the National Principal Authority may appoint. Any such animals caught accidentally should be thrown back; both vessel and captain's licenses may be permanently revoked for violations. This regulation does not specifically prohibit taking of "conservation wildlife", which would include all species of sea turtle, but should be interpreted as such (Nichols et al. 1991).

Viet Nam

There is no information on recent legislation. Le Poulain (1941) recorded that an Arrêté dated 21 April 1923 forbade the collection, sale, or consumption of turtle eggs. A further Arrêté dated 25 April 1925 prohibited the capture of *Eretmochelys imbricata* in the Gulf of Siam between 1 December and 30 April (Groombridge and Luxmoore 1989). Viet Nam is not a party to CITES (UNEP 1989).

Kampuchea

The author was unable to locate any information on conservation and wildlife protection laws in Kampuchea. Similar confessions have been made by others seeking to define wildlife legislation in this country, especially as it pertains to marine turtles (e.g., Groombridge and Luxmoore 1989). Kampuchea is not a party to CITES (UNEP 1989).

Thailand

The Fisheries Act, B.E. 2490 (1975) prohibits the collection or sale of marine turtle eggs, except with the permission of the appropriate authorities. The principal wildlife law, the Wild Animals Reservation and Protection Act, B.E. 2053 (1960), as amended (1972), was replaced in 1992 by the Wild Animals Reservation and Protection Act, B.E. 2535 (TRAFFIC 1992). Under this legislation, animal species are divided into two categories: "Protected Species" and "Endangered Wildlife". "Protected Species" include animal species listed in the CITES Appendices and those protected in Thailand and listed in existing legislation, including five species of sea turtle. "Endangered Wildlife" includes 15 Thai species determined to be endangered. Ministerial Regulations B.E. 2525 (26 August 1982) promulgated under the Act list the following sea turtles as totally protected: the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), and leatherback (*Dermochelys coriacea*) (Nichols et al. 1991).

A law prohibiting the export of turtle shell without the permission of the Ministry of Commerce was enacted on 19 November 1980 (Jeanne Mortimer, WWF-Malaysia, *in litt.*, 20 August 1991). Thailand became a party to CITES effective 21 April 1983, but lacked specific legislation to implement the treaty. In an effort to pressure Thailand into implementing and enforcing CITES (the CITES Secretariat documented over 100 infractions of the treaty by Thailand from 1988-1991), the Standing Committee of CITES recommended in April 1991 that Parties prohibit all trade with Thailand in CITES-listed species (WWF 1992b). On 2 April 1992, the Secretariat lifted the trade embargo following the approval of a new Thai wildlife law (Wild Animals Reservation and Protection Act, B.E. 2535) which provides for the full implementation of CITES with regard to wild fauna, and the drafting of similar legislation for wild flora (TRAFFIC 1992).

Malaysia

According to the Malaysian Constitution, fish and turtles are the property of the individual states and hence not subject to federal regulation. Consequently, these animals are not included in the otherwise comprehensive Malaysian Wild Life Act (1972) and separate laws must be passed in each state in order to achieve country-wide protection (Moll 1989). Federally, the Fisheries Act of 1985 repealed the Fisheries Act of 1963. Its major contribution is in providing for the objectives of conservation, management, and development of marine resources in general. It also provides a comprehensive basic framework for subsidiary legislation to be enacted for the conservation and management of sea turtles, including the establishment of sanctuaries or other protected areas (J. Mortimer, WWF-Malaysia, *in litt*., 20 August 1991).

In Western, or Peninsular, Malaysia, turtle protection legislation has been enacted in four states. In Kelantan, the Turtles and Turtles' Eggs Enactment (1932, as amended by Enactment No. 8, 1935) prevents the capture and killing of turtles. In Pahang, the Fisheries Enactment (1937) and Fisheries Rules (1938) prohibit the capture, killing, injuring, possession or sale of turtles without authorization; in addition, no person shall prevent or hinder turtles from laying eggs. In Terengganu, the Turtle Enactment (1951) prohibits the killing of turtles and regulates the collection of eggs (Siow and Moll 1982). Turtle Sanctuary (Rantau Abang) Regulations are currently being drafted to regulate activities within the Rantau Abang Turtle Sanctuary. In Melaka, the Fisheries (Turtles and Turtles' Eggs) Rules (1989) provides for the appointment of a licensing officer, establishment of a turtle sanctuary, and restrictions within the sanctuary relative to the collection of turtle eggs, prohibiting cruelty to turtles, and protecting turtle eggs (J. Mortimer, WWF-Malaysia, *in litt*., 20 August 1991).

According to Groombridge and Luxmoore (1989), protective legislation in Sarawak, Eastern Malaysia, includes the Turtle Trust Ordinance (1957), the Turtle Rules (1962), and the Wildlife Protection Ordinance (1 January 1958, as amended 22 February 1973). *Chelonia mydas*, *Eretmochelys imbricata*, and *Dermochelys coriacea* are listed as protected animals. They may not be hunted, killed, or captured, except under license. The animals, trophies thereof, or their flesh, may not be sold, possessed, or exported. Rights granted under the Turtle Trust Ordinance are exempted from these provisions [N.B. This Ordinance ensures that only turtle eggs marketed by the Turtles Board are legal; the Board, which is under the control of the Sarawak Museum, is the sole marketing body responsible for collection and sale, as well as conservation, of eggs laid at the Sarawak Turtle Islands.] Nichols et al. (1991) explain that the Wildlife Protection Ordinance of 1990 has replaced the Wildlife Protection Ordinance of 1958. The new law creates more comprehensive provisions for the protection of wildlife, and also contains measures to establish and protect wildlife sanctuaries. All marine turtle species (Cheloniidae and Dermochelyidae) are listed on the First Schedule to the Ordinance, which identifies "Totally Protected Animals". Such animals cannot be hunted, killed, captured, sold, offered for sale, imported, exported, or held in possession except for certain scientific, educational or conservation purposes. The Customs (Prohibition of Export/Import) Order of 1988 specifically bans the export and import of turtle eggs to and from all countries.

In Sabah, Eastern Malaysia, the Fauna Conservation Ordinance 1963 (Act No. 11) partially protects members of the Cheloniidae. National and international trade in *Chelonia mydas* and *Eretmochelys imbricata* is regulated, the hunting of these species is permitted only under license, and the taking of eggs is controlled. Natives may collect eggs in specified areas without licenses. Areas may be designated as "turtle farms", where exclusive rights to collect eggs are granted. The Fauna Conservation (Turtle Farms) Regulations 1964 regulates the taking of *C. mydas* and *E. imbricata* eggs. The collection of turtle eggs from designated "turtle farms" [N.B. 8 islands were so designated (de Silva 1982)], or from any area reserved for the collection of turtle eggs, is prohibited during the month of March. The Chief Game Warden is empowered to suspend or cancel the right to collect turtle eggs in the event of any breach of the regulations. The import and export of *C. mydas* and *E. imbricata*, including shell, skin, calipee, and oil, is prohibited by Customs (Prohibition of Imports) (Amendment) Order 1971 (8 May 1971) and Customs (Prohibition of Exports) (Amendment) Order 1971 (8 May 1971), respectively (Groombridge and Luxmoore 1989). Turtles are protected in Sabah Turtle Islands Park, established in 1977, which covers an area of 1,740 ha including three islands and surrounding coral reefs and sea and lies 40 km north of Sandakan, close to the Philippines border (de Silva 1982).

Malaysia became a party to CITES effective 18 January 1978. Responsibility for implementing CITES and protecting wildlife is divided between the federal authorities in peninsular Malaysia and the states of Sarawak and Sabah, each of which exercises independent administrative and legislative responsibilities in this regard.

Philippines

The principal legislation for wildlife protection is Act No. 2590, An Act for the Protection of Game and Fish (1916, as amended). Memorandum Order No. 6, Series of 1982 (29 April 1982) declared a total ban on the exploitation of sea turtles, stating that no further permits would be issued to collect, possess, transport, remove, export and/or dispose of marine turtles, eggs, and byproducts. However, exception for a limited egg harvest in the Province of Tawi-Tawi is provided for under MNF Administrative Order No. 33, Series of 1982.

Harvest is allowed only under permit and under the following conditions: 30% of all eggs laid shall be reserved for preservation purposes, such nests shall not be disturbed in any way; 10% of all nests may be gathered and sold, the proceeds being given to the Tawi-Tawi Marine Turtle Conservation Foundation; the remaining 60% may be gathered by permittees on payment of a fee to the Municipality. Permits are valid only from April to December (Groombridge and Luxmoore 1989).

By virtue of Executive Order No. 542, signed on 26 June 1979, the Pawikan [Marine Turtle] Task Force was inaugurated by the Government "to ensure the survival of the country's remaining marine turtle populations." The Task Force is responsible for the development and implementation of conservation and protection policies, management and propagation schemes, and public information and education programs. The nationwide project is attached to the Wildlife Division of the Protected Areas and Wildlife Bureau of the Department of Environment and Natural Resources (Trono 1991). Marine Turtle Sanctuaries were established by Administrative Order No. 8 (8 June 1986) and include the following island/islets: Province of Tawi-Tawi (Bancauan Island, Daguan Island), Province of Palawan (Halog Island, Tanobon Island, Panata Cay, Kota Island), and Province of Antique (Panagatan Island). Within these sanctuaries it is prohibited to (a) kill or take marine turtles or gather turtle eggs, (b) destroy or disturb marine turtle habitats, either on land, or in the sea within 250 m of the lowest tide line (Groombridge and Luxmoore 1989).

The Republic of the Philippines acceded to CITES effective 16 November 1981, but lacks specific legislation to implement the treaty (Nichols et al. 1991).

Federated States of Micronesia

The Code of Federated States of Micronesia (Title 23, Section 105) prohibits (a) the taking of *Eretmochelys imbricata* <27 inches (68.6 cm) and of *Chelonia mydas* <34 inches (86.4 cm), (b) the taking of any turtles during the periods 1 June-31 August and 1 December-31 January, (c) the killing of any turtle on the shore, and (d) the collection of any eggs (Groombridge and Luxmoore 1989). The FSM has not acceded to the global CITES treaty which prohibits trade and commerce in listed wildlife, including sea turtles, and their products. Nevertheless, international trade appears to be negligible.

Republic of the Marshall Islands

According to Groombridge and Luxmoore (1989), the U. S. Endangered Species Act applied to the Republic of the Marshall Islands, as a former unit of the U. S. administered Trust Territory of the Pacific, until November 1986. The islands now have their own legislation, apparently modeled after the Trust Territory Code. The Code (Title 45, Section 2) prohibits (a) the taking of *Eretmochelys imbricata* <27 inches (68.6 cm) and of *Chelonia mydas* <34 inches (86.4 cm), (b) the taking of any turtles (any size) during the periods 1 June-31 August and 1 December-31 January, (c) the killing of any turtle on the shore, and (d) the collection of any eggs. Thomas (1989) notes that exceptions to provisions protecting sea turtles and their eggs can be authorized by Cabinet, and the penalty for violating the Code is a US$ 100.00 fine or six months imprisonment. The Republic has not acceded to the global CITES treaty which prohibits trade and commerce in listed species, including sea turtles, and their products. Nevertheless, international trade appears to be negligible.

Kiribati (formerly the Gilbert Islands)

Marine turtles are partially protected in Kiribati by the Wildlife Conservation Ordinance 1975 (29 May 1975). Under this law the taking of any wild turtle on land is prohibited except under license, the taking of green turtles is prohibited in some areas, and the possession of species, their products or eggs which have been illegally acquired is prohibited (Groombridge and Luxmoore 1989). Kiribati has not acceded to CITES (UNEP 1989). A decade ago there were indications that some turtle carapaces were destined for export (Anon. 1979); current information is not available. Fijian Customs records record imports of worked tortoiseshell products from Kiribati in 1973, 1975, 1977 and 1978 (Groombridge and Luxmoore 1989).

Regional and International Treaties and Agreements

There are several regional and international treaties and agreements which actually or potentially offer some degree of protection to sea turtles or oceanic habitats important to them in the North Pacific. These include prominent global agreements such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) which has 118 parties worldwide (USFWS, 1992), many of them bordering the North Pacific. Other agreements with the potential to be effective in the regional conservation of depleted sea turtle stocks are not as widely supported. For example, the Convention on the Conservation of Migratory Species of Wild Animals has as its objective the protection of species that migrate across or outside national boundaries, yet this convention counts among its parties not a single North Pacific nation.

The objective of this section is to provide a brief overview of treaties which have the potential to improve the survival status of sea turtles in the North Pacific region and which involve as parties nations which fall within the geographic scope of this report. The treaties selected were drawn from the *Register of International Treaties and Other Agreements in the Field of the Environment*, recently compiled by the United Nations Environment Programme and current as of 13 December 1988 (UNEP 1989). In each case, the date of adoption is provided, as well as objective(s) and selected provisions. "Entry into force" refers *only* to North Pacific nations, including the nations of Central America and Colombia which are not otherwise included in this report, as well as Indonesia, Kiribati, and Ecuador which straddle the equator. It is not intended to display a comprehensive list of parties. For further information and analysis, the reader is referred to Lyster (1985), Bräutigam (1987) and UNEP (1989).

In addition to the treaties annotated below, an agreement which is not yet in force is worth mentioning. In early 1986, representatives of the western hemisphere nations bordering the Pacific met in San José, Costa Rica, and drafted a "Regional Agreement for Investigation and Management of Marine Turtles of the American Pacific". The primary purpose of this agreement was to recognize the international movements of sea turtle stocks in the eastern Pacific, their economic, scientific, and educational value, and provide a vehicle for co-operative international management by the nations involved. It would establish an international commission charged with establishing priority action needs, standardizing management techniques, receiving and dispersing financial resources, and recommending policy/regulatory needs to the respective nations. The agreement was ratified by Ecuador, Costa Rica and Honduras; however, the requirement was that it be ratified by six nations within a period of 24 months. This did not occur, and the treaty never materialized. Future ratification by all nations from Mexico to Ecuador will be necessary if the treaty is to be fully effective. Such ratification is believed to be attainable (Jack Woody, FWS, *in litt.*, 25 September 1991).

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

Date of adoption: 3 March 1973 (amended 22 June 1979, 30 April 1983). Entry into force: Canada (9 July 1975), China (8 April 1981), Colombia (29 November 1981), Costa Rica (28 September 1975), Ecuador (1 July 1975), El Salvador (29 July 1987), Guatemala (5 February 1980), Honduras (13 June 1985), Indonesia (28 March 1979), Japan (4 November 1980), Malaysia (18 January 1978), Mexico (30 October 1991), Nicaragua (4 November 1977), Panama (15 November 1978), Philippines (16 November 1981), Thailand (21 April 1983), USSR (8 December 1976), USA (1 July 1975). Objectives: To protect certain endangered species from overexploitation by means of a system of import/export permits.

Provisions: Includes animals and plants whether dead or alive, and any recognizable parts of derivatives thereof (art. 1); Appendix I covers endangered species (including all species of sea turtle), trade in which is tightly controlled; Appendix II covers species that may become endangered unless trade is regulated; Appendix III covers species that any party wishes to regulate and requires international cooperation to control trade; Appendix IV contains model permits; permits are required for species listed in appendices I and II stating that export/import will not be detrimental to the survival of the species (art. 3, 4).

Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere (Washington, or Western Hemisphere Convention)

Date of adoption: 12 October 1940. Entry into force: Costa Rica (12 April 1967), Ecuador (20 January 1945), El Salvador (1 May 1942), Guatemala (1 May 1942), Mexico (27 June 1942), Nicaragua (22 August 1946), Panama (16 June 1972), USA (1 May 1942). Objectives: To preserve all species and genera of native American fauna and flora from extinction, and also preserve areas of wild/human value. Provisions: Establishment of national parks and reserves (art. 2); strict wilderness areas to remain inviolate (art. 4); protection of species listed in the annexes is declared to be of special urgency and importance (art. 8); controls are imposed on trade in protected fauna and flora and any part thereof (art. 9). Five species of sea turtle (*Caretta caretta*, *Chelonia mydas*, *Dermochelys coriacea*, and *Lepidochelys kempi*) are listed (Dodd 1978b), but in practice the annexes have had very limited conservation value (Lyster 1985).

ASEAN Agreement on the Conservation of Nature and Natural Resources

Date of adoption: 9 July 1985. Entry into force: Indonesia (9 July 1985), Malaysia (9 July 1985), Philippines (9 July 1985), Thailand (9 July 1985). Objective: To promote joint and individual State action for the conservation and management of the natural resources of the ASEAN region. Provisions: The Parties agree to promote joint or individual State action to preserve genetic diversity by ensuring the conservation and preservation of all species in their jurisdiction especially by protecting endangered species and conserving endemic species (art. 1, 3, 5); to maintain harvested species through sound management and ensure sustainable utilization (art. 1, 4, 6); to set up protected areas including natural parks and reserves to conserve biological diversity, and especially endangered species; to ensure that the conservation and management of natural resources is an integral part of development planning both at the national and regional levels (art. 2).

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

Date of adoption: 24 November 1986. Entry into force: Marshall Islands (22 August 1990), Federated States of Micronesia (22 August 1990), USA (10 July 1991). Objective: To protect and manage the natural resources and environment of the South Pacific Region. Provisions: Prevent, reduce and control pollution of the Convention area (art. 5-10, 12); take all appropriate measures to protect and preserve rare ecosystems and endangered flora and fauna as well as their habitat in the Convention area (art. 14).

It is noteworthy that, in recognition of the migratory nature of sea turtles, a South Pacific Regional Marine Turtle Conservation Programme has been implemented under the aegis of SPREP. While individual nations have taken steps to protect sea turtles, it is generally accepted that a regional approach is required to ensure the long-term survival of turtles in the region. The overall aim of the SPREP turtle program is "to conserve marine turtles and their cultural, economic and nutritional values for the coastal peoples of countries served by the South Pacific Regional Environment Program." The turtle program comprises the following elements: information gathering, institution building, research and management, traditional knowledge, conservation, education and publicity programs, and international efforts (e.g., encouraging South Pacific nations to accede to CITES) (Daly 1990). Ongoing projects include tagging of sea turtles and public awareness campaigns (SPREP 1992).

International Convention for the Prevention of Pollution of the Sea by Oil

Date of adoption: 12 May 1954 (amended on 11 April 1962 and 21 October 1969). Entry into force: Canada (26 July 1958), Japan (21 November 1967), Mexico (26 July 1958), Panama 25 December 1963), Philippines (19 February 1964), Republic of Korea (31 October 1978), USSR (3 December 1969), USA (8 December 1961; extended to American Samoa, Guam, the Panama Canal Zone, Puerto Rico, the Trust Territory of the Pacific Islands, and the USVI on 9 September 1975 and to the Midway Islands, Wake Island, and Johnston Atoll on 18 March 1976). Objective: To take action to prevent pollution of the sea by oil discharge from ships. Provisions: Regulates, among other things, discharges (quantity and quality), facilities at ports and oil-loading terminals, and record-keeping.

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

Date of adoption: 29 December 1972. Entry into force: Canada (13 December 1975), China (5 December 1985), Costa Rica (15 July 1985), Guatemala (30 August 1975), Honduras (1 June 1980), Japan (14 November 1980), Kiribati (17 May 1982), Mexico (30 August 1975), Panama (30 August 1975), Philippines (30 August 1975), USSR (29 January 1976), USA (30 August 1975). Objectives: To control pollution of the sea by dumping, and to encourage regional agreements supplementary to the Convention. Provisions: Waste materials are categorized under three annexes, whereby dumping of Annex I substances is prohibited and Annex II and III substances require special permit (art. 4); parties with particular interests in certain areas of the seas may enter into regional agreements to prevent marine pollution (art. 8); parties to collaborate in training personnel, supplying equipment for research and monitoring, and disposing of and treating wastes (art. 9).

International Convention for the Prevention of Pollution From Ships (MARPOL)

Date of adoption: 2 November 1973. Entry into force: Colombia (27 July 1981), Republic of Korea (23 October 1984). Objective: To preserve the marine environment by achieving the complete elimination of international pollution by oil and other harmful substances, and the minimization of the accidental discharge of such substances. Provisions: The Convention is a vehicle for enforcement and administration of the detailed provisions in Annexes I-V, the Protocol on Intervention on the High Seas in Cases of Marine Pollution by Substances Other than Oil, and Protocols I and II; Annex I contains Regulations for the Prevention of Pollution by Oil, including a list of oils; Annex II contains Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk, including lists of such substances; Annex III contains Regulations for the Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Forms, or in Freight Containers, Portable Tanks or Road and Rail Tank Wagons; Annex IV contains Regulations for Prevention of Pollution by Sewage from Ships; Annex V contains Regulations for the Prevention of Pollution by Garbage from Ships.

Protocol of 1978 Relating to the International Convention for the Prevention of Pollution From Ships (London Convention, or MARPOL)

Date of adoption: 17 February 1978 (amended 15 March 1985). Entry into force: China (2 October 1983 -- except for annexes III, IV, V of the Convention), Colombia (2 October 1983), Democratic People's Republic of Korea (1 August 1988), Indonesia (21 January 1983), Japan (2 October 1983 -- with a reservation and/or declaration), Marshall Islands (26 July 1988), Panama (20 May 1985), Republic of Korea (23

October 1984 -- except for annexes III, IV, V of the Convention), USSR (3 February 1984), USA (2 October 1983). Provisions: Modifies various provisions of the 1973 Convention (in particular, Annex I) and postpones entry into force of Annex II for a period of at least 3 years.

BIOLOGICAL REVIEW

Loggerhead Sea Turtle, *Caretta caretta*

Taxonomy

The generic name *Caretta* was introduced by Rafinesque (1814). The specific name *caretta* was first used by Linnaeus (1758). The name *Caretta* is a latinized version of the French word "caret", meaning turtle, tortoise, or sea turtle (Smith and Smith 1980). Smith and Smith (1980) suggested that the Indo-Pacific and Atlantic populations were differentiated at the subspecific level, but this conclusion has been challenged by Hughes (1974) and Pritchard and Trebbau (1984). In recent synopses of the biological data available on this species, Dodd (1988, 1990) considered *Caretta* to be monotypic. For a detailed discussion of taxonomy and synonymy, see Dodd (1988).

Morphology

The species is characterized by typically five pairs of lateral scutes, the anterior-most one touching the cervical (=nuchal), vertebral scutes broader than long, and three poreless inframarginals on the bridge. A median vertebral keel becomes progressively smoother with age. The posterior marginal rim of the carapace is serrated in juveniles, but also becomes smoother with age. The carapace is reddish brown, sometimes tinged with olive; the scutes are often bordered with yellow. Bridge and plastron are yellow to cream colored. The head is comparatively large (to 25 cm wide in adults, Pritchard et al. 1983) and varies from reddish or yellow chestnut to olive brown, often with yellow-bordered scales. Limbs and tail are dark medially and yellow laterally and below. Hatchlings are uniformly colored gray, or reddish or olive brown (hawksbill hatchlings are similar in color, but have four pairs of lateral scutes and four pairs of inframarginals). Two claws occur on the forelimbs. Males have comparatively narrow shells gradually tapering posteriorly, and long, thick tails extending beyond the edge of the carapace (description from Ernst and Barbour 1989).

Adults normally weigh 80-150 kg, although Pritchard (1967) has suggested that a large skull (width 28.4 cm) in the Bell collection at Cambridge University indicated a whole animal weight of about 540 kg.

With the exception of Mediterranean loggerheads which are comparatively small (nesting females average 80 cm CCL: Margaritoulis 1982), the worldwide average for an adult female is 95-100 cm CCL (summarized by Dodd 1988). Based on data collected during 1969-1979 at Gamouda beach, Tokushima Prefecture, females nesting in Japan average 89.0 cm SCL (range 72.0-107.5, n = 118) and 96.8 kg (range 53.0-125.0, n = 15) (Uchida and Nishiwaki 1982). Females nesting in Queensland average 95.8 cm CCL (range 80.0-113.5, n = 2,207) and 100.7 kg (range 70.3-146.1, n = 112) (Limpus 1985). Adult males, measured at feeding grounds in Queensland, averaged 96.6 cm CCL (range 89.0-104.0, n = 43) (Limpus 1985). Detailed morphological descriptions are given in Deraniyagala (1939) and Dodd (1988). Embryology is reviewed by Agassiz (1857), Fujiwara (1966), Blanck and Sawyer (1981), and Miller (1982, 1985).

Population Units

Research requisite to define "population units" has not been done. In the past managers have relied on the standard, functional definition of a population as an assemblage of adults which returns repeatedly and at predictable intervals to nest at a specific site. Site fidelity is relatively high, and if the criteria for beach selection is based on natal homing, then maternal lineages might be expected to characterize nesting populations. Studies of mitochondrial DNA (mtDNA), which is maternally inherited, indicate that loggerhead nesting assemblages are demographically independent (Bowen et al. 1993a). An electrophoretic survey conducted to assess the relevance of genetic variation to loggerhead breeding structure in Queensland revealed that discrete breeding populations were larger than previously thought. The geographic distribution of alleles suggests that loggerheads nesting on the mainland beaches and on the cays of the Capricornia Section of the Great Barrier Reef form a panmictic population (Gyuris and Limpus 1988). The extent to which the nesting assemblages remain cohesive during non-breeding seasons (returning, for example, to defined and predictable foraging grounds) has not been determined. Further research is needed on this fundamental aspect of loggerhead ecology.

Nesting Habits and Areas

Mating often takes place just prior to the nesting season in waters adjacent to nesting beaches (Hopkins and Richardson 1984). The gravid female approaches the beach at night, selects a nest site, prepares a body pit, excavates a nesting cavity, deposits her eggs, covers and disguises the nest, and returns to the sea (Bustard et al. 1975; Dodd 1988). The nesting sequence generally lasts 45-90 min (e.g., Hirth 1980; Geldiay et al. 1982; Kaufmann 1973). Clutch size averages about

110 eggs in the Indian Ocean, 120 eggs in the western Atlantic, and 130 eggs in Queensland, Australia (summarized by Dodd 1988). Inter-nesting intervals at Pacific Australian nesting sites average 13-14 days, and adult females remain associated with a single underwater refuge adjacent the nesting beach throughout the entire breeding season (Limpus and Reed 1985). In Japan, three or more clutches of eggs are deposited during the nesting season. Remote-sensing studies suggest that loggerheads nesting on the Gamouda beach, Japan, swim offshore into the Kuroshio current for the first several days of the inter-nesting interval, perhaps to find warmer water temperatures suitable for clutch preparation (Naito et al. 1990). Females typically return to the same beach to lay their eggs, both within and between years. In Queensland, the average remigration frequency is 3.75 yr (range 1-8) (Limpus 1990). Reviews of the reproductive physiology of both males and females, including changes associated with migration, mating and nesting, are available from Owens (1980) and Wibbels et al. (1990).

Major nesting grounds are generally located in warm temperate and subtropical regions. Scattered nesting occurs in the tropics, but represents a small fraction of total effort. The largest loggerhead nesting colonies in the world are found on Masirah Island, Oman, and the Atlantic coast of Florida, USA (Groombridge 1982). An estimated 30,000 loggerheads nest on Masirah Island each year (Ross and Barwani 1982; Salm and Salm 1991), while an estimated 14,150 nest annually on the beaches of Florida (Murphy and Hopkins 1984; Ehrhart 1989). Nesting also occurs in the Pacific basin, but is restricted to the western region. There is no nesting on Pacific shores of Canada, the USA, or Mexico, nor is nesting reported from Palau, Guam (Gerald Davis, Guam DAWR, *in litt*., 22 August 1991), the Northern Mariana Islands, or the unincorporated U. S. territories in the North Pacific (Balazs 1982a). The following discussion of the distribution of nesting is adapted from Dodd (1988), and is presented with the caveat that there is considerable confusion concerning the identification of *Caretta* and *Lepidochelys* in the herpetological literature of the western Pacific (Nishimura 1967), particularly for Burma, Thailand, Indonesia, Malaysia, China, Taiwan, Japan, and Korea (see Dodd 1988 for a review).

Nesting in China occurs between April and August, with gravid females digging nests 33-65 cm deep and laying 60-150 eggs per clutch (Chu-Chien 1982). Márquez (1990) concluded in a recent review that "in China, [loggerhead] nesting occurs along the coasts of the South China Sea, principally on Hainan Island." Data are few, but it seems likely that nesting is a rare occurrence in China. No mention of egg-laying was made by Zhou (1983) or Frazier et al. (1988), although in the latter case loggerheads of reproductive size (captured at sea) were described. Nishimura (1967) reviewed the status of *Caretta* in Japan and noted that references to *Lepidochelys* in Japanese waters were probably based on *Caretta*. Loggerheads nest along the Pacific coast of Japan's mainland, most often between 24°N and 36°N (Naito et al. 1990), but occasionally as far north as Fukushima Prefecture at 37°N (Uchida and Nishiwaki 1982). On the Japanese islands, loggerheads nest "in abundance" in Shizuoka Prefecture, Kii Peninsula, Shikoku, and the east coast of Kyushu; nesting on the Ogasawara (Bonin) Islands is more rare.

The breeding season extends from late May through August, apparently initiated when 20°C isothermal waters approach the coast of Japan in the spring. Nesting is preceded by courting offshore in 20-30 m of water (Uchida and Nishiwaki 1982). A recent survey (1983-1988) revealed 201 loggerhead nests on 45 beaches of 13 islands belonging to the Amami, Miyako and Yaeyama Groups in the Ryukyu Archipelago and established that the loggerhead nests with the highest frequency of any turtle along almost the entire range of this archipelago (Kamezaki 1989), in contrast to earlier reports (Uchida and Nishiwaki 1982; Uchida 1982) that nesting was relatively rare in the southern islands. There are no nesting records for the coast of Indochina, although both Bourret (1941) and Huong (1978 cited *in* Dodd 1988) listed *Caretta olivacea* from Viet Nam, suggesting that loggerheads or olive ridleys (probably the latter) might occur or might once have occurred in coastal waters.

There are few sightings of loggerhead turtles around the many islands of the southwestern North Pacific and the species is considered rare or vagrant in this area. Gomez (1980) reported no recent observations of either loggerheads or olive ridleys in the Philippines. Similarly, the species does not appear to occur in greater Micronesia, being absent from Pritchard's (1982a) review of that region. Only hawksbill and green turtles are included in a recent overview of the natural diversity of the northern Marshall Islands; loggerheads are not mentioned (Thomas 1989). In the central Pacific, Balazs (1983a) noted that nesting occurs only at Tokelau, a New Zealand dependency south of the equator (8°-10°S, 171°-173°W), and there the species is considered rare. In his account, an informant, considered an "outstanding authority on all aspects of Tokelauan life", confided that a "reddish turtle comes from far away to nest, and when it does a greater number of green turtles can be expected." There is no evidence of nesting in Kiribati. Notable Pacific colonies outside the scope of this report are found in Queensland, Australia, where an estimated 3,000+ gravid females arrive to nest each year. There are three major rookery areas in Queensland: the Capricorn/ Bunker group of islands, including Wreck Island (which receives approximately 1,000 nests per annum) and Tryon Island; the Bundaberg to Round Hill Head coastline, including the Mon Repos and Wreck Rock beaches; and the Swain Reefs of the southern Great Barrier Reef (Limpus 1982).

Insular and Pelagic Range

Loggerheads are circumglobal, inhabiting continental shelves, bays, estuaries and lagoons in the temperate, subtropical, and tropical waters of the Atlantic, Pacific and Indian oceans (Dodd 1990). With the exception of juveniles foraging on pelagic crabs off the coast of Baja California, Mexico (discussed below), loggerheads are generally found feeding on benthic invertebrates in hard bottom habitats. Based on the research of Limpus (1973a), Bustard (1974, 1976), and Moody (1979), Dodd (1988) concluded that the diet of loggerheads in Queensland, Australia (the only Pacific location for which data are available) consists of cnidarians, cephalopods, a wide variety of gastropods and pelycepods, decapods, echinoderms, and fish. The stomachs of three loggerheads drowned in shrimp trawls in inter-nesting habitat off Mon Repos rookery (Queensland) contained fish, shrimp, and cuttlefish (Limpus 1973a), although the sample may have been biased by the consumption of trawling bycatch (Balazs 1985). Based on intermittent (February-July, 1985-1987) censuses of loggerheads off the coast of Baja California Sur (BCS), Mexico, at Las Barrancas and a more systematic survey (March-July, 1988) between Punta Santo Domingo and Todos Santos (Bahia Magdalena), Cruz et al. (1991) concluded that the presence of loggerheads was not occasional but reflected a migration pattern probably related to their feeding habits. The zone of their study is characterized by dense concentrations of the pelagic red crab, *Pleuroncodes planipes*.

In the eastern Pacific, loggerheads are reported as far north as Alaska where a juvenile (64.2 cm SCL) stranded dead in December 1991 at Shuyak Island (58°33.9'N, 152°32.2'W) (Bane 1992) and as far south as Chile (52°57'S) (Frazier and Salas 1982). Occasional sightings are also reported from Washington (e.g., Grays Harbor area 47°00'N, 124°11'W: Wash. Dept. Game; Ilwaco 46.18°N, 124.03°W: Hodge 1982), but most records are of juveniles off California (Stinson 1984; Guess 1981a,b) and Mexico. Large aggregations of juveniles (>100,000 turtles) have recently been described by Bartlett (1989) off the western coast of BCS in a band starting about 30 km offshore and extending out at least another 30 km. Peak populations were observed offshore Bahia Magdalena. Bartlett reported sizes ranging from 20-80 cm carapace length (avg. 60 cm) and concentrations of 1-5 turtles per km^2 at peak sightings in good weather. He speculated that the area provided "unlimited feeding on a high quality food", mostly the pelagic red crab (*P. planipes*). The crab's distribution coincides with that of the young turtles, and analysis of both stomach contents and fecal material confirmed the turtles were "stuffed with parts of the red crab" (Bartlett 1989). Cruz et al. (1991) measured 39 juveniles (avg. 46.75 cm carapace length, range 32-58 cm) in 1988 during a census offshore central BCS and, based on data collected from 1985-1988, estimated a peak abundance of 15,000 turtles in July 1986 in the zone between Punta Santo Domingo and Todos Santos. Further south, 41 loggerheads were captured incidentally in gill nets by a single fishermen from 1985 to May 1987 in the vicinity of Bahia de la Paz, BCS (Alvarado and Figueroa 1990).

The documented at-sea range of the loggerhead in the western North Pacific consists mainly of records around Japan (Nishimura 1967; Uchida and Nishiwaki 1982; Iwamoto et al. 1985; Nishemura and Nakahigashi 1990; see also Dodd 1988) and China, with the northernmost record being Peter-the-Great-Bay, Maritime Province, Russia (Terentjev and Chernov 1949 *in* Dodd 1988). The species is reported from Chinese and Taiwanese waters (e.g., Fang 1934 *in* Nishimura 1967; Chu-Chien 1979, 1982), either as *Caretta caretta*, *C. c. olivacea*, or *C. olivacea* (see Dodd 1988 for review). Frazier et al. (1988) surveyed the south-eastern Chinese provinces of Fujian and Guangdong and concluded that loggerheads were relatively common, at least in the East China Sea. Records spanned March to October, and from Hainan Island (19° 40'N) north to Pingtan Island (25°30'N). Mean size was 82.0 cm CCL (range 74.5-102.5 cm, n = 16) and the majority were immature. Of six logger-heads captured by local fishermen in the coastal waters of China's Jiangsu Province (ca. 31°-35°N) in 1980-1982, one captured on 4 June 1980 had been marked and released from Miyazaki, Japan, on 24 July 1979, some 900 km to the east (Zhou 1983). Carapace lengths for four of the Jiangsu turtles were 69.2, 70.0, 73.0, and 82.5 cm (Zhou 1983).

Loggerheads were reported in Korea, the Ryukyu Archipelago (Japan), and Formosa (now Taiwan) by Takeshima (1958), although Nishimura (1967) suggested that these observations may have been of olive ridleys as well as loggerheads. Won (1971) records a specimen caught in 1958 in Heungnam Harbor and another caught in a fixed shore net near Ham Kyong Nam Do Province (North Korea) in 1962. The species is probably rare and is not included in other herpetological reviews of Korea (Shannon 1956; Szyndlar 1991) or Taiwan (Mao 1971). Similarly, loggerheads are reported from the waters of Thailand (Polunin 1977; Phasuk 1982) but are "the rarest of the five Thai sea turtles" (Humphrey and Bain 1990). No documentation of sightings in Malaysia, the Philippines, FSM, Palau, Marshall Islands, Kiribati, or the unincorporated U. S. territories could be found. Among the only central North Pacific sightings are from Hawaii. There are four records from Hawaii, including two juveniles from the southeastern portion of the archipelago, a juvenile recovered from the stomach of a tiger shark at Kure Atoll (Balazs 1979), and an adult female which has recently taken up residence off Waikiki Beach, Oahu (George Balazs, NMFS, pers. comm., 1991). These individuals most likely drifted or traveled to Hawaii from Mexico to the east or Japan to the west. Similar cases of loggerheads crossing considerable distances of open ocean have been described for the Atlantic (see Life Cycle Overview below). Evidence that loggerheads inhabit the high seas of the Pacific is provided by data showing that the species is commonly caught in pelagic North Pacific driftnets (Gjernes et al. 1990; Balazs and Wetherall 1991).

Growth

Published studies of growth rates in the wild are largely confined to the western Atlantic, with the exception of Limpus (1979) who measured rates of 0.625-1.375 cm/yr and 0-0.26 cm/yr for subadults (76-88 cm initial CCL, n = 4) and adults (90.5-100.5 initial CCL, n = 4), respectively, in eastern Australia. Additional study revealed that loggerheads in eastern Australia grow, on average, ≤1.0 cm/yr (Limpus 1985). In contrast, western Atlantic values include 14.8-17.2 cm/yr CCL in southern Bahamas (23.8-24.8 cm initial CCL, n = 3) (Bjorndal and Bolten 1988a), 1.8-10.1 cm/yr (mean = 5.90 cm/yr, ca. 50-80 cm initial SCL, n = 13) in Mosquito Lagoon, Florida USA (Mendonça 1981) and, for adult females (mean = 92.0 cm SCL) measured over successive nesting seasons at Melbourne Beach, Florida, an average of 0.57 cm/yr (n = 67 females; Bjorndal et al. 1983). Zug et al. (1986) estimated growth rates in sequential size classes of loggerheads stranded on Cumberland Island, Georgia USA, from incremental growth marks in the skeleton. They concluded that mean annual growth rate varied from 11.7 cm (55-60 cm CCL size class) to 1.8 cm (95-100 cm CCL size class).

These data, admittedly scant for the Pacific, suggest that Pacific loggerheads may grow more slowly than do their conspecifics in the Western Atlantic. In all cases, growth rates decline dramatically as sexual maturity is reached. Mean curved carapace length at first breeding in Queensland is 93.0 cm (Limpus 1990).

Conservation Status

According to the Code of Federal Regulations (50 CFR 17.11), the loggerhead sea turtle is listed as Threatened throughout its entire range under the U. S. Endangered Species Act of 1973, as amended. Similarly, the species is classified as Vulnerable in the IUCN *Red Data Book*, where taxa so classified are considered "likely to move into the Endangered category in the near future if the causal factors continue operating" (Groombridge 1982). Loggerheads are included on Appendix I of the Convention on International Trade in Endangered

Species of Wild Fauna and Flora (CITES), a designation which effectively bans trade in specimens or products except by special permit. Such permit must show that the trade is not detrimental to the survival of the species and is not for primarily commercial purposes (Lyster 1985). For a summary of national legislation protecting loggerhead turtles in the North Pacific, see an earlier section of this report.

Life Cycle Overview

Eggs and Hatchlings --As summarized by Nelson (1988), egg size ranges from 35-49 mm in diameter (mean = 42 mm), average egg weight is 38.4 g, egg size does not change substantially with adult female body size, clutch size or date laid, and small, yolkless eggs 28-30 mm in diameter are occasionally deposited. Hatchlings emerging at the Mon Repos-Bundaberg rookery in Australia average 43.4 mm in length (range 39-49.6 mm, n = 837) and 20.7 g (n = 817); similarly, hatchlings from Japan average 45.8 mm (range 43-55 mm, n = 60) and 24.2 g (summarized by Márquez 1990). Ambient conditions, including temperature, moisture, and gas diffusion, are important to successful embryo development (e.g., Ackerman 1981a,b; Maloney et al. 1990). Ambient temperatures during incubation influence hatchling sex. A predominance of females are produced at temperatures >32°C, whereas males are favored at temperatures <28°C (Yntema and Mrosovsky 1982). Hatchling sex ratios shift with prevailing weather conditions over the course of a breeding season, as demonstrated in South Carolina and Georgia (USA) where 0%, 80%, and then 10% females were produced from eggs laid in late May, early July, and early August, respectively (Mrosovsky et al. 1984a; see also Mrosovsky and Provancha 1989).

Eggs hatch in about 45-65 days (mean = 60 days). An "emergence lag," averaging 5.4 days (range 4-7 days) and defined as the interval between first pipping and the mass emergence of hatchlings at the surface, has been observed (Christens 1990). Hatch success in *in situ* nests ranges from 0-100%, with a global average of nearly 75% (estimated from Dodd 1988). Hatchlings rely substantially on anaerobic metabolism during both nest emergence and subsequent rapid movement to the surf (Dial 1987). Newly hatched loggerheads are strongly influenced by certain wavelengths of light (Witherington and Bjorndal 1991a,b), which presumably aids in their sea-finding ability. In contrast, light stimuli does not appear to be important in offshore orientation (Salmon and Wyneken 1990), which seems to be accomplished using a "wave compass", whereby hatchlings continue on offshore headings by swimming into oceanic swells and wind-generated waves (Salmon and Lohmann 1989). Literature accounts of the predation of eggs and hatchlings at Pacific nesting grounds are available from Australia, and include a wide variety of invertebrates (e.g., ants, crabs), as well as fishes, reptiles, birds and mammals (Bustard 1972, 1974; Limpus 1973b, 1985; Dodd 1988).

The dispersal of loggerhead hatchlings from natal beaches in the North Pacific is unstudied. However, it is noteworthy that loggerhead hatchlings from the southeastern USA apparently enter driftlines composed of *Sargassum* and other flotsam and are transported by currents to Europe and the Azores and back before taking up juvenile developmental habitats in coastal zones of the western North Atlantic (e.g., Brongersma 1972; Carr 1986, 1987). Carr (1987) noted that during early development the young turtles are passive migrants in driftlines in the surface water of the open sea. Fletemeyer (1978) followed hatchlings from shore and documented their taking shelter in floating sargassum habitats. There is apparently ample prey available to the young turtles, both within the *Sargassum* community and in the surrounding waters. In a study of the gut contents of two Sargassum-associated hatchlings, Richardson and McGillivary (1991) reported that macroalgae and marine invertebrates accounted for about half of the items, while a third major category consisted of terrestrial insects carried by wind currents far out to sea. Sustained swimming speed in loggerhead hatchlings can be heat limited, and thus their initial dispersal (speed and direction) from the nesting beach may be partially constrained by ambient water temperatures. In laboratory tanks, swimming speeds of about 20 cm/sec were sustainable at temperatures between 25.6-28.9°C, while temperatures of 30.0-33.0°C significantly reduced this speed (O'Hara 1980).

Juveniles--No comprehensive data are available concerning distribution and abundance, growth rate, sex ratio, survivorship, habitat use, or diet for juvenile loggerheads in the North Pacific. It is likely that the transition from newborn to young juvenile occurs in the open sea and involves transpacific movement. Juvenile loggerheads present in abundance off the southwestern coast of Baja California, Mexico (see Insular and Pelagic Range) are some 10,000+ km from the nearest significant nesting beaches in Japan. In at least one case, a young loggerhead tagged and released as part of a head-start project near Okinawa, Japan, was recovered 75 km west of San Diego (32°39'N, 117°58'W) 2.3 years later (Uchida and Teruya 1988 *in* Balazs 1989). Estimates that juveniles are captured by the several hundreds per year in North Pacific high-seas large-mesh driftnets (Balazs and Wetherall 1991) only reinforce the conclusion that the normal range for this species encompasses both coastal and pelagic waters. This is the case in the North Atlantic, where hatchlings emerging on the beaches of Florida are entrained into major currents and travel across the ocean before returning to coastal USA waters a number of years later. Loggerheads found in the southeastern USA are typically <10 cm or >50 cm SCL; intermediate size classes are found in the waters of the eastern Atlantic, such as in the Azores more than 5,000 km to the east (Bolten and Bjorndal 1991). Bolten and Bjorndal (1991) documented for the first time the pelagic phase of North Atlantic loggerheads, specifying it to include turtles 8.5-65.0 cm SCL. Most turtles take up coastal residence at about 50 cm SCL, but transatlantic travel is sometimes undertaken by larger individuals (Eckert and Martins 1989; Bolten et al. 1992).

Recent data on loggerheads growing up in the Great Barrier Reef off eastern Australia indicate that puberty in females (enlargement of the oviducts to adult size) lasts four years. While first breeding may occur 2-4 years following completion of the enlargement of the oviducts, the majority of females will not ovulate the first season of vitellogenesis. Most will ovulate following their second season of vitellogenesis, 2-3 years following the first. Thus, approximately a decade will pass for the average large immature female from the time her oviducts commence to enlarge until her first ovulation. The average female does not recruit to the breeding population at the minimum breeding size. Rather, the average female recruits at a size slightly smaller than the average breeding size for the entire population (Limpus 1990). There are no comparable data for juvenile males.

Adults--Frazer and Ehrhart (1985) fitted growth data for Florida loggerheads to both logistic and van Bertalanffy curves. They estimated age at sexual maturity to be 12-30 years, based on the size of the smallest female (74 cm SCL) and the mean size of all nesting females (92 cm SCL), and predicted that the upper estimate was the more realistic indication of mean age at first maturity. Comparable data are not presently available for populations in the North Pacific, but it is likely that Pacific individuals mature at a later age since juveniles appear to grow more slowly in Pacific waters (see Growth Rate). Upon maturity, females migrate at (typically) multiple year intervals to suitable nesting beaches. Individuals have been shown to return faithfully to the same nesting area over many years, a trait which presumably characterizes the entirety of their reproductive lives. Beyond the predictable return of gravid females to established nesting beaches and recent studies of inter-nesting behavior in the western Pacific (Limpus and Reed 1985; Sakamoto et al. 1990a,b; Naito et al. 1990), little is known of the larger issues of fecundity, sex ratio, survivorship, age class distribution, foraging range, longevity, the timing and routing of migration, etc. Virtually nothing is known about the behavior or movements of adult males, especially during the non-breeding season. Diet is discussed under Insular and Pelagic Range.

Green Sea Turtle (complex), *Chelonia mydas*

Taxonomy

The generic name *Chelonia* was introduced by Brongniart (1800). The specific name *mydas* was first used by Linnaeus (1758). The genus *Chelonia* is generally regarded as comprising the single species *C. mydas*, often with two distinct subspecies recognized: *C. m. agassizii* (Bocourt 1868) in the eastern Pacific from Baja California south to Peru and west to the Galapagos Islands, and the nominate *C. m. mydas* (Linnaeus 1758) in the rest of the range. Nonetheless, there is considerable confusion in the literature on this point, with some arguing the *agassizii* form, or so-called black turtle, deserves specific rank. A thoughtful analysis is provided by Groombridge and Luxmoore (1989), who conclude their discussion by quoting Hirth (1971): "it is best to use the binomial, *Chelonia mydas*, for all green turtles until a detailed taxonomic study is made." In light of mounting genetic evidence suggesting that *agassizii* warrants neither specific nor subspecific rank (see Population Units), the genus *Chelonia* will be considered monotypic for the purposes of this report. The ultimate resolution of the taxonomic question is important to the management of the *Chelonia* complex in the Pacific basin.

Morphology

The description below was taken from Carr (1952). The genus *Chelonia* is readily distinguished from other sea turtle genera by a single pair of prefrontal scales, four pairs of lateral scutes, and five vertebral scutes. The carapace is broad, low, and more or less heart-shaped; it is smooth, without keels, and the scutes are placed side by side (as opposed to imbricated as in the hawksbill). The shell color is light to dark brown, sometimes shaded with olive, with radiating wavy or mottled markings of darker color or with large blotches of dark brown. The plastron is whitish to light yellow. The scales on the upper surface of the head are light brown in the center and the spaces between them are yellow; those on the sides of the head are also brown but with broad yellow margins, giving a yellow cast to the temporal region. The neck above is dusky; below and near the shell it is yellow. The upper surface of the legs and tail are colored like the shell above and are yellowish white beneath, sometimes tinged with green, and darker near the tips. The east Pacific race, or black turtle, can be differentiated by the predominantly brown, dark gray, or black ground color of the carapace and skin and a slightly different conformation of the carapace, which is higher, narrower, and more constricted over the hind limbs. Considerable gray or black pigment infuses the plastron.

Mean hatchling carapace length varies among populations from 46.9 mm (South Yemen) to 54.0 mm (northeast Australia); similarly, mean body weight ranges from 21.6 g (Comoros, French Polynesia) to 31.0 g (Hawaii) (summarized by Márquez 1990). According to Carr (1952), the carapace and upper limb and head surfaces are dark brownish in hatchlings, while the central keel and the feeble, discontinuous ridges across the laterals are light tan. Margins of the shell and limbs are edged with white, as are the head scales in some specimens. The under surfaces are white except for the terminal areas of the flippers, which are black edged with white. A pair of keels extends down the plastron on either side of the median line. As for the black turtle, the color above is grayish black except for yellowish distal and posterior borders of the flippers and shell edges. Below, the color is even yellow except for the central flipper surfaces, which are grayish black. Development is presented in Miller (1985). Albinism is reported from Sarawak (Harrisson 1963).

Sexual dimorphism is present in adult animals, with the shell of the mature male being more elongate and more gradually tapered behind. The tail of the male is very long (extending 22.5 cm beyond the carapace margin in an example cited by Carr 1952), strongly prehensile in the vertical plane, and tipped with a heavy, flatten scale. A single claw on each flipper is markedly enlarged and strongly curved for grasping the edge of the shell of the female. Recent data from the central Pacific corroborate Carr's earlier observations. Balazs (1980) reported that adult males in Hawaii have a 35-45 cm long prehensile tail that extends beyond the rear flippers when swimming; in contrast, an adult female's tail ranges from 20-25 cm in length. It is generally, but not universally, possible to determine sex on the basis of these external characteristics in turtles >65 cm carapace length (Balazs 1980).

Adult green turtles average 97.3 cm CCL (range 85.1-113.0, n = 415) in Hawaii (Balazs 1980), 99.5 cm CCL at Baguan Island in the Philippine Turtle Islands (Trono 1991), and 104 cm CCL (range 93-117, n = 27) at Olimaroa Atoll, Yap (Kolinski 1991). Adult females range in carapace length (measured both SCL and CCL) from 80-113 cm in Sarawak, Eastern Malaysia (n = 200+, estimated from graphs in Hendrickson 1958 and Leh 1991). Females <90 cm CCL are "rarely recorded nesting" on Heron Island, Australia, and an average sized nesting female measures 107 cm CCL (Limpus and Walter 1980). In the eastern Pacific, black turtles nesting in Michoacán, Mexico, average 82 cm CCL (range 60-102, n = 718) (Alvarado and Figueroa 1990). Similarly, the mean carapace length of 73 females nesting at Playa Naranjo, Costa Rica, was 82.9 cm SCL (range 73-97, n = 73) (Cornelius 1976). Márquez (1990) noted that of mature and immature black turtles captured in the Gulf of California, females averaged 74.6 cm CCL (range 59-107, n = 171) and males averaged 80.9 cm CCL (range 60-99, n = 49). Carapace length-body weight relationships are presented by Caldwell (1962a) for the black turtle in the Gulf of California.

Population Units

As explained in the section entitled Taxonomy, there is controversy over the taxonomic status of the east Pacific green turtle *(C. m. agassizii* Bocourt 1868). On the one hand, clear morphometric differences exist between the dark pigmented and diminutive *agassizii* form in Mexico and the larger *mydas* form in Costa Rica using principal component analysis (Figueroa and Alvarado 1990). On the other hand, light colored *C. m. mydas*-type turtles can be observed nesting at major east Pacific rookeries (Carr 1961; Pritchard 1971a) and dark pigmented *C. m. agassizii*-type turtles occasionally occur at Indian Ocean rookeries (Carr 1975; Frazier 1971). Given the widespread distribution of the dark morphotype, it is not surprising that three independent lines of genetic evidence do not support the evolutionary distinctness of *C. m. agassizii* from *Chelonia* populations in other regions of the Pacific Ocean or the world (Bowen et al. 1992; Karl et al. 1992; Bowen et al. 1993b). The question of species rank ultimately must be resolved by taking both these lines of reasoning into account; that is, both morphometric and genetic aspects. In the meantime, nesting aggregates in the east Pacific should be managed and conserved as distinct population units (especially since mtDNA data indicate that all *C. mydas* nesting populations are isolated on a regional or rookery-specific level).

With regard to the globally distributed *Chelonia* complex, distinct mtDNA genotypes characterized most nesting beaches surveyed in an analysis of 226 specimens from 15 rookeries worldwide, indicating that green turtle nesting beaches in general constitute isolated reproductive units (Bowen et al. 1992). Bowen et al. (1992) found a fundamental phylogenetic split distinguishing all rookeries in the Atlantic-Mediterranean from those in the Indian-Pacific Oceans, as well as geographic population substructure within the Pacific basin. Several Pacific nesting colonies, including French Frigate Shoals in Hawaii and the Ogasawara (=Bonin) Islands in Japan, contain unique mtDNA genotypes not observed elsewhere in the world. Preliminary evidence indicates that distinct population units are also associated with major archipelagoes outside the purview of the present report, including French Polynesia and the Galapagos, as well as with mainland rookeries in Oman and Queensland, Australia. Nest site philopatry is high in green turtles, and is presumably what maintains observed population structure. Bowen's research validates to a large extent the conventional view that sea turtle "populations" are composed of genetically distinct subregional nesting aggregations, and suggests that management and conservation should proceed with an intent to conserve as many individual rookeries as possible.

Nesting Habits and Areas

Eggs are deposited seasonally on tropical sandy beaches at both mainland and island sites. Mating precedes egg-laying by 25-35 days (summarized by Owens 1980). Gravid females typically nest nocturnally, acting out an instinctual sequence which involves crawling onto the beach, selecting a nest site, preparing a body pit, digging a nest chamber, egg laying, covering the eggs, camouflaging the site, and returning to the sea (Hendrickson 1958; Hirth 1971). The entire sequence generally consumes 60-90 minutes (Cornelius 1986). Reproductive statistics for the well-studied population at French Frigate Shoals, Hawaii (ca. 23°N, 166°W), are as follows (from Balazs 1980). Clutch size averages 104 eggs (range 38-145, n = 50 nests), with larger females laying significantly (P<0.05) more eggs per clutch. Females return to re-nest at mean intervals of 13.2 days (range 11-18, n = 89 records) and remain in close proximity to the nesting grounds during this time, sometimes hauling out onto the beach to bask during the day. Nesting commences in mid-May, peaks in late June, and tapers off in August. As many as six clutches may be laid in a season (mean = 1.8, n = 208 turtles). Eggs incubate for 54-88 days (mean = 64.5 days, n = 38), calculated from oviposition to hatchling emergence from the nest. The most common remigration interval is two years, with a secondary peak at three years and uncommon intervals of more than three years. In contrast, 56.2% of the males studied returned to the breeding grounds on one-year cycles. Nesting beach fidelity is high, with <5% of females depositing clutches on multiple islands intra-annually.

With the exception of clutch frequency, similar data are reported from a 1950s study of green turtles nesting at the Sarawak Turtle Islands (ca. 2°N, 110°E). Gravid females were observed to lay up to 11 times per season at average intervals of 10.5 days (range 8-17 days, n = 4,493 records). Clutch size varied from 3-184 eggs (mean = 104.7 eggs, n = 8,147 nests). Incubation periods ranged from 48-80 days (n = 328), with seasonal variation in mean incubation time assumed to be a function of ambient temperature. Again, a pronounced homing ability was observed. Of 5,748 records of females returning to the beach to lay after an average absence of about 10 days at sea, only 215 (3.7%) changed islands, with the great majority of these shifting between the two Talang Talang Islands which are <500 m apart (Hendrickson 1958). Recent data from Baguan Island Marine Turtle Sanctuary, Philippine Turtle Islands, indicate a mean inter-nesting interval of 14.5 days (n = 74 records), mean clutch size of 95.6 eggs (n = 146 nests), mean incubation of 54.3 days (n = 146), and a mean remigration interval of 2.5 years (n = 24 records); annual clutch frequency was not reported (Trono 1991). In the Xisha Islands, China, females lay three times per year at intervals of about two weeks; incubation is generally 40-50 days (Chu-Chien 1982). At well-studied Australian rookeries, females deposit an average of 5.5 clutches per breeding season (Limpus 1980a).

In the eastern North Pacific, at Playa Naranjo, Costa Rica, black turtles nest at least twice and perhaps as many as six times during a nesting season, usually at 14 day intervals. The peak nesting months are October-March, but occasional nesting occurs in all months of the year; females may nest in consecutive years (Cornelius 1986). Mean clutch size at Playa Naranjo is 87 eggs (range 65-107, n = 10 nests) (Cornelius 1976). At Michoacán, Mexico, black turtles deposit an average of 2.5 clutches per season (range 1-7) at 12-14 day intervals. Clutch size averages 65 eggs (range 1-130, n = 916 nests). Preliminary radio-tracking data suggest that females remain in the vicinity of the nesting beach throughout the breeding season. Nesting beach fidelity is high. According to Alvarado and Figueroa (1990), the turtles arrive as early as August and may stay as late as January. These authors document mating in waters offshore the nesting beach at Colola (Michoacán) and describe courtship as consisting of five phases: male searches for and detects potential female mate, male examines female visually, male makes physical contact with female, female accepts or rejects the male, acceptance is followed by mounting and intromission. In contrast to other populations where females do not engage in mating once egg-laying has commenced (e.g., Australia: Booth and Peters 1972; Hawaii: Balazs 1980), mating has been described both prior to and between successful bouts of egg-laying at the Michoacán rookery (Alvarado and Figueroa 1990). Reviews of the reproductive physiology of both males and females are available from Owens (1976, 1980) and Licht et al. (1980, 1985).

Nesting areas are distributed throughout the eastern, central and western Pacific Ocean, with the most important areas in the North Pacific being Mexico, USA (Hawaii only, there is no nesting on the U. S. Pacific mainland), Palau, the Philippines, and Malaysia. The only major nesting sites for the black turtle in North America are two nearly adjacent beaches at Maruata Bay and Colola, Michoacán, Mexico (18°N, 103°W). The black turtle in Michoacán is an example of a formerly abundant resource which was utilized at a subsistence level for centuries, but which is now in peril because of commercial exploitation. Native Nahuatl Indians claim that nesting was 10-20 times higher in 1970 than in 1977, with an estimated 25,000 females nesting at Colola annually (Cliffton et al. 1982). In the late 1960s an estimated 500-1,000 females nested nightly in Colola during peak season; today that number has dropped to 60-100, or about 800-1,000 turtles per year. In the 1960s and 1970s, foreign markets for skin and leather and an expanding national market for sea turtle products brought settlers to the coast and "heavy exploitation of both adults and eggs resulted in a black turtle population collapse" (Alvarado and Figueroa 1991). From 1981-1987, an estimated 940 to 5,586 females nested throughout the state of Michoacán. Post-nesting dispersal is both to the north and to the south, spanning >5,000 km (Alvarado and Figueroa 1990). Nesting also occurs on the Islas Revillagigedos, Mexico (Brattstrom 1982; Awbrey et al. 1984) and along the Pacific coast of Central America (summarized by Cornelius 1976, 1982); quantitative data are largely unavailable.

Green turtles are distributed throughout the Hawaiian archipelago, but >90% of all nesting (100-250 females/yr) occurs at French Frigate Shoals, a 35-km long crescent-shaped atoll situated in the middle of the archipelago. Small groups of turtles and separately nesting individuals using Laysan and Lisianski Islands and Pearl and Hermes Reef account for the remaining reproductive effort, with a "few" nestings recorded at Kure and Midway (Balazs 1978a, 1980). Courtship and copulation usually take place in shallow waters adjacent the nesting beach; in the case of French Frigate Shoals, within 2 km of the 11 small islands of the atoll and generally during the early portion of the breeding season (mid-April to early June). Nesting is reported from mid-May to as late as mid-September, with a peak in June. Tag returns indicate that turtles migrate to the nesting grounds at French Frigate Shoals from resident foraging areas to the southeast (the main islands) and to the northwest (Laysan and Lisianski Islands, Pearl and Hermes Reef), sometimes traveling more than 1,000 km one-way. Mating is thus occurring between males and females that live in areas separated by as many as 2,150 km (Balazs 1980). Tag recovery data from 87 males and 207 females over a period of 18 years indicate that Hawaii-tagged adults have never been recaptured outside the Hawaiian archipelago (Balazs 1983b).

A low level of nesting has been recorded at a few unincorporated U. S. territories in the North Pacific. On the Midway Islands, a single occurrence of nesting on Sand Island and a single occurrence of basking on Eastern Island have been recorded. Similarly, some nesting may occur on Sand Island, Johnston Atoll, but this has not been confirmed (Balazs 1978a). There are no recent reports of nesting at Palmyra Atoll, Kingman Reef, or on the islands of Howland, Baker, Wake, or Jarvis, although in the latter case low density nesting was recorded along the west coast in the 1930s (Balazs 1982a). In the Northern Mariana Islands and Guam, green turtles are said to nest only "sporadically" and turtle meat is rare in the markets (Pritchard 1982a). In Guam nesting has been recorded on beaches at the north end of the island, including Tarague Beach and the Naval Facility area, and at a few isolated sites in the east and south; <10 nests were recorded per year from 1980-1986 (H. Kami, *in litt.*, October 1986 to Groombridge and Luxmoore 1989). In 1991, as of 1 August, one nest was reported from Nomna Bay which hatched in mid-July, two from Turtle Cove (one hatched 27 July), one near Andersen Air Force Base, and 4 in the Tarague area (Gerald Davis, Guam DAWR, *in litt.*, 22 August 1991).

Palau, the westernmost island group in Micronesia, may be among the most important green turtle nesting areas in Oceania. Pritchard (1977) estimated that a maximum of several dozen turtles nested nightly at the southern islands of Merir (4°19'N, 132°19'E) and Helen Reef (3°00'N, 131°50'E) at the time of his report. In contrast, an estimated six nests (range 2-11) were laid per night at Merir Island and there was "virtually no nesting" on the islands of Helen Atoll during peak season (mid-June) in 1992 (Jim Maragos, The Nature Conservancy, pers. comm., 1992). The persistent harvest of turtles and eggs by residents and supply ship crews has been implicated in the loss of the nesting population at Helen. Earlier investigations reported nesting on the islands of Ngaruangl, Pelelieu, Tobi, Sonsorol, and Pulo Anna (Pritchard 1982a; Johannes 1986), but today there is little if any nesting at Tobi, Sonsorol, Pulo Anna, or Fana (J. Maragos, unpubl. data).

Elsewhere in Micronesia (Yap, Tuk [Chuuk], Pohnpei, Kosrae), low density nesting appears to be restricted to small uninhabited islands and atolls, including Oroluk, Pikelot, East and West Fayu, Gaferut, Ngatik, Nukuoro, Mokil, and Pingelap (Pritchard 1982a; Herring 1986; McCoy 1982). Carr (1965) cited nesting on Ujelang. Naughton (1991) considered Oroluk Atoll in Pohnpei State to be the most important area for green turtles in the Eastern Caroline Islands since it supported both nesting and foraging turtles, the latter of varying size classes. However, recent surveys indicate that nesting has declined considerably at Oroluk from an estimated average of 9-15 nests per night (Pritchard 1977) to an observed average of 2.3 and 3.4 nests per month (May-August) in 1985 and 1986, respectively (Edson and Curren 1987). Taken together, dramatic declines at Merir, Helen and Oroluk, once among the most important nesting areas in Oceania, illustrate the serious plight of this species in the region. Declines are also reported at major rookeries in the Philippines and Malaysia (discussed below).

Nesting by green turtles in the Republic of the Marshall Islands is concentrated on uninhabited islands, but limited nesting is widespread on the more remote and uninhabited islets of larger inhabited atolls (Johannes 1986). Bikar Atoll (12°N, 170°E), one of the northernmost Marshallese territories, is generally thought to have the highest concentration of nesting green turtles in the Republic, with Bikini and Taongi Atolls ranked second in importance (Pritchard 1982a). In late June 1971, Hendrickson (*in* Pritchard 1982a) reported 34 green turtles nesting on Bikar Islet in six days. In a more recent survey, Bikar "exhibited signs of intensive nesting activity" (Thomas 1989). A brief survey (20 May 1992) of nesting beaches on Loj, Enego, and Erikup islets in Erikup Atoll revealed numerous campsites with large piles of turtle bones and other turtle remains, as well as 26, 81 and 98 nesting pits, respectively (Eckert 1992). Based on interviews with turtle fishermen at Wotje Atoll, Eckert (1992) reported that nesting has declined by as much as 50% in some areas over the last decade and is attributed solely to over-harvest. Nesting is also reported on Canton and Enderbury Islands, northernmost of the Phoenix Islands, in Kiribati (Balazs 1978a) where "a fairly large number of [green turtles] may be involved" (Balazs 1975). Kiribati's Line Islands also support nesting; harvest is ongoing (Balazs 1982a).

In the Philippines, the principal nesting sites are on the Turtle Islands (Tawi Tawi Province), a group of islands shared with Sabah in the southern Sulu Sea. Nesting once occurred elsewhere in the Sulu Sea, such as on the islands of Cavili, Arena, Lumbucan, and Bancoran (Martin 1952-53 *in* Hirth 1971) and still occurs on the islets of Tubbataha Atoll, now a Marine Park, where 14 nests were observed in May 1991 (Louella Dolar, Silliman Univ., pers. comm., 1993). Today populations have greatly declined and remain in significant numbers only around the Turtle Islands of Baguan, Taganak, and Langawan. The second most important green turtle rookery is reportedly the San Miguel Islands (7.8°N, 118.5°E). Although information is sparse, some additional nesting is likely to occur widely within both the Palawan and Sulu Archipelagoes, as well as in southern Negros (summarized by Groombridge and Luxmoore 1989). From 1984-1989, 4,116,710 green turtle eggs were protected out of a total reported production of 6,727,400 eggs at Baguan Island Marine Turtle Sanctuary (Trono 1991), indicating an annual average of >2,000 nesting females. Trono (1991) also reports "high density green turtle nesting" at Bancauan Island, also in Tawi Tawi Province. On the Malaysian side of the border, Sabah Turtle Islands Park (comprised of Pulau Selingaan, Pulau Bakkungan Kechil, and Pulau Gulisaan) received an annual average of 2,680 green turtles (1984-1988; J. Mortimer, WWF-Malaysia, *in litt.*, 29 August 1991). Nesting occurs year around, with 64% of nests laid July-December and the balance January-June (data courtesy Sabah Parks).

Elsewhere in Sabah, green turtles nest at Pulau Sipadan, where the population has declined over the last four decades as a result of the over-exploitation of eggs ("almost every egg clutch laid is harvested"); an estimated 1,360-1,740 females nested in 1990 (Mortimer 1991a). The green turtle is also recorded from the Turtle Islands of western Sarawak (Talang Talang Besar, Talang Talang Kecil, and Satang Besar), where nesting occurs throughout the year with a peak in July-October. The nesters are believed to be migrants, as there are no feeding grounds around these islands (Leh 1985). Between January 1971 and December 1975, 11,726 green turtles came ashore to lay 1,194,391 eggs on the Sarawak Turtle Islands (Chin 1975), whereas prior to 1960, one- to more than three-million eggs were routinely collected from this area annually (Banks 1986). The ten-fold decline is suspected to have been precipitated by persistent egg collection, harassment on the nesting beach, increased trawling activity, marine and land-based sources of pollution, increased oceanic traffic of transport vessels, the slaughter of turtles outside the territorial waters of Sabah, and bright lights along the coast (Chin 1975; de Silva 1982; Leh 1991). Mortimer (1991a) concludes, "Unless egg harvest is stopped soon, the nesting population is doomed to extinction, and with it will go most of the turtles now seen in the waters offshore. The majority of the green turtles encountered underwater are members of the ... breeding population."

In peninsular Malaysia, nesting is relatively uncommon on the west coast (Groombridge and Luxmoore 1989). Nesting is reported from the States of Kelantan (rare), Terengganu, Pahang, and Johore on the east coast, where an estimated 401,400 eggs were collected per annum at the time of Siow and Moll's (1982) paper, mostly from Terengganu. Most nesting in Terengganu occurs on the offshore island, Palau Redang, where "virtually every egg" has been collected for at least two decades and perhaps much longer (Mortimer 1989). Other significant areas are the beaches on both sides of the Terengganu-Pahang border, as well as the islands offshore. Green turtles begin nesting on mainland beaches as early as January and finish in October, with a peak in May-July (Leong and Siow 1980). Population estimates do not appear to be available. Several hatchery projects are now in place throughout Malaysia in an attempt to conserve remaining stocks. Nesting is also reported to the north in Thailand, where activity peaks June-August. Egg harvest is widespread and efficient, but several Thai Provinces have implemented hatchery programs as a conservation measure (Phasuk 1982). The major nesting site on the east coast (Gulf of Thailand) is Ko Kram; Ko Kra off Nakhon Si Thammarat and other beaches in the Gulf are also used. West coast nesting is reported from the Provinces of Satun, Phuket, Phangnga, and "other suitable sites". East coast nesting peaks in June, west coast nesting peaks December-January and incubation is 45-60 days (Humphrey and Bain 1990).

Green turtles were considered "common" all around the coastline of the former French colonies in Indochina, which would include modern Kampuchea and Viet Nam, at the time of Bourret's (1941) paper.

Nesting appeared to have been mainly limited to the offshore islands, notably off the west coast of "Cochin China". Cochin China seems likely to refer in part to islands and waters now within Kampuchean territory, but largely to islands, including Quan Phu Quoc, now in Vietnamese territory. The Poulo Wai Group is the only nest site specifically named in the literature, and seems likely to be the same as the Ko Way Group, situated in the northeast Gulf of Thailand some 60 km from the coast of Kampuchea (summarized by Groombridge and Luxmoore 1989). The present status of these populations is unknown. Mao (1971) stated that green turtles had been captured in the waters of Taiwan, but nesting sites were not specified. Kamezaki (1989) surveyed 19 beaches on Taiwan in July 1988 and found no evidence of nesting. Chu-Chien (1982) and Frazier et al. (1988) specified the Xisha Islands (=Paracel Islands; ca. 16°N, 113°E) as the green turtle's main breeding ground in China. From fishery statistics, Groombridge and Luxmoore (1989) estimated that nesting numbers were perhaps in the low hundreds per annum. Mating is "often observed" during January-April and the nesting season extends from April to December, with a May-July peak. Nesting is sporadic and of little significance on Hainan Island and on the mainland, with the exception of Huidong County where the nesting beach (22°33'N, 114°54'E) was declared a Nature Reserve in 1984. In 1985 and 1986, 87 and 122 green turtles, respectively, nested at the Reserve (Zhou Kaiya, Nanjing Normal Univ., *in litt.*, 8 May 1991). Numerous local informants reported to Frazier and Frazier (1985) that significant nesting once occurred at several sites in China, but today these turtles are gone. Over-fishing and habitat loss were implicated.

Green turtles nest exclusively in the southern islands of Japan to about 30°N (Yakushima, Kagoshima Prefecture, is the northernmost nesting site recorded), both in the Ryukyu Archipelago and the Ogasawara Group (=Bonin Islands; 25°-27°N, 142°E) (Uchida and Nishiwaki 1982). The Ogasawaras, where nesting has been confirmed on the islands of Chichijima and Hahajima and may occur more widely, is believed to be the most important site. However, the numbers of green turtles have greatly declined there and today about 200 females nest per year (Kurata 1979; Suganuma 1985). Nesting occurs during May-August (Tachikawa and Suganuma, *in litt.*, 19 December 1986 to Groombridge and Luxmoore 1989). Kamezaki (1989) surveyed 122 beaches on the Amami, Miyako and Yaeyama Island groups (24°-29°N) in the Ryukyu Archipelago from 1983-1986 and found 115 green turtle nests on 20 beaches. These included the islands of Kakeromajima and Ukejima in the Amami Group, Ikemajima Island in the Miyako Group, and the islands of Ishigakijima, Iriomotejima, Kuroshima, Haterumajima, and Yonagunijima in the Yaeyama Group. Of these, 97 nests (84.3%) were recorded from Iriomotejima at the southern terminus of the archipelago, of which 89 nests were observed on four beaches along the southern coast; the number of nests laid per annum fluctuated among years. Few data are available, but it seems that nesting does not occur in Korea (Shannon 1956; Won 1971).

Insular and Pelagic Range

During warm spells, sea turtles, like many other tropical species, may be found considerably farther north than might otherwise be expected (Hubbs 1960; Radovich 1961; Stinson 1984). This is certainly true for green turtles, which are on rare occasions sighted as far north as Eliza Harbor, Admiralty Island, Alaska (57.16°N, 134.15°W) (Hodge 1981) and Ucluelet, British Columbia (48.15°N) (Carl 1955). Adult and juvenile green/ black turtles (typically reported as green turtles) have also been reported either from gill nets or from beach strandings as far north as 47° (Copalis Beach area, data courtesy Washington Dept. Game). Stinson (1984) reviewed sighting records from northern Baja California, Mexico (29°45'N) to the Gulf of Alaska and concluded that *Chelonia mydas* was the most commonly observed hard-shelled sea turtle on the western coast of the USA; 62% of green turtle sightings were reported from northern Baja California and southern California. One or two green turtles are caught in the intake at San Onofre Nuclear Generating Facility per year; two subadults 24 and 25 cm SCL were caught in September 1990 and released in good condition (Kevin Herbinson, S. Calif. Edison, pers. comm., 1990). Perhaps the northernmost resident green turtles in the eastern Pacific reside in San Diego Bay, where a small population (20-30?) of mature and immature turtles appear to favor the warm effluent discharged by the San Diego Gas and Electric Company power plant (Stinson 1984; Dutton and McDonald 1990).

In Hawaii, mixed aggregations of adults and immature animals (>35 cm SCL) reside in coastal waters throughout the archipelago where they feed on several species of benthic algae (Balazs 1980, 1982a). Pelagic waters are also important. In August 1992, three adult females were satellite-tracked during the return migration from nesting at French Frigate Shoals. Two traveled to Oahu and one to Johnston Atoll. All avoided island-to-island routes, choosing instead to traverse exceedingly deep, featureless water and generally against prevailing winds and currents (NMFS 1993). Elsewhere under U. S. jurisdiction, dense patches of sea grass provide potential foraging habitat in the Northern Mariana Islands (Pritchard 1982a), but green turtles play a small role in island diet and may be relatively rare (Johannes 1986). The species is known to occur in the waters of Guam (the southern terminus of the Marianas) during all months of the year, although not in great abundance (Pritchard 1982a). During October 1989-April 1991 aerial surveys of Guam, 65.8% of the 76 turtles sighted were identified as green turtles (Gerald Davis, Guam DAWR, *in* *litt.*, 22 August 1991). In the unincorporated U. S. island territories, both mature and immature turtles are "regularly observed" foraging in the shallow waters surrounding Johnston Atoll and Wake Island; foraging is also reported at Palmyra Atoll. There are reports of turtles being "abundant" around Howland and Baker Islands in the 1930s, but current population status is not known (Balazs 1982a). Three adults (two females, one male) tagged at Johnston Atoll were later sighted at French Frigate Shoals, some 830 km to the north; the females were nesting (Balazs et al. 1990). Finally, green turtles are common in Palau and are most often encountered in the northern and southern extremes of the territory, rather than in the Palau Lagoon (Pritchard 1982a). The lagoon at Helen Atoll is an important feeding area with a "very large" resident population of juvenile and adult green turtles (Jim Maragos, The Nature Conservancy, pers. comm., 1992).

Eastern Pacific records of this species south of the USA are typically reported as "black turtles". They are widely distributed in the waters of Mexico and Central America (e.g., Caldwell 1962b; Hirth 1971; Cliffton et al. 1982; Cornelius 1976, 1982, 1986; Groombridge and Luxmoore 1989; Alvarado and Figueroa 1989, 1990) and are known to hibernate in bottom sediments of the Gulf of California, Mexico (Felger et al. 1976; King 1982). Tag returns establish that the turtles travel long distances between foraging and nesting grounds. One turtle tagged in October 1985 at the nesting beach in Michoacán, Mexico, was recovered in October 1986 at El Faro, Charambira, Colombia, some 3,160 km away. Seventy-five percent (44/58) of tag recoveries from 1982-1990 were from turtles that had traveled more than 1,000 km from Michoacán. The recaptured turtles were taken from coastal waters both purposefully (gill nets, spears) and incidentally to other fisheries (gill nets, trawls); shrimp trawling may be a major source of mortality (Alvarado and Figueroa 1990). The species is not confined to coastal waters, as indicated by 1990 sightings records from the NOAA research vessel *Surveyor* which documented green turtles 1,000-2,000 statute miles from shore (e.g., 9°42'N, 120°04'W; 11°31.1'N, 124°51.7W; 13.03.6°N, 128.18.04°W; data courtesy NMFS). The southernmost record appears to be from Chile, where a carapace was found on Guarello Island in the Madre de Dios archipelago (about 50°S) and another on the island of Navarino (50°S, 67°50'W) (Chandler 1991).

In the western North Pacific, green turtles are reported from the waters of Korea at Paeka, offshore the west coast Province of Kyonggi Do (Keiki Do), by Doi (1936 *in* Shannon 1956) and near Backa Island, Inchon (Won 1971). In Japan, sightings are mostly around the main island of Honshu with fewer records in the southern Ryukyu Islands (Uchida and Nishiwaki 1982). Green turtles are migratory in Japan, being found in the Ogasawaras (=Bonin Islands), for example, only between February and September. Turtles tagged in the Ogasawaras have been recovered mainly on the Pacific coast of the Japanese Archipelago, and this may constitute their main foraging grounds (Kurata 1979 *in* Groombridge and Luxmoore 1989). In Taiwan, green turtles are most often captured in December and January, whereas they are "very rare" June-September. The meat is (or at least was) commonly used as food and products such as medicine and soap were made from body parts. The turtle can be caught at "various parts" along the Taiwan coast, and is (or was) "especially common" around the port city of Nanfangao (Mao 1971).

According to Groombridge and Luxmoore (1989), green turtles occur widely in Chinese waters from Shandong Province in the north to Guangdong Province in the south, also around Hainan Island and the Dongsha, Xisha (=Paracel) and Nansha island groups. However, Zhou (1983) did not mention this species in his review of turtles caught by local fisheries in Jiangsu Province, an area south of Shandong Province. Frazier et al. (1988) examined 130 specimens, mostly adults (80-108 cm CCL), although juveniles as small as 20.0 cm CCL were included. Specimens were collected during April-October and were mostly (79%) recorded from the Xisha Islands and Hainan Island in the south/ southeast; the remainder were from elsewhere in the Guangdong (5%) and Fujian (16%) Provinces. While sea turtles (presumably including green turtles) can be seen around the Xisha and Nansha Islands year around, at least some of the green turtles in China are known to be migratory (Chu-Chien 1982). Important feeding grounds have not been identified.

Recent data from the waters of Viet Nam could not be located; however, there is historical evidence that green turtles were "common" all around the coastline of the former French colonies in Indochina, which would include modern Viet Nam and Kampuchea (Bourret 1941). In Thailand, green turtles are reportedly the most common sea turtle in the Gulf of Thailand (Phasuk 1982; Humphrey and Bain 1990). It is not clear whether these animals are resident or itinerant. No extensive sea grass meadows are known in Thai waters, but Polunin (1975 *in* Humphrey and Bain 1990) reported that possibly there were grasses along the west coast of Ko Samui in the Gulf, as well as Makan Bay and Chalong Bay, Phuket Province, on the western Thai coast (Andaman Sea). Green turtles are present in the waters of Western Malaysia, as indicated by incidental capture data from Terengganu; estimated annual catch in trawl and drift/gill nets is 245 and 100, respectively (Chan et al. 1988). In Eastern Malaysia, feeding areas occur all along the Sabah coastline (Jeanne Mortimer, WWF-Malaysia, *in litt.*, 29 June 1991). Green turtles reportedly "abound" offshore Pulau Sipadan (Mortimer 1991a) and foraging may occur around Palau Tiga Park (Mortimer 1991b). In Sarawak the species is believed to be a reproductive migrant, as there are no known feeding grounds around the mainland or the Talang Talang islands (Hendrickson 1958; Leh 1985, 1991).

Green turtles are widely distributed but declining in the Philippines (summarized by Groombridge and Luxmoore 1989). Foraging is likely to occur in the vicinity of the Turtle Islands, which are rich in suitable lagoons and aquatic vegetation. Fourteen of 16 international tag returns from green turtles tagged while nesting in the Sabah Turtle Islands have been from the Philippines, some individuals having traveled >1,000 km (de Silva 1986). General accounts of the occurrence of green turtles in Micronesia are found in McCoy (1974, 1982), Pritchard (1977, 1982a), and Johannes (1986), but precise data on the distribution and abundance of populations in this vast region are not available. Both juveniles and adults forage around the high volcanic islands (M. McCoy, *in litt.*, 24 August 1988 to Groombridge and Luxmoore 1989) and Oroluk Atoll in Pohnpei State is a regionally important feeding area (Naughton 1991). Some information on the distribution of nesting on the islands and atolls of the Marshall Islands is available (e.g., Pritchard 1982a; Johannes 1986), but systematic data on the occurrence, seasonality, and size distribution of turtles offshore are lacking. Green turtles are "seen regularly but are not numerous" at Enewetak Atoll and are rare at Arno Atoll (Johannes 1986). In a recent survey of the Marshall Islands, green turtles were encountered at Taka, Rongerik, and Erikub Atolls (Thomas 1989). Green turtles forage throughout Kiribati; details are not available.

Growth

The mean growth rates of immature green turtles (37-59 cm SCL) occurring at seven resident areas in the Hawaiian Archipelago ranged from 0.08-0.44 cm/month [=0.96-5.28 cm/yr]. Growth increments in larger turtles were occasionally imperceptible; a 68 cm subadult from French Frigate Shoals showed no increase in SCL after an interval of 20 months. Growth typically slows upon reaching maturity, as evidenced by an average growth rate of 0.04 cm/month [=0.48 cm/yr] (range 0.01-0.12 cm/mo) among 17 females and one male returning over multiple years to the breeding grounds at French Frigate Shoals (Balazs 1980). Balazs (1980, 1982b) speculated that differences in growth rates measured for mature turtles may reflect sources and abundance of food at the resident area, and provided preliminary corroborative data. Few growth data are available outside of Hawaii in the Pacific Ocean. Immature wild green turtles (60-90 cm CCL) resident in the vicinity of Heron Island, Australia, exhibit a mean annual growth rate of 1.35 cm/yr, indicating that the average turtle requires 23 years to attain a minimum breeding size of 90 cm from a size of 60 cm CCL (Limpus and Walter 1980). Somewhat faster rates of growth are reported from the Western Atlantic (for review, see Frazer and Ladner 1986; Boulon and Frazer 1990).

Based on growth rates observed in wild turtles, age at first reproduction (minimum 81 cm SCL) for green turtles in the Hawaiian Archipelago is estimated to be roughly 10-50 years, depending on locale. Because most areas were represented by fewer than five turtles, small sample sizes may have influenced the widely disparate values. At French Frigate Shoals, the most thoroughly studied site (recapture data available from 19 immature turtles), the estimated average age at 81 cm SCL was 47.9 years (Balazs 1982b). Skeleto-chronological studies later predicted that Hawaiian turtles may require 40-50 years to reach minimum breeding size (Zug and Balazs 1985). Ongoing capture-recapture studies (through 1991) at Hawaiian green turtle foraging pastures have documented an overall average annual rate of growth of about 2 cm/yr. Based on these data, it is estimated that an average of at least 25 years would be needed to achieve sexual maturity (George Balazs, NMFS, pers. comm., 1992). Growth rates and age at sexual maturity in other North Pacific populations remain unquantified.

Conservation Status

According to the Code of Federal Regulations (50 CFR 17.11), the breeding colonies of green sea turtles in Florida and on the Pacific coast of Mexico are listed as Endangered and all other breeding colonies are Threatened under the U. S. Endangered Species Act of 1973, as amended. The species is classified as Endangered in the IUCN *Red Data Book*, where taxa so classified are considered to be "in danger of extinction and whose survival is unlikely if the causal factors continue operating" (Groombridge 1982). Green turtles are included on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a designation which effectively bans trade in specimens or products except by special permit. Such permit must show that the trade is not detrimental to the survival of the species and is not for primarily commercial purposes (Lyster 1985). Since Japan ratified CITES with a "reservation" on *Chelonia mydas*, large volumes of green turtle products were imported into that country until 1987 when the reservation was withdrawn. For a summary of national legislation protecting green sea turtles in the North Pacific, see an earlier section of this report.

Life Cycle Overview

Eggs and Hatchlings--Eggs from a single clutch (n = 86) at French Frigate Shoals, Hawaii, averaged 47 mm in diameter and 49.6 g (Balazs and Ross 1974). During the approximately two months of incubation, ambient temperature influences sex determination (see Miller 1985 for review). At Talang Talang Besar, Sarawak Turtle Islands, clutches produced 75-100% female hatchlings when the mean temperature during the middle trimester of incubation did not fall below 29.5°C (Leh et al. 1985). At Michoacán, Mexico, 47 black turtle clutches were monitored in 1984 and 1985 to determine the sex ratio of emergent hatchlings. Average temperatures <27°C (range 26.4-27°C) during the middle trimester resulted in 100% males; whereas average temperatures between 27.5-31°C resulted in a mixed ratio and those >31°C (range 31-32.9°C) produced 100% females (Alvarado and Figueroa 1987). After hatching, siblings work together to reach the surface. Hatchlings are lethargic at high temperatures and are most likely to emerge in the evening, an adaptation that presumably enhances survival by protecting them from high surface temperatures and visually-oriented predators (Hendrickson 1958; Mrosovsky 1968). Hatch success, which is at least partially influenced by nest chamber humidity, grain size, proximal vegetation, and ambient thermal and chemical regimes (Bustard and Greenham 1968; Bustard 1971; Mortimer 1990), varies widely within and among rookeries. Predators include a wide variety of invertebrates, fishes, reptiles (snakes, varanid lizards), birds, and mammals (Hendrickson 1958; Hirth 1971; Balazs 1980; Márquez 1990).

The ocean-finding cue appears to be primarily one of light attraction. Upon reaching the water, hatchlings demonstrate a strong orientative reaction to environmental motion, aligning themselves against any water movement, whether this be continuous current or intermittent wave wash, and swimming strongly against the direction of water movement (Hendrickson 1958). This ability may be similar to the "wave compass" proposed for loggerhead hatchlings (Salmon and Lohmann 1989). Once in the open sea, hatchlings may seek shelter in an offshore convergence or weed line. It is well known that *Sargassum* seaweed rafts shelter hatchling green turtles and also harbour a diverse, specialized fauna, including many kinds of little fishes, crustaceans, worms, mollusks, tunicates, and coelenterates; these may provide food for the young turtles (Carr, 1987). Post-hatchlings remain epipelagic (surface dwelling in the open sea) for an undetermined number of years before taking up residence in continental shelf habitats. In the case of hatchlings leaving the Sarawak Turtle Islands, the epipelagic stage is concluded when the young turtles reach feeding grounds in the Great Barrier Reef or Indian Ocean, whereupon they begin feeding on sea grass and other marine plants (Hendrickson 1958; Leh 1991).

Juveniles--In Hawaii, green turtles recruit into coastal waters and commence feeding as herbivores at about 35 cm SCL (Balazs 1980). The precise distribution and abundance of juvenile size classes >35 cm is unquantified, but the literature is replete with reports of subadult green turtles foraging in lagoons and coastal areas. Carr et al. (1978) describe the developmental habitats of young green turtles in the western Atlantic as follows. Having left the pelagic "lost years" to assume a coastal existence, "...the juveniles turn up in various inshore estuarine or reef-system habitats, often on a regular schedule of arrival and departure times. The resident habitat is protected warm water not too deep for photosynthesis, where the turtles feed on bottom vegetation." The extent to which the pelagic zone also serves as important habitat to size-classes >35 SCL is unknown. There is some evidence of oceanic distribution, as indicated by sighting records 1,000-2,000 statute miles from shore (see Insular and Pelagic Range). Diet in blue water is open to speculation. Far northern records may represent waifs. A juvenile (18.75 in [47.6 cm] carapace length, 32 lbs) stranded on a gravel beach at Spring Cove, Ucluelet Inlet, British Columbia (48.15°N) in December 1954. It was weak, covered with "oil and slime", and died a week later (Carl 1955).

Groupers (Serranidae) prey upon juvenile green turtles (Witzell 1981), as do other large predator fishes such as sharks (summarized by Hirth 1971; see also Balazs 1980). It is assumed, and has been shown for other turtle species (Frazer 1983a; Iverson 1991), that survivability increases with age; presumably because the probability that an oceanic predator will be successful in debilitating a large, heavily armored turtle decreases with increasing turtle size. Average age at sexual maturity (minimum 81 cm SCL) for immature green turtles ($n = 19$) feeding at French Frigate Shoals, Hawaii, has been estimated at 47.9 years (Balazs 1982b). No detailed information is available concerning natural mortality and survivorship in North Pacific populations. Habitat use, movement, diel behavior, and quantitative temporal and spatial abundance are also poorly known in most areas of the North Pacific. In Hawaii, diet consists of some 56 species of algae, one marine angiosperm (sea grass), and nine types of invertebrates, with nine species of benthic algae predominating (summarized by Balazs 1980). Growth is discussed in a previous section and may vary widely with diet and ambient conditions.

Adults--Adult green turtles are benthic herbivores, subsisting mainly on algae and sea grasses. Their diet would seem to restrict them to the photic zones surrounding islands and continents. Nonetheless, they are also known to be highly mobile. As juveniles they inhabit an undetermined number of developmental habitats potentially encompassing vast regions of the Pacific, and as adults they embark on long-distance migrations between resident foraging grounds and nesting beaches. Imprinting to the nesting beach and its environs occurs in both males and females and appears permanent, at least over several years (Dizon and Balazs 1982). Tag returns have shown that breeding and non-breeding areas in the North Pacific can be separated by many hundreds of kilometers (e.g., Balazs 1980; Green 1984; de Silva 1986; Alvarado and Figueroa 1990). Homing mechanisms are well-developed, nesting beach fidelity is high, and several Pacific rookeries show unique population-level genotypes based on recent mtDNA research (see Population Units). Nesting occurs on multiple year intervals and may be regulated, at least around northern Australia and Indonesia, by the Southern Oscillation, a coherent pattern of atmospheric pressure, temperature and rainfall fluctuations which dominates the interannual variability of the climate of the tropical Pacific (Limpus and Nicholls 1988).

Non-breeding range is typically tropical and can extend some 500-800 statute miles from shore, as indicated by incidental capture data from tuna purse-seines off Central and South America (e.g., 70 cm CCL turtle captured at 7.04°N, 91.2°W; NMFS, unpubl. data). The species is also known from northern waters, where on rare occasions it ventures as far north as Admiralty Island, Alaska (57.16°N, 134.15°W) (Hodge 1981), and has also been caught at 41°-44°N by Japanese pelagic driftnet vessels (Gjernes et al. 1990). Adult sex ratios may be biased in favor of females, both in black turtles (68-92% females; Caldwell 1962a) and green turtles. Studies of basking green turtles at French Frigate Shoals, Hawaii, report a sex ratio of 66% females (range 50-81%). Observations of adults basking at other locations in the northwestern Hawaiian islands have revealed ratios of 71% female (Necker Island), 62% female (Lisianski Island), and 60% female (Pearl and Hermes Reef), although it is not known whether males and females would be expected to bask with equal probability (Balazs 1980). In a more recent study, Ross (1984) reported a nearly 1:1 sex ratio (47% female) after examining turtles which died of natural causes (beach carcasses), were killed for food, and were captured by hand in foraging grounds at Masirah Island, Oman.

A life-threatening disease of unknown etiology afflicts turtles in the Pacific, having been reported from California, Hawaii, Australia, Malaysia, and Japan (McDonald and Dutton 1990; Jacobson 1991). During 1989 and 1990, the disease, known as marine turtle fibropapilloma, was present in 77% and 85% of the turtles stranded on the Island of Maui, mainly in the Kahului Bay area (Balazs 1991a). In 1991, 31% of green turtles examined in Kaneohe Bay, Oahu, were afflicted (Aguirre 1991). The Research Plan for Marine Turtle Fibropapilloma (Balazs and Pooley 1991) recommends that research to determine the cause of the disease be a priority for the U. S. National Marine Fisheries Service. Long-term research on population dynamics should also be a high priority.

It is clear from data reviewed in the present report that green turtles are declining virtually throughout the tropical Pacific, with the possible exception of Hawaii, as a direct consequence of an historical combination of over-exploitation and habitat loss. The survival of the green turtle in the Pacific is dependent on the implementation of scientifically sound conservation programs, which in turn should be based on a more complete understanding of survivability, fecundity and longevity, and rates of recruitment and stock replacement.

Leatherback Sea Turtle, *Dermochelys coriacea*

Taxonomy

The generic name *Dermochelys* was introduced by Blainville (1816). The specific name *coriacea* was first used by Vandelli (1761) and adopted by Linneaus (1766) (Rhodin and Smith 1982). The binomial refers to the distinctive leathery, scaleless skin of the adult turtle. For the most recent detailed discussion of taxonomy and synonymy, see Pritchard and Trebbau (1984).

Morphology

Whereas other sea turtles have bony plates covered with horny scutes on the carapace, the moderately flexible carapace of the leatherback is distinguished by a rubberlike texture. The carapace is about 4 cm thick and is constituted mainly of tough, oil-saturated connective tissue raised into seven prominent ridges and tapered to a blunt point posteriorly. A nearly continuous layer of small dermal bones lies just below the leathery outer skin of the carapace. The narrow ribs lack pleural flanges and remain separated throughout life. No sharp angle is formed between the carapace and the plastron, resulting in the animal being somewhat barrel-shaped. The scaleless epidermis is black with varying degrees of pale spotting. The underside is mottled, pinkish-white and black; the proportion of light to dark pigment is variable. The front flippers are proportionally longer than in other sea turtles and may span 270 cm in an adult. Hatchlings are likewise predominately black, with mottled undersides, but differ in being covered with tiny polygonal or bead-like scales. The flippers are margined in white and rows of white scales appear as stripes along the length of the back. Front and rear flippers lack claws. In both adults and hatchlings, the upper jaw bears two tooth-like projections, each flanked by deep cusps, at the premaxillary-maxillary sutures.

Adults exhibit broad thermal tolerances and are reported in the Pacific as far north as Alaska and the Bering Sea and as far south as

Chile and New Zealand (see Insular and Pelagic Range). The core body temperature for adults in cold water has been shown to be several degrees C above ambient (Frair et al. 1972). This may be due to several features, including the thermal inertia of a large body mass, an insulating layer of subepidermal fat, countercurrent heat exchangers in the flippers, potentially heat-generating brown adipose tissue, and a relatively low freezing point for lipids (Mrosovsky and Pritchard 1971; Frair et al. 1972; Greer et al. 1973; Neill and Stevens 1974; Goff and Stenson 1988; Davenport et al. 1990). The skeleton remains highly cartilaginous, even in adult animals, and the species is unique among turtles in showing an extensive cartilage canal vascular system in the long bones (Rhodin et al. 1981). For a detailed discussion of anatomy, including embryonic development, see Deraniyagala (1932, 1936a), Dunlap (1955), Pritchard (1971b), and Pritchard and Trebbau (1984). Adult size is discussed below.

Population Units

In Michoacán, Mexico, females nesting during 1980-1988 averaged 144.9 cm CCL (range 119-176, n = 2591) (Laura Sarti M., UNAM, unpubl. data). In contrast, adult females nesting in eastern Australia and peninsular Malaysia averaged 162.4 cm CCL (1974-1982, Limpus et al. 1984) and 159.4 cm CCL (Scott Eckert, HSWRI, unpubl. data), respectively. Despite the size dichotomy between eastern and western Pacific nesting colonies, conclusions of evolutionary distinctness may be unwarranted. Preliminary data indicate that genetic (mtDNA) population structuring is shallow in leatherbacks relative to other vertebrates. In a preliminary survey of mtDNA sequence data, Atlantic and Pacific populations were genetically distinct but closely related (Brian Bowen, GAC/ BEECS, unpubl. data), implying a common ancestor in recent evolutionary time. Additional study is necessary to define the relationships among breeding assemblages in the Pacific basin. In the interim, usage should imply the standard, functional definition of a population as an assemblage of adults which returns repeatedly and at predictable intervals to nest at a specific site.

Nesting Habits and Areas

Reproduction is seasonal. In Mexico, the nesting season extends from November to February, although some females arrive as early as August (Sarti et al. 1989). In the western Pacific, nesting peaks in May and June in China (Chu-Chien 1982), June and July in peninsular Malaysia (Chan and Liew 1989), and December and January in Queensland (Limpus et al. 1984). In the western Atlantic, gravid females engage in routine migrations between boreal, temperate and tropical waters, presumably to optimize both foraging and nesting opportunities (Bleakney 1965; Lazell 1980; Eckert and Eckert 1988). Similarly, the presence of adult females at major eastern and western Pacific nesting grounds is seasonal, suggesting that migration between nesting and non-nesting areas may be characteristic of Pacific stocks.

The timing and routing of reproductive migrations in the Pacific are unknown. However, migratory corridors most likely exist along the western seaboard of the Americas (post-nesting females may travel north and south from Mexican rookeries; Stinson 1984; Márquez and Villanueva 1993) and Bustard (1972) reports "an important migration route ... down the east coast of Australia judging by personal sightings and reports of capture in shark nets." In the Caribbean Sea there is some evidence that mating takes place in temperate latitudes prior to or during the reproductive migration (Eckert and Eckert 1988). There are no literature accounts of mating in Pacific waters.

Nesting is generally nocturnal. The nesting sequence is composed of a beach landing, an overland traverse to and selection of a suitable nest site, excavation of a body pit and nest chamber, oviposition, filling the nest, covering and concealing the nest site, and returning to the sea (Deraniyagala 1936b; Carr and Ogren 1959; Pritchard 1971). The sequence, from landing to surf reentry, requires some 80-140 minutes. Preferred nesting beaches are typically on continental (as opposed to island) shores and have unobstructed, often deep offshore access (Hirth 1980, Mrosovsky 1983; Eckert 1987). In Pacific Mexico, females lay 1-11 clutches per annum (mean = 5.7) at 9-10 day intervals; clutch size averages 64 yolked eggs (Sarti et al. 1987; Laura Sarti M., UNAM, unpubl. data). Clutch size is somewhat larger in the western Pacific. In Terengganu, Malaysia, clutches are composed, on average, of 85-95 yolked eggs (Chua and Furtado 1988). Similarly, clutch size averages 83 yolked eggs in Pacific Australia (Limpus et al. 1984). Each clutch contains a complement of yolkless eggs. These sometimes comprise 50% or more of total clutch size, a unique phenomenon among sea turtles. Yolkless eggs, typically smaller than yolked eggs and in many cases misshapen, are generally deposited last.

Some of the largest nesting colonies of leatherback turtles in the world border the Pacific Ocean. The largest known colony, comprising perhaps nearly half the known number of adult females, breeds on the Pacific coast of Mexico, notably the states of Michoacán, Guerrero and Oaxaca (Pritchard 1982b). During the 1986-1987 breeding season, 5,021 crawls, including 4,796 nests, were recorded during nightly foot patrol of 4.5 km of beach at Mexiquillo, Michoacán (Sarti et al. 1987). An estimated 1,200 nests were laid at this site in 1990-1991, slightly up from a low of about 1,074 nests in 1989-1990 (Eckert 1992a). In addition to Mexiquillo, high density nesting is reported in many areas of Guerrero and Oaxaca, including Tierra Colorada, Guerrero, and Bahía Chacahua, Oaxaca (Márquez 1976b; Márquez et al. 1981). On the southeast coast of Guerrero between Bahia Dulce and Barra de Teconapa, an estimated 5,000 females nest each season (Groombridge 1982). Lower density nesting occurs further north in Jalisco (Pritchard 1971b; Márquez 1976b) and in Baja California, where the northernmost eastern Pacific nesting sites are found (Fritts et al. 1982). In total, it has been estimated that some 30,000 leatherbacks nest on the Pacific coast of Mexico each year (Pritchard 1982b). Nesting on a much smaller scale is also reported from Pacific Central America and peaks in November and December (e.g., Pritchard 1971b; Cornelius 1982, 1986).

In the western Pacific, at least 13,000 leatherback nests were reported in 1984 on 17.8 km at Irian Jaya, Indonesia (Bhaskar 1985). Terengganu, Malaysia, once considered a major nesting area, has declined dramatically, largely as a result of intensive egg collection. The data show a steady drop in nesting activity from nearly 11,000 landings in 1956 to 6,721 landings in 1968 to 280 in 1990 (Hendrickson and Alfred 1961; Chua 1988; J. Mortimer, WWF-Malaysia, *in litt.*, 29 August 1991). Nesting does not occur in Sabah (de Silva 1982) or Sarawak (Leh 1985). Other breeding grounds within the geographic scope of this report appear confined to China and Thailand, but quantitative data are lacking. In China, Chu-Chien (1982) reports leatherbacks in Guangdong (Kwangtung), Guangxi (Kwangsi), Fujian (Fukien), Zhejiang (Chekiang), Jiangxi (Kiangsi), Shandong (Shantung), and Liaoning, but does not specify nesting sites. Nesting peaks in May and June, 90-150 eggs are laid per clutch, and incubation is 65-70 days; no indication of nest density or population size was provided (Chu-Chien 1982). Field surveys were conducted during June-August 1985 in Fujian and Guangdong Provinces, but no evidence of nesting was found (Frazier et al. 1988). Mao (1971) reported that "eggs are eaten wherever available" in Taiwan and the weight of an adult female "photographed at Nanfangao" was 252 kg; nesting sites, if any, were not specified. In the Phuket area on the central west coast of Thailand, "nesting was found to be maximum from October to April" (Phasuk and Rongmuangsart 1973).

Nesting apparently does not occur on the South China Sea shores of Thailand, Vietnam, or Kampuchea (Groombridge 1982; Humphrey and Bain 1990), nor in Korea (Groombridge 1982), Japan (Uchida and Nishiwaki 1982; Kamezaki 1989), the Philippines (Pejabat and Siow 1977), Guam (Gerald Davis, Guam DAWR, *in litt.*, 22 August 1991), Micronesia (Pritchard 1977, 1982a), Hawaii, or any of the unincorporated U. S. territories (islands and atolls) in the North Pacific (Balazs 1978a, 1982a). Nesting would not be expected in Palau, the Marshall Islands, or Kiribati; data are not available.

Insular and Pelagic Range

Leatherbacks have the most extensive range of any living reptile (Pritchard and Trebbau 1984). These two factors significantly complicate systematic study of their abundance and distribution. Sightings and incidental capture data indicate that leatherbacks are found in Alaska as far north as 60.34°N, 145.38°W and as far west as the Aleutian Islands (Hodge 1979; Stinson 1984). Documented encounters extend southward through the waters of British Columbia (Logier and Toner 1961; MacAskie and Forrester 1962; Gregory and Campbell 1984), Washington and Oregon (Eisenberg and Frazier 1983; Brueggeman 1991; Washington Dept. Game, unpubl. data; Craig Webster, NWMMSN, *in litt.*, 29 October 1990), California (Van Denburgh 1905; Lowe and Norris 1955; Dohl et al. 1983; Stinson 1984) and Baja California, Mexico (Smith and Smith 1980; Clifton et al. 1982). After analyzing some 363 records of sea turtles sighted along the Pacific coast of North America (from 29°45'N northward), Stinson (1984) concluded that the leatherback was the most common sea turtle north of Mexico. She noted that their arrival in southern California coincides with the summer arrival of the 18-20°C isotherms which move seasonally north from Mexico, and that July-September sightings north of Point Conception likely include individuals originating in offshore portions of 13-15°C isotherms pushed inshore in late summer. Adults are seasonally abundant off Mexican breeding grounds at Michoacán, Guerrero, and Oaxaca (Márquez 1976b; Pritchard 1982b; Sarti et al. 1987, 1989) and are found as far south as Chile (Chiloé Island, ca. 42°S: Philippi 1899 *in* Pritchard 1980; 89 km west of Isla Mocha, 38°22'S, 176°06'W: Frazier and Brito Montero 1990). Leatherbacks are captured in large numbers incidental to the Chilean swordfish fishery (Frazier and Brito Montero 1990).

In the western Pacific the species is found as far north as the Bering Sea (Mys Navarin, USSR, ca. 62°N) (Bannikov et al. 1971) and as far south as Tasmania and New Zealand (Graham 1964; McCann 1966, 1969). In China, Zhou (1983) documented 10 adult and subadult leatherbacks (112-135 cm carapace length, n = 7) caught by the local fisheries from the coastal waters of Jiangsu Province, 1980-1982. Several were captured in coastal waters near Lüsi, one near Lianyungang Port (a city near the border with Shandong Province to the north), and another one near Haimen, a delta city of the Yangtze River. Further to the south, Frazier et al. (1988) examined nine adult and subadult specimens (mean = 131.8 cm CCL, range 115.5-152.5, n = 7) captured in the waters of Fujian and Guangdong Provinces during May-October; the largest and smallest specimens were both males. Leatherbacks are also recorded in Korean waters near Mokp'o, Cholla Namdo Province, South Korea (Doi 1936 *in* Shannon 1956) and off Pyongwon county, South Pyongan Province, North Korea (Tong and Yon

1961 *in* Szyndlar 1991). Won (1971) notes that the species only appears at rare intervals in Korea, usually with the flow of warm current. Mao (1971) quotes fishermen who say that the species is "frequently captured from October to March, and occasionally in other months" in Taiwan; during the "prosperous season" 2-5 turtles (most >150 kg) could be seen on the wharf per day. Multiple sightings are documented in the waters of Japan (Pritchard 1980; Uchida and Nishiwaki 1982), including a subadult (120 cm SCL) that died after becoming entangled in a gill net off Hyogo Prefecture (Balazs 1985). Adults are present at least seasonally in the waters of the South China Sea (see Nesting Areas and Habits) and incidental catch in this region has been documented (Aikanathan and Kavanagh 1988; Chan et al. 1988).

Few quantitative data are available concerning the seasonality, abundance or distribution of leatherbacks in Oceania or the central North Pacific. The species is not typically associated with insular habitats, particularly those characterized by coral reefs or other habitats potentially injurious to the leathery turtle, but individuals are occasionally encountered in deep water proximal to prominent archipelagoes, such as the Philippines (de Celis 1982), the Northern Mariana Islands, Micronesia, and Hawaii. On very rare occasions, leatherbacks are caught in seasonal (February-June) nearshore driftnets in the Sulu Sea (Louella Dolar, Silliman Univ., pers. comm., 1993). Only 2.6% of the turtles recorded during aerial surveys of Guam (October 1989-April 1991), the southern terminus of the Marianas, were leatherbacks (Gerald Davis, Guam DAWR, *in litt.*, 22 August 1991). On rare occasions individuals have been sighted or captured at sea in the Truk, Yap, and Pohnpei (Ponape) States of Micronesia (McCoy 1974; Pritchard 1977). A leatherback caught near Woleai (Yap) in 1971 was captured and eaten (McCoy 1974). An adult (444 kg, 2.167 m total length) was caught off Parem Reef, Ponape Island (Pritchard 1982b) and a small juvenile (69.4 cm carapace length) captured near Satawal (Yap) was tagged and released (McCoy 1974). Leatherbacks are "regularly sighted" in offshore waters at the southeastern end of the Hawaiian archipelago. During August 1979 at least ten individuals, including juveniles, were sighted in pelagic waters northwest of the archipelago (40-42°N, 175-179°W) (Balazs 1982a). In December 1982 a large (682 kg) female became entangled at night two miles offshore Kailua-Kona, Hawaii, in a "parachute anchor", dragging the boat for several hours before being killed (Balazs 1985). No documented sightings exist for the unincorporated U. S. territories.

Further insight into coastal and pelagic range may be gained from reports of incidental catch. In the eastern North Pacific these include entanglement in gill nets off the coast of Washington and Oregon (Stick and Hreha 1989) and California. A leatherback was killed in October 1990 in a gill net set off central California

(36°55'N, 122°40'W) (Scott Eckert, HSWRI, pers. comm., 1991). Eleven leatherbacks were captured in gill nets by a single fishermen from Bahia de la Paz, Baja California, 1985-May 1987; mortality was not reported (Alvarado and Figueroa 1990). In the ETP, juveniles and adults are occasionally caught in tuna purse-seines (S. Eckert, pers. comm., 1991). A very young individual (about 15 cm carapace length) was captured in a purse-seine in April 1976 about 180 nautical miles west of San José, Guatemala (11°03'N, 92°20'W) (Robert Pitman, NMFS, pers. comm., 1991). In the western Pacific, 77 and 33 leatherbacks were estimated to have been captured in drift/gill nets set in the South China Sea off the nesting beach at Terengganu, Malaysia, in 1984 and 1985, respectively, while estimated trawl catch during these same years was 402 and 240 (Chan et al. 1988). Typical Malay driftnets are 600-3,000 feet in length, while Thai-style nets can exceed 5 km; both are left at sea day and night. Trawl nets pull for 2-3 hours at a time and account for some 60% of the incidental catch (Aikanathan and Kavanagh 1988). Leatherbacks (presumably adults) are ensnared in nets off Sabah, Eastern Malaysia (Jeanne Mortimer, WWF-Malaysia, *in litt*., 29 August 1991).

Longlines (e.g., Anon. 1935, 1958, 1967; Pritchard 1977) and active and abandoned driftnets (Balazs 1982c; Gjernes et al. 1990) have a long history of ensnaring and killing leatherbacks in the central North Pacific. Balazs (1982c) reported at least five dead leather-backs floating at the surface entangled in pieces of monofilament squid net, probably cut adrift by Japanese or Taiwanese fishermen (35°-45°N, east of 170°E). Data collected by observers aboard pelagic squid driftnet vessels in 1989 identified nine of 22 turtles caught as leatherbacks; only three survived their capture (Gjernes et al. 1990). It is clear that incidental catch poses a problem in pelagic foraging and transit areas, as well as in coastal feeding grounds and potential migratory corridors, such as along the western seaboard of the USA. Despite a lack of comprehensive data, it is likely that established migratory routes also occur in the western Pacific between temperate latitudes and nesting grounds in China, Malaysia, and Indonesia.

Oceanic distribution of leatherbacks may reflect the distribution and abundance of macroplanktonic prey. Analyses of stomach samples have shown that adults feed primarily on cnidarians (jellyfish, siphonophores) and tunicates (salps, pyrosomas) (Brongersma 1969; Den Hartog and Van Nierop 1984; Davenport and Balazs 1991). Isolated reports of foraging in North Pacific waters include that of Eisenberg and Frazier (1983), who observed an adult feeding on the jellyfish *Aurelia* off the coast of Washington state. There is some evidence that leatherbacks follow the 16°C isotherm into Monterey Bay, where the length of their stay "seems more dependent on local prey availability than on temperature regimes" (Chris Starbird, San José

State Univ., *in litt.*, 8 April 1991). Aerial surveys of California, Oregon, and Washington waters have shown that most leatherbacks occur in slope waters, while fewer occur over the continental shelf. Recorded sea surface temperatures at the Oregon and Washington sightings ranged between 13-18.5°C, with the majority in the 15-16°C range (Brueggeman 1991). The data suggest that leatherbacks occur north of central California during the summer and fall when sea surface temperatures are highest (Dohl et al. 1983; Brueggeman 1991). Information is needed on the diet of leatherbacks in northern waters, and the spatial/temporal distribution of preferred prey species.

Growth

Growth rates in captivity are widely disparate (see Pritchard and Trebbau 1984 for review) and wild growth rates have not been studied. Nonetheless, based on the unusual features of the leatherback skeletal system, as well as evidence that some individuals have grown quite rapidly in captivity, Rhodin (1985) has speculated that leatherbacks may grow to sexual maturity at an earlier age than other sea turtles. One of the unusual features of the leatherback skeletal system is a distinctly mammalian-like growth pattern, hence there is no periosteal layering. A preliminary study of sclerotic ossicles shows distinct layering and lines of arrested growth (Zug 1990). These growth layers may provide data for aging leatherbacks, but analysis has been impeded by the absence of ossicles from juvenile specimens; no reliable means exist to estimate the periosteal diameters of earlier growth stages (Zug 1990). Quantitative information on the growth trajectories of wild leatherbacks is needed before age at maturity can be accurately predicted.

Conservation Status

According to the Code of Federal Regulations (50 CFR 17.11), the leatherback sea turtle is listed as Endangered throughout its entire range under the U. S. Endangered Species Act of 1973, as amended. Similarly, the species is classified as Endangered in the IUCN *Red Data Book*, where taxa so classified are considered to be "in danger of extinction and whose survival is unlikely if the causal factors continue operating" (Groombridge 1982). Leatherbacks are included on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a designation which effectively bans trade in specimens or products except by special permit. Such permit must show that the trade is not detrimental to the survival of the species and is not for primarily commercial purposes (Lyster 1985). For a summary of national legislation protecting leatherback turtles in the North Pacific, see an earlier section of this report.

Life Cycle Overview

Eggs and Hatchlings--In Pacific Mexico (Mexiquillo, Michoacán) and Australia (south Queensland), eggs average 5.3 cm in diameter (López and Sarti 1989; Limpus et al. 1984). Embryology is discussed in Deraniyagala (1932, 1936a). Embryo development is completed during an incubation period which lasts 55-75 days. In Mexiquillo, hatchlings measure 5.0-6.3 cm SCL (mean = 5.64 cm, n = 2800) and weigh 32.4-50.0 g (mean = 41.2 g, n = 2937) (Laura Sarti M., UNAM, unpubl. data). Similarly, Queensland hatchlings measure 5.1-6.5 cm SCL (mean = 5.88 cm, n = 39) and weigh 38.3-54.2 g (mean = 46.86 g, n = 39) (Limpus et al. 1984). Hatchling emergence from the nest is a cooperative activity which takes place over several days. Emergence is typically at early evening. As is the case with other sea turtle species, sea-finding orientation is based largely on light, specifically the brightness differential between the open ocean horizon and the darker vegetation to the landward side (Mrosovsky 1972, 1977). Nesting results vary widely, with the proportion of turtles hatching and the proportion of those successfully emerging from the nest averaging 62.8% and 58.1%, respectively, in Mexiquillo (Mexico) during the 1988-1989 season (Sarti et al. 1989). Nest temperature during incubation influences the sex of hatchlings. The "pivotal temperature" (ca. 1:1 sex ratio, Mrosovsky and Yntema 1980) has been estimated to be 29.25°C-29.50° in Surinam and French Guiana (Mrosovsky et al. 1984b; Rimblot-Baly et al. 1986-1987). Pivotal temperatures have not been defined for Pacific nesting sites.

Predation is poorly known in the Pacific, but elsewhere in the world important predators are crabs, varanid lizards, and a variety of mammals (genets, mongooses, foxes, raccoons, coatis, wild pigs) and birds (night herons, vultures) (summarized by Eckert 1992a). In Michoacán, Mexico, egg predators reportedly include dogs and crabs (*Ocypode occidentalis)*, while dogs, crabs, and a wide variety of birds (*Larus argentatus, Sterna maximus, Fregata magnificens, Casmerodius albus, Pandion haliaethus*) feast on the hatchlings (López and Sarti 1988; Villaseñor 1988). Predator fishes take hatchlings at sea (Fretey 1981). Nothing is known about the dispersal pattern of leatherback hatchlings in the Pacific, nor of the abundance or distribution of juveniles. Comprehensive discussions of the early pelagic stage of sea turtle development (the "lost years"), which include sightings of post-hatchling stage loggerhead, green, and hawksbill turtles associated with Sargassum weed, do not mention sightings of young *Dermochelys* (e.g., Carr 1987). Mortality and survivorship statistics are lacking, as is basic information on diet, activity patterns, and growth rate.

Juveniles--Few immature leatherbacks are seen anywhere in the world, and the North Pacific is no exception. A very young individual (about 15 cm carapace) was accidentally captured in a tuna purse-seine some 180 nautical miles west of San José, Guatemala, in 1976 (Robert Pitman, NMFS, pers. comm., 1991). Another juvenile (69.4 cm carapace length) was captured near Satawal (Yap District, FSM) on 2 September 1972 and tagged and released (McCoy 1974). Larger juvenile size classes are reported from China's coastal waters (Zhou 1983; Frazier et al. 1988; see Insular and Pelagic Range). With the exception of these isolated encounters, there are no data regarding the abundance or distribution of juvenile leatherbacks in the North Pacific region. Mortality and survivorship statistics are lacking, as is basic information on diet, growth rate, behavior, and movement.

Adults--A suite of physiological adaptations have allowed the leatherback sea turtle the most extensive range of any extant reptile (see Morphology). The species is highly migratory and difficult to study. Trans-Pacific movement is likely. Aside from the predictable arrival of gravid females at nesting beaches, a few observations of foraging turtles, and a growing database on incidental catch (see Insular and Pelagic Range), distribution and life history data are not available for adult leatherbacks in the Pacific. Based largely on evidence from the western Atlantic, we assume that adults are primarily open water in their distribution, that they feed on medusae, salps, siphonophores and related prey in the water column and at the surface, and that at least the adult females engage in reproductive migrations on two or three (or more) year intervals for the purpose of egg-laying in tropical latitudes (see Nesting Habits and Areas). At the nesting ground, gravid females dive incessantly during inter-nesting intervals, as shown by recent studies in Terengganu, Malaysia (Scott Eckert, HSWRI, unpubl. data). Mating has not been observed. The movements of males are unstudied. Predators include the killer whale in Mexican waters (Sarti et al. 1991) and presumably the larger sharks. Mortality and survival statistics are unavailable, age at maturity and longevity have not been determined.

Hawksbill Sea Turtle, *Eretmochelys imbricata*

Taxonomy

The generic name *Eretmochelys* was introduced by Fitzinger (1843). The specific name *imbricata* is attributed to Linnaeus (1766) and refers to the over-lapping nature of the carapace scutes. Two subspecies, *E. i. imbricata* in the Atlantic Ocean and *E. i. squamata* in the Pacific Ocean, have been described on the basis of differences in coloration and carapace shape (see Witzell 1983 for review). The criteria have proven unreliable in distinguishing the two forms, however, and subspecific designations are rarely used (Meylan 1984). The genus *Eretmochelys* is currently considered to be monotypic (Witzell 1983).

Morphology

Hawksbills are distinguished from other sea turtles by two pairs of prefrontal scales; thick, posteriorly overlapping carapace scutes; four pairs of costal scutes, the anteriormost not in contact with the nuchal scute; and two claws on each flipper. Some scute variation occurs in both adults and hatchlings (Limpus et al. 1983). The carapace is typically serrated along the posterior margins and "tortoiseshell" in color and pattern, dorsal laminae show radiating streaks of brown, black and amber. Carapace color is geographically variable and may also change with age (see Witzell 1983 for review). The head is relatively narrow, the beak tapers to a point, and the maxilla projects slightly beyond the mandible. The scales of the head are dark brown with pale yellow margins. Hatchlings are uniform in color, usually gray or brown. A detailed discussion of anatomy is found in Deraniyagala (1939), a general biological synopsis in Witzell (1983), and more recent in-depth discussions in Pritchard and Trebbau (1984) and Groombridge and Luxmoore (1989).

Mean straightline carapace length (SCL) of adult females ranges from about 66 cm to 86 cm worldwide (Witzell 1983). Weight is typically to 80 kg (Pritchard et al. 1983), with an historical record of a 280 pound [127 kg] individual caught at Great Sound, Grand Cayman, in the Caribbean Sea (Carr 1952). Females arriving to nest at the Campbell Island, Torres Strait, rookery in Australia, 1978-1979, averaged 76.3 cm SCL (range 70.7-83.3, n = 22) and 51.5 kg (range 38.5-68.0, n = 20) (Limpus et al. 1983). In Thailand waters adults commonly weigh <50 kg, but specimens up to 140 kg are known (summarized by Humphrey and Bain 1990). Females nesting in the Solomon Islands average about 60 kg (range 36.0-77.3, n = 83) (McKeown 1977; Vaughan 1981). Morphometric statistics appear not to be available for adults in North Pacific waters. Adult males are distinguished by a long, thick tail that extends well beyond the carapace margin and well developed, recurved claws on the fore flippers (Witzell 1983).

Population Units

Carr and Main (1973) reported that carapace color and morphology were sufficiently variable as to allow the discernment of populations unique to certain islands or island groups in the southwestern Pacific. The implication was that the hawksbill is a sedentary species, characterized by populations living in relative isolation in waters proximal to their natal beaches. This hypothesis has since been overturned, both by the observations of Limpus et al. (1983) and growing evidence that hawksbills, like other sea turtles, are highly migratory (see Life Cycle Overview). Populations are presently defined as assemblages of adults which return repeatedly to breed at fixed sites. In their recent global review of the species, Groombridge and Luxmoore (1989) concluded that of 65 geopolitical units where estimates of relative hawksbill nesting density exist, 38 of them have hawksbill populations that are suspected or known to be in decline and an additional 18 have experienced well-substantiated declines. Equating populations with nesting assemblages is the full extent of our present knowledge of stock distinctness. Genetic research on Pacific populations is ongoing (Colin Limpus, Australia NPWS, pers. comm., 1992) and will ultimately provide valuable insight into this important area of hawksbill ecology.

Nesting Habits and Areas

Mating occurs on the surface in shallow waters adjacent to the nesting beach and may last several hours; polyandrous breeding behavior is implied (Witzell 1983). Gravid females most often nest on isolated (typically insular) nesting beaches with well developed supralittoral vegetation. Nests are commonly, but not universally, placed amongst woody vegetation (Mortimer 1982a; Ryder et al. 1989). Nesting consists of landing, selecting a nest site, clearing the site and excavating a shallow body pit, digging the nest chamber, egg-laying, refilling the nest and concealing the site, and returning to the sea (Carr et al. 1966). Nesting is mainly nocturnal, but some populations nest infrequently (Limpus et al. 1983) or nearly entirely (Diamond 1976) during the day. Time ashore to complete the nesting sequence averages 120-130 minutes. Average clutch size (typically 110-150 eggs in the western and central Pacific) varies geographically and appears to be strongly correlated with mean carapace size among rookeries (Limpus et al. 1983; Witzell 1985). Hatch success in 13 undisturbed nests in Palau ranged from 29.8% to 96.2% in 1991 (Sato and Madriasau 1991).

Nesting is seasonal, but the season is often extended and at a few localities nesting may occur throughout the year with one or two peaks (Groombridge 1982). In Palau, for example, peaks are reported in June-August and December-January (Maragos 1991). Despite relatively few intensive tagging studies of nesting populations, some data are available concerning clutch frequency. At the Campbell Island rookery (Australia), females deposit an average of three clutches per season at intervals of 14.7 days (Limpus et al. 1983). Similar data are reported from China (Chu-Chien 1982), Thailand (Humphrey and Bain 1990), and Micronesia (Pritchard 1982a). These data notwithstanding, it is possible that clutch frequency is higher. An ongoing Caribbean study, unique in that every female is marked with a tag, has shown that hawksbills consistently nest 4-5 times per season (Corliss et al. 1989; Richardson et al. 1989). Nest site fidelity is well developed (e.g., Pritchard 1982a). One tagged female returned to breed at Sabah (Malaysia) after two years and three after three years; data from elsewhere suggest that females breed every one to six years (Meylan 1984).

Nesting beaches are distributed circumglobally, roughly from 30°N to 30°S, and can be identified in the Eastern and Western Atlantic Ocean, Eastern (rare), Central and Western Pacific Ocean, and Indian Ocean; the non-nesting range is equally extensive (Witzell 1983). Broad distribution should not be confused with abundance. On the contrary, nowhere do hawksbills nest in large numbers and many areas have experienced noticeable population declines (Groombridge and Luxmoore 1989). Mexico is a case in point, since the species was once common along the Pacific coast and tortoiseshell had been traded there "since ancient times" (Cliffton et al. 1982). The Tres Marias Islands may have been a major breeding ground (Parsons 1962). In addition, nesting may have occurred in scattered localities south of the desert coast of Sonora, but there has been no recent activity (Cliffton et al. 1982). Márquez (1990) suggested that nesting may still occur "rarely with small concentrations" on the Mexican Pacific islands, but Groombridge and Luxmoore (1989) appear to have discarded this notion in their recent global review, referring only to nesting on Gulf of Mexico and Caribbean shores. Low density nesting occurs at selected beaches along the Pacific coast of Central America (Cornelius 1982; Witzell 1983; Groombridge and Luxmoore 1989).

In the western Pacific nesting is said to take place during December-February in Kampuchea and Viet Nam, including islands in the northeastern Gulf of Thailand (Le Poulain 1941; Groombridge and Luxmoore 1989), and during March-April in China (Chu-Chien 1982). The current status of nesting populations in these areas is unknown. Frazier et al. (1988) found no recent evidence of nesting in China; 10 specimens examined were all juveniles. In Japan nesting is very rare and confined to the southern islands, namely, the Yaeyama (Kamezaki 1986, 1989) and Okinawa (Teruya and Uchida 1988 *in* Kamezaki 1989) Groups of the Ryukyu Archipelago; it may occur as far north as the Tokara Group (Uchida 1985 *in* Groombridge and Luxmoore 1989). During a thorough survey of the Yaeyama Group (1983-1988), Kamezaki (1989) reported only six hawksbill nests on three beaches on Kuroshima and Aragusukujima. Korea is too far north for hawksbill nesting (Shannon 1956; Szyndlar 1991). In Taiwan the eggs are considered "quite relishable" (Mao 1971), suggesting that nesting may once have occurred. A July 1988 survey of 19 Taiwanese beaches found no evidence of nesting (Kamezaki 1989). In Thailand nesting occurs year-around (Penyapol 1958) and peak activity is influenced by monsoon periods (Phasuk 1982). Thai nesting occurs on both east and west coasts, as well as on some offshore islands; specifically, Ko Klang and Ko Kai in Tarutao National Park, Ko Kra and Ko Rung in the Ko Kut/Ko Chang Group (near the Thai-Kampuchea border), Ko Kra (in the Gulf, off the Thai peninsula), Similan Islands, Sulin Islands, Songkhla Province, Pattani Province, and Narathiwat Province (summarized by Groombridge and Luxmoore 1989). At some east coast beaches and offshore islands (e.g., two islands in the Ko Kut/Ko Chang Group) the hawksbill is the most common nesting turtle (Humphrey and Bain 1990). Population sizes are unavailable.

Nesting is also reported virtually year-around in Western (peninsular) Malaysia as summarized by Witzell (1983). The most important area on the west coast is in Melaka, where each year several hundred clutches are laid on beaches from Tanjung Keling to the northern State boundary, and also on the offshore islands; nesting peaks January-September (Jeanne Mortimer, WWF-Malaysia, *in litt.*, 29 August 1991). To the south, nesting once occurred at Tanjong Kling, about 11 km west of Malacca, where in peak season it is said that five females nested in six nights (Kiew 1975 *in* Siow and Moll 1982). Today the beach is a well-lit tourist and industrial area; the last nest was recorded on 13 April 1978 (Chua 1979). Some of the offshore islands may once have been important nesting sites, but intensive trawling and a highly developed tourist industry have rendered contemporary nesting sporadic at best (Siow and Moll 1982). The major east coast nesting beaches are in Pulau Redang, Terengganu (50 clutches in 1990, Mortimer 1991c) and the islands off the Pahang-Johore border; nesting peaks March-June. An estimated 100-200 clutches are laid in Johor, and another 100 in Pahang (Mortimer 1991d,e). Data from licensed egg collectors indicate that during the mid-1970s 10,700 hawksbill eggs were collected per year from Terengganu State, with lesser amounts from Pahang (5,400 eggs) and Johore (2,500 eggs) (estimated by Siow and Moll 1982). In Eastern Malaysia, hawksbill nesting in both Sabah and Sarawak peaks during the early months of the year; past exploitation has been heavy (de Silva 1982; Leh 1991; Mortimer 1991a). The most important rookeries are Pulau Selingaan, Pulau Bakkungan Kechil, and Pulau Gulisaan, the three islands which comprise Sabah Turtle Islands Park at about 6°N, 118°E (de Silva 1986). From 1983-1988, 77.4% of nests in the Park were laid during January-July, with the balance laid August-December (data courtesy of Sabah Parks); a combined average of 360 hawksbills per year nested at these three islands from 1984-1988 (Jeanne Mortimer, WWF-Malaysia, *in litt.*, 29 August 1991).

Hawksbills are widespread throughout the Philippines. Nesting grounds are relatively poorly known, however, and population abundance has not been quantified. Alcala (1980) reported nesting in the central Philippines on the Visayan Islands. Based on the observations of Domantay (1953), de Celis (1982) indicated that nesting occurred on the Turtle Islands and that significant declines had been observed in the populations there following decades of intensive harvest. Domantay's (1953) post-war study concluded that egg yields had dropped sharply at the time of his writing from pre-WWII levels; only six of 1,352 nests he counted over six weeks on the Turtle Islands were by hawksbills. Groombridge and Luxmoore (1989) concluded that nesting numbers appear to be "very low" and concentrated on the more remote and least disturbed islands and archipelagoes fringing the Sulu Sea, from the Visayas in the north to the Turtle Islands in the south. [N.B. The Philippines Turtle Islands are part of the Tawi Tawi Group and are located at about 6°N, 118°E near the eastern coast of Sabah, Malaysia; the islands are contiguous with the Sabah Turtle Islands Park.] Large amounts of hawksbill shell have been exported from the Philippines (Pejabat and Siow 1977; Cato et al. 1978; Milliken and Tokunaga 1987; de Celis 1982; Groombridge and Luxmoore 1989).

The Palau nesting population of hawksbills is the largest in Oceania north of the equator, and nesting is concentrated on the small beaches of the Rock Islands area between Koror and Peleliu islands (Maragos 1991). The three most important clusters are several sites in Ngerukewid, Kmekumed, and Omekans. Wiles and Conry (1990) also refer to the Ngerukewid Islands as "a favored nesting area". Of 40 sites where turtles once nested in Palau, 28 have either been abandoned by the turtles or are considered disturbed; all sites are subject to poaching (Maragos 1991). Johannes (1986) mentioned nesting in the Seventy Islands area of Palau Lagoon, where eggs have been collected and eaten for centuries, and noted that "older Palauan fishermen seemed unanimous in their opinion that turtles [greens and hawksbills] were far less abundant than they had been 10-20 years before." According to Pritchard (1982a), hawksbills nest "sporadically" in Guam and rarely, if ever, in the Northern Marianas. In the FSM State of Truk, hawksbills nest (mainly May-October) in small numbers, perhaps 1-2 turtles per night on the islands of Holap, Tora, Ruac, Lap, Ushi, Onao, Tonelik, Pis, Alanenkobwe, Lemoil, and Falalu. In the Lower Mortlocks, occasional hawksbill nesting is reported on the atolls of Etal, Lukunor, and Satawan. In Pohnpei (Ponape) State, nesting appears to be "sparse at best." The extent to which hawksbills frequent the Marshall Islands is not clear. They are reported from some areas, but data are scarce. During a 2-3 July 1971 visit to Bikar Atoll, Hendrickson noted that only one of 35 tracks belonged to a hawksbill (*in* Pritchard 1982a). Data are uncertain for Kiribati; nesting has not been recorded on any inhabited islands (Anon. 1979).

McCoy (1982) presents a thorough discussion of the subsistence hunting of turtles in the FSM, but does not differentiate between green and hawksbill turtles; it seems that green turtles are far more abundant than hawksbills. In an earlier report he concluded that hawksbills were "extremely rare" throughout the Central Carolines, although nesting had occurred historically (McCoy 1974). Informants of Herring (1986) reported that about 10 females nest on Rugureru Island of Kapingimarangi Atoll, that "many" turtles (greens and hawksbills) nest on Mokil, and about 30 nests are made annually on Nikuoro (both species), although this is considered unlikely (M. McCoy, *in litt.*, 24 August 1988 to Groombridge and Luxmoore 1989).

Elsewhere in the central Pacific, nesting occurs in Hawaii on the islands of Hawaii and Molokai (Balazs 1982a), and may occur on Oahu (Balazs 1978a). The most consistently used sites seem to be at Kamehame Point on Hawaii, and a black sand beach at the river mouth of Halawa Valley at the east end of Molokai. Probably not more than three hawksbills per year nest at each of these two locations (NMFS 1992). There are no data to suggest that hawksbills nest on any of the unincorporated U. S. territories in the North Pacific, although in many cases adequate survey efforts have yet to be undertaken. In summary, available data suggest that hawksbill populations have been greatly reduced in size over the course of this century, as measured by steep declines at virtually all Pacific rookeries.

Insular and Pelagic Range

Hawksbills forage on coral reefs and other hard-bottom habitats in open bays and coastal zones throughout the tropical Pacific. Despite a wide variety of foods consumed (see Witzell 1983), recent studies in the Caribbean indicate that these turtles may specialize on sponges, and predominately on two orders of Demospongea (Meylan 1988). Ten species of sponges accounted for 79.1% of the dry mass of all sponges identified in the stomachs of hawksbills from seven Caribbean countries (Meylan 1988). The predominance of specific taxa in the digesta suggests a degree of selectivity, perhaps related to distinctive properties of the sponges with respect to spongin and collagen (Meylan 1985). Balazs (1978b) reported that the stomach and intestines of a dead hawksbill (75.6 cm SCL) entangled in a monofilament gill net (Kaneohe Bay, Hawaii) were filled with food, consisting of three kinds of unidentified sponges. Illness and even death have been attributed to the consumption of hawksbill meat in Sri Lanka, China (Taiwan), Philippines, Indonesia, Malaysia, Papua New Guinea, and Australia (Torres Strait), as well as central Pacific and Caribbean islands (Halstead 1970, 1980; Márquez 1990). The toxins are believed to originate in food items consumed by the turtle.

Dietary considerations would appear to constrain the hawksbill to tropical coastal zones where benthic prey, typically associated with coral reefs, are available. However, very young juveniles are known to associate with pelagic flotsam. Carr (1987) documented the presence of hatchling and post-hatchling hawksbills in pelagic circumstances, including individuals associated with *Sargassum* communities. A hawksbill about 15 cm SCL was incidentally captured in a tuna purse-seine which had been set on a log at 3°03'S, 144°38'E (north of Papau New Guinea) in February 1978 (Robert Pitman, NMFS, pers. comm., 1991; photo available), and a similar-sized turtle was dip-netted from the Gulf of Siam, Thailand (7°22'N, 100°43.5'E) in August 1980 (Carr 1987). Immature hawksbills have also been known to cross ocean basins. In July 1990, a large juvenile (74 cm SCL) tagged six months before in Brazil was killed in Dakar, Senegal, some 3,680 km across the Atlantic Ocean (Marcovaldi and Filippini 1991). It is possible that immature turtles in both oceans are occasionally carried by currents far beyond their normal range, and thus represent individuals which would never rejoin their population units. Conversely, the pelagic zone may represent important habitat for juvenile age classes. Additional data are needed on this important life-history aspect.

The hawksbill is currently considered rare in the eastern North Pacific. It still occurs in Mexican waters, but at much lower densities than in the past. Seri Indians and fishermen in the Gulf of California region tell of an abundance of hawksbills only 20-30 years ago; the demand for tortoiseshell is implicated in their widespread demise. Today juveniles are much more likely to be encountered than adults (Cliffton et al. 1982). One individual was recently captured in a gill net, apparently set near Bahia de la Paz, Baja California Sur (Alvarado and Figueroa 1990). The species does not appear to venture north of Mexico. It is not mentioned in Stinson's (1984) exhaustive summary of sea turtle sightings in the coastal northeastern Pacific from central Baja California to the Gulf of Alaska. Only four of 2,742 sea turtle sightings in the ETP over a period of 15 years were identified as hawksbills; these individuals were encountered in waters 9°-15°N (Pitman 1990).

In the western North Pacific, hawksbills, characterized as "fierce and scarce", are widely distributed in China along the coasts of Guangxi (Kwangsi), Guangdong (Kwangtung), Fujian (Fukien), Zhejiang (Cheking), Jiangsu (Kiangsu), and Shandong (Shantung) where they reportedly feed mainly on fish, shrimp, crabs, mollusks, and algae (Chu-Chien 1982). Frazier et al. (1988) presented data from 10 juveniles (max 65 cm CCL) taken during the summer months (May-October) from the Xisha Islands (=Paracel Islands; ca. 16°N, 113°E) in the south to Pingtan Island (25°30'N) and Lianjiang (26°06'N) on the north side of the Minjiang River, Fujian. Little is known of the distribution or abundance of hawksbills in Japan. Kamezaki and Hirate (1992) obtained 18 juveniles (39.3-63.1 cm SCL) in six months (February-July 1988) from coastal waters of the Yaeyama Islands (Ryukyu Archipelago, Japan) through fishermen who caught them by diving. Juveniles are also reported from Taiwan, where two specimens brought into the fishing port of Nanfangao measured 23.6 and 38.7 cm CCL (Mao 1971). Bourret (1941 *in* Groombridge and Luxmoore 1989) considered the species to be common all along the coasts of the former French colonies in Indochina, which would include modern Viet Nam and Kampuchea. The Kampuchean villages of Samit and Lucson were said to be centers for turtle fishing, presumably for both hawksbills and green turtles. The hawksbill was most abundant off the west coast of the "Cochin China" region. In Viet Nam, large domestic markets for tortoiseshell are supplied by animals killed in Ha Tien (Kien Giang Province) and Vung Tau (Baird 1993). The current status of hawksbill populations in Indochina is not known.

Hawksbills were once common at certain localities in Thailand, especially at Ko Klang in the Ko Adang Group in what is now Tarutao Marine National Park in the Andaman Sea. Today the species is rare, being heavily exploited for eggs and shell and less so for meat (Humphrey and Bain 1990). Further to the south, individuals of all sizes are "regularly found foraging in the waters of Melaka and Negri Sembilan" and are commonly captured in driftnets with mesh >2 inches. On the eastern coast, in the Gulf of Thailand and south into the waters of peninsular Malaysia, the species is less common. Fishermen report that trawling vessels have caused "much mortality during recent decades, especially near the islands of Pahang and Johor [Malaysia] where the turtles used to be fairly abundant" (Jeanne Mortimer, WWF-Malaysia, *in litt.*, 29 August 1991). In Eastern Malaysia, hawksbills can be found in Sarawak (Leh 1985), but details concerning distribution, abundance, and size class are unavailable. In Sabah, most of the 18 hawksbills encountered during an October-November 1990 survey of Palau Sipadan appeared to be juveniles. The reefs there are in excellent condition and provide good forage (Mortimer 1991a). In many areas of Sabah, with the exception of the Turtle Islands, "fish bombing" may destroy corals, and thus degrade important hawksbill habitat; several government agencies are presently monitoring this activity (Laurentius N. Ambu, Sabah Wildlife Dept., *in litt.*, 17 June 1991).

Hawksbills are reported throughout the archipelago of the Philippines and are second in abundance to the green turtle (de Celis 1982; Trono 1991; E. D. Gomez, *in litt.*, 28 May 1991). No systematic survey of their distribution or abundance has been undertaken. Historically, major sources of tortoiseshell have been the Philippine Turtle Islands, Lubang Island in Mindoro Occidental, Surigao del

Norte, Negros, Antique, Sitangkai, Bungao, Davao, Basilan, Cotabato, Lanao del Norte, Quezon, and Sorsogon (de Celis 1982). Large scale destruction of coral reefs, which provide essential foraging habitat and refugia for the turtles, has occurred due to the illegal use of chemicals in the collection of fish for the pet trade. It is estimated that >1,000,000 kg of sodium cyanide have been sprayed over coral reefs in the Philippines in the last 20 years, killing the live coral and other reef invertebrates (Rubec 1986; WWF 1989; IMAC 1990). In addition, ongoing practices of fishing with explosives and dropping rocks on living coral to scare fish into waiting nets have contributed to the loss of vast areas of reef in the Philippines (Louella Dolar, Silliman Univ., pers. comm., 1993). The extent to which habitat modification has affected the status of hawksbill stocks in Philippine waters has not been quantified.

In the central North Pacific the species is generally regarded as less common than the green turtle, with the possible exception of Palau Lagoon where hawksbills were present in abundance at the time of Pritchard's (1982a) paper. During recent aerial surveys of Guam (October 1989-April 1991), 13.2% of 76 turtles sighted were hawksbills, as opposed to 65.8% green turtles (Gerald Davis, Guam DAWR, *in litt.*, 22 August 1991). On the whole, literature written on the subject of sea turtles in Palau, the FSM, Marshall Islands, Northern Mariana Islands, and Kiribati is very general in nature and hawksbills and green turtles are not fully differentiated in the text (e.g., McCoy 1974; Balazs 1982a; Pritchard 1982a; Johannes 1986). It is clear, and not surprising, that detailed surveys of this vast region have not been undertaken with regard to the distribution and abundance of sea turtles and particularly hawksbills. Since hawksbills feed predominately on reef invertebrates (mainly sponges), for the present we should assume that any healthy coral reef ecosystem is potential foraging habitat. The Hawaiian population is small and only known to occur in coastal waters of the eight main and inhabited islands at the southeastern end of the 2,450 km-long archipelago (Balazs 1982a). An adult female was found entangled and decomposing in a monofilament gill net in Kaneohe Bay, Oahu, in August 1977 (Balazs 1978b) and an emaciated juvenile (36 cm SCL, 5.4 kg) washed ashore at Kahana Bay, Oahu, in October 1984 (Balazs 1985). There are no documented sightings in waters proximal to the various unincorporated U. S. territories in the North Pacific (Groombridge and Luxmoore 1989), although, with the exception of Johnston Atoll (see Balazs et al. 1990), sufficient marine surveys are generally lacking.

Growth

On the Great Barrier Reef (GBR) of Australia, growth in wild hawksbills does not differ markedly from that of green turtles (Limpus

1979, 1980b). After nearly two decades (1969-1988) of study, it is clear that (a) individuals recruit to the GBR feeding grounds at a minimum size of 35 cm CCL, (b) there are significant differences in growth rate among size classes, with the maximum mean growth rate (2.17 cm/ year) recorded for turtles in the 50-60 cm CCL range, and (c) a small turtle (35 cm CCL) recruiting to the feeding grounds can be expected to begin breeding about 31 years later (Colin Limpus, Australia NPWS, pers. comm., 1991). One young hawksbill captured and then recaptured off the coast of Japan grew at a rate of 5.5 cm/yr over the intervening 18 months. The turtle (36.7 cm carapace length) was first captured at Kuroshima (24°15'N, 134° 0'E), Japan, on 15 February 1985 and tagged and released. It was recaptured 18 months later about 9 km north of Kuroshima; it had gained 8.3 cm and 2.9 kg (Kamezaki 1987). Comparative data are available from the western Atlantic. Preliminary results from capture/recapture studies in the U. S. Virgin Islands suggest that wild juveniles (size range 27-64 cm SCL, n = 14) grow an average of 3.4 cm per year (Nat Frazer, Mercer University, pers. comm., 1990). In the southern Bahamas, four juveniles (40-70 cm SCL) grew at an annual rate of 2.4-5.9 cm (Bjorndal and Bolten 1988b). Mature females grow at an average rate of 0.3 cm per year at Tortuguero, Costa Rica (Bjorndal et al. 1985). Age at maturity is unknown.

Conservation Status

According to the Code of Federal Regulations (50 CFR 17.11), the hawksbill sea turtle is listed as Endangered throughout its entire range under the U. S. Endangered Species Act of 1973, as amended. Similarly, the species is classified as Endangered in the IUCN *Red Data Book*, where taxa so classified are considered to be "in danger of extinction and whose survival is unlikely if the causal factors continue operating" (Groombridge 1982). Hawksbills are also included on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a designation which effectively bans trade in specimens or products except by special permit. Such permit must show that the trade is not detrimental to the survival of the species and is not for primarily commercial purposes (Lyster 1985). Since Japan ratified CITES with a "reservation" on *Eretmochelys imbricata*, an enormous volume of trade has taken place over the last two decades [N.B. Japan imposed a zero quota on the import of hawksbill products as of 31 December 1992; Donnelly 1991]. For a trade summary, as well as an overview of national legislation protecting hawksbills in the North Pacific, see an earlier section of this report.

Life Cycle Overview

Eggs and Hatchlings--Embryology and ontogeny are discussed by Deraniyagala (1939). Eggs average 36.0 mm in diameter (range 32.3-40.7, n = 470 eggs) and 26 g (range 19.5-32.5, n = 470 eggs) at the Campbell Island rookery, Queensland, while hatchlings measure 41.1 mm (range 38.2-43.8, n = 70) (Limpus et al. 1983). Similar statistics are reported from Micronesia (Fukada 1965 *in* Witzell 1983), Western Samoa (Witzell and Banner 1980), and Indonesia (Sumertha 1979 *in* Witzell 1983). Incubation is generally 50-70 (sometimes 90) days at Pacific nesting grounds (summarized by Witzell 1983). The sex of the hatchlings appears influenced by incubation temperature, with cooler temperatures producing males (Dalrymple et al. 1985). Hatch success is relatively high, often averaging 70-90%. After emergence from the nest, hatchlings crawl quickly to the sea. Once they leave the natal beach, virtually nothing is known of their movements or their distribution, abundance or survival. A brief study conducted in Puerto Rico suggests that hatchlings orient toward open ocean once they enter the surf (Hall 1987). There is some evidence that hatchlings and post-hatchlings associate with *Sargassum* and buoyant debris in zones of current convergence and weed lines in the pelagic Atlantic (Meylan and Carr 1982; Carr 1987).

Terrestrial and marine predators are abundant. Early survivorship is assumed to be low. Crabs, *Varanus* and *Ameiva* lizards, birds, including night herons (*Nyctanassa violacea*) and barn owls (*Tyto alba*), and mammals, including mongooses (*Herpestes auropunctatus*), wild pigs (*Sus scrofa*) and domestic dogs, prey on eggs and/or hatchlings while on the beach. At sea, hatchlings, juveniles and adults fall prey to tiger sharks (*Galeocerdo arcticus* [=*cuvier*]), groupers (*Epinephelus itajara*) and crocodiles (*Crocodylus porosus*) (summarized by Witzell 1983 and Eckert 1992b). Of 300 crocodile stomachs examined in Palau, six contained remains of hawksbills (Pritchard 1978). Hatchlings were attacked by a black-tipped reef shark (*Carcharhinus spallanzani*) in Samoa (Witzell and Banner 1980).

Juveniles--Hawksbill turtles of various size classes presumably occupy hard bottom habitats throughout the tropics, but no systematic study of their distribution or abundance has been undertaken. Juveniles have been recorded in waters off China (<65 cm CCL, Frazier et al. 1988), Thailand (Carr 1987), and Hawaii (36 SCL, Balazs 1985). As is the case with most Pacific sea turtle species, the habits of hawksbills during the years prior to sexual maturity are largely unknown. Research conducted in the Great Barrier Reef region of eastern Australia suggests that juveniles abandon the pelagic stage, the so-called "lost years", at about 35 cm CCL to take up residence in coastal waters and begin feeding on benthic invertebrates (see

Growth). Few data are presently available concerning diet, growth rate, movements, or survivorship.

Adults--Adults are distributed circumglobally and are the most confined of all the North Pacific sea turtles to tropical waters. They are sometimes described as sedentary, or as having "given up migration" (Hendrickson 1980). This stereotype has persisted in part because of early reports (Carr and Main 1973) that carapace color and morphology varied by island (or island group) in the southwestern Pacific and were unique, allowing indigenous peoples to discern distinct populations over rather restricted geographic areas. There is skepticism, however, that such uniformity exists (Limpus et al. 1983). The sedentary hypothesis is further eroded by records of long distance movements of several hundred to several thousand km (e.g., Carr and Stancyk 1975; Nietschmann 1981; Vaughan 1981; Meylan 1982; Parmenter 1983; Marcovaldi 1991). One individual travelled 713 km in 40 days, having been tagged on 12 February 1977 at Bakkungan Kechil (6°10'N, 118°06'E), Turtle Islands Park, Sabah, and recaptured on 23 March 1977 in Culasi, Philippines (11°26'N, 122°03'E) (de Silva 1986). It is likely that additional tagging in nesting and foraging habitats will demonstrate migratory behavior in hawksbills.

Anne Meylan, in a brief synopsis delivered to the Second Western Atlantic Turtle Symposium, explained why we persist in our ignorance of hawksbill ecology (Meylan 1989). She noted that, unlike other species of marine turtle, the hawksbill nests diffusely throughout its range, with few known breeding aggregations. This diffuse distribution and the fact that nesting may occur for six or even nine months of the year at some locations make this species one of the most difficult to study. Few intensive investigations have been undertaken and our knowledge of key aspects of reproductive biology (e.g., clutch frequency, remigration) is poor. With few tagging programs, knowledge of migratory habits and patterns has also remained fragmentary. In addition to low density nesting, other factors render hawksbill populations difficult to census, including a predilection for nesting on comparatively inaccessible beaches (widely separated oceanic islands, small pocket beaches, beaches obstructed by coral reefs), the ephemeral nature of a hawksbill's track in the sand, and a tendency to prepare a nest amid dense vegetation.

Despite our ignorance of detail, it is abundantly clear that hawksbills are declining throughout their range and that there are several areas, specifically former nesting grounds, in the North Pacific where the species once occurred but occurs no longer. Hawksbills are long-lived, as evidenced by recent Australian data indicating sexual maturity sometime after 31 years of age (see Growth), and thus we can expect that damage done in decades past will force a continued decline in present stocks irrespective of present conservation actions. By the same token, it is essential that conservation actions be implemented without delay if future benefits, including the recovery of depleted populations, are to be realized. For the present time we should assume that adults forage in healthy coral reef systems throughout the tropical North Pacific, that sexually mature females embark on migratory journeys every two or three (or more) years between foraging and nesting grounds, and that adult males also display some degree of ability for long distance movement.

Olive Ridley Sea Turtle, *Lepidochelys olivacea*

Taxonomy

The generic name *Lepidochelys* was introduced by Fitzinger (1843). The specific name *olivacea* was first used by Eschscholtz (1829), but in conjunction with the genus *Chelonia*. Soon thereafter the binomial *Caretta olivacea* was published (Rüppell 1835), and there were subsequent modifications as well (summarized by Márquez 1990). Dispute surrounding taxonomic designation is not uncommon, but in the case of the olive ridley the literature reflects widespread bewilderment regarding both the proper binomial and an observer's ability to distinguish between loggerheads (*Caretta caretta*) and olive ridleys (*Lepidochelys olivacea*) in the field. The confusion persisted well into the twentieth century and only relatively recently have systematic efforts been made to clarify past mistakes (e.g., Nishimura 1967; Brongersma 1982; Frazier 1985). Distributional and historic records for this species will undoubtedly have to be modified once the extent of taxonomic misinformation is known (Frazier 1985; Dodd 1988). The genus *Lepidochelys* also includes a second species, *L. kempi*, confined to the Gulf of Mexico and temperate North Atlantic (Groombridge 1982; Ernst and Barbour 1989; Ross et al. 1989).

Morphology

According to Carr (1952), the olive ridley is a relatively small sea turtle with six to eight and occasionally five or nine pairs of lateral scutes; asymmetry relative to the number of scutes on either side is not uncommon. The anteriormost lateral scute is in contact with the cervical (=nuchal) scute. Scutes do not overlap one another. The broadly heart-shaped carapace is uniform olive in color, the bridge and plastron are greenish white to yellow, and the legs and neck are olive above and lighter below. The head is relatively large compared with *Chelonia* or *Eretmochelys*. Márquez (1990) notes that front flippers have one or two visible claws on the anterior edge and rear flippers have two claws. A small glandular pore is present near the rear margin of each of the four pairs of inframarginal scales.

The function of these pores is unresolved. Some investigators have speculated that they may exude pheromonal secretions to aid in species recognition and mating (Cornelius 1986). Carapacial (dorsal) and plastral (ventral) keels are visible in young juveniles but disappear with age.

Carr (1952) described two hatchlings (40 mm, 41 mm) from Sinaloa, Mexico, to be nearly uniform grayish black in color, except for a lighter shade on the ventral keels, which were strong and sharp from humerals to anals. Dorsal keels were strong on all the centrals (but absent on the precentral) and on all of the six lateral scutes on both sides of both specimens. Deraniyagala (1952) observed four color phases: (a) pigmentation commences in 18-day embryo (carapace length 15 mm), by 30 days (carapace length 25 mm) dorsal pigment is glaucous and plastron is white; (b) dorsal color becomes bluish-green with dark scute margins, eventually changing to sooty black dorsally and ventrally with brownish plastral ridges, carapace and flippers possess thin white margins at hatching; (c) 307-day animal (carapace length 210 mm) is dark gray dorsally with diffuse gray radiating streaks on each scute, carapace margin yellow, mandible and throat white, plastron yellow with a dark patch on some inframarginals (inframarginal pores pink); (d) adult is uniform olive green to a dark olive brown dorsally, pale yellow or greenish yellow ventrally. The most thorough treatise on embryology, anatomy, and captive growth for the species in the Indo-Pacific is provided by Deraniyagala (1939). Useful discussions of embryological development are also found in Crastz (1982) and Mohanty-Hejmadi (1988).

Sexual dimorphism is evident in adults. Males have a long prehensile tail with a heavy terminal nail (a female's tail barely reaches the rear margin of her carapace), a relatively soft and concave plastron, a more gently sloping lateral profile, and strongly developed, curved claws on each front flipper (Wibbels et al. 1991). Adult females in Pacific Central America and Mexico range in weight from about 35 to 45 kg (Cornelius 1986) and measure 49-71 cm SCL (mean = 60.6 cm, n = 1,563) in La Escobilla, Mexico and 57-72.5 (mean = 65.2 cm, n = 53) at Playa Nancite, Costa Rica (summarized by Márquez 1990). Márquez et al. (1976) reported that the carapace lengths of 13 adult males from Baja California, Mexico, were 58.5-69.0 cm. Frazier et al. (1988) measured a sample of 22 turtles from Fujian Province and one from Hainan, Guangdong Province, in China and reported a range of 43.0-70.0 cm CCL, including both juveniles and adults. A ridley nesting in 1986 at Pulau Selingaan, Sabah Turtle Islands Park, measured 66 cm CCL and weighed 37 kg (de Silva 1987). No morphometric data are available from the Central Pacific.

Population Units

On the basis of a provisional mtDNA clock calibrated from other marine turtles (0.2-0.4% sequence divergence per million years), it has been suggested that the olive ridley (*L. olivacea*) and the Kemp's ridley (*L. kempi*) diverged some 3-6 million years ago (Bowen et al. 1991). In contrast, Atlantic (Suriname) and Pacific (Costa Rica) stocks of olive ridleys are genetically distinct but have diverged in very recent evolutionary time, as indicated by an mtDNA phylogeny (Bowen et al. 1993b). Pritchard (1969b) commented on the morphological and behavioral similarities among olive ridley populations around the world and hypothesized that the species may have only recently colonized the Atlantic via the Cape of Good Hope. Contemporary oceanic current patterns and the presence of olive ridleys in southeast Africa are both compatible with this hypothesis (Hughes 1972). Genetic study of east Pacific populations by Alberto Abreu (BITMAR, Mexico) is ongoing and will provide invaluable insight into population structuring in the eastern Pacific. At the present time we can assume only that there is a degree of stock cohesiveness within the major eastern Pacific *arribada* groups (there is no evidence that Mexican ridleys routinely nest in Costa Rica, or vice versa), and a similar individuality to western Pacific nesting populations which has arisen over many generations based on nesting ground fidelity.

Nesting Habits and Areas

The olive ridley is a circumglobal species, present in tropical regions of the Atlantic, Indian, and Pacific Oceans. It typically nests nocturnally on mainland shores near the mouths of rivers or estuaries (Cornelius 1986) and is rare throughout the islands of Oceania and southeast Asia. Overall, although the olive ridley remains relatively widespread and abundant, most nest sites support only small or moderate-scale nesting and most populations are known or thought to be depleted (Groombridge 1982). Nesting may take place either singly, in small colonies, or, where population densities are high enough, in synchronized aggregations known as *arribadas* which can comprise up to 150,000 females. Very large *arribadas* now occur in only two areas; namely, in Orissa State (northwestern Bay of Bengal, India) and at Nancite and Ostional beaches on the Pacific coast of Costa Rica. The *arribadas* generally follow a monthly schedule. The precise impetus for the event is unknown. Ongoing investigations of reproductive ecology (radio-tracking, testosterone analysis) at Nancite suggest that females lay two clutches of eggs per season (Pam Plotkin, TAMU, *in litt.*, 21 April 1993). A review of the reproductive physiology of *Lepidochelys*, including changes associated with ovulation and nesting, is available from Licht et al. (1982).

The major *arribada* sites in Pacific Mexico were El Playón de Mismaloya (Jalisco), Piedra del Tlacoyunque (Guerrero), Bahia Chacahua, La Escobilla (Oaxaca), and El Morro Ayuta (Oaxaca). Of these only La Escobilla retains mass nesting (Groombridge 1982), although the number of turtles arriving each year has been greatly reduced. Indeed, the Oaxaca population has been described as "severely depleted and showing signs of collapse" (Cliffton et al. 1982) (see also Importance of North Pacific Sea Turtles to Human Populations: Mexico). In 1987, a comparatively good year, six *arribadas* took place. The number of females participating in each of the relatively small July *arribadas* was estimated at roughly 15,000, whereas there were some 57,000 in the largest *arribada* in mid-September (Ruiz and Marin 1988). Nesting in smaller numbers occurs in the states of Sinaloa, Colima, Michoacán, and Baja California Sur (Márquez et al. 1976). During August-September 1978 aerial surveys of Baja California Sur (24°N to Cabo San Lucas), Fritts et al. (1982) counted 102 nests on both sides of the peninsula, the majority of them likely to be olive ridleys. The biggest nesting colonies in the eastern Pacific are further south, in Costa Rica, where 50,000 to 150,000 turtles take part in the largest *arribadas* (Hughes and Richard 1974; Cornelius 1986). Low density nesting is reported throughout Central America, including Guatemala, El Salvador, Honduras, Nicaragua, and Panama (Cornelius 1982). The nesting sequence (site selection, digging, egg-laying, etc.) is similar to other species of sea turtle and is described by Carr (1952), Hughes and Richard (1974), and Cornelius (1986).

In the western North Pacific there are a few sightings from Japan, but no report of egg-laying (Uchida and Nishiwaki 1982; Kamezaki 1989). Similarly, there are no nesting records from China (Chu-Chien 1982; Frazier et al. 1988), Korea (Shannon 1956; Szyndlar 1991), or Taiwan (Mao 1971). No information is available from Viet Nam or Kampuchea. No mention is made of occurrence or breeding in the Gulf of Thailand; however, olive ridleys are recorded "all along the west [Thai] coast" (Groombridge 1982) and breed at a few sites (e.g., Laem Phan Wa reserve at Phuket Marine Biological Center) (Humphrey and Bain 1990). Nesting is known to occur on both the eastern and western coasts of peninsular Malaysia, mainly in the northern States. Siow and Moll (1982) estimated the annual yield from east coast rookeries to be 305,000 eggs; the highest density nesting was reported from Terengganu with 240,000 eggs collected per annum. In contrast, only 187 nests were reported from Terengganu in 1990 (data courtesy Department of Fisheries, Malaysia). In Eastern Malaysia, olive ridleys nest very rarely in Sabah (de Silva 1987; Mortimer 1991a) and only a few records are available from Sarawak, mainly during the early months of the year (Harrisson 1969; de Silva 1982). There are no records of nesting in the Philippines. In the central Pacific a single nesting was reported in September 1985 on the island of Maui, Hawaii (Balazs and Hau 1986). Falanruw et al. (1975) observed a mating pair in M'il Channel, northwest of Yap, in Micronesia. There are no records of nesting on the unincorporated U. S. territories in the North Pacific (Balazs 1982a).

The largest *arribadas* occur during August-October in Pacific Mexico (Ruiz and Marin 1988) and Costa Rica (Cornelius 1986). In contrast, most nesting occurs between February and July along peninsular Malaysia (Leong and Siow 1980) and October to February at Phuket, Thailand (Humphrey and Bain 1990). Mating may occur along migratory routes or at other chosen points at sea, and is not confined to waters adjacent to nesting beaches. Pitman (1990) reported the locations of 29 pairs of mating (=mounted) olive ridleys in the ETP. He noted that mounting had been observed during all months except March and December and that it regularly occurred in the open ocean, at least as far as 1,850 km from the nearest mainland. The August-September peak in Pitman's data corresponds to early peak breeding activity for the species in the east Pacific. Hubbs (1977) reported mating off the coast of San Diego on 29 August 1973, 615 miles north of the nearest nesting ground in Magdalena Bay, southern Baja California (Stinson 1984). No information is available concerning the timing or geography of mating in the western Pacific.

Insular and Pelagic Range

Surprisingly little is known of the oceanic distribution of the olive ridley, the most populous of North Pacific sea turtles. Pritchard (1991) suggests that for both the olive ridley and the leatherback, post-hatchling and juvenile life stages occupy a pelagic habitat so poorly known that very few such specimens have ever been reported. Only recently, as data have become available from research cruises and fishery observer programs, has there been confirmation that juveniles (and adults) frequent the open waters of the Pacific. In a three year (1987-1989) study of communities associated with floating objects in the ETP, Arenas and Hall (1992) found sea turtles, mostly (75%) olive ridleys, present in 15% of observations and suggested that flotsam may provide the turtles with food, shelter, and/or orientation cues in an otherwise featureless landscape. Based on nearly 15 years of data, Pitman (1990) describes the range of the olive ridley in the ETP as bounded to the north by the cold California Current that veers southwest off the southern tip of Baja California and to the south by the cold Humboldt Current that veers northwest off the coast of northern Peru at about 5°S. Of 247 positively identified ridleys, most were observed between the mainland and 120°W; however, some were quite far from shore (e.g., 10°39'N, 139°47'W) (Pitman 1990). Ridleys are most abundant in Mexican waters during the nesting season (see Nesting Habits and Areas). Some enter the Gulf of California, where they are occasionally captured in gill nets (Alvarado and Figueroa 1990).

While it is essentially true that olive ridleys have an "emphatically tropical range" (Pritchard 1989), individuals do occasionally venture further north. In October 1957, one of several periods during the last century when surface sea temperatures were unusually warm along the Pacific coast of North America, a young olive ridley (carapace length 24.1 cm) was captured in Humboldt Bay, northern California (Houck and Joseph 1958). Stinson (1984) documented a 19 November 1962 stranding in Seaside, Oregon (46°00'N). She reported ridleys throughout the year in 15-20°C water south of Point Conception, California, as well as predominately October-December sightings north of Point Conception (these were found at 12°-14°C water; those at 12°C were either dead or emaciated and lethargic). On 11 November 1989, a juvenile (57.2 cm CCL, 63.5 cm CCW) stranded dead on Copalis Beach, Washington, about 47°N (Keith Aubry, Univ. Washington Burke Museum, *in litt.*, 2 June 1991). There are no documented records of olive ridleys in Canada or Alaska, but fishermen informally report encountering ridleys in Gulf of Alaska waters (Robert Hodge, pers. comm., 1993) and some authors have included the Gulf in the species' range (Márquez 1990). [N.B. The turtle reported by Gjernes et al. (1990) to be an olive ridley captured in July 1989 by a Japanese driftnet vessel at about 42°N, 159°W was misidentified (George Balazs, NMFS, pers. comm., 1992)].

In the western Pacific the species has been reported in both the East and South China Seas. At the time of Mao's (1971) paper, olive ridleys could "usually be obtained" in Taiwan at Nanfangao, a fishing port on the coast near Suao, and at Lanyu Island, about 49 nautical miles off the southeast coast of the main island. Frazier et al. (1988) summarized records from Hainan Island (19°40'N) to Zhejiang Province (about 27°N) in China. All but two of 24 specimens examined were from Fujian Province, both juveniles and adults were included, and maximum abundance was noted to be June-July. Just north of Zhejiang Province a juvenile (47 x 50 cm carapace length and breadth, respectively) was caught near Lüsi (Jiangsu Province) on 1 October 1981 by a local fisherman (Zhou 1983). No information could be found with regard to the species' potential distribution in the waters of Korea, Japan, or the South China Sea/Gulf of Thailand nations of Viet Nam, Kampuchea and Thailand. Olive ridleys are said to be "common" in the waters off Terengganu, Malaysia, where an estimated 443 are incidentally captured in trawl and drift/gill nets each year (Chan et al. 1988). In 1973, fishermen operating a bottom long line for rays "caused a massive kill of ridleys at Setiu, Terengganu" (Siow and Moll 1982).

Olive ridleys feed occasionally in Sabah (Laurentius N. Ambu, Sabah Wildlife Department, *in litt*., 17 June 1991; Jeanne Mortimer, WWF-Malaysia, *in litt*., 29 June 1991), although they have not been recorded from the waters of Sarawak (Leh 1985). They are present in the Philippines (de Celis 1982; Trono 1991) and throughout Papua New Guinea (Spring 1982), but are encounted only rarely in the waters of the central North Pacific. There are no records from Guam (Gerald Davis, Guam DAWR, *in litt*., 2 August 1991). According to Pritchard (1982a), olive ridleys were first recorded in Micronesia by Falanruw et al. (1975), who observed a mating pair northwest of Yap and also reported a young juvenile (29 cm) from Lamotrek, in the eastern Yap District. Other records include incidental catch by long lines and plankton nets (Cushing 1974) and an immature stuffed specimen, reportedly locally caught and prepared, for sale in a souvenir shop on Saipan in 1976 (Pritchard 1982). The species is a rare visitor in Hawaii, but has been recorded in increasing numbers during recent years (Balazs 1983a). Incidences of the entanglement of juveniles and adults in marine debris around the Hawaiian islands include Kilua-Kona (Hawaii), Pukoo (Molokai), Hana (Maui), and Oahu (Balazs 1985).

The non-nesting range presumably reflects the availability of prey. Olive ridleys are carnivores, consuming primarily mollusks, sessile and pelagic tunicates, fishes and fish eggs, jellyfish, and crabs, shrimps, amphipods and other crustaceans such as the red lobsterette (*Pleuroncodes planipes*) (Fritts 1981; Mortimer 1982b; Márquez 1990). In a study carried out in Oaxaca, 24 adult males had fed mainly on fishes (57%), salps (38%), crustaceans (2%) and mollusks (2%). Adult females (n = 115) fed on salps (58%), fishes (13%), mollusks (11%), algae (6%), crustaceans (6%), bryozoans (0.6%), sea squirts (0.1%), sipunculid worms (0.05%), and fish eggs (0.04%) (Márquez 1990). Similarly, stomach content analysis of two males washed ashore at Nancite, Costa Rica, revealed a diet of salps (primarily), shrimp, mollusks, and crabs (Pam Plotkin, TAMU, *in litt*., 21 April 1993). Ridleys may dive deeply for their prey. They have been captured in prawn trawls at depths of 80-110 m and observed feeding on crabs at 300 m in the Sea of Cortez (Landis 1965, species identified in Eckert et al. 1986).

Pritchard and Trebbau (1984) report great concentrations of olive ridleys near the coast of Ecuador, where optimal feeding conditions may result from the confluence of the warm Panama Current and the cold, highly productive Humboldt Current.

Olive ridleys are migratory in the Pacific. Long distance movement is recorded from nesting grounds in Mexico and Central America southward to feeding grounds off Ecuador (Groombridge 1982). Cornelius (1986) documented post-nesting dispersal to the north, south, and west from Costa Rica to every country (with the exception of Honduras) in the east Pacific from Mexico to Peru; one turtle was found more than 2,400 km west of the nesting beach in the open sea. Preliminary results of ongoing research at Nancite, Costa Rica, show that post-nesting females can travel 9,000-plus km in 16 months (Pam Plotkin, TAMU, *in litt*., 21 April 1993). Oliver (1946) observed what may have been a migratory aggregation in deep water off Guerrero, Mexico, in late November 1945. Nothing is known of the migratory patterns of western Pacific ridleys, largely because systematic tagging has not been undertaken.

Growth

Captive growth rates have been described (e.g., Deraniyagala 1939; Phasuk and Rongmuangsart 1973), but comprehensive studies of growth rate in wild olive ridleys have not been undertaken. Growth rate and age at maturity are unknown for this species.

Conservation Status

According to the Code of Federal Regulations (50 CFR 17.11), the breeding colonies of olive ridleys along the Pacific coast of Mexico are listed as Endangered and all others as Threatened under the U. S. Endangered Species Act of 1973, as amended. The species is classified as Endangered in the IUCN *Red Data Book*, where taxa so classified are considered to be "in danger of extinction and whose survival is unlikely if the causal factors continue operating" (Groombridge 1982). Olive ridleys are included on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), a designation which effectively bans trade in specimens or products except by special permit. Such permit must show that the trade is not detrimental to the survival of the species and is not for primarily commercial purposes (Lyster 1985). Since Japan ratified CITES with a "reservation" on *Lepidochelys olivacea*, the import of olive ridley products (mostly skins) into that country continued until 1992 when the reservation was withdrawn. For a summary of national legislation protecting olive ridleys in the North Pacific, see an earlier section of this report.

Life Cycle Overview

Eggs and Hatchlings--As summarized by Márquez (1990), *arribadas* are repeated two to seven or eight times each season, but the mean number of nests laid by each turtle generally does not exceed two. The reproductive cycle is nearly annual, with >60% of the turtles nesting every year. The number of eggs laid per clutch ranges from a couple of dozen to more than 155; the mean is generally 100-110 (e.g., Mexico mean = 105.3 eggs, n = 1120 nests; Costa Rica mean = 105 eggs, n = 20 nests). Mean egg size differs among populations, with eggs ranging from 32.1 to 44.7 mm in diameter and 30 to 38 g in weight. Hatchlings emerge from the nest after about 45 to 65 days. Hatchling size varies among populations, with data from Pacific Mexico indicating a mean size of about 39 mm SCL (range 37-42 mm, n = 329) and mean body mass of nearly 14 g (range 12-21.5 g, n = 329).

The sex of olive ridley hatchlings is influenced by temperature. In Gahirmatha, Orissa, eggs incubated at 26.5°-28.0°C produced 100% male offspring, those incubated at 29.5°C produced 40% males and 60% females, and those incubated at 30.0°-31.5°C produced 100% females (Mohanty-Hejmadi et al. 1985). Hatch success is typically low on *arribada* beaches. It has been calculated to be a mere 5% in some years at Nancite, Costa Rica (Cornelius 1986). Eggs are destroyed by subsequent nesting activity, as well as by erosion (which varies greatly from season to season) and predators. Rates of nest destruction by turtles increase with each successive night of an *arribada*. In a 1981-1984 study, the average percentage of females encountering a nest rose from 11.4% on first nights to 34.7% on fifth nights (Cornelius et al. 1991). In addition, many seemingly undisturbed nests show little evidence of embryo development; as many as 50% of nests laid during an *arribada* or nearly 85% of those that are not destroyed by other factors, do not contain successful eggs (Cornelius 1986). Microorganisms, especially fungi, have been implicated. Natural hatch success at other potentially important rookeries, specifically Terengganu, Malaysia, is difficult to gauge since in the past virtually every egg was collected for sale.

Most hatchlings emerge at night, which may partially protect them from predators, although in some studies (Hughes and Richard 1974) most hatchlings emerged at dawn or shortly thereafter. Cornelius (1986) documents that black vultures, coatis, raccoons, coyotes and crabs consume eggs laid on the Pacific coast of Costa Rica, while hatchlings are eaten by mammals, birds (night herons, ruddy turnstones, oystercatchers, black vultures, magpie jays, black hawks, and frigate birds), reptiles (crocodiles, iguanid lizards), and crabs. Other egg predators at Playa Nancite, Costa Rica, include the snake *Loxocemus bicolor* (Mora and Robinson 1984) and the opossum *Didelphis marsupialis* (Hughes and Richard 1974). With the exception of the reptilian predators, a similar array of species prey upon eggs and hatchlings at the Mexican rookeries (Richard Byles, FWS, pers. comm., 1991). At Nancite, predation rates are strongly linked to vegetative cover; nests laid on the open beach are far less likely to be violated (Cornelius et al. 1991). Once in the sea, the young turtles fall prey to carnivorous fishes. Literature specific to egg and hatchling predation in the western North Pacific is lacking.

Nothing is known of the dispersal of hatchlings from their natal beaches, nor of their subsequent survivorship or ecological requirements. An epipelagic stage lasting as long as several years is likely.

Juveniles--Encounters with juvenile olive ridleys in the Pacific Ocean are reported from several locations, including the ETP where they are occasionally caught in tuna purse seines (Scott Eckert, HSWRI, pers. comm., 1991), Hawaii, Micronesia, and China. The northernmost record is that of a juvenile stranded near Copalis Beach, Washington (see Insular and Pelagic Range). Robert Pitman (NMFS, unpubl. data) observed about a dozen juveniles (20-30 cm carapace length) over one six hour period in September 1989, 60-130 nautical miles off the coast of Mexico (between 16°07'N, 100°29'W and 15°17'N, 101°06'W). Olive ridleys are commonly associated with floating objects (e.g., logs) and oceanographic discontinuities (e.g., fronts, driftlines) (Arenas and Hall 1992). Balazs (1985) described two Hawaiian records, one (22 cm SCL) washed ashore at Pukoo, Molokai, entangled in synthetic line and a second (38 cm SCL) found floating, entangled in green synthetic net 6-7 miles offshore Oahu. Falanruw et al. (1975) reported a small juvenile (29 cm) from Lamotrek, Yap District. Zhou (1983) reported on a juvenile (47 cm) caught by a fishermen off Jiangsu Province, and Frazier et al. (1988) provided more southerly Chinese records for ridleys as small as 43 cm CCL. With the exception of isolated records such as these, which indicate usage of both coastal and oceanic waters, the distribution of young olive ridleys in the North Pacific is unknown. Survivorship statistics are lacking, as is information on diet, growth rate, behavior, movement, and abundance.

Adults--The most comprehensive studies of adult olive ridleys in the North Pacific have been conducted at nesting beaches in Costa Rica and Mexico. Thus, while somewhat detailed information is accessible concerning *arribadas*, and fragmentary data are available on the subjects of diet and post-nesting movement, little has been learned about age at maturity, sex ratios, survivorship, age class distribution, foraging range, migration, longevity, etc. Even the details of nesting behavior are unclear at breeding grounds in the western Pacific, where nesting does not occur in *arribada*-style. We know simply that adult ridleys return, as is the case for other species of sea turtle, to a chosen nesting beach year after year. The chosen beach is presumed to be the natal beach, although this remains speculative. The cue(s) for and timing and routing of the pre-reproductive migration have not been identified, nor has the homing mechanism been explained.

At eastern Pacific nesting beaches, thousands of gravid females congregate *en masse* offshore, awaiting their cue(s). In the interim, solitary nesters land on the beach. For a week or more the number of solitary nesters increases each night until 50 or more are emerging. Finally the time is right and "the urge to nest overwhelms the thousands of others remaining cautiously beyond the waves and the invasion is on in force" (Cornelius 1986). *Arribadas* may be precipitated by such climatic events as an offshore wind, or by certain phases of the moon and tide. Once the phenomenon commences, nocturnal nesting persists for up to several days. Diurnal nesting sometimes occurs (Caldwell and Casebeer 1964; Cornelius 1986). There is no "typical" inter-nesting interval and gravid females apparently have the ability to wait for weeks while holding a clutch of fully shelled eggs. This ability may be an important aspect of the *arribada* phenomenon, ensuring synchrony among the females and with the relevant ambient cues (Pritchard 1991). Females nesting outside of *arribada* zones generally exhibit an inter-nesting interval of 15-17 days (e.g., Honduras: Minarik 1985).

When an individual has deposited all her eggs (generally two clutches), she returns to her non-breeding foraging ground(s). The post-nesting migration tends to be a "fanning out" in all directions, rather than a definite shift to a different area such as occurs with green sea turtles (Pritchard 1989). During non-breeding times, the olive ridley has a wide distribution in the Pacific, both coastal and pelagic (see Insular and Pelagic Range). Satellite-tracking data indicate that the movements of post-nesting females from Nancite, Costa Rica, are characteristically nomadic and wide-ranging (as far as 9,000-plus km in one 489 day interval). Females swim actively during the migratory period (presumably feeding en route), stay primarily near zones of upwelling (nutrient-rich, cold water), and spend about 14% of their time at the surface (compared to 4% surface time in waters adjoining the nesting beach) (Pam Plotkin, TAMU, unpubl. data). The majority of adults appear to be confined to tropical waters, but specimens have been encountered as far north as Seaside, Oregon (Stinson 1984). Diet is presented under Insular and Pelagic Range. Virtually nothing is known about the behavior or movements of males.

FACTORS IMPORTANT TO ASSESSING IMPACTS OF HIGH-SEAS DRIFTNET FISHERIES

Likelihood of Survival Following Entanglement in Driftnets, Based on Experience With Trawls and Other Fishing Gear

Ability of sea turtles to survive prolonged submergence

The typical reaction to forced submersion is an imbalance in the acid/base homeostasis. In laboratory studies of sea turtle responses to forced submersion (Berkson 1966, 1967; Hochacka et al. 1975; Lutz and Bentley 1985; Stabenau et al. 1991) and in one case of a freely diving but fleeing green turtle (Wood et al. 1984), the physiological response has been increased plasma lactates and decreased blood pH. In contrast, blood pH remains steady in freely diving but tank confined turtles (Lutcavage and Lutz 1991). Several investigators predict that the stress associated with forced submersion requires long periods of recovery (e.g., Lutz and Bentley 1985; Lutz and Dunbar-Cooper 1987).

A recent study undertaken to determine the effects of "trawl stress" on the blood gas, acid-base, and ionic status of Kemp's ridley sea turtles (*Lepidochelys kempi*) demonstrated that even short-term forced diving coupled with vigorous apneic swimming is beyond the aerobic capacity of these turtles (Stabenau et al. 1991). Turtles were placed in a commercial shrimp trawl equipped with a turtle excluder device (TED) and forced to endure a very brief forced submergence (max. 7.3 min) before they escaped the trawl via the TED or were released manually by a SCUBA diver. The trawl tests induced a significant non-respiratory (metabolic) acidosis, and a post-trawl 9- to 10-fold increase in breathing frequency was reported over pre-trawl observations (Stabenau et al. 1991). Given the magnitude of the observed imbalance, complete recovery of acid-base homeostasis in these turtles may have required 7-9 hours, based on the earlier calculations of Lutz and Dunbar-Cooper (1987).

The most convincing data available to assess whether shrimp trawling is responsible for sea turtles deaths come from NMFS studies relating tow time to the percentage of dead sea turtles among those captured (National Research Council 1990). Henwood and Stuntz (1987) analyzed incidental catch data from 26,714 hours of observer effort in the Gulf of Mexico and southern North Atlantic and concluded that the dependence of mortality on tow time was strongly significant ($r=0.98$; $P<0.001$). They attributed low (as compared to the Gulf) mortality rates for the Atlantic coast to shorter average tow duration in the Atlantic. Mortality rates based on minutes fished were not different among sea turtle species, although this may have been an artifact of the data as there were small numbers of captures for species other than loggerheads. Mortality rates were <1% in tows <60 min (Henwood and Stuntz 1987). In a later study involving trawling off the east coast of Florida, the mortality rate was 55% in tows >60 min (Wibbels 1989).

Systematic studies such as that of Henwood and Stuntz (1987) provided the basis for conclusions later reached by a special study committee convened by the National Research Council. The ability of sea turtles to survive prolonged submergence was summarized in the final report, *Decline of the Sea Turtles: Causes and Prevention* (National Research Council 1990), as follows:

"Under conditions of involuntary or forced submergence, as in a shrimp trawl, sea turtles maintain a high level of energy consumption, which rapidly depletes their oxygen store and can result in large, potentially harmful internal changes. Those changes include a substantial increase in blood carbon dioxide, increases in epinephrine and other hormones associated with stress, and severe metabolic acidosis caused by high lactic acid concentrations. In forced submergence, a turtle becomes exhausted and then comatose; it will die if submergence continues. Physical and biological factors that increase energy consumption, such as high water temperature and increased metabolic rates characteristic of small turtles, would be expected to exacerbate the harmful effects of forced submergence because of trawl capture.

"Drowning can be defined as death by asphyxiation because of submergence in water. There are two general types of drowning: 'dry' and 'wet'. In dry drowning, the larynx is closed by a reflex spasm, water is prevented from entering the lungs, and death is due to simple asphyxiation. In wet drowning, water enters the lungs. For nearly drowned turtles, the wet type would be more serious, because recovery could be greatly compromised by lung damage due to inspired seawater. The exact mechanism of sea turtle drowning is not known, but a diagnostic condition of the wet-drowning syndrome -- the exudation of copious amounts of white or pink froth from the mouth or nostrils -- has been observed in trawl-captured turtles.

"Turtles captured in shrimp trawls might be classified as alive and lively, comatose or unconscious, or dead. A comatose turtle looks dead, having lost or suppressed reflexes and showing no sign of breathing for up to an hour. The heart rate of such a turtle might be as low as one beat per 3 minutes. Lactic acid can be as high as 40 mM, with return to normal values taking as long as 24 hours. It take 3-5 hours for lactic acid to return to 16-53% of peak values induced by trawl capture. Although the fate of comatose turtles directly returned to the sea is unknown, it is reasonable to assume that they will die (Kemmerer 1989).

"In 1989, NMFS conducted a tow-time workshop to analyze data on tow times and turtle conditions from seven research projects. The projects spanned 12 years, during which 4,397 turtles were encountered. The numbers of dead and comatose turtles increased with tow time. Small increases in tow time between 45 and 125 minutes resulted in large, steep increases in the numbers of dead and comatose turtles. For most tow times, there were more comatose than dead turtles. Few turtle deaths were related to tow times of less than 60 minutes. Tow times are thus a critical element in determining turtle mortality associated with shrimp trawls."

In situ studies of turtle physiological response to entanglement in a driftnet are necessary in order to determine the exact nature and extent of the associated stress. These studies will need to quantify the degree of struggling which ensues, the proportion of turtles which remain able to reach the surface for air, and the average length of submergence for those unable to reach the surface. These data are not currently available, but the scenario detailed above (National Research Council 1990) could be expected to describe the fate of any struggling sea turtle following entanglement and involuntary submergence. Sea turtles occasionally successfully avoid trawl capture by engaging a powerful burst of swim speed to out-distance the trawl, and then veering to one side of the approaching net in order to pass in front of the trawl doors and out of harm's way (Ogren et al. 1977). There are no data to suggest the extent to which sea turtles are able to avoid, by luck or design, the threat posed by an active or abandoned driftnet in the open sea. It should be noted that while full understanding of how and why turtles die as a result of forced submergence is ultimately important to both science and management, the immediate need from a regulatory standpoint is to quantify the capture and mortality of sea turtles in driftnets and implement measures to reduce or eliminate these impacts.

Effects of handling

Careful handling is important to the survival of sea turtles captured in commercial fishing gear. Effective 2 September 1981, NMFS amended regulations requiring fishermen to attempt resuscitation of comatose sea turtles incidentally caught in commercial fishing operations by turning them on their back and pumping their breastplate by hand or foot (50 CFR 227. 72(e)(1)(i)(1980)). The amendment provides two methods of resuscitation: (a) placing the comatose turtle on its breastplate (plastron) and elevating its hindquarters several inches for a period of one to 24 hours, or (b) placing the turtle on its back (carapace) and pumping its breastplate with hand or foot. The amendment further requires that turtles being resuscitated be shaded and kept wet or moist, that they be released over the stern of the boat in areas where they are unlikely to be recaptured in trawls or injured by vessels, and that the vessel's engine gears be in neutral and trawls not be in use when turtles are released. The amendment concludes, "[NMFS] has determined that the permanent implementation of these regulations is required in order to mitigate the loss of these threatened species [and] the effective implementation of these regulations...will be of significant benefit to the threatened turtle populations in the southeast United States." (Federal Register, 2 September 1981, 46(170):43976-43977).

Resuscitation procedures are not presently required aboard north Pacific driftnet vessels, but they are mandated for vessels with U. S. or Canadian observers. In the absence of onboard observers, turtles are either discarded overboard with other unwanted bycatch or retained by the crew. Observer data (June-December 1989) reveal that green turtles, olive ridleys, leatherbacks and, most likely, loggerheads are captured by the Japanese driftnet fishery for neon flying squid. During a sample of 1,402 retrievals, 22 turtles were counted, including nine leatherbacks and 13 "unspecified" turtles (Gjernes et al. 1990). Only three of nine leatherbacks and seven of the 13 other turtles reportedly survived their capture. An earlier account documented five dead leatherbacks wrapped up in sections of squid driftnet, apparently between 35° and 45°N in the Pacific (Balazs 1982c).

RESEARCH AND MONITORING NEEDS FOR IMPROVED IMPACT ASSESSMENT

Basic Biology

There are three basic biological topics which should be pursued in order to allow a reasonable assessment of the impact of pelagic driftnet fisheries on North Pacific sea turtle populations. Highest priority should be to obtain a clear picture of the number, taxonomic diversity, and fate of sea turtles captured incidental to driftnet fishing on the high seas of the North Pacific. At the present time only a small fraction of driftnet vessels are equipped with biologists serving as onboard observers (Gjernes et al. 1990). This is an important beginning, but the proportion of vessels participating in the observer program should be increased in order that a predictive model of catch rate with an acceptable degree of confidence (coefficient of variation) can be developed for the industry. Important to such a model are seasonality and geographic distribution of fishing effort, fishing techniques, and gear types. The data collected on sea turtle bycatch should include species, carapace length and width, condition (e.g., previously dead, killed during capture or processing, released unharmed, released injured, escaped from net, treated as catch), whether the turtle was tagged, and details of time, date, and location of catch. Ancillary data, such as whether the turtle was associated with flotsam or other fauna prior to capture, would be very useful.

Second priority in understanding the full impact of incidental capture by driftnet fisheries is identifying the reproductive assemblage from which an individual turtle was derived and the size of the stock. Mitochondrial DNA (mtDNA) analysis can provide important information about stock identity. The conservation value of population genetic data is readily apparent, because populations are the fundamental units of species management. mtDNA sequence information has proven useful for population definition in several sea turtle genera, including *Chelonia* (Bowen et al. 1989, 1992; Meylan et al. 1990), *Caretta* (Bowen et al. 1993a), and *Lepidochelys* (Bowen et al. 1993b). The genetic markers revealed in these studies may eventually be used to assist in the census of sea turtles on feeding grounds or during migration. Genetic analysis also offers the potential for identifying the geographic origin (nesting assemblage) of sea turtles captured by driftnet fisheries.

The third priority is for a better comprehension of the short- and long-term effects of capture on individual turtles, effects which may also be species-specific. The most obvious short-term aspect is mortality. Some information on instantaneous rates of mortality is currently available, including mortality rates calculated by onboard fishery observers. However, the cause(s) of death are not well understood. Non-lethal experiments designed to illustrate the effect of prolonged forced submersion are necessary and should include investigations into acid/base homeostasis, oxygen storage and management during submergence, characterization of flight or fright responses, and the mechanisms which control these responses. Some pertinent laboratory research has already been done (e.g., Berkson 1966, 1967; Hochacka et al. 1975; Lutcavage and Lutz 1991; Lutz and Bentley 1985; Stabenau et al. 1991) and our increasing understanding of the biology of submergence should be augmented with comprehensive studies *in situ* of free-swimming sea turtles (cf. Soma 1985; Eckert et al. 1989; Byles and Keinath 1990).

Long-term affects can be physical, as in an incapacitating injury which may reduce an animal's ability to feed or to avoid predators, or physiological. Among the physiological effects are those which may require an animal to recover physiological homeostasis over an extended period of time, or may compromise or reduce reproductive fitness. Shrimp fishermen of the Bryan County Cooperative in Georgia, USA, have noticed that mortality in trawl-caught sea turtles is relatively low the first time around. However, it seems to increase markedly if the same individual is subjected to repetitive capture. It appears that turtles are unable to recover from trawl stress before being caught again, even if several hours has passed in the interim (Captain Joe Webster, pers. comm. to Scott Eckert, 1990). This observation has been corroborated by experimental research indicating that stress, measured by changes in blood chemistry, associated with trawl capture requires long periods of recovery (up to 20 hours) (Lutz and Bentley 1985; Lutz and Dunbar-Cooper 1987; Stabenau et al. 1991). Longer-term impacts are best measured in terms of energetics, and thus complementary research into sea turtle energetics is needed. Turtles operate on relatively slow time scales. For instance, a turtle's readiness and subsequent ability to reproduce may be established up to two years prior to her showing up on the nesting beach (Limpus and Nicholls 1988). For this reason, cause and effect relationships between high energetic output (stress) and slowed development, enhanced vulnerability to disease, and impaired reproductive capacity need to be better understood. This should not be viewed as a strictly theoretical exercise. It is fundamentally important to estimate mortality, which means that the proportion of those turtles released alive that will ultimately expire as a result of the capture experience should be known with some degree of confidence.

Population dynamics and stock monitoring

An ability to recognize the origin of sea turtle stocks ensnared in North Pacific driftnet fisheries is a priority, as noted above. Once the affected nesting populations have been identified, long-term monitoring should be initiated. Field monitoring programs, especially involving regular surveys to determine nesting numbers, reproductive output and hatch success, as well as rates of survival, recruitment and remigration, will enable regulatory agencies to quantify decline or recovery, as the case may be. It is intuitive that driftnet fisheries are not solely responsible for observed declines on the nesting beach. However, large juveniles and breeding-age adults constitute the bulk of sea turtle bycatch in North Pacific driftnets and it is well documented that elevated mortality in these age classes, which is very low in nature, can accelerate the demise of declining populations and eventually precipitate the decline of healthy populations (e.g., Crouse et al. 1987; Frazer 1983b, 1989). Careful tagging programs are necessary to the success of any monitoring program. Three tagging centers have been established in the North Pacific (Costa Rica: Chaves 1991; Hawaii: Balazs 1991b; Japan: Suganuma and Kamezaki 1991) and new efforts should seek to collaborate with existing programs.

Long-term research is needed in the area of population dynamics. An enhanced understanding of growth and survivorship among consecutive life history stages (hatchling, juvenile, subadult, adult), longevity, fecundity, and natural stock replacement and recovery rates would vastly improve the ability of regulatory agencies to prioritize recovery actions and evaluate the success of ongoing efforts. Investigations into the dynamics of sea turtle populations should be undertaken both on the nesting beach and at sea. To this end, long-term ecological research (LTER) sites, one for each species of Pacific-occurring sea turtle, should be identified and supported by national and international donors and expertise. The terrestrial sites need not support the region's largest nesting assemblages, but must be accessible to research personnel and protected from commercial and other potentially degrading coastal development. Monitoring juveniles is more problematic. Fortunately, systematic studies ongoing in Hawaii and Australia's Great Barrier Reef are assembling important baseline data. Additional sites, particularly for olive ridleys and hawksbills, need to be found and projects initiated. Long-term research on foraging populations of juvenile and adult leatherbacks may not be possible, as it is likely that these animals are primarily pelagic. Specific foraging grounds have never been identified.

Pelagic Distribution and Ecology

Our knowledge of the pelagic distribution and ecology of sea turtles in the North Pacific and throughout the world is fragmentary at best. We are largely ignorant of temporal and spatial patterns of distribution and abundance, migration corridors, and geographically specific developmental habitats. Data are particularly scarce for species such as the leatherback and, to a lesser extent, the loggerhead and olive ridley which appear to have extended pelagic life history stages. Satellite tracking of nesting females and juveniles captured at sea (in particular, those captured incidental to driftnet fishing) would improve our ability to predict the movements of stocks involved as bycatch in the pelagic driftnet fishery. Advances in recent years in technology and miniaturization have made equipment requisite for the detailed study of pelagic movement readily available. Research efforts should concentrate first on the species most often captured by pelagic North Pacific driftnets, namely, loggerheads and leatherbacks. Long-term tagging programs on the nesting beach and at sea, the latter undertaken both at foraging grounds and by onboard fishery observers, will provide additional information on the oceanic movements of sea turtles. Tagging aboard fishing vessels can also provide quantitative insight into the residency time of turtles in active fishing zones, based on the number of times a turtle is recaptured.

In addition to pursuing information on basic movement and residency patterns, and especially how patterns of movement and residency change as turtles mature, dietary studies are necessary to understanding site-specific habitat use. The diet of turtles found in the open sea is poorly known. Specimens brought aboard driftnet vessels could be employed to further our knowledge in this area if dead specimens were to be dissected and live specimens lavaged. Stomach contents could be preserved onboard for detailed analysis at shore-based facilities. Finally, sightings programs should be implemented aboard both fishing and research vessels and designed to promote an understanding of habitat preference by quantifying biotic and abiotic factors. These would include the association of turtles with other organisms or pelagic debris, as well as the documentation of water temperature, current patterns, and other relevant ambient factors. It should be noted that while sightings efforts can provide potentially valuable information with respect to habitat use, the merit of quantifying populations using sighting or survey programs is dubious and is not recommended.

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Table 1. Reference guide to information contained in this report on the distribution of five species of sea turtle inhabiting the waters of the North Pacific Ocean. N = nesting; NN = non-nesting. Page numbers are in parentheses.

Nation	Loggerhead	Green	Leatherback	Hawksbill	Ridley
Canada	N (47) NN (49)	N (-) NN (65)	N (-) NN (77)	N (-) NN (-)	N (-) NN (100)
USA	N (47) NN (49-50)	N (60) NN (65)	N (-) NN (77)	N (88) NN (91)	N (-) NN (100)
Unincorporated US territories	N (47) NN (50)	N (60) NN (66)	N (76) NN (78)	N (88) NN (91)	N (99) NN (-)
Mexico	N (47) NN (49)	N (59) NN (65-66)	N (75) NN (77)	N (85) NN (89)	N (98) NN (99)
Japan	N (48) NN (50)	N (64) NN (66)	N (76) NN (78)	N (85) NN (90)	N (98) NN (100)
Korea	N (-) NN (50)	N (65) NN (66)	N (76) NN (77)	N (85) NN (-)	N (98) NN (100)
China	N (47) NN (50)	N (64) NN (67)	N (76) NN (77)	N (85) NN (89)	N (98) NN (100)
Taiwan	N (-) NN (50)	N (64) NN (67)	N (76) NN (78-79)	N (85) NN (90)	N (98) NN (100)
Vietnam	N (48) NN (-)	N (64) NN (67)	N (76) NN (-)	N (85) NN (90)	N (98) NN (100)

Table 1. Continued.

Nation	Loggerhead	Green	Leatherback	Hawksbill	Ridley
Kampuchea	N (-) NN (-)	N (64) NN (67)	N (76) NN (-)	N (85) NN (90)	N (98) NN (100)
Thailand	N (-) NN (50)	N (63) NN (67)	N (76) NN (-)	N (85) NN (90)	N (98) NN (100)
Malaysia	N (-) NN (50)	N (62) NN (67)	N (76) NN (79)	N (86) NN (90)	N (98) NN (101)
Philippines	N (48) NN (50)	N (62) NN (68)	N (76) NN (78)	N (86) NN (90)	N (98) NN (101)
FSM	N (48) NN (50)	N (61) NN (68)	N (76) NN (78)	N (88) NN (91)	N (99) NN (101)
Palau	N (47) NN (50)	N (61) NN (66)	N (76) NN (-)	N (87) NN (91)	N (-) NN (-)
Marshall Islands	N (48) NN (50)	N (61) NN (68)	N (76) NN (-)	N (87) NN (91)	N (-) NN (-)
Kiribati	N (48) NN (50)	N (62) NN (68)	N (76) NN (-)	N (87) NN (91)	N (-) NN (-)

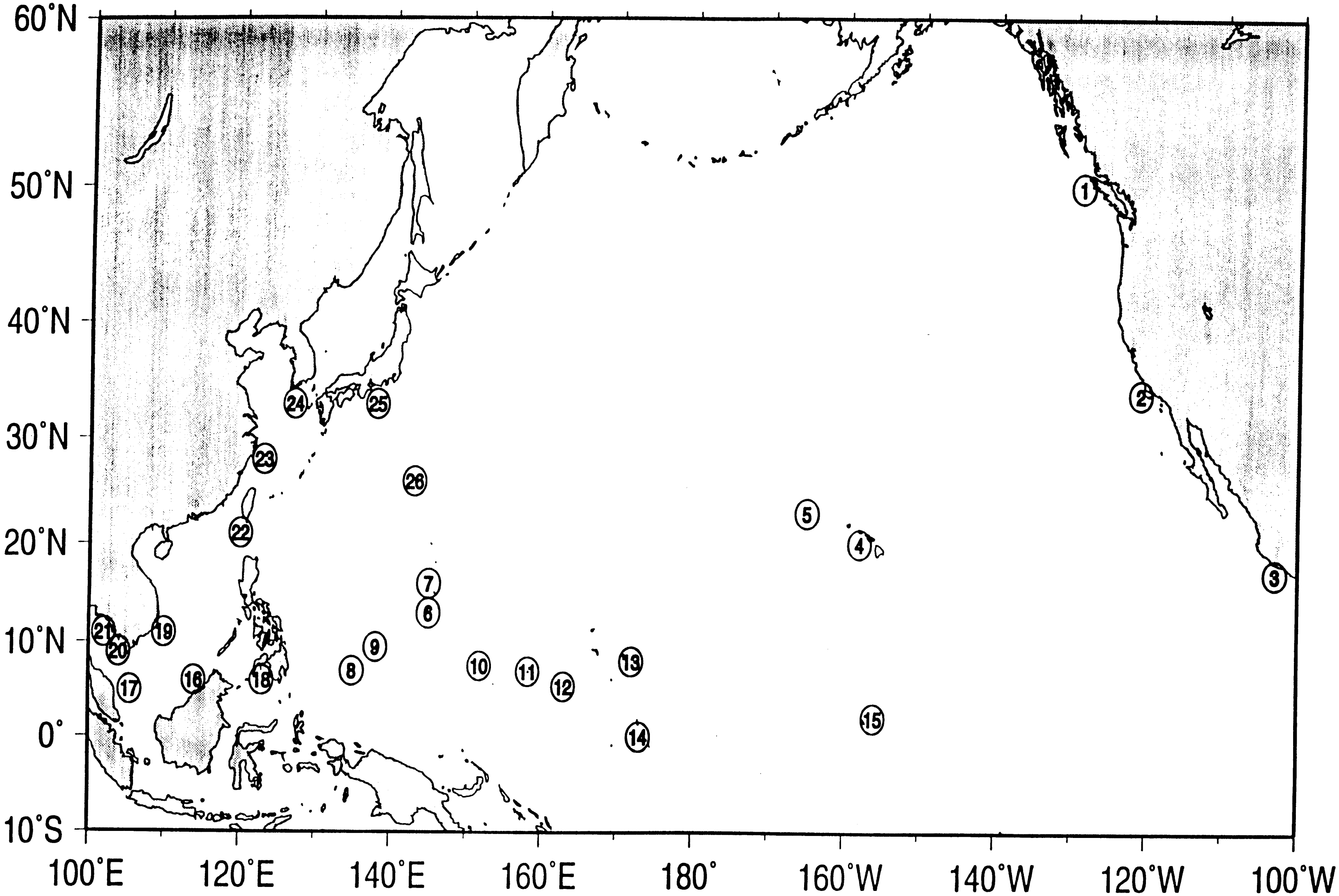

Figure 1. Principal locations referenced in the text.

Figure 1. (continued)

Map Location Key

1. Canada
2. United States (Mainland)
3. Mexico
4. United States (Main Hawaiian Islands)
5. United States (Northwestern Hawaiian Islands)
6. United States (Guam)
7. United States (Northern Mariana Islands)
8. Palau
9. Federated States of Micronesia (Yap)
10. Federated States of Micronesia (Truk)
11. Federated States of Micronesia (Pohnpei)
12. Federated States of Micronesia (Kosrae)
13. Marshall Islands
14. Kiribati (Western)
15. Kiribati (Eastern)
16. Malaysia (Eastern)
17. Malaysia (Western)
18. Philippines
19. Viet Nam
20. Kampuchea
21. Thailand
22. Taiwan
23. China
24. Republic of Korea
25. Japan
26. Japan (Ogasawara Islands)

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