

The Hawksbill Turtle, *Eretmochelys imbricata*: a Perspective on the Species

Jeffrey Miller

Turtle Research Group, Queensland Department of Environment & Heritage, Townsville

Abstract

The biological information on the hawksbill turtle is reviewed with emphasis on the South Pacific region. Aspects covered include: identification, life history, distribution of major foraging and breeding areas, population sizes and structure, regional status, research priorities and management issues.

Introduction

The hawksbill turtle, *Eretmochelys imbricata*, is a medium sized sea turtle that lives in association with coral reefs throughout the warm tropical waters of the world (Groombridge & Luxmoore, 1989); the life history of the species is poorly understood. Data derived from turtles at nesting beaches comprise the majority of the information about the species (Witzell, 1983). Details of the population structure and foraging area biology are lacking.

The principal problem affecting the long term survival of regional populations has been the tortoiseshell (Bekko) trade (King, 1982). Japan imported 743,296 kg of tortoise shell between 1970 to July 1990 from several countries (Milliken & Tokunaga, 1987; Greenpeace International, 1990); this equals about 701,222 hawksbill turtles. Harvesting has occurred without an adequate knowledge of the biology and population dynamics of the species. Although recently the importation of tortoise shell by Japan has been reduced dramatically (Liberman, 1991; Donnelly, 1991; Steiner, 1992) the long term impact on the harvested populations cannot be adequately assessed on the current database. It is safe to say that the populations would be numerically healthier had the harvest not occurred.

Groombridge & Luxmoore (1989) attempted to review the status of hawksbill turtles. Unfortunately, much of their data was based on inadequate surveys which tended to over-estimate the number of nesting hawksbill turtles (Greenpeace International, 1990). The information available from the Caribbean (Greenpeace International, 1990) and from the South Pacific region (SPREP, 1991) suggest that the hawksbill turtle populations have been seriously depleted. As a result of wide-spread harvesting without the control of conservation management practices, the status of the worldwide hawksbill turtle

populations may be worse than previously imagined.

The following review brings together results of studies and other review efforts (Meylan, 1984, 1989; Groombridge & Luxmoore, 1989; Witzell, 1983; Limpus, 1992) to provide a synopsis of the biology of the hawksbill turtle and to provide a context for future research and conservation management of the species in the Australasian region. Data from the Pacific region have been selected to illustrate various points.

Identification

The hawksbill turtle, *Eretmochelys imbricata*, can be distinguished from all other sea turtles by the combination of the following characters:

1. two pairs of prefrontal scales,
2. the anterior most costal scale not touching the nuchal,
3. two claws on each flipper,
4. a beak like mouth on a narrow head,
5. thick, posteriorly overlapping scutes on the carapace.

Adult hawksbill turtles are small to medium sized marine turtles. The straight carapace length of nesting adults is typically in the range of 60 to 95 cm and the weight is usually in the range of 40 to 77 kg (Table 1).

Hatchlings are typically a mid-brown colour dorsally with a black ventral surface. The face has a black mask over the lower 1/3 to 1/2 and is brown above. Hatchlings are typically about 4 cm long and weigh about 14 grams (Table 2).

The affinities of *Eretmochelys* to other genera within the Cheloniidae are based on osteological evidence and serum protein analysis (Frair, 1979) which indicate closer relationship with *Caretta* and *Lepidochelys* than with *Chelonia*. Recently *E. imbricata* was shown to be more closely related to *Caretta* than to *Lepidochelys* and *Natator* and even further from *Chelonia* than previously indicated (Limpus *et al.*, 1988).

Life History Summary

The general life history of marine turtles divides into several phases (embryonic, juvenile, prepubescent, pubescent, and adult). Detailed

information on each is required for comprehensive, biologically based management. With only minor adjustment the general life cycle depicted for green turtles (Lanyon, *et al.*, 1989) also describes the life cycle of hawksbill turtles as it is currently understood.

Eggs of hawksbill turtles are buried in relatively shallow nests (Top = 25 cm, Bottom = 45 cm; Witzell, 1983). The eggs are small (approximately 36 mm, Table 3) in comparison to those of most other sea turtles. However, the number of eggs per clutch is large in comparison to clutches laid by other species (as many as 150+ /clutch). The mean number of eggs per clutch varies throughout the range of the species (Table 4), as does the number of yolkless eggs in each clutch. There is a reasonable relationship between the average straight carapace length and the average number of eggs laid when examined on a world level (Hirth, 1980; Miller, 1989); however, the relationship may not be valid within a given region (McKeown, 1977; Garnett, 1978).

Developmental stages from fertilisation to pipping and emergence have been described in detail based on sequential changes in morphological characteristics (Miller, 1985). In general, development proceeds in a predictable sequence with generic characteristics appearing about Stage 25/26 or about 60% of incubation for all cheloniid sea turtles (Miller, 1985). Hawksbill turtle embryos are subject to movement induced mortality as are the embryos of other sea turtles. The hatching success of translocated nests is often reduced; whereas, the hatching success of undisturbed nests is typically 80% or higher (see Witzell, 1983).

The mass of the eggs is influenced by the hydric conditions during incubation; eggs in drier conditions lose mass and those in moist conditions gain mass (Miller, Unpub. Data).

The duration of incubation is temperature dependant and varies from approximately 50 days to 70 days (Table 5); higher temperatures result in shorter incubation periods within embryonic tolerance limits. Embryogenesis is limited by extremes in temperature; the minimum constant temperature below which development is not successful is about 23°C and the maximum constant temperature above which development is not successful is about 34°C, as is the case with other sea turtles (Miller, 1985).

Short duration excursions of temperature below 23°C typically result in an increase in the incubation period by retarding the rate of development. Cool temperatures may cause some

morphological and/or metabolic problems depending on when during embryogenesis they occur. However, the greatest impact on successful development results from the increased risk of inundation, predation and/or erosion.

Short duration exposure to temperatures above 33°C results in malformation of the embryo, if exposure occurs in the first trimester. Thereafter, the impact may be expressed through metabolic stress (heart rate, O₂ consumption or CO₂ production, etc) or morphological change depending on the stage of development. The tolerance of embryos to hotter temperatures is restricted to a narrow range (about 20°C) and to short duration; whereas, embryos survive a wider range of temperatures and for longer periods when exposed to cool temperatures (Miller, Unpub. Data).

Sex is determined by the temperature during embryogenesis with cooler temperatures resulting in males and warmer temperatures resulting in females (Dalrymple & Hampp, 1983; Dalrymple *et al.*, 1985). The pivotal temperature is not known for any hawksbill turtle population; it is presumed to be between 28°C and 30°C. Incubator and beach-based studies are required to elucidate the details.

Emerging hatchlings are subject to predation by birds, other reptiles, mammals and fish as are the hatchlings of other marine turtles (Stancyk, 1982; Witzell, 1983). Larger turtles are probably consumed by predators similar to those that eat other species of marine turtles. Vaughan (1981) reported that 24% of the nesting hawksbill turtles in the Solomon Islands exhibited some form of damage by predators.

Growth Rates

Hatchling hawksbill turtles disappear from the near shore habitats and presumably exist for several years in a pelagic phase. They are not seen until they have grown substantially.

Juvenile turtles are first captured on reefs of the Great Barrier Reef when they are about 30 to 35 cm in curved carapace length (CCL) (Limpus, 1992); hawksbill turtles below this size are very seldom encountered. The recapture of tagged turtles at the same reef (e.g. Limpus, 1992) suggests that once a juvenile has settled on a reef system, it remains there for a number of years.

Only a few growth records are available for free-living hawksbill turtles. Limpus (1979) reported growth of 1.76 cm/yr in a subadult sized (67 cm curved carapace length - CCL) turtle and 1.62 cm/yr in an adult sized (81 cm CCL) female. At

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Heron Island Limpus (1992) recorded "43 growth increments over intervals greater than 11 months"; the mean growth rates for various size classes ranged from 0.0575 cm/yr in adults (80-90 cm CCL) to 2.168 cm/yr in immature turtles (50-60 cm CCL). Recent work at Green Island has given growth rates in the same general range (Miller, unpublished data). Very fast growth rates (0.82, 0.71 cm/month) were reported from released, pond reared hawksbill turtles in Torres Strait (Kowarsky & Capelle, 1979); however, these two animals were recaptured after only about 6 months and at least part of the growth is the result of energy reserves gained while in captivity.

Growth rates vary between regional study sites. Although slightly different methods of measurement were used, Bjorndal *et al.*, (1985) found faster growth rates (0.3 cm/yr Straight Carapace Length) for nesting hawksbill turtles in the Caribbean than reported for free ranging adult sized turtles (0.05 cm/yr Curved Carapace Length) from the southern Great Barrier Reef by Limpus (1979; 1992).

The growth rate seems to slow with increasing size (Limpus, 1992). The average growth rate for hawksbill turtles in the southern Great Barrier Reef is about 1.2 cm/year; the most rapid (2.16 cm/yr) was in the 50-60 cm size class and the slowest (0.05 cm/yr) rate occurred in the 80-90 cm size class (Limpus, 1992). The variation in growth rates of individuals within and between regions probably results, in part, from variations in the quality and quantity of food available, as well as genetically controlled assimilation metabolism.

Developmental Migration

Although immature hawksbill turtles may be captured at nearly every reef in the southern portions of the Great Barrier Reef, adults seldom are found south of Green Island near Cairns (Limpus, pers. comm.). Because nesting does not occur south of Princess Charlotte Bay (Miller & Limpus, 1991), at least some of the immature turtles live in habitats that are not utilised extensively by adults.

Time to Maturity

The time required to reach sexual maturity will vary as a result of variation in the rate of growth. Hawksbill turtles do not achieve sexual maturity at a uniform size; some grow beyond the minimum and average sizes before maturing (Limpus *et al.*, 1983; Limpus, 1992). The only estimate of the time required for hawksbill turtles to reach sexual maturity that has persuasive data in support is greater than 30 years presented by Limpus (1992) for the southern Great Barrier Reef. As has been

demonstrated for green turtles (*Chelonia mydas*) (see Balazs, 1982; Bjorndal & Bolten, 1988; Limpus, 1979; Limpus & Walter, 1980), growth rates of hawksbill turtles may vary between populations in different regions. There are no reliable data on longevity.

Distribution of Major Foraging Habitats

Sub-adult and adult hawksbill turtles are found principally in association with coral reef systems and other complex, hard substrate habitats (Meylan, 1984, 1989) where the omnivorous turtle feeds principally on reef associated benthic organisms (e.g. sponges, sea anemones, sea urchins, tunicates, and algae: Acevedo *et al.*, 1984; Den Hartog, 1980; Meylan, 1985; 1988). Other items also occur in the dietary samples including: sea grass, ascidians, molluscs, bryozoans, and plastic (see Table XVI in Witzell, 1983). The turtles may also be found in coastal areas in the subtropical and tropical Pacific, Indian and Atlantic oceans (Groombridge & Luxmoore, 1989; Witzell, 1983) near submerged rock outcrops where food occurs rather than in soft bottomed, silty areas (Meylan, 1984, 1989), although some do inhabit mangrove fringed bays and estuaries in the eastern Pacific (Witzell, 1983). The turtles tend to inhabit areas at the outer edges of reefs and in lagoons which typically have complex vertical surfaces rather than flat areas of sand or silt. They may also be found on coralline reef flats at high tide.

In the South Pacific region, foraging areas used by hawksbill turtles are widely distributed; the turtles occur, at least in low numbers, in virtually all countries in the region from which some information is available (Groombridge & Luxmoore, 1989). Although at the present time the emphasis of the regional research efforts is directed at tagging and censusing nesting turtles, the research program (SPREP, 1991) will eventually link the nesting sites and foraging areas used by the hawksbill turtles in the South Pacific region through the recapture of tagged turtles.

In Australia, the general foraging area extends along the eastern coast including the Great Barrier Reef, through Torres Strait and encompassing the archipelagos of the Northern Territory and Western Australia, possibly as far south as Shark Bay or beyond. In Queensland, foraging areas extend from Moreton Bay (possibly even further South) northward along the Great Barrier Reef, through Torres Strait and into the Gulf of Carpentaria. A few resident hawksbill turtles may be found wherever the right mix of habitat and food occurs.

Migration

Contrary to the suggestions in the literature that hawksbill turtles are non-migratory (Carr, 1952; Carr & Main, 1973; Bustard, 1979), hawksbill turtles do migrate long distances from their foraging area to a nesting site to reproduce. While it may be true that some hawksbill turtles migrate only a few tens of kilometres from their foraging area to their nesting site, at least some and perhaps most hawksbill turtles migrate a few hundred kilometres or more. Several long distance migrations have been reported for a hawksbill turtles: 500 km in the Caribbean (Carr & Stancyk, 1975); 713 km between Sabah and Antique, Philippines (De Silva, 1982); 1400 km between the Solomon Islands and Papua New Guinea (Vaughan and Spring, 1980); 1600+ km between Torres Strait and the Solomon Islands (Parmenter, 1983). When more turtles have been tagged and more recovered in various habitats, the question concerning migration in hawksbill turtles will be clarified. Nietschman (1981) summarised the situation in four points:

1. Hawksbill turtles move around much more than previously thought.
2. Hawksbill turtles sometimes make long distance journeys.
3. Some of these journeys are to distant nesting (or resident) areas, bypassing locally available areas on the way.
4. Hawksbill turtles cross international boundaries.

Mating

Mating takes place near the nesting sites. Although not described in the literature, mating is assumed to be similar to that practiced by other marine turtles (i.e. multiple insemination during a short oestrus period prior to commencing the nesting season) (Witzell, 1983).

Nesting Behaviour

Nesting behaviour follows that described for other sea turtles (Carr *et al.*, 1966; Hirth, 1980; Ehrhart, 1982) with two notable variations. First, hawksbill turtles complete the nesting process rapidly, if conditions allow; nesting typically requires only about 1 hour or slightly longer. Second, hawksbill turtles typically do not dig deep body pits before beginning to excavate the nest chamber. This results in a shallower egg chamber. The top eggs are situated close to the beach surface (about 25 cm deep) and are potentially subject to higher temperatures, greater desiccation and, possibly, detection by predators.

Like green turtles, hawksbill turtles often abandon a nest excavation effort (for whatever reason) and crawl a few meters to a new site to begin nesting again. Two or more such attempts may precede oviposition. A tendency to abort nesting attempts or to dig multiple body pits and egg chambers before oviposition has been noted in some populations (Diamond, 1976; McKeown 1977); however, much of this behaviour may be attributed to physical characteristics of the nesting site (coarse material, roots, buried obstacles, etc.; Limpus *et al.*, 1983) rather than to presumed reproductive strategies of the turtles.

Nesting occurs almost exclusively at night, although nesting at some sites does occur during daylight (see Witzell, 1983; Limpus *et al.*, 1983). Hawksbill turtles exhibit a strong site fixity as is typically found in other marine turtles (Carr & Stancyk, 1975; Witzell, 1983). There appears to be no consistent pattern of weather conditions required by nesting hawksbill turtles. They will nest through a wide range of local weather conditions, including rough seas, high winds, monsoon rains as well as drier, calmer periods (see Witzell, 1983).

Nesting Habitats

The nesting habitats used by hawksbill turtle encompass a wider range of beach types including many that would be marginal or unacceptable to other species (McKeown, 1977; Vaughan, 1981; Mortimer, 1982). Beaches used by hawksbill turtles may be shaded by trees such as at Campbell Island in Torres Strait (Limpus *et al.*, 1983) or may be completely devoid of shading vegetation such as those in the Arabian Gulf and Red Sea regions (Miller, 1989).

Nesting Season

The nesting by hawksbill turtles in the South Pacific region may occur all year round as it does in Micronesia and the Solomon Islands or be restricted to a few months of the year as in Western Samoa and Fiji (see Table II in Witzell, 1983). However, when these areas are surveyed in detail, the reported nesting seasons may well be modified (Table 6). In general, the major nesting period of hawksbill turtles in the South Pacific appears to be September through March; year round nesting occurs in the western Pacific. In the Great Barrier Reef and Torres Strait region, the peak nesting period occurs between January and April (Limpus & Parmenter, 1986).

Number of Nests Per Season

The average number of nests laid during one season by an individual is not precisely known. Current values suggest the 2.7 times per season reported by de L. Brooke & Garnett (1983) is

conservative because nesting areas have seldom been patrolled during the entire season; individual turtles have been recorded nesting at least 4 times per season (Diamond, 1976; Limpus *et al.*, 1983). The reported number of nests laid during a season will increase when long-term monitoring of the nesting turtles occurs.

Renesting Interval

The average renesting interval is slightly longer than two weeks; the few data that are available suggest that mean intervals of 15 to 20 days may elapse between nesting efforts (Diamond, 1976; McKeown, 1977; Garnett, 1978; Limpus *et al.*, 1983). Unfortunately too few detailed, full season studies have been conducted to allow the interval to be defined any better.

Period Between Nesting Seasons

The mean interval between nesting seasons has not been determined for any population. The cycle may be 2-6 years or more (Table 7). The idea that hawksbill turtles nest only once (see Hughes, 1982) may result, at least in part, from tag loss problems (see Henwood 1986).

Distribution of major breeding areas

Sternberg (1981) and Witzell (1983) provide world maps and lists of known nesting locations. The major breeding sites occur within the tropics with only a few exceptions (Sternberg, 1981; Witzell, 1983). The Arabian Gulf is an exception because the shallow geomorphology in the region makes conditions similar to those of the tropics (Miller, 1989). Groombridge & Luxmoore (1989) provide a country by country estimate of the current status of nesting by the species. The overwhelming impression given by Table 11 in Groombridge & Luxmoore (1989:53-57) is that there are very few nesting sites which host over 1000 hawksbill turtles per season; even when countries are grouped into regions, the total number of nesting hawksbill turtles is small.

On most of the islands in the South Pacific region, nesting by hawksbill turtles occurs only at low density (Groombridge & Luxmoore, 1989), although when considered on a regional basis the region hosts several thousand nesting hawksbill turtles annually. The distribution and status of the nesting populations are currently being assessed by each country under the general coordination of the South Pacific Regional Environment Program (SPREP, 1991). Data on the distribution and magnitude of the regional nesting populations determined through surveys and tagging programs should be available in the next few years.

Along the Great Barrier Reef, hawksbill turtles nest in low density from just north of Princess

Charlotte Bay northward on the inner shelf islands (both continental and sand cays) into Torres Strait (Miller & Limpus 1991), although a few bodies have been found on sand cays of the outer reef (Limpus *et al.*, 1991). Few of the islands host more than 10 nesting hawksbill turtles per night.

The nesting distribution in northern Australia shows a concentration in the northern Great Barrier Reef and Torres Strait region (Miller & Limpus 1991) with at least scattered nesting in the Northern Territory and Western Australia. Unfortunately, the distribution of hawksbill turtle nesting outside of Queensland is poorly documented (Limpus, 1982). An important nesting area occurs in the Dampier Archipelago; several others may possibly occur. Low density nesting occurs on many islands in the Northern Territory.

Population Sizes And Structure

There is a paucity of data concerning the size and structure of hawksbill turtle populations (Groombridge & Luxmoore, 1989); however, this information is essential to understanding the biology of the turtle and to developing conservation management practices. Further, because the details of the necessary biological parameters are lacking, there are no reliable population models for hawksbill turtles.

Relative Abundance

Hawksbill turtles seldom occur in large numbers in foraging habitats that have been intensely studied (Limpus 1992); in other words, they do not contribute massive amounts to the total biomass on the reef. The biomass for hawksbill turtles at Heron Island was estimated to be 2300 kg based on a population estimate of 94 turtles. This corresponds to about 0.8 kg / ha or a density of 3.34 hawksbill turtles / km² (Limpus, 1992).

Structure

There are few published data on the structure of any hawksbill population. The distribution of 189 individuals captured in the foraging area at Heron Island among size classes demonstrated a strong bias toward smaller turtles (0-30 cm = 0; 30-45 cm = 40; 45-60 cm = 54; 60-75 cm = 68; 75-90 cm = 27) (Limpus, 1992).

Sex Ratio

Limpus (1992) reported a overall sex ratio of 2.57 females to 1 male or about 72% females in the population of hawksbill turtles at Heron Island; there was also a strong bias toward females in each size class.

Status

Hawksbill turtles around the world have been harvested for the thick scales of the carapace for several hundred years (King, 1982) without adequate knowledge of the impact on the populations. Today about one "half of all known nesting populations" of hawksbill turtles are in decline (or are suspected to be declining) (Groombridge & Luxmoore, 1989:3).

The greatest threat to the long term survival of the hawksbill turtle world-wide has been the tortoiseshell (Bekko) trade (King, 1982; Groombridge & Luxmoore, 1989), even acknowledging the recent reduction in the importation of shells by Japan (Liberman, 1991; Donnelly, 1991; Steiner, 1992). The world-wide figures for tortoise shell trade during the last decade stand in stark contrast to the current estimates of nesting populations (Groombridge & Luxmoore, 1989; Greenpeace International, 1990). The impact of the harvest on the population can only be inferred from the trade statistics. However, there are many documented examples of populations of marine turtles being severely depleted or taken to extinction through over-exploitation (King, 1982; Ross, 1982).

The killing of sub-adult and adult hawksbill turtles for the stuffed curios and tortoiseshell trade diminishes the population by removing numbers of reproducing adults and by removing a portion of the pre-reproductive (prepubescent & pubescent) animals as well. A staged-based population model developed for loggerhead turtles (Crouse *et al.*, 1987) clearly shows that excessive mortality among the large juveniles and adults will have a devastating impact on the long term survival of the population. Because the key demographic characteristics that account for the results of the model (high mortality from hatching to reproductive adult & decades required to reach sexual maturity) are shared by hawksbill and other marine turtles (NRC, 1990), the general conclusion of the model that reduced mortality in these two groups is vital to the survival of the population can be applied to the other species. However, the answers to questions such as 'can a population recover?', 'how completely will a population recover?' and 'how long will recovery take?', depend on the extent of harvesting in the context of the population structure and reproductive biology of the species. The status of regional hawksbill turtle populations is not precisely known but harvesting has occurred over many years (Groombridge and Luxmoore, 1989). In an attempt to evaluate the status of world populations on a country by country basis, Groombridge and Luxmoore (1989) classified hawksbill turtle populations into a numerical

ranking system based on size as well as geographical and political boundaries (Table 8) based on information supplied to them in various forms and with varying degrees of reliability (see Groombridge and Luxmoore, 1989). Although this evaluation provides a starting point, much detailed assessment must be completed before the status of the population(s) in the region will be known because population trends may not be evident when surveys encompass less than a decade (NRC, 1990).

Research is currently underway in eastern Australia and in the SPREP member nations of the South Pacific region to assess the current status of the population(s). Work is directed at identifying nesting and, to a lesser extent, foraging areas to ascertain the number of turtles in the region (SPREP, 1991). Unfortunately, the stability of the regional population cannot be determined by short term monitoring of the number of turtles nesting each year (Bjorndal *et al.*, 1985); decade long monitoring projects that are linked to the foraging areas are required to detect changes in the population. As more data become available, the status of populations at specific locations in the South Pacific region will change (Table 8).

In the South Pacific region nearly all nations have conferred at least some degree of protection on hawksbill turtles (see SPREP, 1991). In Queensland, hawksbill turtles received protection in 1968; when Australia signed CITES in 1977, hawksbill turtles were protected in the rest of their Australian habitat.

Research Priorities

If hawksbill turtles are to continue to survive in the South Pacific region and elsewhere in the world, much more information must be gathered on their biology and populations. Specific studies need to be conducted to develop the database necessary for conservation and management.

The genetic associations among regional and international populations must be determined to identify biological and managerial affinities. The regional surveys should be conducted to determine the distribution of nesting sites and to obtain an index of nesting intensity.

Detailed study of morphometrics and fecundity should be undertaken at major nesting sites on a regional basis to determine similarities and subtle differences. The structure and dynamics of foraging area populations require definition; size classes, sex ratios, maturity ratios, breeding ratios and growth must be determined in order to develop biologically based management practices.

The foraging areas and the nesting sites need to be linked through intensive tagging programs at major nesting locations and subsequent tag recoveries from animals in the foraging areas.

The pivotal temperature for determining the sex ratio of hatchlings on the beach should be assessed in at least two different regions.

Management Issues To Be Addressed

Conservation problems cannot be solved by one or two years of research. Answers to some important questions may require a decade or more of research.

Most management issues operate at more than one level. Often the international problems are the summation of cross regional problems or reflect the lack of cross regional cooperation.

The impact of harvest on regional populations needs to be determined. Local and regional harvest regulations need to be established and coordinated across regions to reduce trafficking of products.

The causes of incidental mortality require identification and solutions to these situations need to be developed.

Hatchery management techniques need to be developed so that wherever hatcheries are deemed to be necessary for protection of eggs, they can be established with the greatest potential for successful production of hatchlings.

Appropriate husbandry techniques need to be investigated so that captive reared turtles are maintained in good health.

Because of the pattern of low density nesting it is extremely difficult to protect extensive portions of nesting habitat.

The general strategy of

- (1) habitat protection (foraging & nesting),
 - (2) protective legislation & enforcement,
 - (3) regulation of trade (national and international),
 - (4) reduction of incidental capture,
 - (5) reduction of egg & hatchling mortality,
- and
- (6) public education,

will assist in the effort to conserve hawksbill turtles (Bjorndal, 1982). Each is very important to a total program; cost and politics will determine which are implemented and which are successful.

Education programs are vitally important, yet tend to be bypassed in favour of more 'hands on' efforts. Promotion of conservation needs while providing direction for resource management will take time but will also yield long term positive results.

Summary

Hawksbill turtles exhibit most of the characteristics that are common to other marine turtles (Dodd, 1988; Groombridge & Luxmoore, 1989; Hirth, 1971; Marquez et al. 1976; Pritchard, 1968; Witzell, 1983).

In general hawksbill turtles:

- . use long established nesting sites;
- . disperse as hatchlings into ocean currents after emergence;
- . grow slowly and require decades to maturity;
- . have low survivorship from hatchling to sexual maturity;
- . have a long reproductive life;
- . migrate;
- . do not breed every year;
- . lay several clutches within one breeding season;
- . nest at slightly longer than fortnightly intervals;
- . nest in a low density, diffuse pattern.

Unfortunately, the detailed biology of the species is poorly documented. The summary material available contains many assumptions (Groombridge & Luxmoore, 1989).

The hawksbill turtle has been the subject of very few intensive studies and, as a result, data on many of the important aspects of its biology are lacking. Comparison with what is known about other marine turtle species and inferring from the available data allows construction of a general life cycle but enough crucial data are lacking to prevent the development of detailed conservation management programs.

Some basic information such as the size of nesting females and the number of eggs laid is known from partial surveys but the number of times a female nests per season is not known with any certainty. The interval between nesting seasons is not known either. Also lacking are data on population dynamics (sex ratio, maturity ratios, etc.).

Part of the problem of inadequate knowledge about the species stems from the diffuse nesting pattern practiced by hawksbill turtles. The turtles may nest at a site for eight or nine months per year but

the location is often very remote and difficult to access.

It is an understatement to say that much field work remains to be done to describe the biology of the hawksbill turtle. This information is urgently needed to form the basis of local, regional and global conservation efforts.

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Table 1. Carapace lengths and weights of adult hawksbill turtles nesting in the South Pacific (based on Witzell, 1983).

CARAPACE LENGTH (cm)				
LOCATION	MEAN	RANGE	NUMBER	SOURCE
Western Samoa	68.6	60.0 - 73.5	7	Witzell & Banner, 1980
Solomon Is.	80.5	68.0 - 93	85	McKeown, 1977
Solomon Is.	84.6*	60.0 - 95.5	43	Vaughan, 1981
Australia	76.4	71.6 - 82.7	10	Limpus, 1980
Australia	76.35	70.7 - 83.3	22	Limpus <i>et al.</i> , 1983

* Note : curved carapace length; others are straight carapace length.

WEIGHT (kg)				
LOCATION	MEAN	RANGE	NUMBER	SOURCE
Solomon Is.	66.3	41.8 - 77.3	40	McKeown, 1977
Solomon Is.	57.8	36.0 - 72.5	43	Vaughan, 1981
Australia	49.5	45.5 - 55.0	8	Limpus, 1980
Australia	51.5	38.5 - 68	20	Limpus <i>et al.</i> , 1983

Table 2. Straight carapace length (cm) and weight (g) of hawksbill turtle hatchlings from the Pacific region.

CARAPACE LENGTH (cm)				
LOCATION	MEAN	RANGE	NUMBER	SOURCE
Western Samoa	3.9	3.8 - 4.1	235	Witzell & Banner, 1980
Australia	4.1	3.82 - 4.38	70	Limpus <i>et al.</i> , 1983

WEIGHT (g)				
LOCATION	MEAN	RANGE	NUMBER	SOURCE
Australia	14.6	12.5 - 16.0	11	Limpus, 1980
Australia	14.3	12.7 - 16.8	70	Limpus <i>et al.</i> , 1983
Solomon Is.	13.2		120	Vaughan, 1981

Table 3. Diameter (cm) and weight (g) of hawksbill turtle eggs from turtles nesting in the South Pacific region.

EGG DIAMETER (cm)

LOCATION	MEAN	RANGE	# OF EGGS	SOURCE
Western Samoa	3.4	3.4 - 3.6	235	Witzell & Banner, 1980
Indonesia	3.6	3.3 - 3.9	20	Sumertha, 1979
Australia	3.6	3.3 - 3.9	70	Limpus, 1980
Australia	3.6	3.23 - 4.07	470	Limpus <i>et al.</i> , 1983

EGG WEIGHT (g)

LOCATION	MEAN	RANGE	# OF EGGS	SOURCE
Indonesia	24.2	20.0 - 31.6	20	Sumertha, 1979
Australia	26.4	22.5 - 30.5	60	Limpus, 1980
Australia	25.9	19.5 - 32.5	470	Limpus <i>et al.</i> , 1983

Table 4. Number of hawksbill turtle eggs recorded in nests laid in the South Pacific region.

LOCATION	MEAN	RANGE	NUMBER	SOURCE
Western Samoa	149.5	60 - 219	23	Witzell & Banner, 1980
Fiji	116.8	68 - 168	8	Raj, 1976
Solomon Is.	137.5	75 - 250	175	McKeown, 1977
Solomon Is.	151.0	37 - 234	198	Vaughan, 1981
Australia	111.7	62 - 142	29	Limpus, 1980
Australia	131.8	89 - 192	47	Limpus <i>et al.</i> , 1983

Table 5. Incubation period (days) for hawksbill turtle eggs in the South Pacific region (based on Witzell, 1983).

LOCATION	MEAN	RANGE	NUMBER	SOURCE
Western Samoa T	62.0	59 - 70	23	Witzell & Banner, 1980
Fiji T	63.0	61 - 66	4	Raj, 1976
Solomon Is. U	64.4	43 - 90	174	McKeown, 1977
Solomon Is. S	66.5	49 - 91	198	Vaughan, 1981
Australia U	55.0	52 - 57	5	Limpus <i>et al.</i> , 1983

Note: T = transplanted nest,
 U = undisturbed,
 S = status not reported.

Table 6. Hawksbill turtle nesting seasons in the South Pacific region (based on Witzell, 1983).

LOCALITY	NESTING SEASON	PEAK PERIOD	SOURCE
TORRES STRAIT	YEAR ROUND	FEB	Limpus & Parmenter, 1985
WESTERN AUSTRALIA	???	DEC - JAN	Morris, 1986
NORTHERN TERRITORY	???	*	Cogger & Linder, 1969
MICRONESIA	MAY - SEPT	??	Herring, 1986
FIJI	AUSTRAL SUMMER	JAN	Bustard, 1970
VANUATU	SEPT - JAN	*	Groombridge & Luxmoore, 1989
INDONESIA	JAN - JUNE	*	Schulz, 1987
NEW CALEDONIA	AUSTRAL SUMMER	*	Groombridge & Luxmoore, 1989
PAPUA NEW GUINEA	MARCH - SEPT	*	Spring, 1982 - 1983
SOLOMON Is.	YEAR ROUND	MAY - AUG	Vaughan, 1981
		NOV - DEC	Vaughan, 1981

Note: * = not defined by original source.

Table 7. Remigration intervals for hawksbill turtles from around the world (from Meylan, 1983).

LOCALITY	REMIGRATION INTERVAL (No. of observations)	SOURCE
Tortuguero, Costa Rica	2 years (1)	Carr & Stancyk, 1975
	3 years (4)	
	4 years (3)	Carr, Unpub. Data
	6 years (1)	
Eastern Nicaragua	3 years (1)	Nietschmann, 1981
Cousin Island, Seychelles	2 years (14)	de L. Brooke & Garnett, 1983
Sabah, Malaysia	2 years (1)	de Silva, 1982
	3 years (3)	
Masirah Island, Oman	1 year (1)	Ross, 1981

Table 8. Size and exploitation of nesting populations in the South Pacific region. (Based on Groombridge & Luxmoore, 1989.)

LOCALITY	POPULATION		EXPLOITATION		EGG
	NEST	NUM	ADULT	NUM	
Australia, Queensland	(4) ?	-	L	-	H
Australia, W. Australia	(4) ?	1k ?	?	-	?
Australia, N. Territory	?	-	-	-	-
Australia, Island Terr.	?	-	-	-	-
Cook Islands	?	-	?	-	?
Fed. Micronesia	(1-2)	-	L	-	?
Fiji	?	-	M	-	?
French Polynesia	?	-	L	-	-
Indonesia	5++	7-9k ?	vH	-	H
Kiribati	?	-	?	-	?
Malaysia, Sabah	2-3	>100	L	-	H
Malaysia, Sarawak	(1) ?	-	L	-	H
Malaysia, West	2-3	-	L	-	vH
Marshall Islands	?	-	?	-	?
New Caledonia	?	-	-	-	-
Palau	?	-	L	-	H
Papua New Guinea	(4) ?	-	L	-	M
Phillipines	(1-2)	-	H	-	M
Seychelles	5	1-1.8k	H	500+	L
Solomon Islands	3-4	500 ?	?	-	H
Tokilau Islands	?	-	?	-	?
Tonga	?	-	?	-	?
US Pacific Islands	?	-	-	-	-
Vanuatu	?	-	-	-	-
Western Samoa	1-2	<45	H	-	H

NOTES:

POPULATION

NEST : 1 = <25, 2 = 25-100, 3 = 100-500, 4 = 500-1000, 5 = >1000. ? = nesting certain or possible.

NUMBER : Estimate of nesting numbers, k = 1000s.

EXPLOITATION

ADULT : L = Low, M = Moderate, H = High, ? = Believed to occur, 0 = None.

NUMBER : k = Estimate of harvest, 1000s

EGG : L = Low, M = Moderate, H = High, ? = Believed to occur, 0 = None.