

Nearshore Marine Resources of the South Pacific

**Information for Fisheries Development
and Management**

Edited by

Andrew Wright & Lance Hill

Institute of Pacific Studies, Suva
Forum Fisheries Agency, Honiara
International Centre for Ocean Development, Canada

1993

Library

NOAA, National Marine Fisheries Service
SWFC Honolulu Laboratory F/SWC2
2570 Dole Street
Honolulu, HI 96822-2396

SH
321.5
1042
1993
C 2

USP Library
Cataloguing-in-
Publication Data:

Nearshore marine resources of the South Pacific /
Andrew Wright, Lance Hill, editors. - Honiara
[Solomon Islands], Suva [Fiji] : Forum Fisheries
Agency [FFA] Institute of Pacific Studies [IPS],

1993.

[xvi], 710 p. : ill. ; 21 cm.

Includes bibliography.
ISBN 982-02-0082-2

1. Fishery resources - Oceania 2. Marine
resources - Oceania I. Wright, Andrew II. Hill,
Lance III. Canada. International Centre for
Ocean Development

SH319.A2N43 333.95610995

Copyright ©

IPS and FFA 1993

Publishers:

IPS, Suva
FFA, Honiara
ICOD, Canada

Cover:

Images from the Solomon Islands. The band of fish is
based on a dance stick; from Guadalcanal. The deity
Waumauma graces a casket designed to hold the bones
of deceased heroes in the custom house; from Santa
Ana.
Jo Uluinaceva, USP Media Centre

Typesetting:

Times New Roman PS 10.5/12.5,
Mark Garrett, Matt Wilson Limited, Suva

Production:

Linda Crowl, IPS

Printing:

Singapore National Printers

Marine Turtles

Harold F. Hirth

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 kemp*i (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

a global market economy, and the lack of long-range conservation strategies - many marine turtle populations are now endangered. All marine turtles are listed on Appendix I of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). For signatory nations, this means that international trade in the species and their products and derivatives is prohibited, except under exceptional circumstances.

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

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

II. LIFE HISTORY AND POPULATION BIOLOGY

IDENTIFICATION AND TAXONOMY

A key to the marine turtles in the South Pacific Ocean is provided in Appendix 1. The leatherback turtle is easily recognizable by its large adult size and leathery shell. The dorsal colouration is predominately black, with white spots. Although the leatherback is a circumglobal species, it is most prudent, at this time, to consider each breeding population, or regional populations, as a unique assemblage. The taxonomy of the leatherback complex, as well as the systematics of the other circumglobal species, is now being examined by researchers. The common name of the green turtle is derived from the colour of its fat. As their names suggest, the loggerhead turtle has a large head and the hawksbill turtle has a tapering "beak". The carapacial scutes of the hawksbill are the tortoiseshell of commerce. The olive ridley turtle is the smallest sea turtle found 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

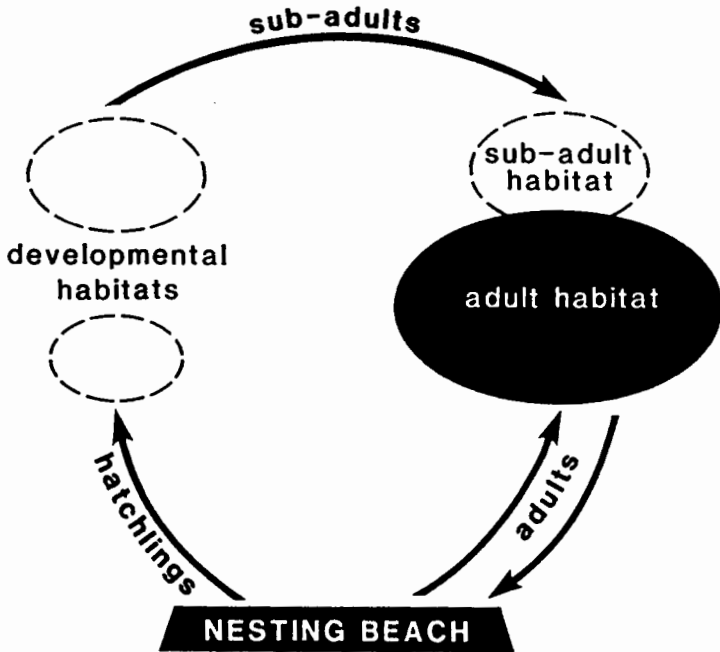


Figure 1. A generalized life cycle of marine turtles (modified from the model of Hirth and Hollingworth in FAO, 1973).

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. A available information indicates a tendency for oceanic island nesters to disperse less than mainland nesters between nesting emergences and for some species to disperse more than others.

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

Females, and presumably males, make gametic remigrations to the same nesting 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 |
|--|---|--|
| <i>Natator depressa</i> Australia | benthic invertebrates, jellyfish | Limpus <i>et al.</i> , 1988; Zangerl <i>et al.</i> , 1988 |
| <i>Caretta caretta</i> Australia | crabs, jellyfish, prawns, gastropods, pelycepods, fish | Limpus, 1973; 1979; Moody in Dodd, 1988 |
| New Zealand | urochordates | McCann, 1966 |
| <i>Eretmochelys imbricata</i> 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 |
| <i>Chelonia mydas</i> Australia | algae, seagrasses | Limpus, 1978; Garnett and Murray, 1981; Garnett <i>et al.</i> , 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 <i>et al.</i> , <i>ms.</i> |
| Solomon Is. | algae, seagrasses | Vaughan, 1981 |
| Tokelau | algae | Balazs, 1983 |
| Tonga | seagrasses | Hirth, 1971a; Hirth <i>et al.</i> , 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 Islands | green, hawksbill, olive ridley | growth rates, headstart | McKeown, 1977; McElroy & Alexander, 1979; Vaughan, 1981. |
| Tonga | hawksbill | headstart | Wilkinson, 1979. |
| Western Samoa | 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 connotes 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 re-nesting 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 re-nest 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 - A void 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.

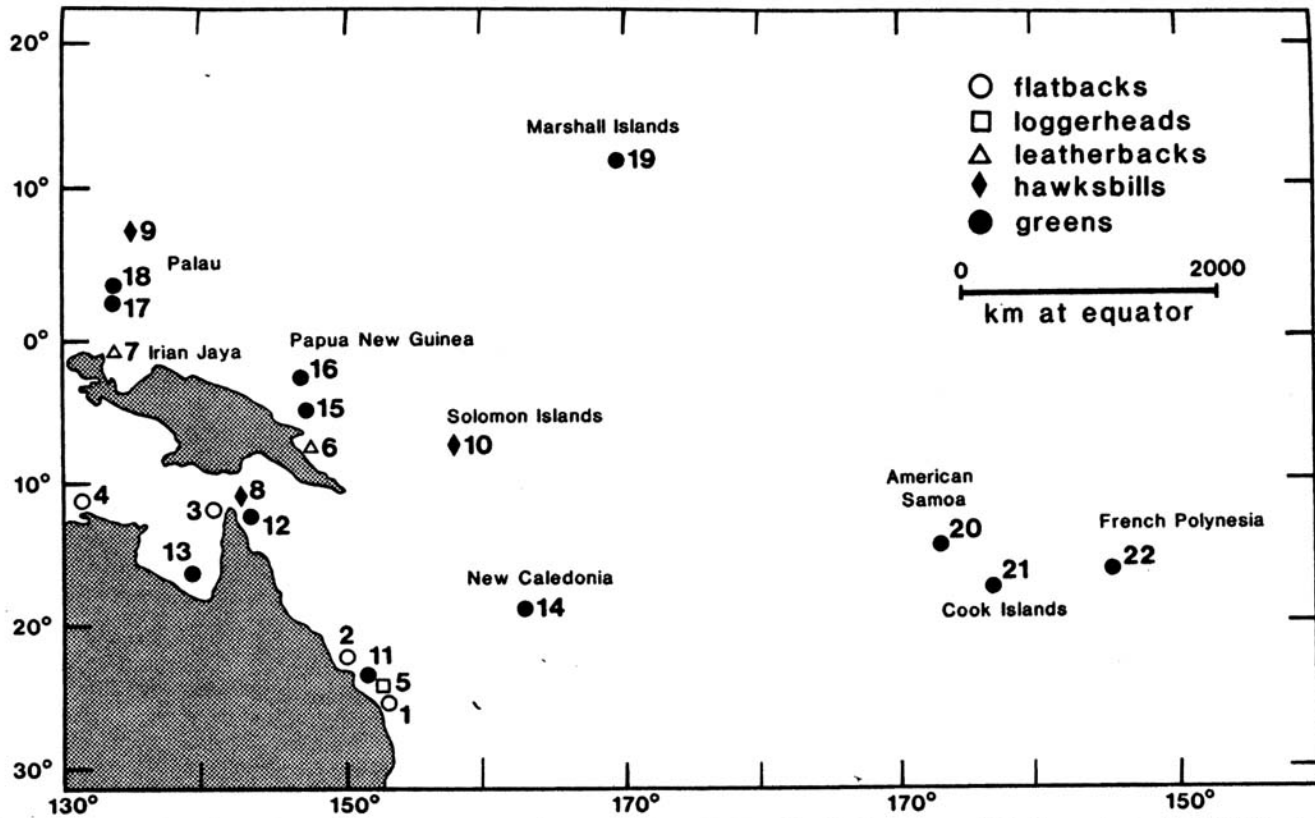


Figure 2. Some of the major and/or well-known nesting sites of marine turtles in the South Pacific Ocean area. 1-Mon Repos, Australia; 2-Wild Duck-Avoid Islands, Australia; 3-Crab Island, Australia; 4-Greenfield Island, Australia; 5-Queensland beaches, Australia (see text); 6-Piguwa, Papua New Guinea; 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 |
|-------------------------------|------------------------------|--------------------------------------|---------------------|---------------------|-------------------|---------------------------|--------------------------|--------------------------------|-----------------------|--|
| <i>Natator depressa</i> | | | | | | | | | | |
| 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 <i>et al.</i> , 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 <i>et al.</i> , 1984a |
| <i>Caretta caretta</i> | | | | | | | | | | |
| 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 |
| <i>Eretmochelys imbricata</i> | | | | | | | | | | |
| 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 |

| 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 |
|---|------------------------------|--------------------------------------|---------------------|---------------------|-------------------|---------------------------|--------------------------|--------------------------------|-----------------------|------------------------------|
| 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 <i>et al.</i> , 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 |
| <i>Chelonia mydas</i> 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 Islands (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 the 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 levels (Limpus, 1987). Bramble Cay in the Torres Strait may have been a major rookery 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 islands in the Torres Strait but their numbers need to be determined.

Many green turtles nest on the Islands of Surprise, Leleixour, Fabre and Huon in 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 tag 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.

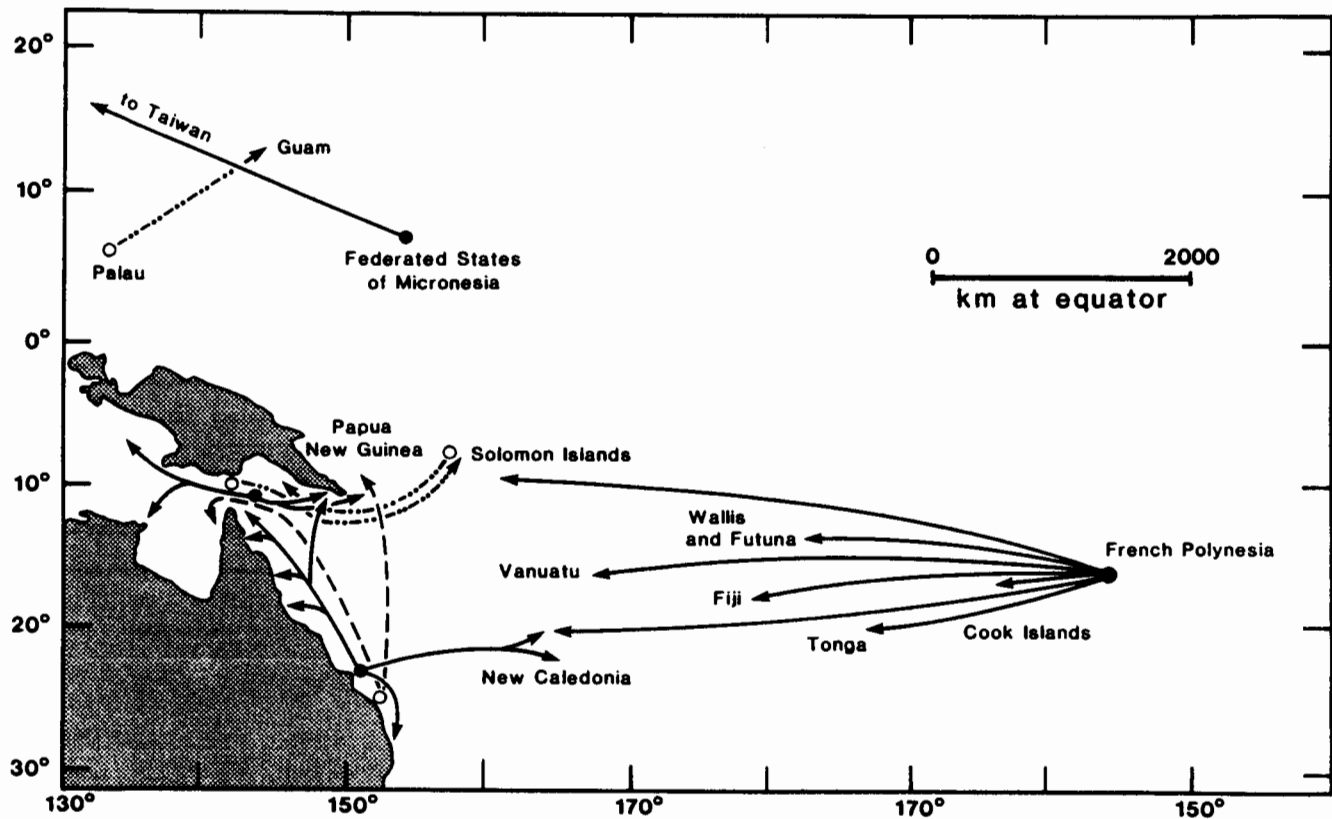


Figure 3. Some long-range movements of South Pacific sea turtles. Solid lines, green turtles; dashed lines, loggerhead turtles; dot-dash lines, hawksbill turtles. Arrows indicate sites of contact, not routes travelled.

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)}.

| Nation | eggs | Local exploitation ^{b)} | | Significant tortoiseshell export | Party to CITES | Turtle regulations ^{c)} |
|--------------------------------|-------|----------------------------------|---------------------|----------------------------------|----------------|---|
| | | flesh | parts ^{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 |

| Nation | eggs | Local exploitation ^{b)} | | Significant tortoiseshell export | Party to CITES | Turtle regulations ^{d)} |
|-----------------------------------|-------|----------------------------------|---------------------|----------------------------------|----------------|--|
| | | flesh | parts ^{c)} | | | |
| 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 the need for international cooperation in the management of the resource.

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

The ultimate factors involved in long-range remigrations of marine turtles are unknown but several models have been proposed or reviewed: geotectonics (Carr and Coleman, 1974; LeGall, 1989; but see Bowen *et al.*, 1989); evolution along a behavioral continuum (Hirth, 1978); and glaciation-associated sea level fluctuations (Moll, 1983). Proximate factors involved in homing and navigation are likewise unknown but several have been described or reviewed: olfactory imprinting and a compass sense (Carr, 1972; but see Brown, 1990); social facilitation model (Owens *et al.*, 1982; but see Meylan *et al.*, 1990); and imprinting (Owens *et al.*, 1986). Currently there is a notable lack of research on the oceanic orientation and navigation of sea turtles, but promising satellite telemetry 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 can be found in the references cited in the table. In some places, the turtles are taken on the nesting beaches; in other places they are taken in the sea. As the human population increases, especially in the coastal areas, and as the numbers of green and hawksbill turtles diminish, the less common or less preferred species may be exploited where they are available. For example, in some areas of the Southwest Pacific Ocean, more flatbacks, loggerheads or leatherbacks may be taken for meat as the green turtles are depleted. In some places, although turtles or their eggs may be protected, the enforcement of conservation regulations is difficult.

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

Currently Solomon Islands still exports significant amounts of tortoiseshell to Japan. Tortoiseshell is known as *bekko* in the Japanese trade. Japan is a signatory to CITES but has placed reservations on the hawksbill and olive ridley turtles. 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 (cheloniotoxin) 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. Cheloniotoxications 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 re-nesting 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

along the midline from the anterior edge of the cervical scute to the posterior-most edge of the marginal scute. In the case of leatherbacks, this is the straight line distance along the midline from the anterior notch to the posterior-most projection of the shell. Other data to collect at time of nesting are date, time, weather, tidal stage, nest site on the beach, condition of turtle, ectoparasites, colouration, turtle's weight, and number of eggs. Nocturnal behavior can be observed with a night vision scope. In rare situations when clutches must be relocated, the transplant should be carefully made within a couple hours after oviposition and with minimal rotation of the eggs. Some of the details of incubation of eggs in containers and the establishment of artificial hatcheries (as well as details of carapace measurements, tags, and other methodologies mentioned in this section) can be found in Pritchard *et al.* (1983). McGehee (1990) emphasizes how appropriate moisture levels are important in artificial hatcheries.

The nascent "Sea Turtle Tag Center of the Pacific" at the University of Hawaii's Institute of Marine Biology, (P.O. Box 1346, Kaneohe, Hawaii, 96744, USA) can provide turtle tags and applicators and it serves as a central registry for resighting information.

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

SURVEYS IN AQUATIC HABITATS

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

AERIAL SURVEYS

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

Most nesting beach surveys are flown in the early morning and are synchro-

nized 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 interesting 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 juveniles 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 critical 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 recovery. International cooperation is required where nations are sharing the same migratory stock.

NESTING BEACH HABITAT

Management of the nesting beach habitat is best achieved by keeping it as natural as possible. Factors impacting on quality nesting habitat include: coastal zone development, man-made structures on or adjacent to the beach, artificial illumination, beach erosion, litter, human activity, vehicular traffic and chemical pollution. Control of predators may be necessary on some beaches. Problems of, and possible solutions for, hatchling disorientation caused by beachfront lighting 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 rates of headstarted ridleys after release. However, no nesting headstarted ridley 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 results 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 ranch can range from cottage-level husbandry to maintaining herds in natural feeding habitats to high technology, land-based factories. The goals of ranchers range from feeding local people to sale of meat and products in local markets to international 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 ranch. 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.

ACKNOWLEDGMENTS

Ms. Maurine Vaughan and Ms. Judy Baker graciously typed and edited several versions of the manuscript and their help on this project, and on others over the years, is especially acknowledged. Ms. Linda Burns, Interlibrary Loan Supervisor, University of Utah, provided timely and valuable assistance in obtaining some obscure references. Mr. George Balazs provided helpful comments on an earlier version of the manuscript.

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; carapace 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*

REFERENCES

- Anon. (1979). Tagging and rearing of the green turtle *Chelonia mydas* conducted in French Polynesia by the Department of Fisheries. *SPC/NMFS Workshop on Marine Turtles in the Tropical Pacific Islands*. Noumea, New Caledonia, 21 pp.
- Anon. (1982) More on Irian Jaya leatherbacks. *Marine Turtle Newsletter* 33, 12.
- Anon. (1987). Hawksbill turtle hatchling recovered. *Micronesian Mariculture Demonstration Center Bull.* (Sept.):1.
- Anon. (1989). Rapport mission d'observation: du 9 au 17 janvier 1989, tortues marines et oiseaux de mer, Iles Surprise et Huon (Récifs d'Entrecasteaux). *Assoc. Sauvegarde Nature Néo-Calédonienne*, 20 pp.
- Adipati, E. and Patay, M. (1984). *Investigations on marine turtles and their nesting sites on beaches of the Kepala Burung, Irian Jaya. Project 1528*. World Wildlife Fund. Jayapura. 13 pp.
- Alvarado, J. and Figueroa, A. (1990). The ecological recovery of sea turtles of Michoacan, Mexico. Special attention: the black turtle, *Chelonia agassizi*. *Final Report*, U.S. Fish and Wildl. Serv., Albuquerque, New Mexico, USA. 97 pp.
- Balazs, G.H. (1975) Marine turtles in the Phoenix Islands. *Atoll Res. Bull.* No. 184, 1-7.
- Balazs, G.H. (1977) *South Pacific Commission Turtle Project : a constructive review and evaluation with recommendations for future action*. Informal report for South Pacific Commission, Noumea, New Caledonia, 54 pp.
- Balazs, G.H. (1980). Synopsis of biological data on the green turtle in the Hawaiian Islands. *NOAA Tech. Memo.* NMFS, Honolulu, Hawaii, 141 pp.
- Balazs, G.H. (1982a). Growth rates of immature green turtles in the Hawaiian Archipelago. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 117-125, Smithsonian Inst., Washington, D.C.
- Balazs, G.H. (1982b). Status of sea turtles in the Central Pacific Ocean. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 243-252, Smithsonian Inst., Washington, D.C.
- Balazs, G.H. (1983). Sea turtles and their traditional usage in Tokelau. *Atoll Res. Bull.* No. 279, 1-30.
- Balazs, G.H. (1985a). Status and ecology of marine turtles at Johnston Atoll. *Atoll Res. Bull.* 285, 1-46.
- Balazs, G.H. (1985b). Impact of ocean debris on marine turtles: entanglement and ingestion. In *Proc. Workshop on Fate and Impact of Marine Debris*. (R.S. Shomura and H.O. Yoshida, eds.), pp. 387-429. 26-29 November 1984, Honolulu, Hawaii (NOAA-TM-NMFS-SWFC-54).
- Balazs, G.H. (1986). Ontogenetic changes in the plastron pigmentation of hatchling Hawaiian green turtles. *J. Herpetol.* 20(2), 280-282.
- Booth, J. and Peters, J.A. (1972). Behavioural studies on the green turtle (*Chelonia mydas*) in the sea. *An. Behav.* 20(4), 808-812.
- Bowen, B.W., Meylan, A.B. and Avise, J.C. (1989). An odyssey of the green sea turtle: Ascension Island revisited. *Proc. Natl. Acad. Sci. USA* 86, 573-576.
- Brandon, D. (1975). Cook Islands. *S.P.C. Fisheries Newsletter* 13, 13-14. Noumea, New Caledonia.

- Broughton, E. (1986). Hawksbill headstarting in Palau. *Marine Turtle Newsletter* 38, 4-5.
- Brown, C.W. (1990). The significance of the South Atlantic equatorial countercurrent to the ecology of the green turtle breeding population of Ascension Island. *J. Herpetol.* 24(1), 81-84.
- Bustard, R. (1972). *Sea Turtles: Their Natural History and Conservation*. Taplinger Co., New York, 220 pp.
- Bustard, R. (1974). Barrier Reef Sea Turtle Populations. In *Proc. Second Int. Coral Reef Symp.* Vol.1. pp. 227-234. Great Barrier Reef Committee, Brisbane.
- Bustard, H.R. (1976). Turtles of Coral Reefs and Coral Islands. In *Biology and Geology of Coral Reefs*. (D.A. Jones and R. Endean. eds.). pp. 343-368, Vol. 3, Biology 2, Academic Press, New York.
- Bustard, H.R. and Limpus, C. (1970). First International Recapture of an Australian Tagged Loggerhead Turtle. *Herpetologica*. 26(3), 358-359.
- Bustard, H.R. and Limpus, C. (1971). Loggerhead Turtle Movements. *British J. Herp.* 4(9), 228-230.
- Carr, A. (1972). The case for long-range chemoreceptive piloting in *Chelonia*. In *Animal Orientation and Navigation*. (S.R. Galler, K. Schmidt-Koenig, G.J. Jacobs and R.E. Belleville. eds.). pp. 469-483. NASA SP-262, Washington, D.C.
- Carr, A. (1975). The Ascension Island green turtle colony. *Copeia* 1975(3), 547-555.
- Carr, A. (1986). Rips, FADS, and little loggerheads. *Bioscience* 36(2), 92-100.
- Carr, A. (1987). New perspectives on the pelagic stage of sea turtle development. *Conserv. Biol.* 1(2), 103-121.
- Carr, A.F. and Main, A.R. (1973). Turtle farming project in northern Australia: report on an inquiry into ecological implications of a turtle farming project. Commonwealth of Australia, Canberra, 41 pp.
- Carr, A. and Coleman, P.J. (1974). Seafloor spreading theory and the odyssey of the green turtle. *Nature* 249, 128-130.
- Carr, A., Meylan, A., Mortimer, J., Bjorndal, K. and Carr, T. (1982). Surveys of sea turtle populations and habitats in the western Atlantic. *NOAA Techn. Memo.* NMFS-SEFC-91.
- Chan, E.H. and Liew, H.C. (1988). A review on the effects of oil-based activities and oil pollution on sea turtles. In *Thirty Years of Marine Science Research and Development* (A. Sasekumar, R. D'Cruz and S.L.H. Lim, eds.), pp. 159-167, Proc. Eleventh Annual Seminar, Malaysian Society of Marine Sciences, 26 March 1988, Kuala Lumpur, Malaysia.
- Chan, E.H., Liew, H.C. and Mazlan, A.G. (1988). The incidental capture of sea turtles in fishing gear in Terengganu, Malaysia. *Biol. Conserv.* 43(1), 1-7.
- Chua, T.H. (1988). Nesting population and frequency of visits in *Dermochelys coriacea* in Malaysia. *J. Herpet.* 22(2), 192-207.
- Chua, T.H. and Furtado, J.I. (1988). Nest frequency and clutch size in *Dermochelys coriacea* in Malaysia. *J. Herpet.* 22(2), 208-218.
- Cornelius, S.E. and Robinson, D.C. (1985). Abundance, distribution and movements of olive ridley sea turtles in Costa Rica, V. *Final report, U.S. Fish Wildl. Ser. Contract* 14-16-0002-81-225. Albuquerque, New Mexico, USA. 54 pp.
- Crouse, D.T., Crowder, L.B. and Caswell, H. (1987). A stage-based population model for loggerhead sea turtles and implications for conservation. *Ecology* 68(5), 1412-1423.

- Davenport, J. (1989) Sea turtles and the greenhouse effect. *British Herpetological Soc. Bull.* 29, 11-15.
- de Silva, G.S. (1986). Turtle tagging and international tag returns for Sabah, East Malaysia. *Sarawak Mus. J.* 36(57), 263-271.
- Dizon, A.E. and Balazs, G.H. (1982) Radio telemetry of Hawaiian green turtles at their breeding colony. *Mar. Fish. Rev.* 44, 13-20.
- Dodd, Jr., C.K. (1982). Does sea turtle aquaculture benefit conservation? In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 473-480, Smithsonian Inst., Washington, D.C.
- Dodd, Jr., C.K. (1988). Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta* (Linnaeus, 1758). *U.S. Fish Wildl. Ser., Biol. Rep.* 88(14), 110 pp.
- Donnelly, M. (1989). The history and politics of turtle excluder device regulations. *Endangered Species Update* 6(11-12), 1-5.
- Donnelly, M. (1991). Japan will ban hawksbill trade by December 1992. *Marine Conservation News* 3, 1, 10.
- Duron-Duffrenne, M. (1987). Premier suivi par satellite en Atlantique d'une tortue luth, *Dermochelys coriacea*. *C.R. Acad. Sci. Paris* 304(15), 399-402.
- Duronslet, M.J., Caillouet, Jr., C.W., Fontaine, C.T., Revera, D.B., Williams, T.D., Williams, J.A., Manzella, S.A., Landry, Jr., A.M. and Stabenau, E.K. (1989). Kemp's ridley headstart and sea turtle research at the Galveston Laboratory: Annual report - fiscal year 1988. *NOAA Tech. Mem. NMFS-SEFC-223*. 40 pp.
- Dutton, P.H., Whitmore, C.P. and Mrosovsky, N. (1985). Masculinization of leatherback turtle *Dermochelys coriacea* hatchlings from eggs incubated in styrofoam boxes. *Biol. Conser.* 31(3), 249-264.
- Dye, T. and Steadman, D.W. (1990). Polynesian ancestors and their animal world. *Amer. Sci.* 78(3), 207-215.
- Eckert, S.A., Eckert, K.L., Ponganis, P. and Kooyman, G.L. (1989). Diving and foraging behavior of leatherback sea turtles (*Dermochelys coriacea*). *Can. J. Zool.* 67(11), 2834-2840.
- Edson, C. and Curren, F. (1987). Report from Oroluk. *Marine Turtle Newsletter* 41, 1-2.
- Ehrenfeld, D. (1982). Options and limitations in the conservation of sea turtles. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 457-463. Smithsonian Inst., Washington, D.C.
- F.A.O. (1973). Report to the Government of the People's Democratic Republic of Yemen on marine turtle management, based on the work of H.F. Hirth and S.L. Hollingworth, marine turtle biologists. *Rep. FAO/UNDP(TA)*, (3178). 51 pp.
- Fontaine, C.T., Williams, T.D. and Camper, J.D. (1987). Ridleys tagged with passive integrated transponder (PIT). *Marine Turtle Newsletter* 41, 6.
- Frazer, N.B. and Ehrhart, L.M. (1985). Preliminary growth models for green, *Chelonia mydas*, and loggerhead, *Caretta caretta*, turtles in the wild. *Copeia* 1985(1), 73-79.
- Frazer, N.B. and Ladner, R.C. (1986). A growth curve for green sea turtles, *Chelonia mydas*, in the U.S. Virgin Islands, 1913-14. *Copeia* 1986(3), 798-802.
- Fukada, H. (1965). Breeding habits of some Japanese reptiles (critical review). *Bull. Kyoto Gakugei Univ. (Ser. B)*, No. 27, 65-82.
- Garnett, S. (1980). A preliminary report on the nutrition and management of turtle hatchlings on Badu Island. In *Management of Turtle Resources*. pp. 36-41. *Research Monogr.* 1, James Cook University, Queensland.

- Garnett, S.T. and Murray, R.M. (1981). Farm management and nutrition of the green turtle, (*Chelonia mydas*). pp. 60-65. *Proc. Melbourne Herp. Symp.*
- Garnett, S.T., Price, I.R. and Scott, F.J. (1985). The diet of the green turtle, *Chelonia mydas* (L.), in Torres Strait. *Aust. Wildl. Res.* 12, 103-112.
- Glazebrook, J.S. (1980). Diseases of farmed sea turtles. In *Management of Turtle Resources*. pp. 42-55. *Research Monogr.* 1, James Cook University, Queensland.
- Glazebrook, J.S. and Campbell, R.S.F. (1990a). A survey of the diseases of marine turtles in northern Australia. I. Farmed turtles. *Diseases Aquatic Organisms* 9, 83-95.
- Glazebrook, J.S. and Campbell, R.S.F. (1990b). A survey of the diseases of marine turtles in northern Australia. II. Oceanarium-reared and wild turtles. *Diseases Aquatic Organisms* 9, 97-104.
- Groombridge, B. (1982). *The IUCN Amphibia-Reptilia Red Data Book. Part I. Testudines, Crocodylia, Rhynchocephalia*. I.U.C.N., Gland, Switzerland. 426 pp.
- Groombridge, B. and Luxmoore, R. (1989). *The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade*. Secretariat CITES, Lausanne, Switzerland. 601 pp.
- Gyuris, E. and Limpus, C.J. (1988). The loggerhead turtle, *Caretta caretta*, in Queensland: population breeding structure. *Aust. Wildl. Res.* 15, 197-209.
- Halstead, B.W. (1988). *Poisonous and Venomous Marine Animals of the World. (Second revised edition)*. Darwin Press, Princeton, New Jersey. 1168 pp.
- Harry, J.L. and Briscoe, D.A. (1988). Multiple paternity in the loggerhead turtle (*Caretta caretta*). *J. Heredity* 79(2), 96-99.
- Hillestad, H.O., Richardson, J.I., McVea, Jr., C. and Watson, Jr., J.M. (1982). Worldwide incidental capture of sea turtles. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 489-495, Smithsonian Inst., Washington, D.C.
- Hirth, H.F. (1971a). South Pacific Islands - marine turtle resources. *Report to the Fisheries Development Agency Project*. FI:SF/SOP/REG/102/2. pp. 1-34. FAO, Rome.
- Hirth, H.F. (1971b). Synopsis of biological data on the green turtle, *Chelonia mydas* (Linnaeus) 1758. *FAO Fisheries Synopsis No.* 85, 1.1-8.19.
- Hirth, H.F. (1978). A model of the evolution of green turtle (*Chelonia mydas*) remigrations. *Herpetologica* 34, 141-147.
- Hirth, H.F. (1980a). *Chelonia*. Catalog. Amer. Amphibians and Reptiles. *Society Study Amphib. Reptiles* 248.1-248.2.
- Hirth, H.F. (1980b). *Chelonia mydas*. Catalog. Amer. Amphibians and Reptiles. *Society Study Amphib. Reptiles*. 249.1-249.4.
- Hirth, H.F. (1980c). Some aspects of the nesting behavior and reproductive biology of sea turtles. *Amer. Zool.* 20, 507-523.
- Hirth, H.F. (1982). Weight and length relationships of some adult marine turtles. *Bull. Mar. Sci.* 32(1), 336-341.
- Hirth, H.F. (1988). Intrapopulation reproductive traits of green turtles (*Chelonia mydas*) at Tortuguero, Costa Rica. *Biotropica* 20(4), 322-325.
- Hirth, H.F., Klikoff, L.G. and Harper, K.T. (1973). Sea grasses at Khor Umaira, People's Democratic Republic of Yemen, with reference to their role in the diet of the green turtle, *Chelonia mydas*. *Fish. Bull. U.S.* 71, 1093-1097.
- Hirth, H.F. and Ogren, L. (1987). Some aspects of the ecology of the leatherback turtle, *Dermochelys coriacea*, at Laguna Jalova, Costa Rica. *NOAA Technical Report NMFS* 56, 1-14.

- Hirth, H.F. and Samson, D. A. (1987). Nesting behavior of green turtles, *Chelonia mydas*, at Tortuguero, Costa Rica. *Carib. J. Sci.* 23, 374-379.
- Huff, J.A. (1989). Florida (USA) terminates "headstart" program. *Marine Turtle Newsletter* 46, 1-2.
- Japan Tortoise Shell Association (1981). Report on basic research in technical cooperation concerning experimental farming of the hawksbill turtle (*Eretmochelys imbricata*) in Micronesia waters. Nagasaki, Japan. 53 pp.
- Johannes, R.E. (1978). Traditional marine conservation methods in Oceania and their demise. *Ann. Rev. Ecol. Syst.* 9, 349-364.
- Johannes, R.E. (1986). A review of information on the subsistence use of green and hawksbill sea turtles on islands under United States jurisdiction in the western Pacific Ocean. *Administrative Report SWR-86-2*. 41 pp. U.S. National Marine Fisheries Service, California.
- Kemmerer, A.J., Leming, T.D. and Gandy, W.F. (1987). MEXUS-Gulf remote sensing and technology research 1977-84. *Mar. Fish. Rev.* 49(1), 42-49.
- Klima, E.F. and McVey, J.P. (1982). Headstarting the Kemp's ridley turtle, *Lepidochelys kempii*. In *Biology and Conservation of Sea Turtles*. (K. A. Bjorndal, ed.), pp. 481-487. Smithsonian Inst., Washington, D.C.
- Kowarsky, J. (1977). Culture trials of young green turtles, *Chelonia mydas*, in Torres Strait, Northern Australia. *Aquaculture* 11(3), 197-215.
- Kowarsky, J. (1982). Subsistence hunting of sea turtles in Australia. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 305-313, Smithsonian Inst., Washington, D.C..
- Kowarsky, J. and Capelle, M. (1979). Returns of pond-reared juvenile green turtles tagged and released in Torres Strait, Northern Australia. *Biol. Conserv.* 15(3), 207-214.
- Lanyon, J.M., Limpus, C.J. and Marsh, H. (1989). Dugongs and turtles: grazers in the seagrass system. In *Biology of Seagrasses*. (A.W.D. Larkum, A.J.McComb and S.A. Shepherd, eds.), pp. 610-634, Elsevier Publ., Amsterdam.
- Lebeau, A. (1985). Essai d'évaluation des pontes de la tortue verte *Chelonia mydas* (Linne) sur l'Atoll de Scilly (Iles-sous-le-Vent, Polynésie française) au cours des saisons 1982-1983 et 1983-1984. In *Proc. Fifth Int. Coral Reef Cong.* Vol. 5. pp. 487-493. Tahiti, French Polynesia.
- LeGall, J.Y. (1989). Tectonique des plaques, biogéographie et migrations: exemple de la tortue verte marine *Chelonia mydas*. *Océanis* 15(2), 143-160.
- Limpus, C.J. (1971). The flatback turtle, *Chelonia depressa* Garman in southeast Queensland, Australia. *Herpetologica* 27, 431-446.
- Limpus, C.J. (1973). Loggerhead turtles (*Caretta caretta*) in Australia: food sources while nesting. *Herpetologica* 29, 42-45.
- Limpus, C.J. (1978). The reef: uncertain land of plenty. In *Exploration North*. (H.J. Lavery, ed.), pp. 187-222. Richmond Hill Press, Victoria, Australia, 250 pp.
- Limpus, C.J. (1979). Notes on growth rates of wild turtles. *Marine Turtle Newsletter* No. 10, 3-5.
- Limpus, C.J. (1980a). Observations on the hawksbill turtle (*Eretmochelys imbricata*) nesting along the Great Barrier Reef. *Herpetologica* 36(3), 265-271.

- Limpus, C.J. (1980b). The green turtle, *Chelonia mydas* (L.) in eastern Australia. In *Management of Turtle Resources*. pp. 5-22. *Research Monogr.* 1, James Cook Univ., Queensland.
- Limpus, C.J. (1982). The status of Australian sea turtle populations. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 297-303, Smithsonian Inst., Washington, D.C.
- Limpus, C.J. (1987). A turtle fossil on Raine Island, Great Barrier Reef. *Search* 18(5), 254-256.
- Limpus, C. J., Parmenter, C. J., Parker, R. and Ford, N. (1981). The flatback turtle *Chelonia depressa* in Queensland: the Peak Island rookery. *Herpetofauna* 13(1), 14-18.
- Limpus, C. J., Fleay, A. and Baker, V. (1984a). The flatback turtle, *Chelonia depressa*, in Queensland: reproductive periodicity, philopatry and recruitment. *Aust. Wildl. Res.* 11, 579-587.
- Limpus, C. J., McLachlan, N. C. and Miller, J. D. (1984b). Further observations on breeding of *Dermochelys coriacea* in Australia. *Aust. Wildl. Res.* 11, 567-571.
- Limpus, C.J., Miller, J.D., Baker, V. and McLachlan, E. (1983a). The hawksbill turtle, *Eretmochelys imbricata* (L.), in north-eastern Australia: the Campbell Island rookery. *Aust. Wildl. Res.* 10, 185-197.
- Limpus, C.J., Parmenter, C.J., Baker, V. and Fleay, A. (1983b). The Crab Island sea turtle rookery in the north-eastern Gulf of Carpentaria. *Aust. Wildl. Res.* 10, 173-184.
- Limpus, C.J., Parmenter, C.J., Baker, V. and Fleay, A. (1983c). The flatback turtle, *Chelonia depressa*, in Queensland: post-nesting migration and feeding ground distribution. *Aust. Wildl. Res.* 10, 557-561.
- Limpus, C.J. and Fleay, A. (1983). Management and turtles. In *Proceedings: Inaugural Great Barrier Reef Conference*. (J. T. Baker, R. M. Carter, P. W. Sammarco and K. P. Stark, eds.), pp. 535-540. Townsville, Aug. 28-Sept. 2, 1983. James Cook University Press.
- Limpus, C.J. and Reed, P.C. (1985). The green turtle, *Chelonia mydas*, in Queensland: a preliminary description of the population structure in a coral reef feeding ground. In *Biology of Australasian Frogs and Reptiles*. (G. Grigg, R. Shine and H. Ehrmann, eds.), pp. 47-52. Surrey Beatty Ltd., New South Wales, Australia.
- Limpus, C.J. and Parmenter, C.J. (1986). The sea turtle resources of the Torres Strait region. In *Torres Strait Fisheries Seminar*. (A.K. Haines, G.C. Williams and D. Coates, eds.), pp. 95-107. Port Moresby, 11-14 Feb. 1985, Australian Government Publication Service, Canberra.
- Limpus, C.J. and Nicholls, N. (1988). The southern oscillation regulates the annual numbers of green turtles (*Chelonia mydas*) breeding around northern Australia. *Aust. J. Wildl. Res.* 15, 157-161.
- Limpus, C.J. and Walter, D.G. (1980). The growth of immature green turtles (*Chelonia mydas*) under natural conditions. *Herpetologica* 36(2), 162-165.
- Limpus, C.J., Reed, P.C. and Miller, J.D. (1985). Temperature dependent sex determination in Queensland sea turtles: intraspecific variation in *Caretta caretta*. In *Biology of Australasian Frogs and Reptiles*. (G. Grigg, R. Shine and H. Ehrmann, eds.), pp. 343-351. Beatty & Sons Ltd., New South Wales, Australia.
- Limpus, C.J., Gyuris, E. and Miller, J.D. (1988). Reassessment of the taxonomic status of the sea turtle genus *Natator* McCulloch, 1908, with a redescription of the genus and species. *Trans. Roy. Soc. South Australia* 112(1), 1-9.

- Limpus, C.J., Zeller, D., Kwan, D. and MacFarlane, W. (1989). Sea-turtle rookeries in north-western Torres Strait. *Aust. Wildl. Res.* 16, 517-525.
- Lohmann, K.J., Salmon, M. and Wyneken, J. (1990). Functional autonomy of land and sea orientation systems in sea turtle hatchlings. *Biol. Bull.* 179(2), 214-218.
- Marquez, M.R., Villanueva, O.A. and Penaflores, S.C. (1976). Sinopsis de datos biológicos sobre la tortuga golfina *Lepidochelys olivacea* (Eschscholtz, 1829). *Inst. Nat. Pesca Sinopsis Sobre La Pesca, No. 2*, 61 pp.
- Marsh, H. and Saalfeld, W.K. (1989). Aerial surveys of sea turtles in the northern Great Barrier Reef Marine Park. *Aust. Wildl. Res.* 16, 239-249.
- Marsh, H. and Sinclair, D.F. (1989). An experimental evaluation of dugong and sea turtle aerial survey techniques. *Aust. Wildl. Res.* 16, 639-650.
- McCann, C. (1966). The marine turtles and snakes occurring in New Zealand. *Rec. Dom. Mus.* Vol. 5. pp. 201-215. Wellington, New Zealand.
- McCoy, M.A. (1982). Subsistence hunting of turtles in the Western Pacific: the Caroline Islands. In *Biology and Conservation of Sea Turtles* (K.A. Bjorndal, ed.), pp. 275-280. Smithsonian Inst., Washington, D.C.
- McElroy, J.K. and Alexander, D. (1979). Marine turtle resources of the Solomon Islands region. Paper presented at *SPC/NMFS Workshop on Marine Turtles in the Tropical Pacific Islands*. Noumea, New Caledonia. Working paper 11, 57 pp.
- McGehee, M.A. (1990). Effects of moisture on eggs and hatchlings of loggerhead sea turtles (*Caretta caretta*). *Herpetologica* 46(3), 251-258.
- McKeown, A. (1977). *Marine turtles of the Solomon Islands*. Fisheries Div., Ministry of Natural Resources. Honiara, 49 pp.
- Mendonca, M.T. (1983). Movements and feeding ecology of immature green turtles (*Chelonia mydas*) in a Florida lagoon. *Copeia* 1983(4), 1013-1023.
- Meylan, A. (1988). Spongivory in hawksbill turtles: a diet of glass. *Science* 239, 393-395.
- Meylan, A.B., Bowen, B.W. and Avise, J.C. (1990). A genetic test of the natal homing versus social facilitation models for green turtle migration. *Science (Wash.)* 248, 724-727.
- Miller, J.D. (1985). Embryology of marine turtles. In *Biology of the Reptilia*. (C. Gans, F. Billett and P.F.A. Maderson, eds.), pp. 270-328. Vol.14. Development A, John Wiley, New York.
- Milliken, T. and Tokunaga, H. (1987). *The Japanese sea turtle trade 1970-1986*. Special Report prepared by Traffic Japan, Tokyo, 171 pp.
- Moll, D. (1983). A proposed origin of nesting location divergence and a shared feeding range in Brazilian green turtle populations. *Copeia* 1983(1), 121-125.
- Mortimer, J.A. (1982). Feeding ecology of sea turtles. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 103-109. Smithsonian Inst., Washington, D.C.
- Mrosovsky, N. (1982). Sex ratio bias in hatching sea turtles from artificially incubated eggs. *Biol. Conser.* 23(4), 309-314.
- Mrosovsky, N., Dutton, P.H. and Whitmore, C.P. (1984). Sex ratios of two species of sea turtle nesting in Suriname. *Can. J. Zool.* 62(11), 2227-2239.
- Mrosovsky, N. and Provancha, J. (1989). Sex ratio of loggerhead sea turtles hatching on a Florida beach. *Can. J. Zool.* 67(10), 2533-2539.
- Murphy, T.M. and Hopkins-Murphy, S.R. (1989). *Sea turtle and shrimp fishing interactions: a summary and critique of relevant information*. Center for Marine Conservation, Washington, D.C. 52 pp.

- Naito, Y., Sakamoto, W., Uchida, I., Kureha, K. and Ebisawa, T. (1990). Estimation of migration route of the loggerhead turtle *Caretta caretta* around the nesting ground. *Nippon Suisan Gakkaishi* 56(2), 255-262.
- Nietschmann, B. and Nietschmann, J. (1981). Good dugong, bad dugong; bad turtle, good turtle. *Natural History* 90(5), 54-63.
- Oliver, W.R.B. (1910). Notes on reptiles and mammals in the Kermadec Islands. *Trans. New Zealand Inst.* 43, 535-539.
- Onions, J.T.V. (1980). Commercial prospects for turtle farming in the Torres Strait, Australia. In *Management of Turtle Resources*. pp. 56-60. *Research Monogr.* 1. James Cook University, Queensland.
- Onorio, B. (1979). Notes on marine turtles of the Republic of Kiribati. Paper presented at the *SPC/NMFS Workshop on Marine Turtles in the Tropical Pacific Islands*. Noumea, New Caledonia. Working Paper No. 7, 16 pp.
- Owens, D.W., Grassman, M.A. and Hendrickson, J.R. (1982). The imprinting hypothesis and sea turtle reproduction. *Herpetologica* 38(1), 124-135.
- Owens, D., Comuzzie, D.C. and Grassman, M. (1986). Chemoreception in the homing and orientation behavior of amphibians and reptiles, with special reference to sea turtles. In *Chemical Signals in Vertebrates, 4. Ecology, Evolution and Comparative Biology*. (D. Duvall, D. Muller-Schwarze and R.M. Silverstein, eds.), pp. 341-355. Plenum Press, New York.
- Packard, G.C. and Packard, M.J. (1988). The physiological ecology of reptilian eggs and embryos. In *Biology of the Reptilia*. (C. Gans and R.B. Huey, eds.), pp. 523-605. Vol. 16. Ecology B. Liss, Inc., New York.
- Pernetta, J.C. and Hill, L. (1984). Traditional use and conservation of resources in the Pacific Basin. *Ambio* 13(5-6), 359-364.
- Poiner, I.R., Buckworth, R.C. and Harris, A.N.M. (1990). Incidental capture and mortality of sea turtles in Australia's northern prawn fishery. *Aust. J. Mar. Freshwater Res.* 41, 97-110.
- Pritchard, P.C.H. (1971). The leatherback or leathery turtle, *Dermochelys coriacea*. *I.U.C.N. Monogr. No. 1*. Morges, Switzerland. 39 pp.
- Pritchard, P.C.H. (1977). *Marine Turtles of Micronesia*. Chelonia Press, San Francisco, USA. 83 pp.
- Pritchard, P.C.H. (1979). Marine turtles of Papua New Guinea. Report on a consultancy. Wildlife Div., Department of Environment and Conservation. Konedobu, Papua New Guinea. 122 pp.
- Pritchard, P.C.H. (1980). *Dermochelys coriacea*. Catalog. Amer. Amphibians and Reptiles. *Society Study Amphib. and Reptiles* 238.1-238.4.
- Pritchard, P.C.H. (1982a). Marine turtles of the South Pacific. In *Biology and Conservation of Sea Turtles*. (K. A. Bjorndal, ed.), pp. 253-262. Smithsonian Inst., Washington, D.C.
- Pritchard, P.C.H. (1982b) Marine turtles of Micronesia. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 263-274. Smithsonian Inst., Washington, D.C.
- Pritchard, P.C.H. (1987). Sea turtles in New Caledonia. Unpublished report of a literature survey and field investigation. 25 pp.
- Pritchard, P.C.H. and Marquez, M.R. (1973). Kemp's ridley turtle or Atlantic ridley, *Lepidochelys kempi*. *I.U.C.N. Monogr. No. 2*, 1-30.

- Pritchard, P., Bacon, P., Berry, F., Carr, A., Fletemeyer, J., Gallagher, R., Hopkins, S., Lankford, R., Márquez, M. R., Ogren, L., Pringle, Jr., W., Reichart, H. and Witham, R. (1983). *Manual of Sea Turtle Research and Conservation Techniques*. Second edition, (K.A. Bjorndal and G.H. Balazs, eds.). Center for Environmental Education, Washington, D.C. 126 pp.
- Pritchard, P.C.H. and Trebbau, P. (1984). The turtles of Venezuela. *Soc. Study Amphib. and Reptiles*. 403 pp.
- Quinn, N.J. and Kojis, B.L. (1985). Leatherback turtles under threat in Morobe Province, Papua New Guinea. *PLES* 1985(1), 79-99.
- Rainey, W.E. (1981). Guide to sea turtle visceral anatomy. *N.O.A.A. Tech. Memo. NMFS-SEFC-82*. Panama City, Florida, USA.
- Raj, U. (1975). USP-based turtle research: progress report 1974-75 breeding season. *S.P.C. Fisheries Newsletter* 13, 10-13.
- Raj, U. (1976). Incubation and hatching success in artificially incubated eggs of the hawksbill turtle, *Eretmochelys imbricata* (L.). *J. Exp. Mar. Biol. Ecol.* 22(1), 91-99.
- Raymond, P.W. (1984). *Sea turtle hatchling disorientation and artificial beachfront lighting*. Center for Environmental Education, Washington, D.C., 72 pp.
- Reichart, H.A. (1982). Farming and ranching as a strategy for sea turtle conservation. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 465-471. Smithsonian Inst., Washington, D.C.
- Ross, J.P., Beavers, S., Mundell, D. and Airth-Kindree, M. (1989). *The status of Kemp's ridley*. Center for Marine Conservation, Washington, D.C. 51 pp.
- Sakamoto, W., Naito, Y., Uchida, I. and Kureha, K. (1990). Circadian rhythm on diving motion of the loggerhead turtle *Caretta caretta* during interesting and its fluctuations induced by the oceanic environmental events. *Nippon Suisan Gakkaishi* 56(2), 263-272.
- Salm, R.V. (1982) Trengganu meets competition : does Irian Jaya harbour Southeast Asia's densest leatherback nesting beaches ? *Marine Turtle Newsletter* 20, 10-11.
- Salmon, M. and Lohmann, K.J. (1989). Orientation cues used by hatchling loggerhead sea turtles (*Caretta caretta* L.) during their offshore migration. *Ethology* 83(3), 215-228.
- Seidel, W.R. and McVea, Jr., C. (1982). Development of a sea turtle excluder shrimp trawl for the Southeast U.S. penaeid shrimp fishery. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 497-502. Smithsonian Inst., Washington, D.C.
- Silas, E.G., Vijayakumaran, M. and Meenakshi Sundaram, P.T. (eds.) (1984). Sea turtle research and conservation. *Central Mar. Fish. Res. Inst. Bull.* 35. Cochin, India. 82 pp.
- South Pacific Commission (1980). *Joint SPC/NMFS Workshop on Marine Turtles in the Tropical Pacific Islands*. Noumea, New Caledonia, 11-14 December 1979. 16pp.
- Spotila, J.R., Standora, E.J., Morreale, S.J., Ruiz, G.J. and Puccia, C. (1983). Methodology for the study of temperature related phenomena affecting sea turtle eggs. *Endangered Species Report* 11. U.S. Fish and Wildl. Serv., Albuquerque, New Mexico. 51 pp.
- Spotila, J.R., Standora, E.A., Morreale, S.J. and Ruiz, G. J. (1987). Temperature-dependent sex determination in the green turtle (*Chelonia mydas*): effects on the sex ratio on a natural nesting beach. *Herpetologica* 43(1), 74-81.

- Spring, C.S. (1982a). Status of marine turtle populations in Papua New Guinea. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 281-289. Smithsonian Inst., Washington, D.C.
- Spring, C.S. (1982b). Subsistence hunting of marine turtles in Papua New Guinea. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 291-295. Smithsonian Inst., Washington, D.C.
- Spring, S. (1983). Marine turtles of Long Island. Unpublished report on an IUCN/WWF sponsored tagging project. I.U.C.N. 39 pp.
- Stancyk, S.E. (1982). Non-human predators of sea turtles and their control. In *Biology and Conservation of Sea Turtles*. (K.A. Bjorndal, ed.), pp. 139-152. Smithsonian Inst., Washington, D.C.
- Suganuma, H. (1985). Green turtle research program in Ogasawara. *Marine Turtle Newsletter* 33, 2-3.
- Tisdell, C. (1986). Conflicts about living marine resources in Southeast Asia and Australian waters: turtles and dugong as cases. *Marine Resource Economics* 3(1), 89-109.
- Vaughan, P. (1981). *Marine turtles: a review of their status and management in the Solomon Islands*. Fisheries Division, Ministry of Natural Resources. Honiara, Solomon Islands. 70 pp.
- Walker, T.A. and Parmenter, C.J. (1990). Absence of a pelagic phase in the life cycle of the flatback turtle, *Natator depressa* (Garman). *J. Biogeography* 17(3), 275-278.
- Wiles, G.J., Amerson, Jr., A.B. and Beck, Jr., R.E. (1989). Notes on the herpetofauna of Tinian, Mariana Islands. *Micronesica* 22(1), 107-118.
- Wiles, G.J. and Conry, P.J. (1990). Terrestrial vertebrates of the Ngerukewid Islands Wildlife Preserve, Palau Islands. *Micronesica* 23(1), 41-66.
- Wilkinson, W.A. (1979). The marine turtle situation in the Kingdom of Tonga. *SPC/NMFS Workshop on Marine Turtles in the Tropical Pacific Islands*. Noumea, New Caledonia. 8 pp.
- Witham, R. (1980). The "lost year" question in young sea turtles. *Am. Zool.* 20, 525-530.
- Witzell, W.N. (1980). Growth of captive hawksbill turtles, *Eretmochelys imbricata*, in Western Samoa. *Bull. Mar. Sci.* 30(4), 909-912.
- Witzell, W.N. (1982). Observations on the green sea turtle (*Chelonia mydas*) in Western Samoa. *Copeia* 1982(1), 183-185.
- Witzell, W.N. (1983). Synopsis of biological data on the hawksbill turtle, *Eretmochelys imbricata* (Linnaeus, 1766). *FAO Fisheries Synopsis No. 137*, 78 pp.
- Witzell, W.N. and Banner, A.C. (1980). The hawksbill turtle (*Eretmochelys imbricata*) in Western Samoa. *Bull. Mar. Sci.* 30(3), 571-579.
- Wood, J.R. and Wood, F.E. (1980). Reproductive biology of captive green sea turtles, *Chelonia mydas*. *Amer. Zool.* 20, 499-505.
- Wood, F. and Wood, J. (1990). Successful production of captive F₂ generation of the green sea turtle. *Marine Turtle Newsletter* 50, 3-4.
- Zangerl, R., Hendrickson, L.P. and Hendrickson, J.R. (1988). A redescription of the Australian flatback sea turtle, *Natator depressa*. *Bishop Museum Bull. Zoology*. 1. Bishop Museum Press, Honolulu, 69 pp.
- Zug, G.R. and Balazs, G.H. (1985). Skeletochronological age estimates for Hawaiian green turtles. *Marine Turtle Newsletter No. 33*, 9-10.
- Zug, G.R., Wynn, A.H. and Ruckdeschel, C. (1986). Age determination of loggerhead sea turtles, *Caretta caretta*, by incremental growth marks in the skeleton. *Smithsonian Contr. Zool. No. 427*, 34 pp.

Foreword

Unlike the majority of contributors to this volume, I was born on an island in the South Pacific where the majority of the resources discussed here were part of our everyday life. My elders knew a great deal about the biology and behaviour of these animals and we spent many hours both in search of our daily food requirements and during leisure periods on the reefs and in the lagoons adjacent to my village. We also spent long periods with community members recognised for their intimate understanding of the marine habitat, the life it contained and the factors affecting the movement and abundance of resources.

It hurts me to admit, however, that few of my contemporaries and fewer still of subsequent generations possess the same intimate understanding of the surrounding sea and the life that it contains as those who preceded us. The resources now have assumed a different context and our children for the most part do not have the same call for the knowledge that was so precious then. They move in a different world and whether we like it or not, global demand for the resources treasured by our ancestors will result in increasing impact in even the most remote rural areas in the region. I worry that in some locations, local extinctions may already be occurring.

It is really only since joining FFA that I have become aware of the valuable work being done by the staff of this and other regional organisations. In the face of growing political pressure to promote economic development, these organisations struggle with limited financial and manpower resources to promote sustainable resource use practices and to ensure that future generations are not deprived as a result of irresponsible and short-sighted action in the pursuit of short-term monetary gain currently dominating many fisheries development initiatives in the region. The regional organisations however cannot work in isolation from national counterparts in member countries. The two should be viewed as complementary, with our activities in FFA being considered an extension of the research, development, management and conservation activities of national authorities responsible for marine affairs. I hope that this relationship will develop in time but I note with some concern that there are indications that it will be a slow process.

In my short exposure to regional fisheries affairs and against my background of active participation in the transition from colonial to local administration, I note with pride that in almost all cases, the fisheries affairs among FFA member countries are firmly in the hands of indigenous people. I will take this opportunity, however, to caution against developing a conscious policy not to involve

expertise from elsewhere in our marine affairs. For the most part, the populations of the Pacific Islands are relatively small and it would be unrealistic to expect that appropriate technical expertise in all fields involving fisheries, in our current time, can be found from among our own populations.

I hope that with the assistance of the kinds of people responsible for this book, that we will start to redress the apparent loss of our traditional knowledge base and as a result of studies planned and implemented using western scientific protocols, come to terms with an improved understanding of the resources with which we are so familiar. I hope that in the near future a conscious effort to explore means by which traditional and western knowledge can be integrated to promote sustainable resource use practices, is thoroughly researched and that the lip service so often assigned to it in international fora becomes a record of real action as opposed to a dream of academics from another hemisphere.

I have perused the chapters contained in this volume. I am aware of the enormous effort involved in encouraging authors to write specifically for an audience in the Pacific Islands. The result will, I am sure, find much broader application. The majority of contributors have established an international reputation either in the field of tropical fisheries science or more specifically in the study of the resource they have written about here. For those of us involved in fisheries in the region, we should be grateful for the time and effort that has been donated to the production of each chapter in this book. I know many hours outside those normally ascribed as working hours have been spent on research and the acquisition of information to ensure that the book contains the latest information of interest to fisheries researchers and managers in the region.

The objective of this publication was to make available the majority of information known for the biology of each nearshore resource of importance in the South Pacific. In addition, the development and subsequent management of fisheries for these resources figured prominently in the construction of each chapter. In this respect, it is my humble view that the authors and editors have fulfilled their task admirably. This book will provide an excellent reference for fisheries administrators and managers, researchers and students alike for many years to come, within the South Pacific and in tropical regions of other oceans.

My only hope is that the next edition of a volume such as this contains the names of more contributors from the Pacific Islands who may have gained inspiration from this valuable work.

Sir Peter Kenilorea, K.B.E.
Director,
Forum Fisheries Agency.
Honiara, Solomon Islands.

Preface

A new entrant to the fascinating world that is fisheries in the Pacific Islands can, with varying degrees of difficulty, access an enormous pool of information. The literature covering man's association with the marine environment in the region is huge and, except for a specialist with access to a large information service, almost impossible to access and absorb. Similarly, the number of publications concerned with the biology of marine organisms and fisheries for some of these is expanding at such a rate that researchers will continue to face an awesome task remaining abreast of latest findings.

In the South Pacific it is the tuna resources that have occupied the forefront of study and discussion in the last 15 years. Tuna are considered the primary renewable resource of the region, and as such attract considerable effort on the part of national and regional fisheries personnel. In the long term, tuna do offer considerable potential to make a significant contribution to the development of national economies, in fact in many countries this is already the case. In this region, it is in the nearshore areas that the greatest impact of any fisheries development initiative is felt at the community level.

In almost all cases, income for access to productive tuna fishing grounds within 200 mile exclusive economic zones is paid into government treasuries. Although these funds are extremely important in terms of total revenue many island governments receive annually, the tangible benefits resulting from their distribution are often difficult to describe. In the nearshore areas, the impact of commercial fisheries development, even on a small-scale, can be gauged across whole communities. This consideration is often neglected by development planners because relatively minor revenue accrues to government as a result of nearshore resource harvesting. It is the large industrial fisheries that in general terms attract the interest of government officials.

This book deals with the resources that are mainly of interest to village fishermen. It is an attempt to compile available information concerning the biology and fisheries for all major resource groups currently targeted by coastal fishing communities in the South Pacific region. It is produced in an attempt to address constraints still experienced by most island fisheries personnel in accessing the enormous body of information that is now available for the marine resources of tropical oceans. For the most part, this information is widely dispersed throughout the scientific and general literature. The majority of fisheries personnel in the South Pacific, either as a result of isolation or of high cost, thus have difficulty in accessing it.

Rapid technological developments in computing and communications are, figuratively speaking, shrinking the South Pacific region. In the early 1950s when the first regional programmes aimed at promoting the exchange and sharing of information on fisheries were established at the South Pacific Commission in Noumea, letters took weeks to traverse the region and radio communications were limited and expensive. Telephone communications remain expensive but now there is little difficulty in establishing an immediate connection by phone among all the small island countries. The facsimile has revolutionised communications in the region in the last five years as has the personal computer which now can be linked to peripherals such as compact discs providing access to large databases that can be perused at a desk station. In fact, without these tools this book may have never been completed.

These tools are also important to promote the sharing of experiences in nearshore resource issues in the region. The majority of resources discussed here are distributed throughout the South Pacific. In most countries, similar development initiatives have been attempted or are planned for each of these groups. There is much to be gained in sharing experiences in the nearshore fisheries sector throughout the region in order to avoid research and development programmes duplicating mistakes from one country to another; mistakes that could have been avoided had discussion between neighbouring countries been established.

This book has been almost 15 years in the making if the initial concept stage is taken into consideration. In fact, from the draft proposal stage to the manuscript being presented to the publishers, just over two years has elapsed; a period of time we would have considered generous in the early planning stages. For those planning similar exercises, be warned. A tight production schedule for a publication attempting to call on the writing skills of expertise spread around the globe will almost always result in disappointment.

However, we feel that the result is close to the reference book that both of us looked for in our early contact with South Pacific marine affairs. It was initially intended to serve as a desk reference for fisheries officers in FFA member countries, an attempt to avoid the considerable time and effort involved in collecting and digesting information spread throughout the literature on the marine resources increasingly targeted by commercial fisheries throughout the region. However, as the chapters were received it was obvious that it would have broader application. To some extent this presented the editors with a difficult task; to ensure that the information was in a form that could be useful for individuals without tertiary training to refer to in their day-to-day administrative and managerial dealings in coastal fisheries affairs in the Pacific while

servicing as a useful reference for students, researchers and others starting out in their association with the marine environment in the region.

There are a number of shortcomings with this publication. Some stem from oversights during the planning stage and others relate to budget and time management. A subject index is an omission that could attract considerable criticism. The inclusion of an index was considered carefully and it was decided that since each chapter is limited in scope in terms of the resource under discussion, the attention of most readers is immediately focused within the chapter dealing with the resource of interest. In addition, each chapter is structured in the same way so that the sections on taxonomy, reproduction, recruitment, etc. are labelled under clear headings within each chapter. The editors also discussed the possible inclusion of an author index. Instead we opted to retain the bibliographic section for each chapter at the chapter's conclusion rather than move these into a consolidated reference section at the end of the book. Thus full citation details for each reference referred to within each chapter are reasonable easy to locate. In addition, some authors have provided references in addition to those actually cited in their contribution. These additional references would not show up in an author index.

There are a number of important resources that have been omitted from this book. These include penaeid prawns, which form the basis for a 1,200 mt. yr⁻¹ trawl fishery in the Gulf of Papua in Papua New Guinea and which are increasingly cultured throughout the region in countries such as Fiji, Solomon Islands and the French territories. Barramundi, a locally important fishery resource on the coast of Papua and Western Province, particularly in the Fly River, in Papua New Guinea has also been omitted. Exports of barramundi approached 800 mt annually during the 1970s, but over the last 15 years, have steadily decreased. The decline of this fishery is possibly related more to the lack of infrastructural support to the development of the fishery rather than a resource limiting issue although the tailings disposal to the Fly River system from the Ok Tedi copper mine in Western Province will have impact on all resources within the Fly River system. Crocodiles, specimen shells and deepwater precious corals are other resources that could have usefully been included in this publication. Perhaps they can be considered if this book were ever to be revised.

Finally, and perhaps more importantly, the editors recognise that throughout this book, relatively little attention has been paid to likely future developments with respect to nearshore fisheries research and resource management issues in the region. Although this is a recognised shortcoming, it is a topic of which we are acutely aware. The sad facts are that there will be increasing pressure in future years to exploit commercially the resources profiled in this

publication. Increasing exploitation will lead to local extinctions of some species within a relatively short period of time. The most frustrating aspect of all this is that the financial and manpower resources available at a national level to promote rational resource management and conservation practices are not improving. In the face of increasing human populations and without some major improvements in the capacity to administer and manage fisheries in the region, South Pacific nearshore marine resources face a bleak future. We hope that this book will assist focusing more attention on this situation.

*Andrew Wright
Lance Hill
Honiara
August 1993*