Nearshore Marine Resources of the South Pacific

Information for Fisheries Development and Management

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CHAPTER 10

Marine Turtles

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I. INTRODUCTION

Marine turtles are found in all oceans of the world. Six of the seven species of sea turtles, and one subspecies, inhabit the South Pacific Ocean region. Leatherback turtles, *Dermochelys coriacea* (Vandelli, 1761) have an extensive circumglobal distribution. Most of their nesting takes place in small groups on tropical beaches, but individuals have been sighted in oceanic habitats at high latitudes. Loggerhead turtles, *Caretta caretta* (Linnaeus, 1758) are also circumglobal and most of their major nesting beaches are in subtropical or warm temperate zones of the world. Loggerheads are much more common in the western Pacific Ocean than in the central or eastern Pacific Ocean. Olive ridley turtles, *Lepidochelys olivacea* (Eschscholtz, 1829) are widely but unevenly distributed tropical sea turtles. A few, large populations nest on tropical mainland beaches in the eastern Pacific Ocean. Most of the major nesting and foraging habitats of hawksbill turtles, *Eretmochelys imbricata* (Linnaeus, 1766) are in the tropics. Like the other sea turtles mentioned, green turtles, *Chelonia mydas* (Linnaeus, 1758) are circumglobal with some important nesting sites in Oceania. Black turtles, *Chelonia mydas agassizi* Bocourt, 1868 are most common in the eastern Pacific Ocean and flatback turtles, *Natator depressa* (Garman, 1880), are endemic to the Australian region and nest only in Australia. The seventh species of marine turtle, Kemp's ridley, *Lepidochelys kempi* (Garman, 1880) inhabits the Gulf of Mexico and contiguous seas and is the most endangered sea turtle.

Humans, all over the world, have been exploiting marine turtles for centuries. Sea turtles are harvested for their meat and eggs, and the body parts of some species are, or have been, sources of fuel oil, cosmetics, medicines and leather. Some hatchlings and juveniles are stuffed and sold to tourists and the scutes of the hawksbill are carved into trinkets and figure significantly in international trade. Sea turtles are usually taken on the nesting beach or by harpooning and netting in shallow water. The advent of SCUBA has facilitated the take of turtles with spearguns and, in some places, significant numbers of turtles are drowned incidentally in shrimp trawls. As a result of a long history of exploitation - exacerbated now by human population growth, the trend toward global market economy, and the lack of long-range conservation strategies - any marine turtle populations are now endangered. All marine turtles are sted on Appendix I of CITES (Convention on International Trade in Endan- ered Species of Wild Fauna and Flora). For signatory nations, this means that ternational trade in the species and their products and derivatives is prohibited, cept under exceptional circumstances.

People in the South Pacific Ocean region have had a long association with arine turtles. The literature of the area is replete with references to sea turtles d accounts of their uses in the cultural milieu. In addition to their being a urce of protein, sea turtles have played a role in religious ceremonies and they ve figured in traditional art and legends. Turtle products have also been put many utilitarian and decorative uses. Some accounts of the relationships tween Melanesians and marine turtles and other marine fauna are given by ietschmann and Nietschmann (1981), Kowarsky (1982), Spring (1982b) and rnetta and Hill (1984). McCoy (1982) and Johannes (1986) describe subsist- ce hunting of turtles in Micronesia. Johannes (1978) and Balazs (1983) scribe traditional use and traditional conservation of sea turtles in lynesia. Recent archaeological work reveals that the early Polynesians relied avily on sea turtles (green, hawksbill, and to a lesser extent, loggerheads) for od on some islands (Dye and Steadman, 1990).

The main purposes of this chapter are to describe some salient aspects of the ology and conservation of marine turtles and to relate what is known of the rine turtle resource in the South Pacific Ocean region (the islands of lynesia, Melanesia and Micronesia plus Australia).

II. LIFE HISTORY AND POPULATION BIOLOGY

ENTIFICATION AND TAXONOMY

A key to the marine turtles in the South Pacific Ocean is provided in Appendix The leatherback turtle is easily recognizable by its large adult size and thery shell. The dorsal colouration is predominately black, with white ts. Although the leatherback is a circumglobal species, it is most prudent, at s time, to consider each breeding population, or regional populations, as a ique assemblage. The taxonomy of the leatherback complex, as well as the stematics of the other circumglobal species, is now being examined by earchers. The common name of the green turtle is derived from the colour its fat. As their names suggest, the loggerhead turtle has a large head and the wksbill turtle has a tapering "beak". The carapacial scutes of the hawksbill the tortoiseshell of commerce. The olive ridley turtle is the smallest sea turtle ind in the South Pacific. The carapace of the flatback turtle is low-domed with upturned margins, except in the hatchlings. The black turtle has only occasionally been reported in the South Pacific Ocean. Some authors have elevated this turtle to species rank. However, systematists have yet to distinguish precisely the black turtle from the green turtle in the eastern and central Pacific Ocean and have yet to delineate the ranges of each. Carr (1975) discerned *agassizi*-like characteristics in *Chelonia* in the Hawaiian and Marshall Islands. Balazs (1980, 1986) describes the colouration of Hawaiian female, male and hatchling *Chelonia* in some detail. Pritchard (1979) recorded one black turtle in Papua New Guinea. The *mydas* complex in the Pacific Ocean warrants careful systematic study.

Sea turtles undergo significant changes in morphology and colour during their ontogeny. Some populations acquire considerable epibionts, especially on the carapace, which can obscure the colouration and scute counts.

A summary of the taxonomy and biological data concerning each species can be found in various reports and synopses: leatherback turtle (Pritchard, 1971, 1980); green turtle (Hirth, 1971b, 1980a, 1980b; Balazs, 1980); black turtle (Alvarado and Figueroa, 1990); loggerhead turtle (Dodd, 1988); hawksbill turtle (Witzell, 1983); olive ridley turtle (Marquez *et al.*, 1976; Silas *et al.*, 1984; Cornelius and Robinson, 1985); Kemp's ridley (Pritchard and Marquez, 1973; Ross *et al.*, 1989); and flatback turtle (Limpus *et al.*, 1988; Zangerl *et al.*, 1988). Some of the older synopses are now being updated. Groombridge (1982) and Groombridge and Luxmoore (1989) should be perused for more recent information not covered in the preceding accounts.

HABITATS

Hatchlings emerge at night from eggs buried on island and mainland nesting beaches and crawl into the sea (Fig. 1). Depending upon the species, the post-hatchlings and juveniles pass through a series of developmental habitats, the early ones of which may be epipelagic. Feeding behavior and diet of these meroplanktonic turtles may change during the ontogenetic shifts. Studies with loggerheads in the North Atlantic Ocean (Carr, 1986; 1987) indicate that the young stages and the feeding habits of these turtles are associated with oceanic convergences and with Langmuir bands. Their juvenile distribution is linked to the North Atlantic Gyre which recycles them between North America and Europe. Little is known of the immature stages of oceanic Pacific sea turtles, but the North Atlantic loggerhead model may have relevance here. It is postulated that the flatback turtle is unique among marine turtles in not exhibiting a pelagic stage in its life cycle (Walker and Parmenter, 1990).

After a number of years subadults and adults are usually found in neritic or shallow water habitats. These habitats can vary from small patch reefs of some hawksbill demes to the extensive seagrass/algal pastures of some green turtle

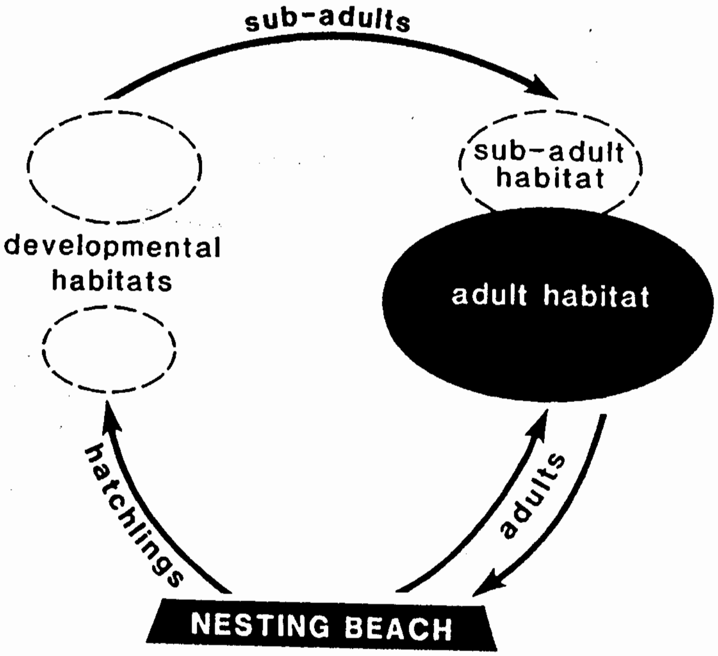

Figure 1. A generalized life cycle of marine turtles (modified from the model of Hirth and Hollingworth in FAO, 1973).

populations. The adult habitat of leatherbacks is probably oceanic. The adult habitats may or may not be some distance from the nesting beach. When mature -from under one decade to over four decades, depending upon the population - both sexes migrate to the nesting site. This is presumed, but not proven, to be the natal beach, and imprinting is presumed, but not proven, to be one of the orienting mechanisms. Several distinct populations may utilize the same adult habitat but migrate to different nesting beaches. Males may, or may not, migrate to and from the breeding site with females. Some turtles may feed during their migration and some may not. Most mating, as far as is known, takes place in shallow water off the nesting beach. Females lay several clutches during the nesting season. Renestings are usually near the site, or in the general area, of the previous nesting. Available information indicates a tendency for oceanic island nesters to disperse less than mainland nesters between nesting emergences and or some species to disperse more than others.

At the end of the breeding season, the turtles migrate back to the adult habitat, ut whether or not this is a direct movement is unknown. The remigrations of ertain adults, and the navigational cues involved, are currently being investiated by satellite telemetry.

Females, and presumably males, make gametic remigrations to the same esting area (philopatry) after intervals of two, three, or four years. Strays have been recorded in several nesting populations and, of course, imperfect philopatry may be one mechanism by means of which new sites are colonized. Some ridleys nest annually. Some male green and male loggerhead turtles remigrate, and presumably breed, annually. When large numbers of turtles of different species utilize the same nesting beach, the peak nesting period of each species is usually at a different time of the year. On a few, remote beaches in the Pacific Ocean region, adult green turtles crawl out to "bask" during the day.

NUTRITION, GROWTH AND SIZE AT MATURITY

Most of the available information about the feeding habits of sea turtles revolves around the nutrition of large juveniles and adults. Post-hatchlings and small juveniles are seldom seen or collected. It is assumed that hatchlings are chiefly carnivorous, but this needs validation.

Large green turtles are chiefly herbivorous, eating a variety of seagrasses and algae. All other marine turtles are mainly carnivorous. Medusae make up a large part of the leatherback's diet. Leatherbacks in the Caribbean Sea may forage at night in the deep scattering layer (Eckert *et al.*, 1989). The olive ridley eats crabs, jellyfish, shrimp and tunicates, among other organisms, but Kemp's ridley is primarily a crab-eater. Loggerheads eat a variety of benthic invertebrates, especially molluscs and crabs. The hawksbills living around coral reefs eat, among other things, sponges, tunicates, molluscs and some algae. Meylan (1988) postulated that hawksbills in the Caribbean area feed almost exclusively on sponges. Flatbacks eat primarily benthic invertebrates. A general review of the feeding habits of sea turtles, especially that of the green turtle, can be found in Mortimer (1982). Some of the major food items of marine turtles in the South Pacific Ocean are listed in Table I (overleaf).

Several recent studies have been conducted on the green turtle feeding pastures in the South Pacific region. Garnett *et al.* (1985) have examined the nutritional strategy of green turtles on the Torres Strait pastures and they conclude that geographical variation in green turtle diets is determined by the availability of seagrass and algae and by the structure of the local herbivore community. Lanyon *et al.* (1989) describe how seasonal fluctuations in total seagrass nutrients may have important consequences for the nutritional status and life history of green turtles. Limpus and Nicholls (1988) have demonstrated a linkage between the ENSO (El Niño Southern Oscillation) and the number of green turtles that breed on eastern Australian beaches two years later. They suggest that the ENSO may regulate nesting numbers via a nutritional pathway.

Depending upon the feeding regimes, abiotic factors of the habitat and the process of natural selection, it is likely that size and age of sea turtles at sexual maturity varies both within and among populations. Limpus (1979) estimated that green turtles living off the southern part of the Great Barrier Reef, Australia,

Table I. Some food items of marine turtles in the South Pacific region. Only the major items are listed. See references for details.

Species and Location	Food	Source
Natator depressa		
Australia	benthic invertebrates, jellyfish	Limpus *et al.*,1988; Zangerl *et al.*, 1988
Caretta caretta		
Australia	crabs, jellyfish, prawns, gastropods, pelycepods, fish	Limpus, 1973; 1979; Moody in Dodd, 1988
New Zealand	urochordates	McCann, 1966
Eretmochelys imbricata		
Australia	algae, ascidians, sponges, bryozoans, molluscs	Limpus, 1978; 1979
New Zealand	hydroids, barnacles, cephalopods, salps	McCann, 1966
Palau	sponges	Japan Tortoise Shell Assoc., 1981
Chuuk(FSM)	algae, seagrasses, sponges	Pritchard, 1977; Japan Tortoise Shell Assoc., 1981
Chelonia mydas		
Australia	algae, seagrasses	Limpus, 1978; Garnett and Murray, 1981; Garnett *et al.*, 1985; Limpus and Reed, 1985
Fiji Islands	seagrasses	Hirth, 1971a
French Polynesia	algae	Hirth, 1971a
Johnston Atoll (USA)	algae	Balazs, 1985a
Kermadec Is. (NZ)	algae	Oliver, 1910
Palau	seagrasses	Pritchard, 1977; Japan Tortoise Shell Assoc., 1981
Papua New Guinea	seagrasses	Spring, 1982a; Hirth *et al.*, ms.
Solomon Is.	algae, seagrasses	Vaughan, 1981
Tokelau	algae	Balazs, 1983
Tonga	seagrasses	Hirth, 1971a; Hirth *et al.*, 1973
Chunk (FSM)	algae, seagrass	Pritchard, 1977
Western Samoa	seagrass	Witzell, 1982

do not reach maturity in fewer than 30 years and that it could take 50 years. Balazs (1982a) stated that a 35 cm green turtle would require from about 9-48 years to reach maturity in Hawaiian waters. Zug and Balazs (1985) using skeletochronological techniques, estimated the age to maturity in Hawaiian green turtles at 40-50 years. Frazer and Ladner (1986) estimated that Ascension

Island green turtles mature at ages between 17-33 years, the Costa Rican green turtles between 12-25 years and the Suriname green turtles between 23 - 35 years. Frazer and Ehrhart (1985) calculated that green and loggerhead turtles off Florida, USA, reach maturity between 18-27 years and 12-30 years, respectively. Using skeletochronological indices, Zug *et al.* (1986) obtained an average age at sexual maturity of 13-15 years for loggerheads in Georgia, USA. The natural growth rates of leatherbacks are unknown but may be rapid. Pritchard and Trebbau (1984) cite some captive growth experiments and a histological study and state that adult size could be reached in under three years, assuming an unlimited supply of jellyfish. Marquez *et al.* (1976) estimate sexual maturity in the olive ridley between 7-9 years and Pritchard and Marquez (1973) estimate Kemp's ridley reaches sexual maturity after about 6 years. The minimum age of sexual maturity in farm-reared green turtles is 8-9 years (Wood and Wood, 1980), but the average age at maturity may exceed 15 years (Wood and Wood, 1990).

There are significant regional differences in the sizes of conspecific nesters (Hirth, 1980c; 1982), and people have measured turtles in different ways. For comparative purposes, however, carapace lengths and weights of typical nesting turtles may be cautiously stated as follows: leatherback, 155 cm and 325 kg; green, 100 cm and 130 kg; loggerhead, 93 cm and 112 kg; flatback, 90 cm and 70 kg; hawksbill, 78 cm and 57 kg; and ridleys 65 cm and 40 kg.

Studies of growth rates have varied greatly. Results are sometimes derived from wild populations based on recaptures of tagged individuals, and sometimes data stem from captive individuals kept under a variety of conditions. Sample sizes in experiments also vary significantly. In spite of these inconsistencies, some projects concerning growth rates of South Pacific marine turtles are cited in Table II (overleaf).

NESTING BEHAVIOUR, FECUNDITY AND ENVIRONMENTAL-DEPENDENT SEX DETERMINATION (ESD)

Most sea turtles, except Kemp's ridleys, nest at night. The nesting behavior is well known and almost every marine turtle station has documented the nesting repertoire of the local turtle population on film. The actual construction and camouflaging of the nest are divided into five stages: digging the body pit, digging the egg chamber, oviposition, filling the egg chamber, and filling the body pit and camouflaging the nest site. Inexperienced and experienced nesters exhibit similar patterns of nesting; this, along with other nesting traits, indicates strong natural selection for a fixed nesting pattern. The nesting behavior of green turtles has been well studied (Hirth and Samson, 1987); a typical female spends about two hours in the five stages of nesting. Other species spend less

Table II. Some projects concerning growth rates, headstarting and ranching in the South Pacific area. Most of the projects were short-lived with little scientific control but some information can be culled from them.

Nation	Species	Project	Source
Australia	green, hawksbill, loggerhead	growth rates, headstarting, diseases, ranch	Carr and Main, 1973; Kowarsky, 1977; Kowarsky and Capelle, 1979; Limpus, 1979; Garnett, 1980; Glazebrook, 1980; Glazebrook and Campbell, 1990a,b; Limpus and Walter, 1980; Onions, 1980; Garnett and Murray, 1981.
Cook Islands	green	rearing, headstart	Brandon, 1975; Balazs, 1982b.
Fiji	hawksbill	incubation, growth	Raj, 1975; 1976.
French Polynesia	green	rearing	Hirth, 1971a; Anon, 1979
Kiribati	green	rearing	Onorio, 1979
Palau	hawksbill	headstart	Pritchard, 1977; Broughton, 1986.
Solomon slands	green, hawksbill, olive ridley	growth rates, headstart	McKeown, 1977; McElroy & Alexander, 1979; Vaughan, 1981.
Tonga	hawksbill	headstart	Wilkinson, 1979.
Western amoa	hawksbill	growth rates, headstart	Witzell, 1980; Balazs, 1982b.

time on the beach for nesting, but there are some demic variations depending on topography, substrate conditions and density of nesters. The ridleys are the smallest sea turtles, and they usually spend the least amount of time (about an hour or less) on the nesting beach. They sometimes nest in an *arribada* ("arrival" in Spanish, and connotates mass emergence and simultaneous nesting by thousands of individuals). Humans, through excessive movements or with lights, can disturb nesters, especially in the early stages of nesting, so that the female returns to the sea without nesting. In these cases, she may re-emerge later that same night at a nearby (or distant) site or she may nest on a different night.

In general, sea turtles deposit about 50 eggs (flatback) to about 130 eggs (hawksbill) at each nesting. However, the number of eggs in an individual's successive clutches may change significantly over the course of the nesting season. On some of the world's beaches, there is year-around nesting (but with seasonal peaks); on other beaches, there are distinct nesting seasons of several months duration.

In many sea turtle populations, as in most reptiles, fecundity is directly related to body size (Hirth, 1980c; Hirth and Ogren, 1987; Dodd, 1988). As a group, sea turtles lay far more eggs per clutch, and their eggs are larger, than most other turtles. The leatherback and flatback lay fewer but larger eggs than the other sea turtles. Fecundity and sizes of eggs and hatchlings are important traits of marine turtles because they relate directly to fitness. The leatherback, and some hawksbills, for unknown reasons, also lay from one to two dozen small, yolkless eggs along with each clutch of fertile eggs.

Hatching success in natural nests of all species of sea turtles varies widely but averages between about 60 and 90 per cent, except on beaches where density-dependent nest destruction prevails or on certain cheloneries where significant numbers of nesters make poor nest site selections.

The size of the hatchling is associated with many factors including the size and number of eggs in the clutch, length of incubation, and the moisture, temperature and gases in and around the egg chamber (Hirth, 1988; Packard and Packard, 1988; McGehee, 1990). In general, the hatchlings of leatherbacks and flatbacks are the largest (carapace lengths about 60 mm) and those of ridleys and hawksbills are the smallest (carapace lengths about 42 mm).

Females usually lay several clutches during the nesting season and the renesting interval, depending upon the species, varies from about 10 to 28 days. The available data indicate a tendency for the larger species of sea turtles to renest quicker than the smaller species.

The incubation period varies from about 50 to 65 days. Incubation periods vary among conspecific populations, and there are differences between incubation periods on mainlands and on islands. Weather conditions can affect length of incubation.

Research has shown that sexual differentiation in all sea turtles is determined by the substrate temperature (other factors may also be involved) during incubation (see reviews in Miller, 1985 and Packard and Packard, 1988). This is commonly referred to as ESD (environmental-dependent sex determination). Although the exact temperature thresholds differ slightly among populations, in general, incubation of sea turtle eggs at temperatures above 30° C produce phenotypic females, whereas exposure of developing eggs to temperatures below about 28° C produce males. Between temperatures of 28° and 30° C both sexes are produced. The middle trimester of incubation appears to be the critical period in which temperature directly affects the gonadal differentiation of embryos. This phenomenon raises interesting questions about sex ratios of hatchlings produced on various beaches with different thermal regimes at the level of the clutch. For example, are the sex ratios produced at the northern and southern sites of an extensive latitudinal beach different, or are the ESDs different? What affect do short/long periods of dry/wet weather on a tropical beach have on sex ratios? Considering some of these factors, investigators have found that 93 per cent of the loggerheads produced on one Florida, USA, beach were females (Mrosovsky and Provancha, 1989); that there are intraspecific differences in the ESDs of loggerheads from different regions and that the sex ratio of green turtles hatched on the warm side of Heron Island, Australia, differed from that on the cool side (Limpus *et al.*, 1985); that 67 per cent of the green hatchlings produced on a Costa Rican beach, divided into sunny and shaded zones, were females (Spotila *et al.*, 1987); and that on a Suriname beach more male green and leatherback hatchlings were produced in the cooler, wetter months and more females during the warmer, drier months of the nesting season (Mrosovsky *et al.*, 1984). Davenport (1989) has discussed some possible affects of global warming (greenhouse effect) on sex determination of sea turtles.

Sea turtle hatchlings climb to the sand surface in a group effort, emerge on the sand surface at night, and crawl to the sea using light cues. The neonates swim swiftly through the shallow water. Hatchlings are positively buoyant, thus they swim, and float, at or near the sea surface. Leatherback, loggerhead and green turtle hatchlings use surface waves and swells as orientation cues in their swim out to deep water (Salmon and Lohmann, 1989, Lohmann *et al.*, 1990).

MORTALITY AND SURVIVORSHIP

The human take of sea turtles and eggs is significant at many locales around the world including the South Pacific region (see following section).

Non-human predation occurs at all stages of a sea turtle's life. Significant predators of eggs, depending on the locale, include beach crabs, varanid lizards, small mammals and feral dogs and pigs. Fungal infestations are very detrimental to developing eggs in *arribada*-type nestings. On high density nesting beaches, later-arriving nesters may dig up existing clutches. Beach erosion can destroy entire clutches. Predators of hatchlings include crabs, birds and fish. Sharks, crocodiles and whales take adult turtles. In some areas, (*e.g.* in Hawaiian and Floridian, USA., waters) fibropapilloma disease is significant and needs study. Lagoonal populations of subadult and adult turtles in higher latitudes may be stunned by sudden cold spells and hurricanes can cause surge strandings. Stancyk (1982) summarizes non-human predation of sea turtles and he describes some predator control measures. The synopses cited in the section on Identification and Taxonomy list predators, diseases and parasites of turtles in all parts of the world.

Mortality from incidental catch in shrimp trawls, gill nets, pound nets, beach seines, trammel nets and longlines can be high in some places. Incidental catch of sea turtles on a worldwide scale has been described by Hillestad *et al.* (1982). Murphy and Hopkins-Murphy (1989) have established the relationship between sea turtle mortality and shrimping operations in the north-western Atlantic Ocean and Ross *et al.* (1989) describe the incidental take of the endangered Kemp's ridley in shrimp trawls. The incidental capture of leatherback, ridley and green turtles in Malaysian waters is significant, and the intense fishing activity which coincides with the turtle nesting season aggravates the problem (Chan *et al.*, 1988). Flatback, loggerhead, ridley and green turtles are incidentally taken in Australia's prawn fishery, but the impact of trawl-induced drownings on the turtle populations there is probably not of such proportions as to create immediate concern (Poiner *et al.*, 1990).

The ingestion of plastics and tar balls by sea turtles, their entanglement in debris, and the effects of these factors on morbidity and mortality have been discussed by Balazs (1985b). Chan and Liew (1988) briefly review the affect of oil pollution on various size turtles.

A sea turtle survivorship curve is roughly concave, indicating high egg and hatchling mortality and low adult mortality (under natural conditions). Based on demographics of the loggerhead turtle population in Georgia, USA, Crouse *et al.* (1987) produced a model showing that survival in the juvenile and subadult stages has the largest effect on population growth. In this model annual survivorships of hatchlings (< 1 year age), small juveniles (1-7 years age), large juveniles (8-15 years age), subadults (16-21 years age), and breeders (22-54 years age) were estimated at, respectively, 0.67, 0.79, 0.68, 0.74 and 0.81. The annual survivorship rate of adult, female leatherbacks in Malaysia was calculated to be 0.89 (Chua, 1988).

III. DISTRIBUTION, ECOLOGY AND EXPLOITATION

FLATBACK TURTLES

Some reproductive parameters of flatback turtles are given in Table

III. Flatback eggs are regularly harvested on Crab Island (Fig. 2). It is estimated that in the absence of human predation on eggs, approximately 48-89 per cent of the eggs laid on Crab Island produce hatchlings that successfully reach the sea (Limpus *et al.*, 1983b). At Mon Repos, the average remigration interval is 2.7 years and the estimated annual recruitment rate of new nesters is 27.2 per cent (Limpus *et al.*, 1984a). Mon Repos and the adjacent beaches at Bundaberg are at the southern limit of flatback nesting in eastern Australia. Because of their size, flatback hatchlings escape some of the bird and crab predators that take the smaller green and loggerhead hatchlings on Australian beaches. The nesting flatbacks on Peak Island, an important nesting site off central Queensland, have a mean carapace length of 93.7 cm (range 84-100 cm) and they deposit an average of 54.5 eggs (range 34-76) (Limpus *et al.*, 1981). Limpus (1982) cites Wild Duck - Avoid Islands (and adjacent areas) and Greenfield Island as major flatback nesting areas. Preliminary work indicates that the flatbacks nesting in north-western Torres Strait are smaller and lay smaller eggs than those nesting in the southern Great Barrier Reef (Limpus *et al.*, 1989). The documented distribution of the flatback extends around northern Australia, including the Gulf of Papua, to about 25° S on both eastern and western Australian coasts (Zangerl *et al.*, 1988).

LOGGERHEAD TURTLES

On the south-central coast of Queensland, and on nearby islands, there are three major nesting areas of loggerheads, identified by Limpus (1982) as the Capricorn-Bunker Islands, the Bundaberg to Round Hill Head coastline and the Swain Reefs Islands. Reproductive data for these Queensland populations are summarized in Table III. Preliminary electrophoretic studies (Gyuris and Limpus, 1988) suggest that the loggerheads nesting on the coastline and in the Capricorn region form a panmictic population and that those nesting on the Swain Reefs cays do not interbreed with this population. Recent research indicates that the majority of female loggerheads nesting on Mon Repos may be polyandrous (Harry and Briscoe, 1988). The hatching success of loggerhead eggs on Queensland beaches is between 80.4 and 83.8 per cent (Limpus in Dodd, 1988). Sporadic nesting occurs as far south as Newcastle (33° S) in New South Wales (Limpus, 1982).

Balazs (1983) reported that small numbers of green, hawksbill and loggerhead turtles nest in Tokelau between June and December. There is a possibility that loggerheads occasionally nest on the extreme northern beaches of New Zealand (Pritchard, 1982a). Loggerheads nest in New Caledonia but the size of the nesting population is unknown (Pritchard, 1987). Spring (1982a) reported some nesting in the Trobriand Islands, Papua New Guinea.

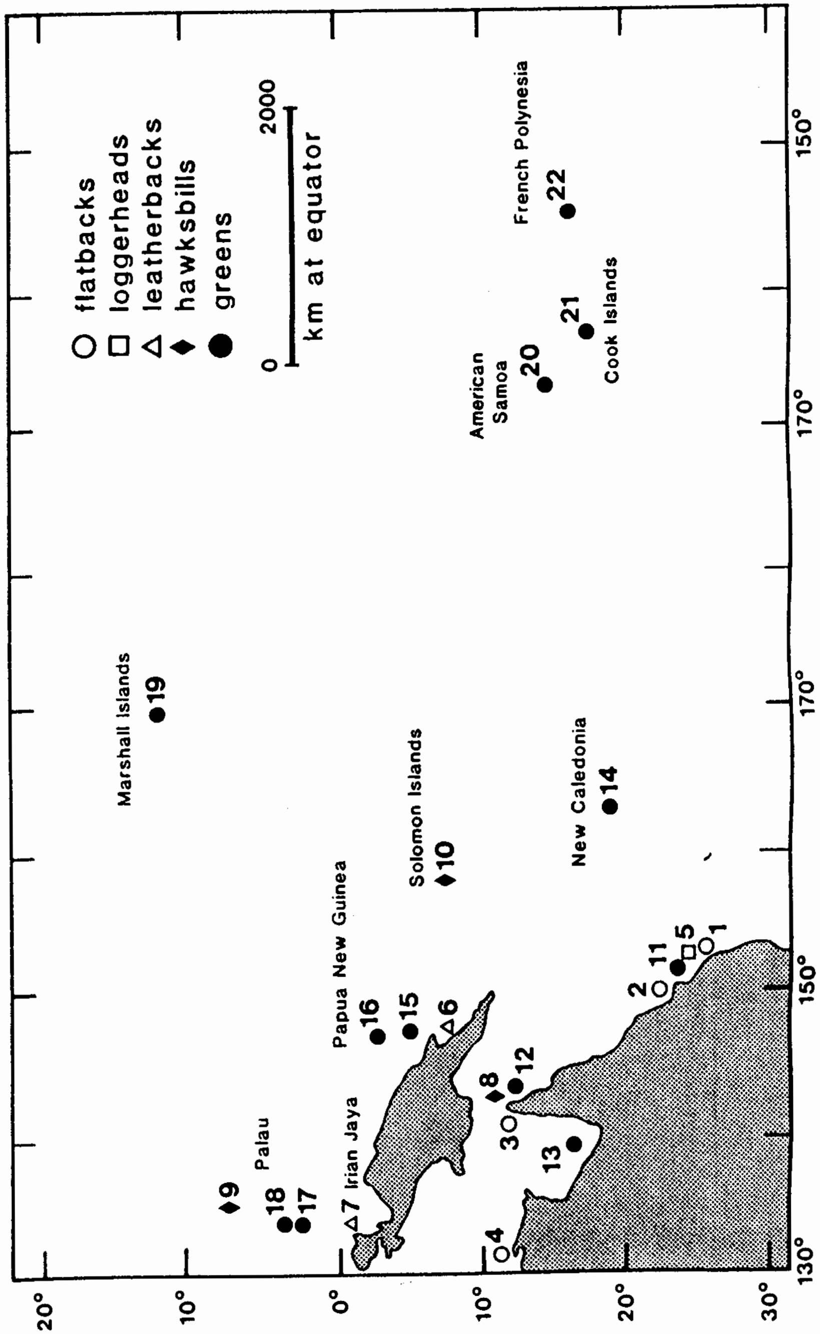

Figure 2. Some of the major and/or well-known nesting sites of marine turtles in the South Pacific Ocean area. 1-Mon Repos, Australia; 2-Wild Duck-Avoid Islands, Australia; 3-Crab Island, Australia; 4-Greenfield Island, Australia; 5-Queensland beaches, Australia (see text); 6-Piguwa, Papua New Guinea; 7-Kepala Burung beaches, Irian Jaya; 8-cays off Cape York Peninsula, Australia; 9-Palau Islands; 10-Arnavon Islands, Solomon Islands; 11-Capricorn-Bunker Groups, Australia; 12-Raine Island-Pandora Cay, Australia; 13-Wellesley Group, Australia; 14-d'Entrecasteaux Reef system, New Caledonia; 15-Long Island, Papua New Guinea; 18-Merir Island, Palau; 19-Bikar Atoll, Marshall Islands; 20-Rose Atoll, American Samoa; 21-Palmerston Atoll, Cook Islands; 22-Scilly Atoll, French Polynesia.

Table III. Some reproductive data of marine turtles in the South Pacific area. (Mean values followed by ranges in parentheses).

Species and Locality	Carapace length nesters (cm)	Nesting season	Diameter eggs (mm)	Weight eggs (g)	Clutch	Renesting interval (days)	Length incubation (days)	Hatchling carapace length (mm)	Weight hatchlings (g)	Source
Natator depressa										
Crab Is., Australia	89.3 (80.5-97.0)	Year round	50.6 (46.6-54.0)	72.7 (50.0-83.5)	56.2 (22-76)			59.7 (53.9-66.5)	39.3 (30.5-51.5)	Limpus *et al.*, 1983b
Mon Repos, Australia	92.3 (88.0-96.0)	Oct-Jan	52.1 (47.5-56.0)	77.8 (63.5-86.7)	50.2 (7-73)	16.0	53.4 (47-58)	61.2 (56.6-65.5)	43.6 (33.3-49.1)	Limpus, 1971 Limpus *et al.*, 1984a
Caretta caretta										
Queensland, Australia	95.8 (80-113.5)	Oct-March	40.4 (34.7-45.7)	36.5 (26.2-43.1)	127 (48-190)	13.9 (9-23)		43.3 (39.0-46.9)	20.9 (14.6-26.5)	Limpus in Dodd, 1988
Eretmochelys imbricata										
Cays off Cape York, Australia	76.4 (71.6-82.7)	Probably all year Aug-Mar documented	36.4 (32.8-38.9)	26.4 (22.5-30.5)	111.7 (62-142)			41.2 (39.1-43.9)	14.6 (12.5-16.0)	Limpus, 1980a
Campbell Is., Australia	76.4 (70.7-83.3)	Probably All year Dec-Feb documented	36.0 (32.3-40.7)	26.0 (19.5-32.5)	131.8 (89-192)	14.7 (13-17)	55 (52-57)	41.1 (38.2-43.8)	14.3 (12.7-16.8)	Limpus *et al.*, 1983a
Islands off Upolu Is., W. Samoa	68.6 (60.0-73.5)	Sept -July	34.7 (34.0-36.0)	24.4 (23.0-25.9)	149.6 (60-219)		62 (59-70)	39.6 (38-41)	12.7 (12.1-13.2)	Witzell and Banner, 1980
Palau		March-Sept	(33.0-36.0)	ca. 23	(63-151)		(60-70)	41	ca. 13	Nakajima in Fukada, 1965
Arnavon Is., Solomon Is.	80.5 (68.0-93.0)	All year peak May-Aug			137.5 (72-250)	18.2 (13-28)	64 (43-90)	ca. 40	ca. 13	McKeown, 1977
Chelonia mydas										
Heron Is., Australia	102.4 (86-121)	Nov-April, peak Dec-Jan	ca. 46	51.6 (44.0-60.4)	110 (50-200)	14.5 (9-21)	56 (42-77)	ca. 50	ca. 21	Bustard, 1972

OLIVE RIDLEY TURTLES

The olive ridley is the smallest and, on a worldwide scale, one of the most abundant sea turtles. However, it is uncommon in most areas of the South Pacific Ocean. Limpus (1982) stated that no major nesting sites exist in Australia but that scattered nesting occurs across northern Australia and a large feeding population is found in the Gulf of Carpentaria. One nester on Crab Island had a carapace length of 66.5 cm and laid 109 eggs with an average diameter and weight of 36.8 mm and 37.7 g (Limpus *et al.*, 1983b). Spring (1982a) mentions several nesting sites in Papua New Guinea that need investigating. Ridleys nest, chiefly in March, on the northern coast of Kepala Burung, in Irian Jaya (Adipati and Patay, 1984). Olive ridleys are rare in New Zealand, New Caledonia, Solomon Islands, Palau and Micronesia (Pritchard, 1982a, 1982b). Nesting patterns of olive ridleys can range from solitary nesters to small groups to *arribadas*.

LEATHERBACK TURTLES

A few leatherbacks nest in southern Queensland, between December and February. The mean carapace length of these nesters is 162.4 cm and the average renesting interval is 9.7 days. The clutch averages 82.8 eggs and the eggs have an average diameter and mean weight of 53.2 mm and 81.9 g. Hatchlings weigh an average of 46.9 g and have a shell length of 58.8 mm (Limpus *et al.*, 1984b).

There is a well-known nesting colony of leatherbacks near the village of Piguwa, in Morobe Province, Papua New Guinea. Most nesting takes place between November and February. Quinn and Kojis (1985) estimated a total female population on this chelonery of between 300 and 500. The ecology of this population is now being described (Hirth *et al.*, *ms*.). Low density nesting occurs on other sites on the northern coast of Papua New Guinea and on some of the larger islands (Spring, 1982a). This species of sea turtle seems to prefer high energy beaches for nesting.

The major leatherback chelonery on the northern coast of Kepala Burung is currently being studied (Salm, 1982; Adipati and Patay, 1984; Anon, 1985). The peak of nesting is May and local residents have noted a decline in the number of nesters over the past 25 years.

Up to ten leatherbacks nest annually on some of the beaches in Solomon slands (Vaughan, 1981). Although leatherbacks are fully protected here, a few are eaten. The leatherback nests only rarely in Fiji. It is sometimes sighted in New Zealand and Hawaiian waters but is only rarely seen in Micronesian seas.

Chua (1988) and Chua and Furtado (1988) provide some useful reproductive data on the well-studied leatherback nesting colony in Terengganu, Malaysia.

HAWKSBILL TURTLES

Reproductive data of hawksbills from two well-known areas off Australia are given in Table III. On Campbell Island, there is a significant positive linear correlation between size of female and size of clutch, as has been recorded at other cheloneries around the world. Hawksbill nesting is widespread in the Torres Strait Islands, and Long Island has been identified as a major rookery (Carr and Main, 1973; Bustard, 1974; Limpus, 1982).

Hawksbills nest, in small numbers, on three small islands in Western Samoa. The peak nesting period is in January and February (Table III). Hawksbills can be found nesting or foraging throughout Solomon Islands. The Arnavon Islands harbor the largest nesting population. Vaughan (1981) found some slightly different biological parameters from those given in Table III at the Arnavon site. Surveys indicate that the numbers of hawksbills in Solomon Islands are decreasing.

Nesting of hawksbills is widespread in Papua New Guinea, but the density of nesting is unknown. They nest from May to September in the East Sepik Province; from June to August in Manus Province; from May to July on Long Island in Madang Province; in March and April in the Trobriand Islands in Milne Bay Province; and in December and January on several islands in the Central Province (Spring, 1982a).

A few hawksbills oviposit in French Polynesia, American Samoa, Tokelau, Cook Islands, Tonga, Fiji, New Caledonia and Vanuatu (Hirth, 1971a; South Pacific Commission, 1980; Balazs, 1982b; Pritchard, 1982a; 1987) and they are occasionally sighted in the sea in other areas of the South Pacific. Eight nests in Fiji had an average of 116.9 eggs (range 68-168) (Raj, 1976).

After the green turtle, the hawksbill is the most commonly sighted turtle in Micronesia. Nesting in the area is reportedly year-around but the peak of nesting appears to be between May and September. In the Palau area, the hawksbill is the most common species but its numbers are declining. More detailed and up-to-date studies should be made on the reproductive parameters of hawksbills in Palau (Table III), and its status as a significant nesting site needs evaluation (Fig. 2). Hawksbills appear to nest regularly in the Ngerukewid Islands Wildlife Preserve in the Palau Islands but illegal egg collecting is a problem (Wiles and Conry, 1990).

There is a little nesting in the Chuuk area from May to October but only sporadic nesting in Guam (Pritchard, 1982b). Hawksbill eggs from Chuuk have an average diameter and weight of 32.6 mm and 20.8 g (Japan Tortoise Shell

Association, 1981), and hatchlings have an average carapace length of 39 mm and a mean weight of 13.8 g (Kurata in Japan Tortoise Shell Association, 1981).

GREEN TURTLES

Some reproductive data on the green turtles nesting on Heron Island, in the Capricorn Group, Australia, are given in Table III. Slightly different measurements of Heron Island turtles and eggs are provided by Limpus (1980b). Limpus and Fleay (1983) estimate that about 5,000 females nest annually in the Capricorn-Bunker Groups, tens of thousands nest annually on Raine Island and Pandora Cay, and more than 5,000 nest yearly in the Wellesley Group Fig. 2). Still unexplained are the large fluctuations in the nesting population on some beaches. For example, on Raine Island "... in the peak nesting season of 1974-75 over 11,000 nesting turtles were ashore simultaneously on 1 night on he 1.7 km long beach" (Limpus, 1982). The following year only about 100 green turtles nested on Raine Island nightly. At Tortuguero, Costa Rica, 31,211 green turtles nested in 1978 and 5,178 in 1979 (Carr *et al.*, 1982). Raine Island has been a turtle nesting site for at least 1,130 years. However, it was not a nesting site during the last ice age; this illustrates that sea turtles can colonize new breeding beaches in response to environmental perturbations, like changing sea evels (Limpus, 1987). Bramble Cay in the Torres Strait may have been a major ookery several decades ago but, due mostly to human exploitation on adults and eggs, only a few hundred may nest here now. Green turtles nest on many other slands in the Torres Strait but their numbers need to be determined.

Many green turtles nest on the Islands of Surprise, Leleixour, Fabre and Huon n the d'Entrecasteaux Reef system of New Caledonia (Pritchard, 1987; Anon, 1989). This important breeding colony should be studied.

Spring (1982a) cites several uninhabited island groups in Manus Province, Papua New Guinea, as important breeding grounds for green turtles. Nesting here is from May to September. Green turtles nest year-around on Long Island, Madang Province, Papua New Guinea, but the peak nesting is from May to August (Spring, 1983). Nesters here have a mean carapace length of 94.7 cm and they lay an average of 107.3 eggs. Five turtles nesting on Long Island have been recaptured in Irian Jaya. Hirth *et al.* (*ms.*) also report the recapture of a green turtle, tagged off Wuvulu Island (Manus Province), in Irian Jaya. Additional ag recoveries will illustrate the extent to which these two countries share the same turtle resource.

Pritchard (1977) postulated that several dozen green turtles nest some nights on Helen Island and on Merir Island in Palau, and that nesting may be year-around. The status of nesting on Bikar Atoll (Marshall Islands) and on Palmerston Atoll (Cook Islands) needs investigating.

Hirth (1971a) counted 336 nesting pits, of varying ages, on Rose Atoll in American Samoa. Short, periodic trips to the atoll are made by fishery personnel from Pago Pago and nesting turtles are tagged. Balazs (*ms.*) is compiling an account of the turtle tagging being conducted by the fishery personnel, and there is one record of a green turtle recovered in Fiji after being tagged on Rose Atoll. A comprehensive study of marine turtles on Rose Atoll is now being planned by the author. Rose Atoll is a U.S. National Wildlife Refuge.

Scilly Atoll is one of the better known green turtle nesting sites in French Polynesia (Hirth, 1971a). Periodic censuses of the nesting population have been made; Lebeau (1985) estimated 300-400 females were nesting on the atoll in the mid-1980s. Green turtles on Scilly Atoll are somewhat unique in their body weight-carapace length relationships (Hirth, 1982). The status of the nesting population on Raroia Atoll needs investigation.

Green turtles nest in small numbers at several sites in Solomon Islands, Vanuatu, Tuvulu, Fiji, Kiribati, Tokelau, Tonga Islands, Cook Islands, French Polynesia, Palau, Guam, the Northern Mariana Islands, the Federated States of Micronesia and the Marshall Islands (Hirth, 1971a; 1971b; Balazs, 1982b; Pritchard, 1982a; 1982b; Wiles *et al.*, 1989). The status of nesting on Canton Island (Phoenix Group) and on Oroluk Atoll (Pohnpei State) needs to be examined. Balazs (1975) estimated that a fairly large number of turtles may nest on Canton. Only a few nested in the summers of 1985 and 1986 on Oroluk (Edson and Curren, 1987).

Green turtles are seen in the sea around New Zealand, Kermadec Islands, Johnston Atoll, Wake Island, Palmyra Island, Western Samoa and Pitcairn (Hirth, 1971a; Balazs, 1982b; Pritchard, 1982a).

About a couple hundred green turtles nest annually at French Frigate Shoals in the Hawaiian Islands. Recaptures of these turtles are within the Hawaiian Archipelago and indicate that this population is genetically isolated from other green turtle populations in the Pacific Ocean (Balazs, 1982b). About 200 green turtles nest annually in the Ogasawara Islands with a peak in June and July (Suganuma, 1985).

Each marine turtle population in the South Pacific Ocean probably exhibits a unique suite of biological traits. Such traits, molded by natural selection, should be studied because they could relate directly to management decisions.

SOME LONG-RANGE MIGRATIONS

Some long-distance movements of flatback turtles are discussed by Limpus *et al.* (1983c). Eight flatbacks from a total of 813 tagged while nesting on Mon Repos, Curtis Is., Peak Is., and Wild Duck Is., have been recaptured along the Queensland coast at distances from 216 to 1,300 km north of their nesting sites.

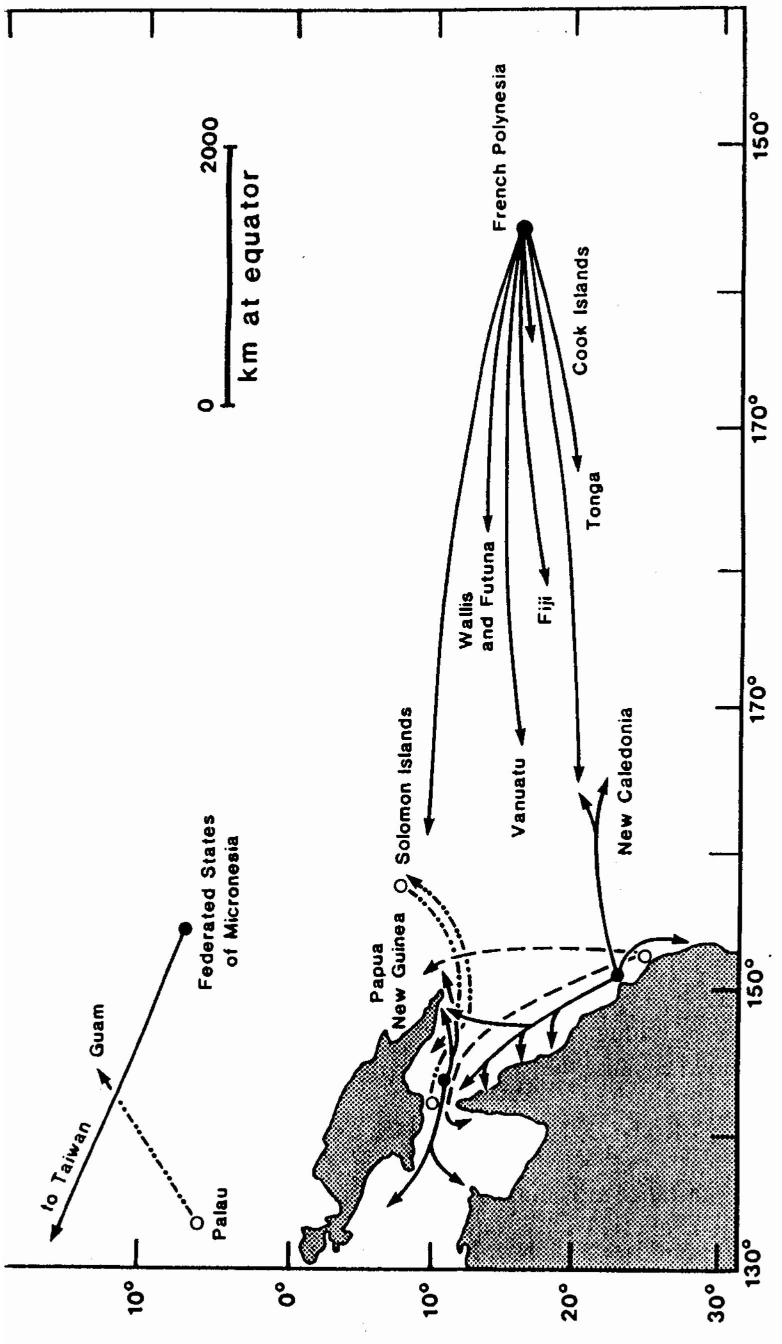

Figure 3. Some long-range movements of South Pacific sea turtles. Solid lines, green turtles; dashed lines, loggerhead turtles; dot-dash lines, hawksbill turtles. Arrows indicate sites of contact, not routes travelled.

A loggerhead turtle tagged while nesting on Mon Repos in January 1969 was recovered 63 days later in the Trobriand Islands, Papua New Guinea (Bustard and Limpus, 1970). This is a straight line distance of 1,760 km (Fig. 3). Another loggerhead tagged on Mon Repos apparently migrated to the vicinity of Weipa in the Gulf of Carpentaria--a minimum distance of 2,160 km (Bustard and Limpus, 1971). Gyuris and Limpus (1988) state that females nesting on Queensland beaches "migrate up to 2,600 km from feeding grounds encompassing a variety of habitats from the Trobriand Islands in the north to southern New South Wales in the south and from Arnhem Land in the west to New Caledonia in the east."

Some of the leatherbacks sighted in the Coral Sea, Solomon Sea and Bismarck Sea may have their origin on the nesting beaches in Morobe Province, Papua New Guinea. A long-range study is now underway there (Hirth *et al.*, *ms.*).

The hawksbill turtle is sometimes considered to be less migratory than the other species of marine turtles but this belief needs to be better documented. There are several long-distance movements of hawksbills in the South Pacific (Fig. 3). A female beached without nesting on Kerehikapa Beach in the Arvanon Wildlife Sanctuary (Solomon Islands) on 5 December 1976 and was later taken by a turtle hunter in February 1979 at Fisherman's Island (Papua New Guinea). The shortest distance between the two points of contact is 1,400 km. Another hawksbill tagged at Sakeman Reef in the Torres Strait on 31 March 1979 later nested at Kerehikapa on 16 February 1980. This turtle swam more than 1,600 km (Vaughan, 1981).

A six-month old hawksbill, raised in a headstart program, was released in March 1986 from Ngermeyaus Beach, Palau, and was recaptured in Guam in July 1987. It traveled a distance of more than 1,300 km (Anon, 1987).

A hawksbill tagged in Sabah, East Malaysia, was retaken 40 days later in the Philippines, having traveled a minimum distance of 713 km (de Silva, 1986).

Some long-range migrations of green turtles tagged after nesting on the Raine Island-Pandora Cay beaches and on the Capricorn-Bunker Islands, are depicted in Fig. 3 (from Bustard, 1976; Limpus and Parmenter, 1986). It is apparent that the green turtles nesting in the Great Barrier Reef system are foraging in a wide area encompassing the Coral Sea, Gulf of Carpentaria and Arafura Sea.

Although only a few green turtles may nest in the summer months on Oroluk Atoll in the Caroline Islands (Federated States of Micronesia), one female tagged there after nesting on 2 June 1986 was recaptured in Taiwan on 18 April 1987 (Edson and Curren, 1987).

The green turtle tagging project on Scilly Atoll, in French Polynesia, was initiated and coordinated by the author in 1970-72; since then the project has been supervised by a number of individuals. A few tags are still being returned from the early years of the project and all recaptures, to date, have been made

Table IV. Exploitation of marine turtles in the South Pacific region. [G = green, H = hawksbill, L = leatherback, F = flatback turtles][a].

	Local exploitation[b]			Significant	Party	
				tortoiseshell	to	
Nation	eggs	flesh	parts[c]	export	CITES	Turtle regulations[d]
American Samoa	G,H	G,H	H		Yes*	all sea turtles protected
Australia	G,H,F	G,H	G,H		Yes	all sea turtles protected, but subsistence take allowed for indigenous people
Cook Islands		G	G		No	no sea turtle regulations
Federated States of Micronesia	G,H	G,H	H		Yes*	size restrictions; closed seasons; eggs protected
Fiji	G,H	G,H	G,H		No	size restrictions; closed seasons; eggs protected; permit required for captives
French Polynesia	G	G,H			No	size restrictions; closed seasons; eggs protected
Guam					Yes*	all sea turtles protected
Kiribati	G	G,H	G,H		No	licence required for taking turtles on land; some area restrictions
Marshall Islands	G	G	H		Yes*	size restrictions; closed seasons; eggs protected
Nauru					No	no information
New Caledonia	G,H	G,H			Yes*	closed seasons; eggs protected; commercial sale of turtle products prohibited
New Zealand					Yes	hunting and export prohibited
Niue					No	no information
Commonwealth of Northern Marianas		G,H	G,H		Yes*	all sea turtles protected
Palau	G,H.	G,H	H		Yes*	size restrictions; closed seasons; eggs protected
Papua New Guinea	G,H,L	G,H	H		Yes	seasonal restrictions on wildlife management areas; export permit required
Pitcairn Island					Yes*	all sea turtles protected
Solomon Islands	G,H	G,H	H	X	No	size restrictions; leatherbacks and eggs protected
Tokelau	G,H	G,H			No	restrictions on egg collecting
Tonga	G	G	G,H		No	seasonal restrictions; leatherbacks protected
Tuvalu	G	G			No	licence required
Vanuatu	G,H	G,H			Yes	eggs protected; sale of hawksbills and shell prohibited
Wallis and Futuna					Yes*	no information
Western Samoa	H	G,H			No	no sea turtle regulations

Footnotes:

[a] Data from interviews and correspondence with government officials; Hirth, 1971a; Johannes, 1986; Limpus and Parmenter, 1986; Milliken and Tokunaga, 1987; Groombridge and Luxmoore, 1989.

[b] Subsistence take, kinship sharing, trade and sales in local markets, ceremonial use.

[c] Includes skin, oil, carapaces, stuffed turtles, ornaments.

[d] Some nations are currently reviewing their regulations.

* Party to CITES by virtue of association with a signatory to CITES. Some countries are currently reviewing their affiliation with CITES.

to the west of Scilly Atoll - i.e., the Cook Islands, Tonga, Wallis and Futuna, Fiji, Solomon Islands, Vanuatu and New Caledonia (Groombridge and Luxmoore, 1989; Hirth *et al.*, *ms.*). Both dispersal and vicariance theories may account for some of the migrations revealed by the Scilly tagging project. The recapture data that have been sent to the author by the turtle hunters reveal that most of the turtles were eaten at their site of capture and, needless to say, this underscores he need for international cooperation in the management of the resource.

de Silva (1986) reports that some green turtles nesting in Sabah have been ecovered in the Philippines and in Indonesia.

The ultimate factors involved in long-range remigrations of marine turtles re unknown but several models have been proposed or reviewed: geotectonics Carr and Coleman, 1974; LeGall, 1989; but see Bowen *et al.*, 1989); evolution long a behavioral continuum (Hirth, 1978); and glaciation-associated sea level luctuations (Moll, 1983). Proximate factors involved in homing and navigation re likewise unknown but several have been described or reviewed: olfactory mprinting and a compass sense (Carr, 1972; but see Brown, 1990); social acilitation model (Owens *et al.*, 1982; but see Meylan *et al.*, 1990); and mprinting (Owens *et al.*, 1986). Currently there is a notable lack of research on he oceanic orientation and navigation of sea turtles, but promising satellite elemetry experiments are planned.

EXPLOITATION

The green and hawksbill turtles are regularly taken in the South Pacific region Table IV). The degree of local exploitation varies among nations; the details an be found in the references cited in the table. In some places, the turtles are aken on the nesting beaches; in other places they are taken in the sea. As the uman population increases, especially in the coastal areas, and as the numbers f green and hawksbill turtles diminish, the less common or less preferred pecies may be exploited where they are available. For example, in some areas f the Southwest Pacific Ocean, more flatbacks, loggerheads or leatherbacks ay be taken for meat as the green turtles are depleted. In some places, although rtles or their eggs may be protected, the enforcement of conservation regulaons is difficult.

Five U.S. islands in the South Pacific region (Rose Atoll, Jarvis Island, ohnston Atoll, Howland Island and Baker Island) have been declared National Vildlife Refuges and all sea turtles are protected. All U.S. Pacific islands are overed by the USA's ratification of CITES.

Currently Solomon Islands still exports significant amounts of tortoiseshell Japan. Tortoiseshell is known as *bekko* in the Japanese trade. Japan is a ignatory to CITES but has placed reservations on the hawksbill and olive ridley rtles. Japan planned to cease its trade in tortoiseshell by December 1992 (Donnelly, 1991). Legislation was drafted and considered by the Fijian Cabinet in November 1990 to prohibit the export of hawksbill turtle shell but this legislation remains to be gazetted.

Halstead (1988) states that three species of marine turtles have been reported as poisonous: green, hawksbill and leatherback. In the South Pacific area, documented cases of hawksbill turtle poisoning have been reported from the Gilbert Islands, Australia, Solomon Islands and Papua New Guinea (summarized in Witzell, 1983). The origin of turtle poison (chelonitoxin) is unknown but most likely is derived from the food chain. Most outbreaks of turtle poisoning have occurred in the Indo-Pacific region; the most dangerous months appear to be April through August. Turtle poisoning is similar to ciguatera in its disjunct distribution and spontaneity. Chelonitoxications may result from ingestion of flesh, fat, viscera or blood. The symptoms vary with the amount ingested and the person. Symptoms develop within a few hours to several days after eating. Initial symptoms include nausea and vertigo, followed by lethargy then, in severe cases, somnolence. Halstead *(ibid)* reports the overall case fatality rate to be 28 per cent. There are no known antidotes hence the treatment is symptomatic. There are no reliable external characteristics which differentiate a poisonous sea turtle from a harmless one.

IV. RESEARCH

TAGGING NESTERS AND RECORDING DATA

After a turtle has completed her entire nesting repertoire, a tag is clamped onto the trailing edge of each front flipper. Two persons make tagging easy, one person can do it. Flipper tags are of metal or plastic. Recently, a passive integrated transponder (PIT) tag has been used on sea turtles. This basically is a pre-programmed microchip capable of receiving and transmitting specific radio signals (Fontaine *et al.*, 1987). PIT tags have been used successfully to mark tuna and marlin. Small turtles are sometimes marked with internal, binary-coded, magnetic tags.

Some taggers offer a reward for a returned tag (or sightings), others do not. Recaptures of tagged turtles on the nesting beach provide information on the number and location of nests laid by an individual over the nesting season and provide data on the renesting and remigration intervals. Recaptures away from the nesting beach provide information on growth, adult habitats, migrations and survivorship. Several precise measurements of the carapace are usually taken by researchers. Unfortunately, the carapace lengths of some sea turtles in the South Pacific have been measured in different ways. The standard straight line carapace length is recommended. This is measured with calipers extended long the midline from the anterior edge of the cervical scute to the posterior-nost edge of the marginal scute. In the case of leatherbacks, this is the straight ine distance along the midline from the anterior notch to the posterior-most rojection of the shell. Other data to collect at time of nesting are date, time, veather, tidal stage, nest site on the beach, condition of turtle, ectoparasites, olouration, turtle's weight, and number of eggs. Nocturnal behavior can be bserved with a night vision scope. In rare situations when clutches must be elocated, the transplant should be carefully made within a couple hours after viposition and with minimal rotation of the eggs. Some of the details of ncubation of eggs in containers and the establishment of artificial hatcheries (as vell as details of carapace measurements, tags, and other methodologies nentioned in this section) can be found in Pritchard *et al.* (1983). McGehee 1990) emphasizes how appropriate moisture levels are important in artificial atcheries.

The nascent "Sea Turtle Tag Center of the Pacific" at the University of Iawaii's Institute of Marine Biology, (P.O. Box 1346, Kaneohe, Hawaii, 6744, USA) can provide turtle tags and applicators and it serves as a central egistry for resighting information.

Hatchling data should include length of incubation, per cent successful hatch, nd the state of hatchlings and eggs remaining in the nest. Live hatchlings can e measured and weighed, providing that these be done quickly. Spotila *et l.* (1983) describe the methodology for the study of ESD on beaches.

URVEYS IN AQUATIC HABITATS

Any empirical information on sea turtles in their developmental and adult abitats is important. Conventional methods in use for studying sea turtles in the vater include aerial surveys, radio tracking, SCUBA and netting. Some inter-sting underwater observations on mating behavior were made by Booth (Booth nd Peters, 1972) on green turtles off Australia. Satellite imagery can be useful or plotting cover of seagrasses and for assessing perturbations in seagrass cosystems. The use of manned submersibles in green turtle pastures would ield valuable information on feeding behavior, social interactions and activity ycles, among other things.

ERIAL SURVEYS

Aerial surveys can be conducted to census sea turtles both when they are at e surface of the sea and when they are nesting. Aerial surveys may be the most ost effective method of documenting nesting activity on the widely scattered slands and atolls of the South Pacific Ocean.

Most nesting beach surveys are flown in the early morning and are synchronized to the tides in order to take advantage of the best opportunity to observe fresh, conspicuous tracks. Single-engine, high-winged planes are flown at relatively low altitudes and at low speeds. Two-engine planes may be too fast to allow accurate observations but they are safer when flying long distances over water. In addition to the pilot, cabin members usually include an observer and a recorder. However, one observer can record information on a tape recorder. Experience is important. Experienced observers can identify species of turtles from the air when the turtles are at the sea surface and they can identify some species by their tracks and nests on the beach. Marsh and Saalfeld (1989) and Marsh and Sinclair (1989) describe some of the problems and successes of aerial surveys of marine turtles and dugongs off eastern Australia.

BIOTELEMETRY

Instrumentation has been useful in tracking short- and long-range movements of marine turtles. Radio and satellite tracking of loggerhead and Kemp's ridley turtles off Mexico and the USA are summarized by Kemmerer *et al.* (1987). Duron-Dufrenne (1987) briefly describes satellite tracking of a leatherback off French Guiana, and more biotelemetry is planned there. Sonic telemetry was used to monitor the behavior of young green turtles in a lagoon off Florida, USA (Mendonca, 1983). Dizon and Balazs (1982) radio-tracked adult male and female green turtles at French Frigate Shoals, Hawaii, during the breeding season. They found movements were restricted to shallow waters surrounding the basking and nesting islands. Naito *et al.* (1990) and Sakamoto *et al.* (1990) attached a time temperature recorder, time depth recorder and a time swimming distance recorder to a loggerhead off Japan to record internesting behavior, circadian rhythms and diving depths.

MARKET SURVEYS

These surveys are useful for assessing trends in numbers of turtles, levels and types of exploitation, and the effectiveness of turtle regulations. Information should be collected over a period of time and should include species, size and parts of turtles, number of vendors, and prices of turtles compared to other items being sold.

INTERVIEWS AND QUESTIONNAIRES

These information-gathering devices are quick, easy ways to obtain information but the validity of the information must be carefully assessed. Quantitative data, especially, must be scrutinized. The demeanor of the interviewer and the wording of the questionnaire are often as important as the actual questions. Taped interviews may be intimidating in some situations. In these types of surveys, information should be obtained on the reliability of the informer, species and sizes of turtles in the area, seasonality of nesting, location of developmental and adult habitats, level of exploitation, changes noticed in the populations of turtles over time, and the degree of compliance with turtle regulations. Traditional fishermen can be a rich source of sea turtle information.

V. CONSIDERATIONS FOR MANAGEMENT

An important component of any marine turtle conservation plan is the maintenance of quality nesting habitats and protection for the eggs, hatchlings and nesters. Eggs should be left in place to incubate, hatchlings should be allowed to crawl to the sea and nesting females should be allowed freedom of the beach. Local residents should be involved in maintaining the nesting habitat and, where traditional or justified, the sustained utilization of the turtle resource should be under local supervision. The Wildlife Management Areas of Papua New Guinea are examples of such local stewardship. Because imprinting to the natal beach is as yet an unproven hypothesis, it is inadvisable at this time to attempt to establish new, nesting colonies by transplanting eggs.

Direct and incidental take of juvenile and adult turtles in the sea by humans must be carefully monitored. As already mentioned, the loggerhead population model of Crouse *et al.* (1987) shows that increasing the survivorship of large uveniles has the greatest effect on population increase, and this model may be applicable to Pacific turtles--at least to the extent that South Pacific populations exhibit life history traits similar to the southeast USA loggerheads.

When more scientific information is available about the developmental and adult habitats of marine turtles, it will be necessary also to maintain the integrity of these habitats. For example, certain coral reefs in the South Pacific may be ritical habitats for hawksbill turtles. Needless to say, concurrent management of all critical stages in the lives of sea turtles is needed for their survival and ecovery. International cooperation is required where nations are sharing the ame migratory stock.

NESTING BEACH HABITAT

Management of the nesting beach habitat is best achieved by keeping it as atural as possible. Factors impacting on quality nesting habitat include: coastal one development, man-made structures on or adjacent to the beach, artificial lumination, beach erosion, litter, human activity, vehicular traffic and chemial pollution. Control of predators may be necessary on some beaches. Problems f, and possible solutions for, hatchling disorientation caused by beachfront ghting are described by Raymond (1984). Dead, stranded turtles of all sizes should be reported to the nearest wildlife authority. The wildlife officer could study stranding patterns in his area and try to figure out causes. Carcasses should be examined and dissected for relevant biological data (Rainey, 1981).

Visible effects of egg protection may not be seen for decades considering the time it takes for some marine turtles to reach reproductive maturity. Even then the benefits may be difficult to assess because of natural fluctuations in nesting populations. Likewise, overexploitation of eggs may continue for decades before a decline in nesters is seen.

MARINE HABITAT

Because little is known about the lives or habitats of marine turtles in the sea, the common sense approach to maintaining quality marine habitats would include rational control of offshore structures, dredging, sewage disposal, commercial and recreational fishing, nearshore boat traffic and chemical, radioactive, and thermal pollution.

Research is needed on the long-term and synergistic effects of sublethal doses of chemicals at the biochemical and cellular levels of organization as well as at the organismal level *(e.g.* changes in behavior, growth, reproduction). For example, besides directly affecting individual growth, chemical pollution on the beach and in the neritic zone could adversely affect imprinting. Education can play a major role in overcoming the "commons" basis for marine pollution.

EGG TRANSPLANTS

In rare cases when or where large numbers of nesters deposit eggs in inappropriate places, such as below the berm, or where poaching is excessive, eggs may be carefully reburied in nearby sites, reburied in a central "protected" hatchery or in extreme cases artificially incubated in styrofoam boxes. As already mentioned, each of these procedures has its limitations (see Pritchard *et al.*, 1983). Consideration must be given to the fact that transplanted eggs in the sand on the beach or in boxes may give unnatural sex ratios through ESD. Mrosovsky (1982) and Dutton *et al.* (1985) report a masculinization effect on eggs incubated in styrofoam boxes.

TURTLE EXCLUDER DEVICES (TEDs)

The development of TEDs to reduce incidental sea turtle capture in shrimp trawls is described by Seidel and McVea (1982). There are now five different types of TEDs and the price varies from US $40 to 400, depending on the size and model (Donnelly, 1989). In a few sites where TEDs might be ineffective (e.g. places with large amounts of benthic vegetation), tow-times should be reduced.

HEADSTARTING

Headstarting may be described as the raising of hatchlings to a size at which they are thought to be less vulnerable to predators before releasing them. The main objective of a headstart program is to increase the breeding stock over what occurs naturally.

Large-scale headstart programs are not recommended at this time. Small, scientifically conducted, experimental projects may be appropriate in some locales, when such projects would not put a stress on the local stocks. These scientific projects may include among other things, research on development of a permanent tag for hatchlings and yearlings, a nonlethal technique of sexing hatchlings, and development of sonic tracking techniques for yearlings.

A 30-year headstart program in Florida, USA, involving the green turtle has revealed some good information on growth rates and survival of captive-reared individuals (Witham, 1980) but no more releases are planned until there is evidence of nesting by headstarted turtles (Huff, 1989).

One of the most elaborate headstarting projects in the world is the cooperative USA/Mexico program involving restoration of the Kemp's ridley turtle. The program has operated for over a decade, and much information has been garnered on captive rearing methodology and on the distribution and survival ates of headstarted ridleys after release. However, no nesting headstarted idley has as yet been identified. This, of course, may take more time, but it seems prudent to refrain from starting more large-scale programs until final esults and methodologies of these ridley and green turtle projects are made known. Some details of the ridley headstart project are in Klima and McVey 1982), Duronslet *et al.* (1989) and Ross *et al.* (1989).

RANCHING

A sea turtle ranch involves the raising of individuals in semi- or complete captivity for a period of time, after which they are slaughtered for meat and products. The sources of the stock are eggs or hatchlings from natural populations. This take of wild stock is sometimes offset by releasing some captive-reared, young turtles into the sea. The degree of sophistication of a anch can range from cottage-level husbandry to maintaining herds in natural feeding habitats to high technology, land-based factories. The goals of ranchers ange from feeding local people to sale of meat and products in local markets to nternational trade. Ranching and farming have been discussed by proponents and opponents (Ehrenfeld, 1982; Reichart, 1982; Dodd, 1982). Groombridge and Luxmoore (1989) describe the operation of the Reunion Island green turtle anch. A variety of captive rearing, headstart and ranching experiments have been run in the South Pacific area (Table II) and Balazs (1977) constructively reviewed some of these projects.

FARMING

A sea turtle farm is a self-perpetuating population in an ersatz habitat. Farming turtles is a complex, controversial and expensive undertaking. The only large farm in existence is the Cayman Turtle Farm on Grand Cayman Island, British West Indies. Some aspects of the farm are described by Wood and Wood (1980) and by Groombridge and Luxmoore (1989). Wood and Wood (1990) report that F_2 hatchlings have now been produced on the farm. Tisdell (1986) has described some socioeconomic parameters of turtle farming with reference to the Australasian region.

INTERNATIONAL COMMERCE

All nations should join and abide by CITES.

EDUCATION

There is a growing awareness among the people of all nations over the role of humans in the stewardship of natural resources. This concern should be emphasized by resource managers in a variety of educational programs. The success of any management scheme is best achieved through education.

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APPENDIX I

A KEY TO SEA TURTLES IN THE SOUTH PACIFIC OCEAN

1a. Carapace leathery and with seven longitudinal keels ... *Dermochelys coriacea*

1b. Carapace covered with scutes 2

2a. One pair of prefrontals; four pairs of costals; nuchal separated from first costal by first vertebral; hatchlings with dark carapace and white plastron 3

2b. Two pairs of prefrontals (sometimes group of 5); four or more pairs of costal.....4

3a. Three postoculars; "greasy" carapace with upturned margins; carapce olive gray; plastron white; middle of front flippers with many small scales or wrinkled skin; hatchlings large .... *Natator depressa*

3b. Four postoculars; carapace heart shaped without upturned margins; carapace varies from tan to gray often with speckled or radiant markings; plastron yellow .... *Chelonia mydas*

3c. Four postoculars; carapace without upturned margins; carapace dark sometimes black; plastron light but with varying infusions of black; often an indentation in carapace margin above hind flippers .... *Chelonia mydas agassizi*

4a. Four pairs of costals; nuchal separated from first costal by first vertebral; carapace scutes thick and overlapping and carapace serrated in rear (except in hatchlings and large individuals). Carapace color variable, usually predominately brown with light spots and streaks; plastron light, sometimes with dark spots; hatchlings are brownish above and below .... *Eretmochelys imbricata*

4b. Five pairs of costals; carapace is reddish brown; nuchal in contact with first costal; yellow plastron; large head; bridge with three enlarged inframarginals and no pores; hatchlings brown above and light brown below...... *Caretta caretta*

4c. Five or more pairs of costals (usually six to eight); nuchal in contact with first costal; bridge with four enlarged inframarginals and pore near rear of each inframarginal; color above is gray in immatures, dark olive green in adults; plastron is white or yellow; carapace may be as wide as long; hatchlings dark gray-brown or black both above and below .... *Lepidochelys olivacea*

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