Biology and Conservation of

Sea Turtles

Revised Edition

Edited by Karen A. Bjorndal

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Front cover: Adult female green turtle, *Chelonia mydas*, at French Frigate Shoals, the major migratory breeding site for this species in the Hawaiian Islands. Photo by G. H. Balazs.

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A Model for Diagnosis of Populations of Olive Ridleys and Green Turtles of West Pacific Tropical Coasts

ABSTRACT

Sea turtle populations along the west coast of Mexico have been studied for several years. The seasonal abundance of both *Lepidochelys olivacea* and *Chelonia mydas agassizii* increase during the reproductive period in front of the respective nesting beaches, during summer and autumn. There are clear differences between the nesting patterns of ridleys and greens. The olive ridley follows clear internesting cycles every 28 days, while the green turtle nests in semi-cycles of 14 days. Nevertheless, the total number of eggs laid per individual is similar for both species.

The mean clutch size by nest is: 115, 95, and 80 (average 95) for *Lepidochelys* and 80, 70, 60, and 50 (average 66) for *Chelonia*. The period between nesting is nearly annual in the ridley (1.3 years) and nearly biennial for the green (1.8 years). The ridley is estimated to take at least 8 or 9 years to reach sexual maturity.

The natural mortality rates for eggs, hatchlings, and adults were analyzed and determined from values of survival rates in each stage of the life cycle (S_{0-17} = 0.592, S_1 = 0.581, S_2 = 0.497, etc.). Using these data, a population model was constructed; changes in the model must be fitted year by year in accordance to the size of the nesting population in the involved season.

Introduction

From all the information published on sea turtles there are no thorough studies on population dynamics. Nevertheless, the actual knowledge nowadays of these species permits us to construct and apply a theoretical model for diagnosing the situation of populations of *Lepidochelys olivacea* and *Chelonia mydas agassizii*. Often it is said that they are over-exploited species, but to what extent have they been or are they being exploited? What is the present abundance? How many individuals can be captured for commercial purposes and when? To reach more accurate conclusions about

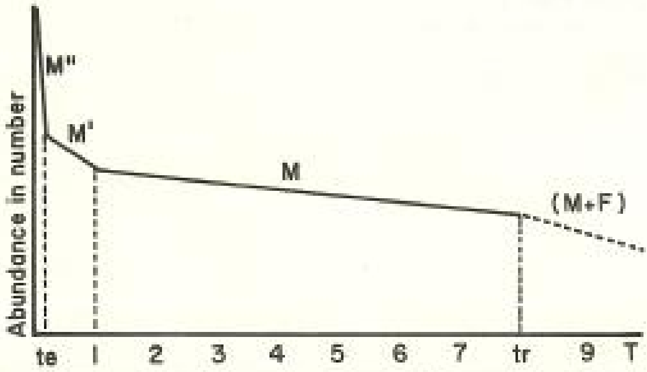

Figure 1. Abundance of population affecting the total number. Where: t_e = eclosion time and t_r = age of recruitment to the fishery.

these questions and improve the model, more information will have to be gathered on past and present capture, fishing effort, nesting sites, abundance of adults, fecundity, sex ratios, recruitment, breeding cycles, age, growth, and so on. Because of this it seems necessary to have a simple model useful for quick assessment of population size with the minimal data now available. This model should also help in the management of these vulnerable resources.

In the present work, as a first step we cover subjects of vital importance: age-specific rates of mortality, derived from tagging, nesting beach census of breeding females and total number of eggs laid in the season. Based on this a table for making predictions of changes in the populations of *Lepidochelys olivacea* was constructed. A similar table for *Chelonia mydas agassizii* will be possible in the near future.

Model

In accordance with Gulland (1971) there are various models for representing the population dynamics of marine species. Considering their behavior with respect to capture, sea turtles could be included in either of the following groups described by Schaefer and Beverton (1963): one as simple units, subject to the law of population growth (Leslie 1957) where the fishing acts as an additional predator in the predator-prey system (Schaefer 1954); the other considers a group of individuals, where changes in biomass are determined by juvenile recruitment in a unit time to the population, by the growth and by the mortality. In this case fishing acts as another source of mortality (Beverton and Holt 1957; Ricker 1975).

Figure 1 represents the change in the abundance of various stages in the life cycle of a population. For the first stage, from egg laying until the hatchlings reach the sea, natural mortality (M") is considered to be equal to total mortality (Z"). In the second stage, from the arrival of the hatchlings to the sea until they are 1-year old M' is considered equal to Z'. At this point in the life cycle it is assumed that habits change slowly until the individual reaches sexual maturity, and it is also assumed that mortality is constant from 1 year of age to shortly before sexual maturity. Natural mortality (M) is assumed to be equal to total mortality (Z). When

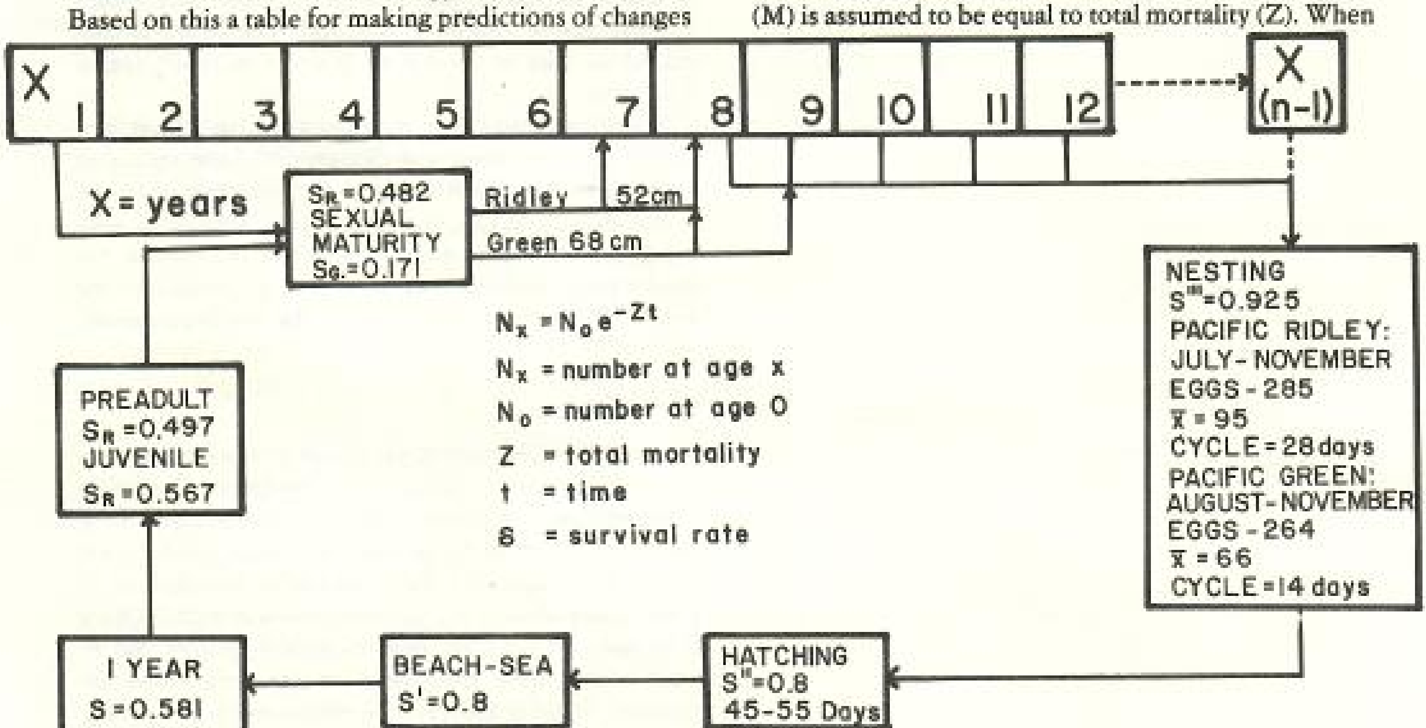

Figure 2. Life cycles of the olive ridleys and Pacific green turtles.

the subadults mature they are subjected to additional pressure from fishery activities, then mortality is affected by fishing (F), and in this stage: $Z = M + F$.

The stochastic model is based on the life cycle, which is described as follows.

Life Cycle

In order to analyze and model population dynamics it is necessary to describe the life cycle. Figure 2 outlines the principal stages and a few important parameters without introducing too many variables which would confuse the process at this stage. In the future it will be necessary to include more variables, in more detail. In accordance with the observations, the olive ridley, is assumed to reach sexual maturity between 7 and 8 years of age with a minimum size, straight carapace length, of nesting females of 52 cm. *Chelonia*, which is larger, is assumed to be sexually mature at 8 or 9 years of age (Márquez and Doi, 1973) with a minimum breeding size of 68 cm. The reproductive cycles vary between the two species, but both seem to depend on lunar effect, most notably in the phases of first quarter and third quarter. Thus, the ridley shows a cycle of about 28 days and the green turtle about 14 days (unpublished data). Seasonal fecundity is also very similar. The ridley lays a greater number of eggs per nest, but less frequently, 2 to 4 times per season; the average clutch is 115, 95, 80 eggs, with an overall average of 95 and a seasonal total of 285 eggs. In green turtles there are fewer eggs per nest, but more nests per season; the average clutch is 80, 70, 60, 50 per nest, with an average of 65 and a seasonal total of 264 eggs (unpublished data).

Lepidochelys olivacea forms nesting aggregations or *arribazones* during which tens of thousands of females may nest in a day or so. The crowding affects egg survival principally at two levels: 1) eggs laid during an *arribazon* may be dug up by nesting females in the same arribazon; 2) eggs from one *arribazon* may be destroyed during a subsequent *arribazon*. These two sources of egg mortality were measured in the 1975 and 1976 seasons, and a mean mortality due to intraspecific nest disturbance was estimated to be $\hat{Z} = 0.0778$, and a mean survival of $\hat{S} = 0.925$.

Natural survival rate of undisturbed nests throughout the incubation period, which may last 45 to 55 days, was estimated from empirical data at $S = 0.8$. Also, the survival of the hatchlings, from leaving the nest to reaching the sea was estimated to be $S = 0.8$. The survival rate for this first stage in the life cycle, some 60 days or 0.17 years, was calculated to be $S = 0.592$ (Márquez et al., in prep.) and mortality is $Z_{0.17} = 0.521$.

Survivorship and mortality values for subsequent years in the life cycle are presented in Table 1. Observed annual survival, S_a, and the calculated survival, $\hat{S}_a$, are quoted for the population of *Lepidochelys olivacea* in the Pacific. Calculated annual survival, $\hat{S}_a$, was derived from the equation:

$$\ell n\ N = -0.0143t + 0.597, \text{ and } Z = \ell n\ \hat{S}_a.$$

The data were derived from the life cycle and fitted by the least squares method. Rate of survival was derived from the formula $S = e^{-Zt}$; the graphical representation is shown in Figure 3. This calculation was fitted with the first year value of total mortality, $\hat{Z}_a = 0.543$, and the theoretical results are quoted in the last column of Table 1.

Evaluation of the *Arribazones*

One of the principal problems in the study of marine turtles is in establishing population size. This can be estimated by several methods including catch effort,

Table 1. Theoretical estimations of annual survival rate and total mortality for *Lepidochelys olivacea* derived from the life cycle

	S_a	$\hat{S}_a$	$\hat{Z}_a$	$S = e^{-Z_a t}$
S_e	1.000	1.000	0.000	1.000
$S_{.17}$	0.597	0.592	0.524	0.912
S_1	0.580	0.581	<u>0.543</u>	0.581
S_2	0.567	0.567	0.567	0.337
S_3	0.553	0.553	0.592	0.196
S_4	0.539	0.539	0.618	0.114
S_5	0.526	0.525	0.644	0.0662
S_6	0.512	0.511	0.671	0.0385
S_7	0.498	0.497	0.699	0.0223
S_8	0.482	0.483	0.728	0.0130
S_9	—	0.469	0.757	0.0075
S_{10}	—	0.456	0.785	0.0044
S_{11}	—	0.442	0.816	0.0025
S_{12}	—	0.428	0.848	0.0015

— No data.

* Was fitted with $\hat{Z}_a = 0.543$, for full calendar year.

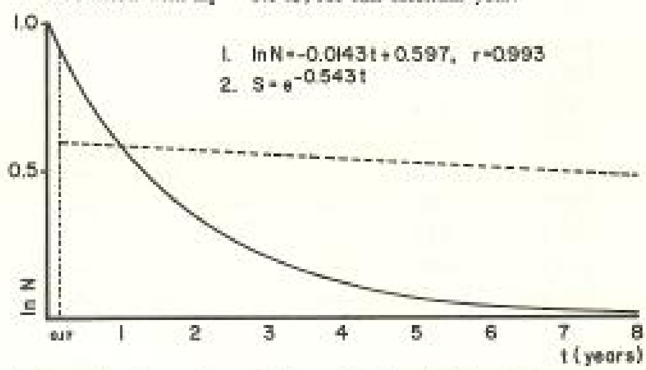

Figure 3. Annual survival rate (broken line) and instant rate of decrease of the population (solid line) for *Lepidochelys olivacea*, derived from the life cycle.

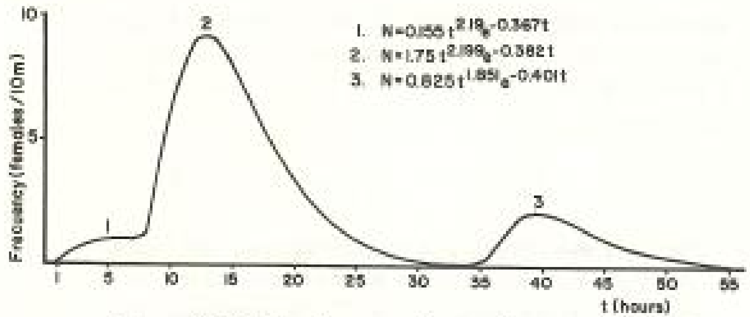

Figure 4. Relation between time and mean number of nesting female *Lepidochelys olivacea* in a sample strip of 10 m on the beach of La Escobilla, Oaxaca, during 11, 12, 13 of August 1979.

Table 2. Yearly data on tagging and tag recoveries of *Chelonia mydas agassizii* in Mexico

Marked		*Recaptured*			
Year	*Number*	*1975*	*1976*	*1977*	*1978*
1975	394	6	3	0	0
1976	1245	—	4	25	2
1977	391	—	—	8	9
1978	583	—	—	—	2
	2613	r_0	r_1	r_2	
		20	37	2	

tagging, and direct censuses. The last method was used in the present study and is described in the following section.

Direct evaluation

This is carried out on the nesting beaches using a method of probability. Instantaneous random sampling consisted of quantifying the turtles that nested each hour in 10-m wide strips, perpendicular to the water line every 200 m along the beach. The action of the turtles was classed in one of three different situations: ascending the beach, descending the beach, and those that were in any stage of nesting (digging, ovipositing, and covering the nest). To estimate the quantity of turtles nesting, the number ascending was added to the number in any nesting phase from which the number descending the beach was subtracted. The data on turtle abundance from each sample group were recorded at hourly intervals during the *arribazon*. It is assumed that the average turtle spends nearly one hour nesting on the beach. To determine the hourly average and variation in turtle number in each strip of beach, the hourly mean values were used to generate the exponential equations, which were used to estimate the number of turtles nesting in each sampled strip.

Figure 4 illustrates the number of nesting females in a 10-m sample strip during the *arribazon* in 1979 showing changes in number through the day and between days. To estimate the total nesting for the *arribazon* the above values were used for each 200 m of beach. This permits an estimate of the number of female turtles which came out to lay eggs in each *arribazon*. This was analyzed with average fecundity per female and annual survival rate to evaluate the size of the population in the sea (Márquez, ms.).

Total Mortality and Survival

Tagging individuals is used principally to study migra-

Table 3. Yearly data on tagging and tag recoveries of *Lepidochelys olivacea* in Mexico and the Central East Pacific coast

Year	*Number*	*66*	*67*	*68*	*69*	*70*	*71*	*72*	*73*	*74*	*75*	*76*	*77*	*78*
1966	153	2	11	2	1	1	0	0	0	0	0	0	0	0
1967	87	—	8	6	5	1	1	0	0	0	1	0	0	0
1968	30	—	—	2	0	0	1	1	0	0	0	1	0	0
1969	26	—	—	—	1	2	0	0	1	0	0	0	0	0
1970	874	—	—	—	—	4	4	2	11	2	5	1	1	1
1971	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1972	16	—	—	—	—	—	—	—	—	—	—	1	—	—
1973	516	—	—	—	—	—	—	—	3	4	8	5	3	5
1974	513	—	—	—	—	—	—	—	—	2	4	1	2	6
1975	1,485	—	—	—	—	—	—	—	—	—	71	2	16	11
1976	2,543	—	—	—	—	—	—	—	—	—	—	8	17	41
1977	2,452	—	—	—	—	—	—	—	—	—	—	—	63	25
1978	3,564	—	—	—	—	—	—	—	—	—	—	—	—	183
		r_0	r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8				
	12,660	347	118	77	32	16	10	1	1	3				

Table 4. Yearly changes in total mortality and survival rate, gathered from tag recoveries in Mexico and the Central East Pacific Coast

	1977		*1978*	
Species	*Z*	*S*	*Z*	*S*
Chelonia mydas agassizii	2.004	0.134	1.766	0.171
Lepidochelys olivacea	0.824	0.438	0.729	0.482

tion and to evaluate a population. It can be used to determine total mortality (Z) and survival rate (S) (Lucas 1975). In this case both Z and S are presented.

The mark-recapture data for *Chelonia* comprise 4 years, 1975–78, and for *Lepidochelys* 12 years, 1966–78. Recaptures, away from the nesting beach, are shown for both species in Tables 2 and 3. This information, notably the values for r_o, r_1, r_2 etc., which represent the number of tagged turtles marked and recaptured the same year, the next year, and in following years, were analyzed by the logarithmic method of least squares to estimate total mortality (Z) and survival rate (S), with assumed 10 percent annual tag loss (Doi 1974). The predicted values are plotted in Figure 5. In Table 4 these parameters are compared with those obtained until 1977. The reliability of data on *Lepidochelys* seems to be better than those for *Chelonia*, probably because of the greater number of marked ridley turtles (4.8 times more) and time worked. The calculated mortality in *Chelonia* is considerably higher, Z = 2.004 and 1.766 compared with *Lepidochelys* (Z = 0.824 and Z = 0.729) and those obtained by Márquez and Doi (1973) for *Chelonia* from the Gulf of California, Z = 0.223 and S = 0.807 (which was derived from ages and size composition).

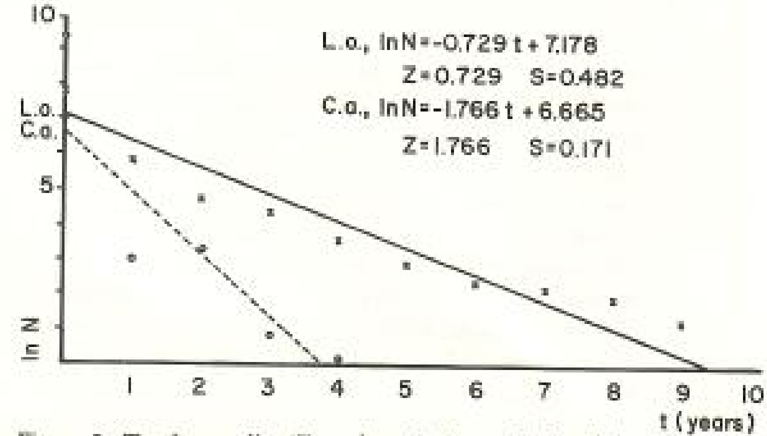

Figure 5. Total mortality (Z) and survival rate (S) for adults of *Lepidochelys olivacea* and *Chelonia mydas agassizii*, derived from tag recoveries.

Change in the Population of *Lepidochelys olivacea*

In treating this subject it is necessary to consider some characteristics of behavior because this is necessary in defining "stocks." Apparently the populations are clearly defined, despite extensive dispersion of adults during migration from the breeding area. In summer and autumn, they aggregate at nesting areas in Mexico and Central America while in winter and spring they are in known feeding areas from South America to Mexico. Consequently, we should define at least the reproduc-

Table 5. Theoretical Population of *Lepidochelys olivacea*

	Spawning	*0.912*	*0.0223*	*0.0130*	*0.00754*	*0.00438*	*0.00255*	*0.00148*	*0.00086*	*0.00050*	*0.00029*	*0.00017*	*0.00009*
Year	*size*	$N_{0.17}$	N_7	N_8	N_9	N_{10}	N_{11}	N_{12}	N_{13}	N_{14}	N_{15}	N_{16}	N_{17}
72	22243	20285	496.0	289.1	167.1	97.4	56.7	32.9	19.1	11.1	6.4	3.8	2.0
73	24575	22412	548.0	319.5	185.3	107.6	62.7	36.4	21.1	12.3	7.1	4.2	2.2
74	19867	18119	443.0	258.3	149.8	87.0	50.7	29.4	17.1	9.9	5.8	3.4	1.8
75	28999	26448	646.7	377.0	218.6	127.0	73.9	42.9	24.9	14.5	8.4	4.9	2.6
76	21706	19796	484.0	282.2	163.7	95.1	55.3	32.1	18.7	10.8	6.3	3.7	1.9
77	9587	8743	213.8	124.6	72.3	42.0	24.4	14.2	8.2	4.8	2.8	1.6	0.9
78	18059	16470	402.7	234.8	136.2	79.1	46.0	26.7	15.5	9.0	5.2	3.1	1.6
79[a]	12497	11808	288.7	168.3	97.62	56.7	33.0	19.2	11.1	6.5	3.7	2.2	1.2
80[b]	11118	10140	247.9	144.5	83.8	48.7	28.3	16.4	9.6	5.5	3.2	1.9	1.0
81[b]	9289	8471	207.1	120.7	70.0	40.7	23.7	13.7	8.0	4.6	2.7	1.6	0.8
82[b]	7461	6804	166.4	97.0	56.2	32.7	19.0	11.0	6.4	3.7	2.2	1.3	0.7
83[b]	5632	5136	125.6	73.2	42.5	24.7	14.4	8.3	4.8	2.8	1.6	0.9	0.5
84[b]	3804	3469	84.8	49.4	28.7	16.7	9.7	5.6	3.3	1.9	1.1	0.6	0.3
85[b]	1975	1801	44.0	25.7	14.9	8.6	5.0	2.9	1.7	0.9	0.6	0.3	0.2

Note: The total population size of any year can be followed after maturity age (8 years) in addition with the others next ages. Example: The class 1979 will be formed after 8 years (1987) with ages 8 through 15, equal to 480,500 adults of both sexes.

a. Data not yet reconfirmed.

b. Fitted with: R = 0.649 m = 1828.629 b = 25747 tive stock of Mexico and Central America. Between them there is probably a certain amount of exchange, not only in individuals, but also genetically. However, there are no known means for differentiating individuals from these two populations from morphological characteristics. However, there may be differences that are natural as well as those induced by man: fishing mortality may have tremendous effect, although in a different manner from nonhuman pressures especially in breeding and feeding areas, where fishing causes selective mortality in the population principally on breeding-size females.

Despite the fact that breeding and feeding areas may be separated by several thousand kilometers, it is necessary to determine whether or not these populations should be analyzed as the same or different stocks. There is evidence from tagging returns that Mexican and Costa Rican stocks are mixed in South America, and it is necessary to define what proportion of new recruits represent population interchange. These data must be made available for management of the species in an international cooperative manner, not in the unilateral, isolated procedure as is done today.

As regards hatchlings, juveniles, and subadults, there is little information. However, they probably interact ecologically, although they occupy separate levels as indicated by the absence of animals below adult size in areas where adults normally occur.

Estimates of annual numbers of eggs produced by *Lepidochelys olivacea* in Mexico were derived from estimates of the number of seasonal nesting females (Figure 4), and the fecundity at the time of nesting (in prep.).

Annual survival rates with the changes during the life cycle (Table 1, Figure 3) were adjusted with the analysis of tagging and recapture data (Tables 2 and 3). These estimates were used to predict population size of various classes, especially for future populations of adults (Table 5). Estimates for age classes after sexual maturity have been presented in detail, this table can be used as a tool in diagnosing the population under investigation. In summary, the prediction for the relevant age class gives the theoretical adult population size for a given year. For example, the composition of the population in 1987 would have 168,300 8-year olds, plus 136,200 9-year olds, plus 42,000 10-year olds, etc.

It can be observed that in 1980 the population would contain 289,100 8-year olds of both sexes and in 1981 there would be 319,500 8-year olds plus 167,100 9-year olds. These values depend on the number of eggs hatched out 8, 9, 10, etc. years before, illustrating that the protection given now greatly determines the future of the species.

Acknowledgments

This work would not have been possible without the help of innumerable persons, principally the cooperative fishermen. In the last 3 years, after forming the "Turtle Fund" for the investigation of marine turtles, we have been able to count on an increase in material and financial help, and it was possible to increase the work on the nesting beaches. The Turtle Fund was formed not only by the cooperatives but also by private industry. Fundamental work and support were carried out by the personnel of the Direccion General de Regulacion Pesquera and the personnel of the Mexican navy. Special acknowledgment to Dr. J. Frazier of the Smithsonian Institution for his critical reading of the manuscript.

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The Population of the Kemp's Ridley Sea Turtle in the Gulf of Mexico—*Lepidochelys kempii*

ABSTRACT

In this work on Kemp's ridley sea turtle, its life cycle is briefly described and used as a basis for the model. In it are included parameters of survival rates for different stages of its development, principally for egg survival during nesting and incubation, and from hatching until adult. It shows the individual fecundity or the seasonal average total number of eggs (140.8), the frequency of nesting (1.304 nests per turtle per season), and the cycle of reproduction which is repeated with yearly, biennial, and triennial, etc. patterns. Recruitment is approached in a preliminary way, and an $R = 0.0572$ was obtained. This is considered still somewhat low, but it has been improving in recent seasons.

A simple model is being developed to evaluate this seasonal nesting population through the fecundity index and following cohorts affected by the instantaneous survival rate. A curve of decrease in the population is developed and used for the assessment of the adult population size in the sea.

Introduction

The principal and only beach that now exists for the nesting of the Kemp's turtle, *Lepidochelys kempii* is located near the upper section of the Tropic of Cancer, between the mouths of the San Rafael River and the sand-bar of Ostionales and 4 km east of the village of Rancho Nuevo, in the municipality of Aldama, Tamaulipas.

Before the sixties it was clear in Mexico City that the trade and consumption of turtle eggs originated from this region, but it was not until 1966 that the Instituto Nacional de Investigaciones Biológico Pesqueras of the Direccion General de Pesca, initiated a systematic protection for sea turtles with the establishment of turtle camps (Chavez, Contreras, and Hernandez 1967). Since then the work has continued without interruption.

Later, to assure the future of the species and to strengthen the investigations, an official decree was

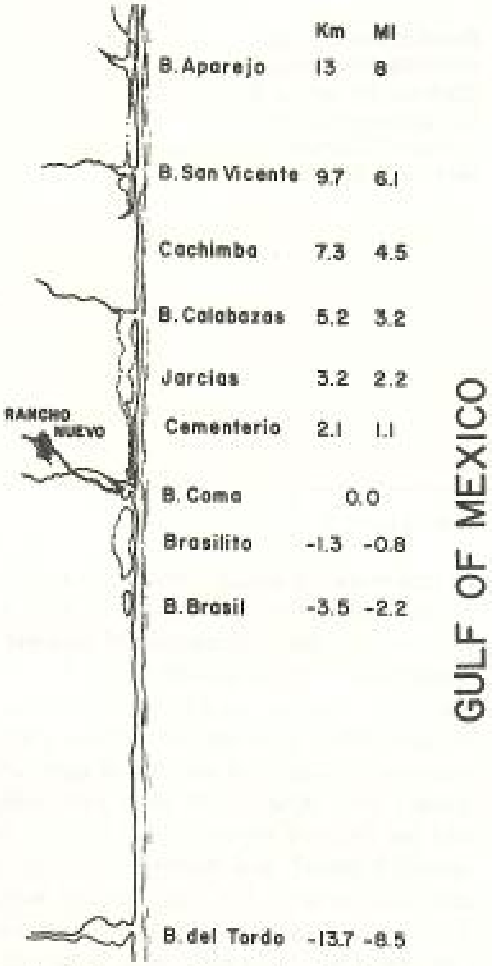

Figure 1. Kemp's ridley sea turtle nesting beach at Rancho Nuevo, Tamaulipas, Mexico.

written (6/1/77) designating the beach at Rancho Nuevo (Figure 1) as a zone of Natural Reserve, prohibiting any fishery under the range of 4 miles around it. This protected the ecology of the zone, which covers a strip of shore about 17.6 km of sandy beaches, and its corresponding ocean up to 50 fathoms. More details in respect to this were quoted by Márquez (1976).

During 1978 an agreement was reached between Mexico (Departamento de Pesca) and the United States (FWS/NMFS). Mexico would provide around 2,000 eggs and a given number of new hatchling turtles. The eggs and turtles are provided for the establishment of a new nesting population on the beach at Padre Island, Texas, and consequently an even greater chance for survival of the whole population.

The information on this species acquired over 14 years of work facilitates the development of the present model for the evaluation of the population of Kemp's ridley.

Life Cycle

Reproduction

The first results of unpublished data indicate that the Kemp's ridley has a reproductive cycle described as follows: turtles nesting every year, 58 percent = 1.000; turtles nesting every 2 years, 29 percent = 0.500; turtles nesting every 3 years, 13 percent = 0.224.

Fecundity

The total fecundity per turtle is obtained easily from the information on the number of times each turtle nests and how many eggs are in each clutch. Table 1 data are applied for the 1979 nesting season.

Nesting Population Size

The average number of eggs per clutch (h) is 105.48 (for the 1979 season) and, applying the following formula, gives a total number of turtles per season:

$$N = \frac{H}{I \times h}$$

where: H is the total number of eggs laid during the season, I is the index of fecundity, and h is the mean number of eggs per female per season.

Survival

In the life cycle (Figure 2) information was presented regarding the survival (Márquez et al., in prep.). This information was obtained by direct observation on the beach (for eggs and hatchlings) and from data during tagging and recapture of adults from the incidental catch and renesting observation (Tables 2 and 3). The survival rate (S_a) for intermediate stages were obtained by extrapolation and afterwards were adjusted in a straight line (Figure 4). The information obtained is shown in Table 5.

Total Mortality

Applying the logarithmic method (Doi 1974) to obtain the total mortality and using data of Tables 2 and 3, two similar results were obtained (Figure 3). The average values of annual survival (S) and mortality (Z) obtained for adults in 1979 are quoted in Table 4, and compared with those obtained in former years. It should be remarked that the species has improved slowly, year by year.

Table 1. Seasonal fecundity index for nesting females of Kemp's ridley sea turtle, *Lepidochelys kempii*

Situation	*Frequency*	*Index*	*Average Eggs*	σ
1	411	1.000	110.16	14.5
2	115	0.2798	101.90	17.1
3	16	0.0389	93.65	22.9
4	3	0.0073	85.39	
		1.3260	140.81	

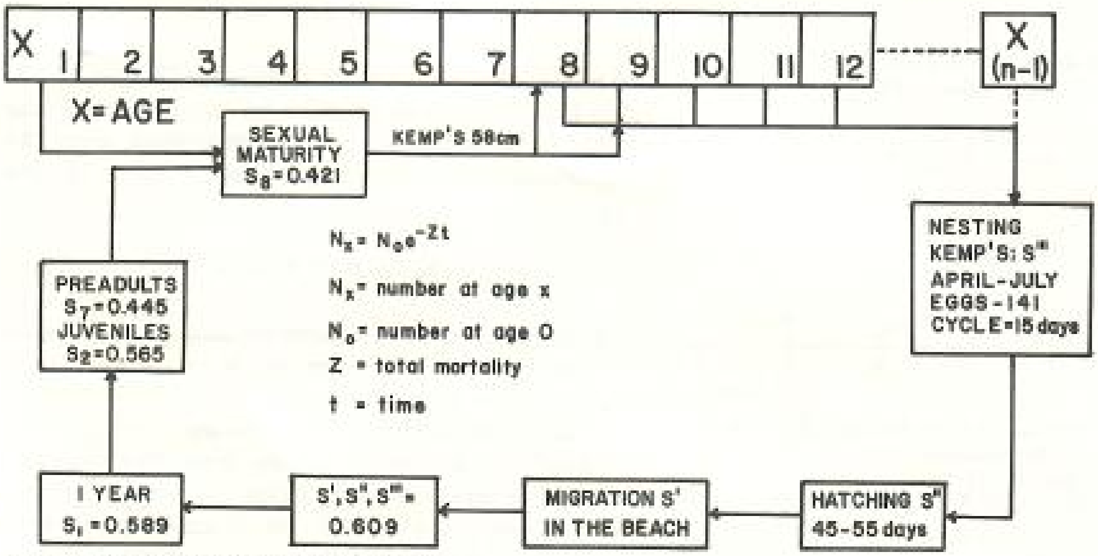

Figure 2. Life cycle of *Lepidochelys kempii.*

Table 2. Yearly information from tagging and tag recoveries of Kemp's ridley sea turtle, *Lepidochelys kempii,* in the Gulf of Mexico

Year	*Number*	*66*	*67*	*68*	*69*	*70*	*71*	*72*	*73*	*74*	*75*	*76*	*77*	*78*	*79*
1966	285	12	7	4	1	3	1	—	—	—	—	—	—	—	—
1967	271	—	9	5	1	1	—	—	1	—	—	—	—	—	—
1968	326	—	—	7	1	2	1	1	—	—	—	—	—	—	—
1969	86	—	—	—	1	3	—	—	—	—	—	—	—	—	—
1970	133	—	—	—	—	5	1	—	—	—	—	—	—	—	—
1971	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1972	41	—	—	—	—	—	—	—	1	—	—	—	—	—	—
1973	76	—	—	—	—	—	—	—	1	—	—	1	—	—	—
1974	77	—	—	—	—	—	—	—	—	1	—	1	—	1	—
1975	105	—	—	—	—	—	—	—	—	—	2	—	—	—	—
1976	127	—	—	—	—	—	—	—	—	—	—	1	1	—	—
1977	81	—	—	—	—	—	—	—	—	—	—	—	—	1	—
1978	251	—	—	—	—	—	—	—	—	—	—	—	—	4	—
	1859														
Annual tag re-		r_0	r_1	r_2	r_3	r_4	r_5	r_6	—	—	—	—	—	—	—
coveries		43	20	8	4	5	1	1	—	—	—	—	—	—	—

Table 3. Yearly nesting and renesting information of Kemp's ridley sea turtle, *Lepidochelys kempii,* in Rancho Nuevo beach, Mexico[a]

Year	*Number*	t_0	t_1	t_2	t_3	t_4	t_5	t_6
1966	285	12	9	6	4	3	2	1
1967	271	9	5	2	1	—	—	1
1968	326	9	5	3	2	2	1	—
1973	76	1	8	—	5	—	—	—
1974	77	7	8	11	1	4	3	—
1975	105	8	16	1	2	2	—	—
1976	127	16	5	12	6	—	—	—
1977	81	10	9	13	—	—	—	—
1978	251	40	30	—	—	—	—	—
1979	371	97	—	—	—	—	—	—
	1970	209	95	48	21	11	6	2

a. Where, t_0 = same year, t_1 = next year, etc.

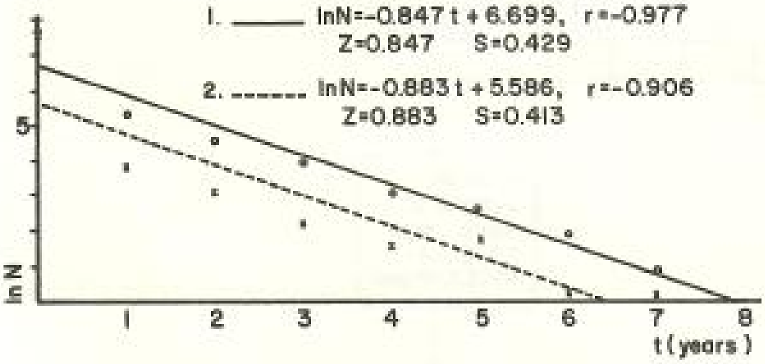

Figure 3. Total mortality (Z) and survival rate (S) for *Lepidochelys kempii* obtained theoretically from renesting information (1) and tag recoveries (2).

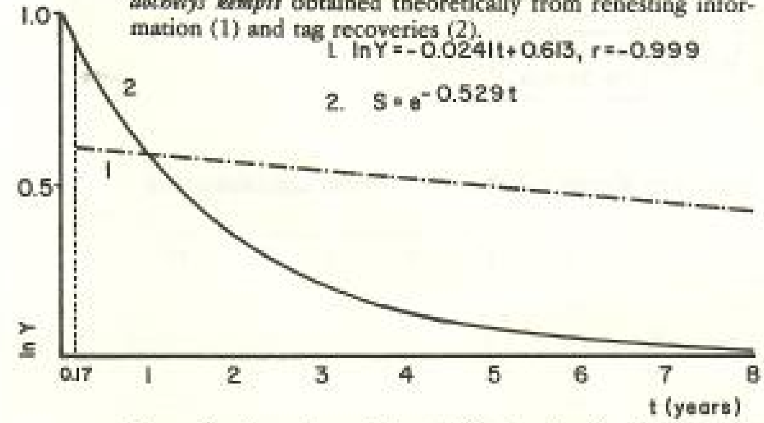

Figure 4. Annual survival rate (broken line) and the instant rate of decrease of the population (solid line) for *Lepidochelys kempii*, derived from the life cycle, tagging and tag recoveries and virgin stock (eggs produced by season).

Table 4. Yearly changes in total mortality and survival rate in adults, gathered from tagging and tag recoveries

Parameter	*1977*	*1978*	*1979*
Z	0.897	0.883	0.847
S	0.408	0.413	0.428

With the theoretical information from the last column in Table 5, a curve was made in Figure 4 which represents the instantaneous change of population and utilizes the value of Z = 0.529 for total mortality (Table 5). Starting with the first calendar year, all details of the instant decreasing rate of the population curve were adjusted; later on this curve was used to form the theoretical table of the annual change of population.

Conclusions

Density of the Breeding Population

An estimation of the number of turtles in the sea may be obtained by several methods. The most adequate in this case, with the available information, was the general survival equation, already mentioned in the above section and used by authors like Ricker (1975) and Doi (1974). This equation being multiplied by the number of individuals in the virgin stock gives the population number at a given time as follows (Figure 2):

$$N_x = N_o e^{-Zt} = N_o S$$

where N_o is the total spawning size, Z is the total mortality, t is time in years and N_x is the number of individuals at age x.

The results of these calculations are shown in Table 6, which can be used to get the population diagnosis at any moment, within the limits that are quoted in it and following the cohorts. For example, in the year 1978, 97,900 eggs were laid on the beach. If 7 years is considered enough to reach the age of sexual maturity, by 1985 there will be around 2,410 turtles that are 7-years old, plus the previous cohort that will then be 8-years old plus those of 9 years, etc. Adding all these individuals gives a population total of 4,272 adults of both sexes in 1985.

It is necessary to clarify certain points on this table in relation to the first two columns of H_r and N_v. H_r is the total annual number of protected hatchlings liberated on the beach (thousands of individuals). N_v is a back calculation and standardized data, as the calculation is based on virgin stock, and indicates thousands of eggs theoretically laid on the beach, in accordance with actual liberated hatchlings. $N_v = H_r/Z$ where Z = 0.496 (mortality during nesting and incubation). Of course Z changes every year, but this figure is used in a general mode to develop Table 6.

Table 5. Theoretical estimations of annual survival rate and total mortality for *Lepidochelys kempii* derived from the life cycle and tag recoveries

	S_0	S_a	$\hat{S}_a$	$\hat{Z}_a$	$S = e^{-Zt*}$
S_v	1.000	1.000	1.000	0.000	1.000
$S_{0.17}$	0.608	0.608	0.609	0.496	0.914
S_1	—	0.590	0.589	0.529	0.589
S_2	—	0.565	0.565	0.571	0.347
S_3	—	0.541	0.541	0.614	0.205
S_4	—	0.518	0.517	0.660	0.121
S_5	—	0.492	0.493	0.707	0.0710
S_6	—	0.469	0.469	0.757	0.0418
S_7	—	0.444	0.445	0.810	0.0246
S_8	0.421	0.421	0.421	0.865	0.0145
S_9	—	—	0.397	0.924	0.00856
S_{10}	—	—	0.373	0.986	0.00504
S_{11}	—	—	0.348	1.056	0.00297
S_{12}	—	—	0.324	1.127	0.00175

— No data.
* Was fitted with Z = 0.529, for full calendar years.

For this reason some data in column N_v and $N_{0\text{-}17}$ seem unreal.

Recruitment

Certain preliminary results can be indicated with regard to recruitment (R). This parameter was obtained through the change of population which is analyzed in Table 6, column N_7 and it was adjusted by a logarithmic linear regression. The results are shown in Figure 5. For this calculation, an estimated average of three year periods was used and the annual rate of recruitment was 0.0572, for the period between 1966–79.

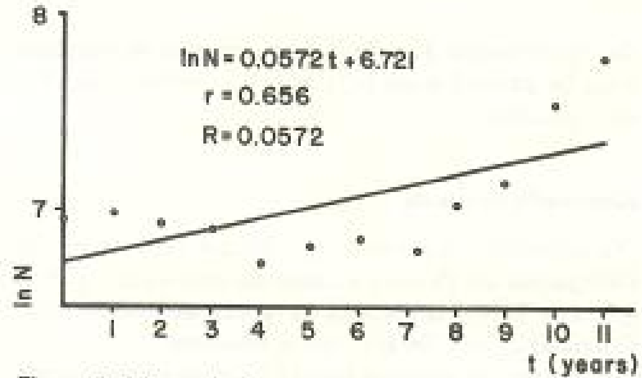

Figure 5. Theoretical annual rate of recruitment for *Lepidochelys kempii*, adjusted by logarithmic linear curve. Period 1967–1978.

Discussion

For a complete description of the life cycle it is necessary to gather more information on habits, behavior and biological phases of each species. With *L. kempii*, and in general for all the marine turtles, little is known of the survival rate from the time when the hatchlings first go to the sea until they return to coastal waters. Hence, in the present study these values were estimated. Data from tagging returns, and hatching success from the hatchery were used to estimate the instantaneous decrease of population, from the virgin stock, that is, total number of eggs laid per season, up to 15 years of age. Table 6 was prepared from these estimates. Total population size of adults is estimated by adding respective values of population sizes for each existing cohort. For example, the estimate for the 1978 population is the sum of the adults recruited in 1978, plus those surviving from previous cohorts, as indicated by the diagonal line.

On this occasion, valuable information was obtained on the fecundity, cycle of nesting, and the average number of eggs per clutch. This is basic for population size estimation, through the use of the evaluated number of females nesting every year. It is worth mentioning that in this work, the corresponding analysis of the information is not completed, but the method for doing this is described.

Regarding the recruitment, as may be observed, it is still low, but it should be clarified that in these last years a positive change has been seen from R = 0.0453 to R = 0.0572, which is a good indication of the recuperation of the species. It should also be noted that during the present year (1979) there was an extraordinary case, on May 20, a small arrival of 20 to 30 nesting females came ashore on Lauro Villar (Washington Beach) near the border between Mexico and Texas, about 400 km north of Rancho Nuevo. This event may be encouraging with regard to the situation of the species or it may be an accidental case due to

Table 6. Theoretical change of populations of *Lepidochelys kempii*

Year	H_t	N_v	$S = 0.914$ $N_{0.17}$	$S = 0.0246$ N_7	$S = 0.0145$ N_8	$S = 0.0086$ N_9	$S = 0.0050$ N_{10}	$S = 0.0030$ N_{11}	$S = 0.0017$ N_{12}	$S = 0.0010$ N_{13}	$S = 0.0006$ N_{14}	$S = 0.0004$ N_{15}
1966	22.1	44.56	40.73	1096	646	381	225	132	78	46	27	16
1967	20.7	41.73	38.14	1027	605	357	210	124	73	43	25	15
1968	20.8	41.94	38.33	1032	608	359	211	125	73	43	25	15
1969	23.5	47.38	43.31	1166	687	406	239	141	83	49	29	17
1970	18.2	36.69	33.53	903	532	314	185	109	64	38	22	13
1971	17.7	35.69	32.62	878	518	306	180	106	62	37	22	13
1972	14.4	29.03	26.53	714	421	248	146	86	51	30	18	10
1973	22.3	44.96	41.09	1106	652	385	227	134	79	46	27	16
1974	20.3	40.93	37.41	1007	593	350	206	122	72	42	25	15
1975	11.2	22.58	20.64	555	327	193	114	67	40	23	14	8
1976	36.9	74.40	68.00	1830	1079	637	375	221	130	77	45	27
1977	28.9	58.27	53.26	1433	845	499	294	173	102	60	36	21
1978	48.6	97.98	89.55	2410	1421	839	494	291	171	101	60	35
1979	65.4	131.85	120.51	3244	1912	1129	665	392	231	136	80	47

Note: The total population size of any year can be estimated after maturity (7 years) by adding succeeding year classes. Example: the class of 1978 will be formed after 7 years (1985) with ages 7 through 15, equal to 4272 adults of both sexes.

the environment. It is clear, however, that recruitment must be studied more fully as it is a definite basis for its protection.

Acknowledgments

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These last years, a group of 5 volunteer North American students coordinated by Dr. Peter Pritchard has given valuable help. These students have reinforced the work and given it a new impulse for the protection of the species.

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An Experimental Population Model for the Loggerhead Sea Turtle (*Caretta caretta*)

ABSTRACT

Sixteen consecutive years of intensive tagging surveys on Little Cumberland Island, Georgia, provide a data base for establishing a population model for nesting female loggerhead sea turtles (*Caretta caretta*). The model incorporates frequency of remigration intervals, probabilities of remigration, and fecundity. The model predicts annual recruitment (39 percent of nesting females), mean longevity of nesting females (3 years as adults), and turnover of nesting females (6 years). The model represents a hypothetical population with stationary age distribution; its similarity to the Little Cumberland population is implied. A survivorship curve is constructed for a hypothetical cohort of female turtles, although age to maturity and survivorship of the juveniles is not known. The cohort replaces 50 percent of itself during the first 3 nesting seasons, 90 percent during the first 13 nesting seasons. Computer simulation through time provides predictions of population doubling times resulting from various changes in hatchling recruitment, juvenile survival, and age to maturity. Observed recruitment to the seasonal nesting population appears to be a potentially sensitive indicator of changes in hatchling production, if hatchlings return to nest on their natal beach. The model can be used to simulate the effects of periodic destruction of the eggs by predators or adverse beach conditions.

Introduction

Population models, particularly those which predict population numbers within statistically defined confidence limits, have been noticeably lacking from the marine turtle literature. Population models for other species of animals are generally constructed from life table data, but certain essential parameters, such as survivorship and age to maturity, continue to elude marine turtle investigators (Bustard 1979). Portions of sea turtle population models have been appearing in the literature for a number of years. Hughes (1974) used annual egg production, egg survival, and observed recruitment to a population of adult nesting female loggerheads to estimate juvenile survival rates. Various investigators have been using remigration-interval frequencies and seasonal population counts to estimate total population size of nesting females. Carr, Carr, and Meylan (1978) provides a general equation for calculating this parameter estimate. Bustard and Tognetti (1969) developed a model for density-dependent population regulation through the mechanism of intraspecific nest destruction.

In this paper we collect existing information on various life history stages of a Georgia loggerhead population and incorporate these data into a population model (Hillestad, Richardson, and Williamson 1977; Richardson and Hillestad 1978). The data upon which this population model is based have been gathered primarily from Little Cumberland Island, Georgia. Our information is derived from beach tagging studies of nesting females and the survival of their eggs on the beach. We do not know the survivorship of the hatchlings to maturity or the average number of years required to reach maturity. Information on the larger (carapace length 45 to 90 cm) juvenile loggerheads has been derived entirely from records of turtles found dead on the beach and those caught incidentally by shrimp trawlermen (Hillestad et al, this volume).

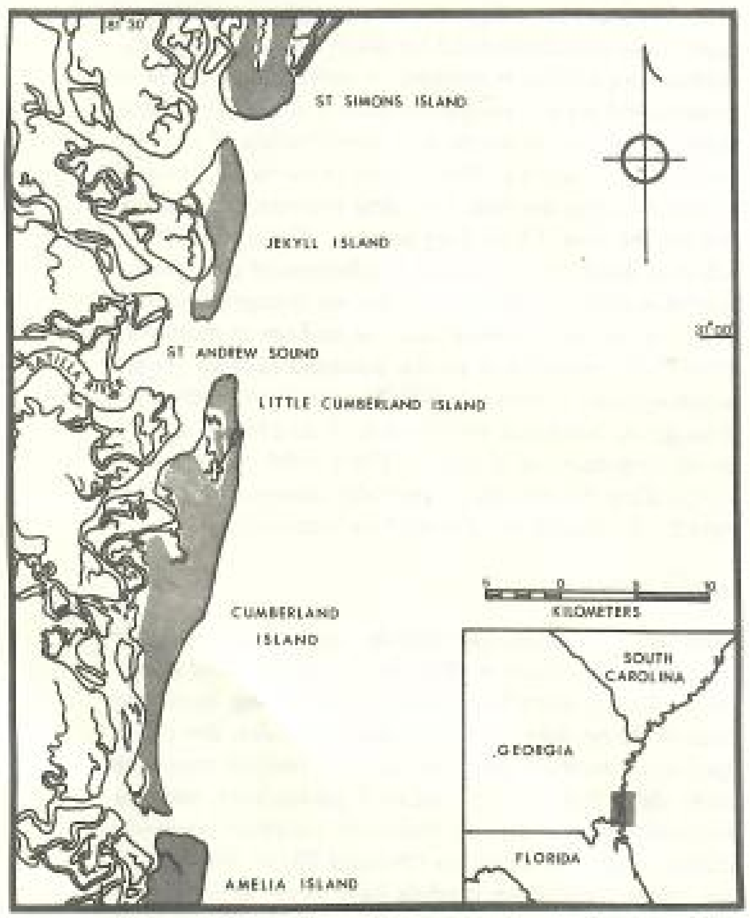

Figure 1. Map of coastal Georgia, showing locations of islands with populations of nesting loggerhead sea turtles.

Because of our uncertainty of the juvenile life history stages, the Little Cumberland population model is still incomplete. It simulates survivorship and fecundity of nesting females after they enter the nesting population, but the model cannot predict population response to changes in hatching success without knowing survivorship and age to maturity of the juveniles. In this respect, the Little Cumberland population model, in its present form, cannot be used as a management device to determine acceptable predation levels or harvest quotas. Survivorship of Little Cumberland nesting females is undoubtedly determined by a complex blend of mortality factors: distant (sharks, food supplies, oceanic weather patterns), local (boat collision, drowning in shrimp trawl nets), and other mortality factors, (parasites, for example). The similarity of this survivorship to the survivorship of loggerheads from other geographic areas or to other species of sea turtles remains to be seen. The Little Cumberland population model represents a preliminary effort to predict population behavior from existing data. The model is meant to stimulate further investigation into marine turtle population models and not to provide definitive predictions of animal numbers, although the latter is the ultimate goal of any population modeling effort.

The Little Cumberland loggerhead project, now entering its eighteenth year of operation, is sponsored by the National Audubon Society and funded in its entirety by the owner-members of the Little Cumberland Island Association. This nesting population study owes its continuity and longevity to the continuing financial support from association members and to the dedicated work of the 24 research assistants who were involved in the all-night field work required by an intensive sea turtle nesting survey. We would also like to recognize the other Georgia nesting studies, particularly those on the adjacent islands of Cumberland and Jekyll. These federal, state, and privately supported studies place the Little Cumberland population data within the context of the entire Georgia coast (Figure 1) and provide critical information concerning nesting overlap between islands.

Results and Discussion

Population Parameters for Nesting Females

Seventeen consecutive years (1964–1980) of population tagging data have been collected from adult female loggerheads nesting on Little Cumberland Island (Richardson et al 1978). During the first 10 years, a 3-year cycle in the numbers of nesting females appearing each year was fairly consistent (Figure 2a). Significant damping of this cycle occurred for unknown reasons at some point proximate to the 1973 season. Nesting studies on other Georgia islands were not in existence for enough years at the time to corroborate this apparent crash in numbers of nesting females recorded for Little Cumberland. Recent evidence (1973–80) suggests that the Little Cumberland population of adult females may be rebuilding from the post-1973 low, as well as maintaining a 3-year cycle (Figure 2b).

It required 6 years to tag the majority of existing members of the Little Cumberland nesting female population, an exercise that must be completed before recruitment (the percentage of unmarked individuals appearing each season) can be identified (Figure 2b). The proportion of recruits to total turtles has remained approximately between 30 percent and 40 percent a season since the 1973 crash (Figure 2c). We are confident, because of the other Georgia tagging programs, that the observed recruitment in recent years on Little Cumberland Island is real and not the result of wandering nesting from adjacent populations. Furthermore, evidence from the Georgia tagging program supports our contention that loggerheads rarely, if ever, shift to another nesting beach when the preferred or "home" nesting beach is altered or destroyed (Bell and Richardson 1978).

The Little Cumberland population model is derived from the following data (Richardson et al. 1978):

- Types of remigration intervals occur with characteristic frequencies.

Interval	*Frequency percentage*
1-year	3
2-year	56
3-year	31
4-year	7
5-year or more	3

- A turtle appearing on the nesting beach for the first time (neophyte turtle) will remigrate (return) to nest during a subsequent nesting season with a 49 percent probability.
- A turtle returning for at least a second nesting season (remigrant turtle) will remigrate for at least a third nesting season with 70 percent probability.

Confidence in these properties of loggerhead population behavior is an essential part of the predictions that follow. Because of the intensity of the beach coverage, virtually all nesting females on Little Cumberland are observed (tagged) each season. Frequencies for Little Cumberland remigration intervals are based on 453 observations from 1964 to 1975. Remigration rate probabilities have been adjusted to compensate for error due to tag loss (Richardson et al. 1978). Nesting beach surveys on either side of Little Cumberland have been recording the presence of Little Cumberland tagged turtles since 1972 (Figure 1). An analysis of interisland nesting overlap has shown that less than 2

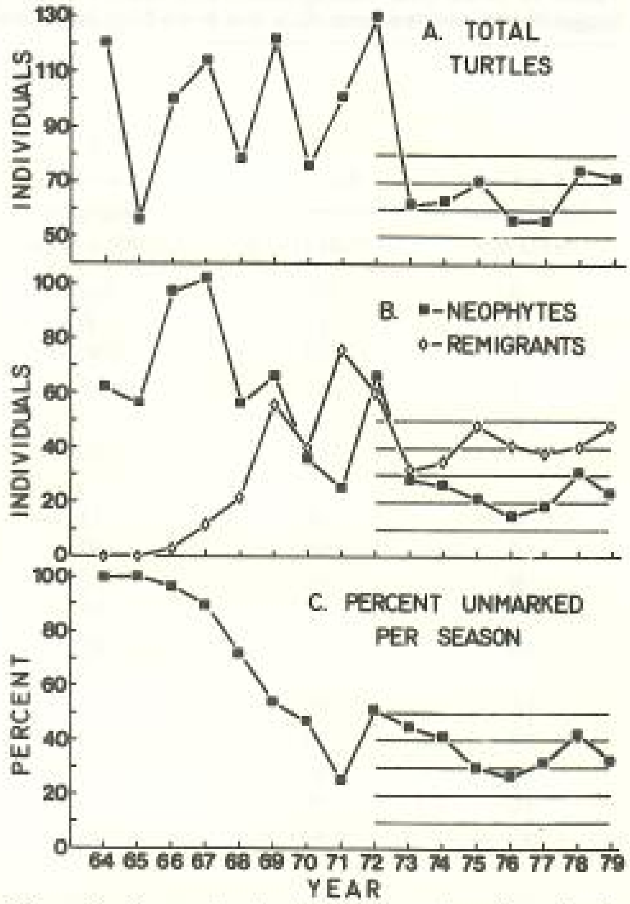

Figure 2a. Fluctuation in the annual number of nesting female loggerhead turtles at Little Cumberland Island, Georgia.

Figure 2b. Total number of neophyte and remigrant nesting loggerheads observed per season at Little Cumberland Island, Georgia.

Figure 2c. Percentage of the annual number of nesting loggerheads not previously observed on Little Cumberland Island, Georgia.

percent of Little Cumberland turtles nest on distant (≥10 km) beaches where they might be missed by tagging crews (Richardson et al. 1977).

The above behavioral characteristics of Little Cumberland nesting loggerheads are used to generate the model, a pattern of predicted nesting appearances for a theoretical population of 1,000 neophyte turtles followed for 25 years (Table 1, column A). Appendix I provides a detailed description of this and all other calculations involved in the development of Table 1. The decision to limit the lifespan of a sea turtle to 25 years is arbitrary, although at least 1 loggerhead has now nested on Little Cumberland Island for a period spanning 17 nesting seasons.

The Little Cumberland model, in its most simple form, simulates a population with a stationary age distribution. Under this hypothetical situation, the pro-

Table 1. A 25-year remigration and survivorship table for cohorts of 1,000 and 389 neophyte female loggerhead turtles entering the breeding population

			Survivorship		
Years of reproductive maturity	A *Seasonal remigration (1,000 cohort)*	B *Seasonal remigration (389 cohort)*	C *Turtles alive at end of year (389 cohort)*	D *Average mortality per year (percentage)*	E *Number of eggs produced (389 cohort)*
0	1,000	389	389	—	116,700
1	15	6	296	24	1,800
2	274	106	234	21	31,800
3	163	63	190	19	18,900
4	147	57	157	17	17,100
5	143	56	134	15	16,800
6	110	43	116	13	12,900
7	103	40	101	13	12,000
8	86	33	88	13	9,900
9	76	30	77	13	9,000
10	68	26	67	13	7,800
11	57	22	58	13	6,600
12	51	20	50	13	6,000
13	44	17	44	13	5,100
14	39	15	38	13	4,500
15	33	13	33	13	3,900
16	30	12	29	13	3,600
17	26	10	25	13	3,000
18	23	9	22	13	2,700
19	20	8	19	13	2,400
20	18	7	17	13	2,100
21	15	6	14	13	1,800
22	13	5	13	13	1,500
23	11	4	11	13	1,200
24	9	3	9	13	900
25	0	0	0	100	0
	2,574	1,000	2,231		300,000

portion of the population in each age class remains constant and the total number of animals in the population does not change. Natural populations rarely maintain stationary age distributions, and the reduction of total nesting females ca 1973 implies the same is true of the Little Cumberland population. However, much can be implied about the behavior of a natural population by comparing its behavior to a model with known properties.

If a stationary age distribution is assumed, the model predicts that neophytes will constitute 39 percent of the seasonal population (1,000/2,574 from Table 1, column A). This prediction agrees with the independent observation that neophytes have accounted for approximately 30 percent to 40 percent of the seasonal nesting population for the last five nesting seasons (Figure 2c) on Little Cumberland Island. A predicted remigration pattern for 389 neophytes (Table 1, column B) satisfies the more general case of 1,000 nesting turtles per season. Hughes (1974) predicted that annual recruitment occurred somewhere between zero and 56 percent for South Africa loggerheads.

Since annual remigrant turtles are seen every year, 2-year remigrants seen every other year (50 percent of these animals are seen each year), and 3-year remigrants seen every third year (33 percent of these animals are seen every year), and so on, a predicted 44 percent of the total Little Cumberland population of nesting females will be on the nesting beach each season. Thus, a seasonal population of 1,000 nesting females would represent a total population of 2,273 adult females. Carr, Carr, and Meylan (1978) provides a general formula for predicting this value.

Based on the remigration pattern predicted for a cohort of 360 neophytes (Table 1, column B), a survivorship table can be generated (Table 1, column C) with associated mortality rates which will be sustained during each year of maturity (Table 1, column D). Mortality, in this sense, means disappearance from the nesting population and not death per se. Actual mortality is only implied. Mortality rates during the first 5 years of maturity have been adjusted to fit the observed remigration probabilities of neophytes (49 percent) and remigrants (70 percent) on Little Cumberland Island.

The Little Cumberland model considers only female turtles; males do not enter the nesting population and are, therefore, lumped with mortality. Adjusting the model to reflect a specific sex ratio (if known) would be a simple task and not significantly affect the model's structure or predictive abilities.

The model predicts the following population attributes:

- Fifty percent of a cohort of neophyte adult females will be gone from the nesting population by the third year of their initial appearance, and 90 percent will be gone after 14 years.
- Nesting turtles observed during a single season represent 44 percent of the existing population. In other words, 56 percent of the total adult female population does not nest in any given year. Little Cumberland nesting loggerheads do not appear in the vicinity of Little Cumberland during their off-nesting years (Bell and Richardson 1978).
- Neophytes are recruited to the existing population at the rate of 39 percent of the seasonal nesting population per year. If total population numbers are stationary, an equivalent number of adult females would be expected to leave the nesting population each year.
- Population turnover occurs every 6 years (2,231/389 = 5.7). In other words, a number of individuals equivalent to the total population size is replaced every 6 years.

Fecundity and Survival of Eggs

Little Cumberland loggerheads lay approximately 2.5 clutches of eggs per turtle per season, and clutches average 120 eggs per clutch (unpublished data). The model predicts that an average Little Cumberland turtle will produce 771 eggs during her lifetime (Table 1, column E). Individual performances vary widely; some turtles appear on the beach but never nest, while others nest repeatedly during a season and over several seasons, accounting individually for several thousand eggs per turtle (Richardson et al. 1978). Hughes (1974) predicts that an average South African loggerhead will lay 4.5 times per season for 4 nesting seasons. This amounts to a lifetime production of 2,052 eggs, given 114 eggs per clutch.

If a population could maintain a stable age distribution, the survival rate of hatchlings reaching maturity would be equal to the number of adults entering the nesting population, divided by the number of hatchlings produced per season. Similarly, the survival rate of eggs becoming mature turtles is equal to the product of the survival rate of eggs on the beach and the survival rate of hatchlings reaching maturity. Hughes (1974) estimated in this manner that no more than 1 or 2 South African loggerhead hatchlings per 1,000 reach maturity after entering the sea, regardless if annual recruitment of nesting females to his population is 10 percent or 50 percent.

The Little Cumberland population model suggests that a seasonal population of 1,000 nesting females would be expected to lay 300,000 eggs during a season, from which 389 females must survive to maturity to satisfy the stationary age distribution of the model. Figure 3 illustrates the relationship between survival of eggs on the beach and the survival to maturity of hatchlings at sea, under this hypothetical situation. If 20 percent of the eggs fail to hatch (optimum hatchery conditions), then 2 hatchlings per 1,000 must survive

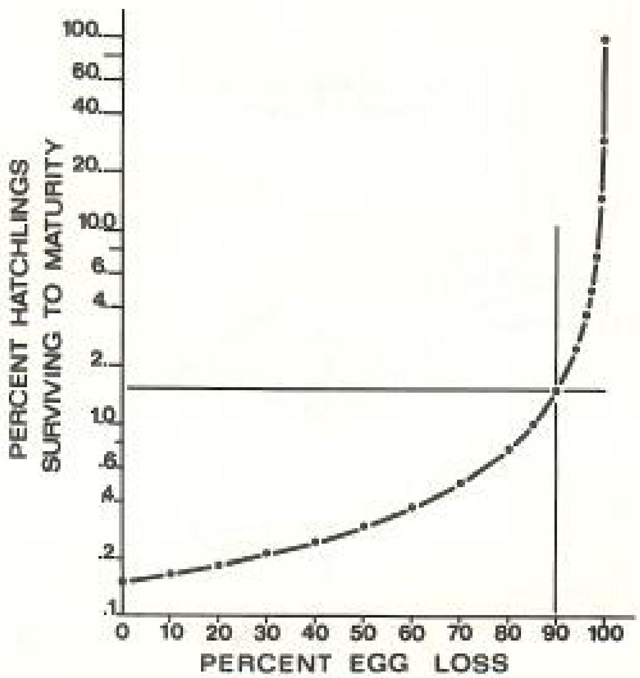

Figure 3. The relation between egg loss and the survival of hatchling to maturity, for a theoretical case where 389 female loggerheads reach sexual maturity per 300,000 eggs laid.

to enter the nesting population as mature females. If 90 percent of the eggs fail to hatch, then 13 per 1,000 of the remaining hatchlings must survive. Clearly, the model suggests that Little Cumberland loggerheads are capable of sustaining considerable variation in egg loss without having to compensate these losses with large variations in hatchling survival rates. However, the actual survival of Little Cumberland hatchlings is not known, so the model cannot yet be used to make statements about sustainable egg loss.

Age to maturity has not been measured for free-ranging Georgia loggerheads, but preliminary estimates from Australia exceed 20 years (Limpus 1979). If mortality of the juveniles is independent of population density and if hatchlings return to their natal beach, then the Little Cumberland population model predicts that the hatchery program (70 percent hatching success; an average 8,000 hatchlings released per season for the last 15 seasons) should ultimately increase recruitment by a factor of 2.3 if previous egg loss was 70 percent, 3.5 if egg loss was 80 percent, and 7.0 if egg loss was 90 percent. If hatchlings, upon reaching maturity, disperse to surrounding nesting beaches, then evidence of recruitment will be more difficult to identify. There has been no evidence to date of increased recruitment to the Little Cumberland population (Figure 2c).

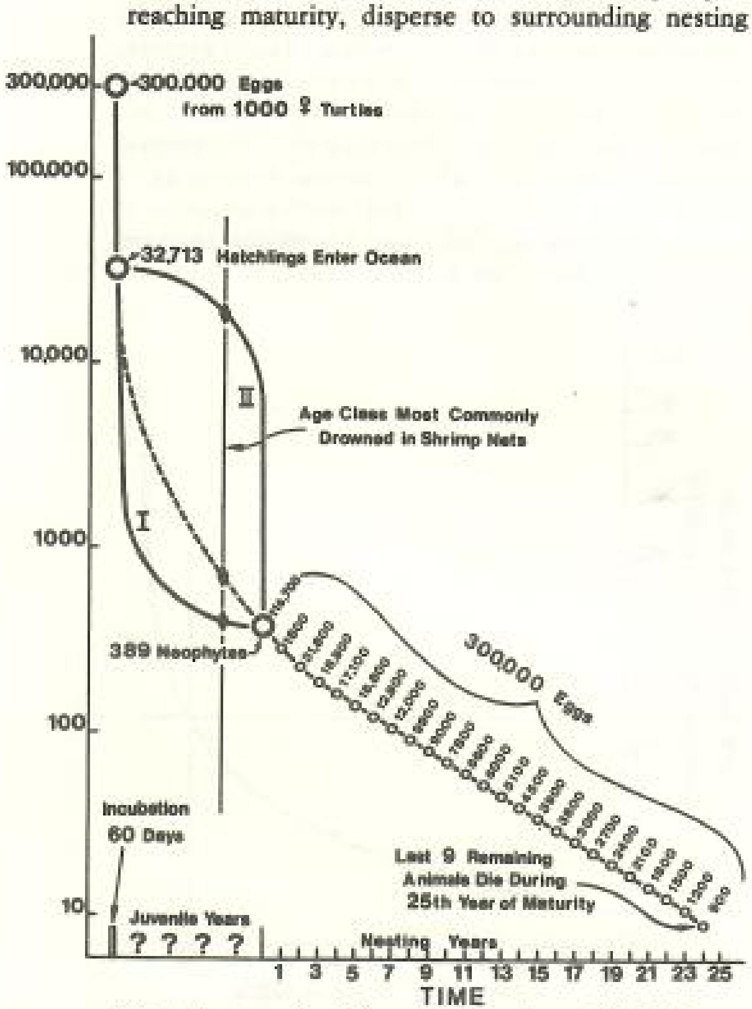

Figure 4. A survivorship curve for a cohort of 300,000 eggs deposited by 1,000 female loggerheads during a single breeding season in Georgia.

Survivorship Curve for Georgia Loggerheads

A survivorship curve provides a graphic interpretation of mortality sustained by a cohort of even-aged organisms through time. Figure 4 depicts the survivorship curve for the Little Cumberland population model. The total number of eggs (300,000) produced during a nesting season by 1,000 female lggerheads (2.5 clutches per turtle; 120 eggs per clutch) is taken as the initial cohort.

An 89 percent loss of eggs on the beach has been arbitrarily chosen since it approximates observed natural mortality (Hopkins et al. 1979). We believe that predation of the eggs on Little Cumberland Island was very high (± 90 percent) for many years prior to the initiation of the hatchery program in 1965 and that the effects of the hatchery on recruitment to the nesting population have yet to be observed because of the many years it apparently takes for wild sea turtles to reach maturity. An 89 percent loss of eggs serves, also, to illustrate a useful attribute of survivorship curves. The vertical axis of the plot (Figure 4) is projected on an exponential scale; absolute vertical distances on the figure are a measure of relative importance. The vertical distance between eggs and hatchlings in the figure is half the vertical distance between hatchlings and neophytes. In relative terms, this means that the loss of 89 percent of the eggs on the beach is only half the magnitude of the loss sustained by hatchlings during the juvenile years at sea. The survivorship curve illustrates the resilient nature of the modeled population to perturbations from egg predation. The similarity of the model to the natural Little Cumberland loggerhead population is suggested.

Little is known about actual survivorship of juvenile loggerheads. Several alternative, theoretical survivorship patterns for the juvenile years are presented in Figure 4. Alternative I illustrates attrition primarily to the very young juveniles, while alternative II illustrates attrition primarily to the older juveniles. The age class most commonly drowned in shrimp nets along the Georgia coast (over-the-curve carapace length 55 to 70 cm) has been arbitrarily located on Figure 4 for illustrative purposes. If alternative I represents the natural population, then shrimping losses would be causing a maximum impact on the nesting population; sustainable losses would be low. If alternative II best represents the real population, then the number of turtles drowned in shrimp nets would probably not have as much effect on population structure; sustainable losses could be higher. Actual survivorship is probably closer to a pattern suggested by the dotted line (Figure 4).

The Little Cumberland model predicts that 389 females from the original cohort of 300,000 eggs will reach sexual maturity and enter the nesting population as neophyte female turtles. These 389 animals must produce 300,000 eggs during their combined lifetimes in order to replace the original cohort. The survivorship curve predicts that 50 percent of the original cohort (300,000 eggs) will be replaced within 3 nesting seasons and that 75 percent will be replaced within 7 nesting seasons. The model clearly illustrates that long-lived adults (10 or more years in the reproductive population) are of reduced ecological importance relative to the combined reproductive potential of the younger members of the population. The last 10 remaining animals are arbitrarily terminated in the survivorship curve during their twenty-fifth year of maturity. At this age, their combined reproductive effort for each additional season survived is less than 0.3 percent of the cohort's total reproductive effort.

Model Simulation

The survivorship curve can be used to simulate changes in population structure for any number of generations, with the help of a computer. The population model will maintain a stationary age distribution for an indefinite number of generations, provided that egg mortality and juvenile mortality combine to produce a recruitment of 389 neophyte nesting females from each 300,000 eggs deposited on the beach. If recruitment is altered, then population numbers will change accordingly. The following examples illustrate the variety of questions (hypothetical conditions) that can be tested with the model. The answers (model predictions) are not meant to imply actual conditions but to provoke discussion of possible population behavioral characteristics.

Figure 5 illustrates the predicted change in seasonal numbers of nesting females if juvenile survival is held at 0.4 percent and egg survival is raised from 30 percent and maintained at 70 percent, which might be expected from the sudden application of a hatchery program. Age to maturity has arbitrarily been set at 15 years, and the introduction of neophytes into the adult nesting population is distributed over a 5-year period around this 15-year maturation date. The effect of increased egg survival is first noticeable on the fourteenth year, particularly the sudden rise in annual recruitment from 39 percent to greater than 50 percent. The population doubles in size by the twenty-second season and doubles again by the thirty-eighth season. Population size grows at a geometrically increasing rate, while recruitment ultimately stabilizes at 48 percent.

Table 2 lists doubling times for selected simulations

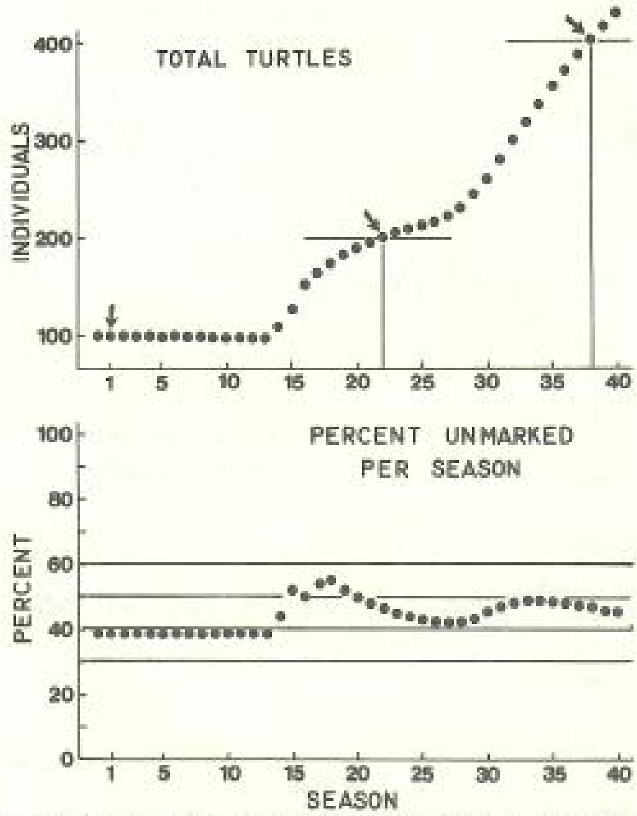

Figure 5. A simulation of loggerhead population behavior through 40 generations. The term "individuals" relates to the number of adult females observed on the nesting beach per season. Conditions are as follows: 70 percent egg survival; 0.4 percent juvenile survival; 15 years for age to maturity.

Table 2. Population doubling times or halving times (−) in years, for selected simulations of the Georgia loggerhead population model

Egg survival	Juvenile survival	Years to maturity	Doubling time in years 1	2	3	4
.30	.004	—	∞	∞	∞	∞
.11	.012	—	∞	∞	∞	∞
.70	.004	10	17	11	11	11
.70	.004	15	22	16	16	16
.70	.004	20	27	21	21	21
.70	.010	15	15	5	10	6
.20	.020	10	12	10	8	9
.00	—	10	12−	5−	4−	4−

of the population model. The results reinforce the conclusions drawn from Figure 3 that very small changes in juvenile survivorship have greatly magnified effects on population growth, while changes in egg survival have less effect. If pre-hatchery conditions on Little Cumberland Island were characterized by 6 percent survival of the eggs and 2 percent survival of the juveniles, then a hatchery program (70 percent survival

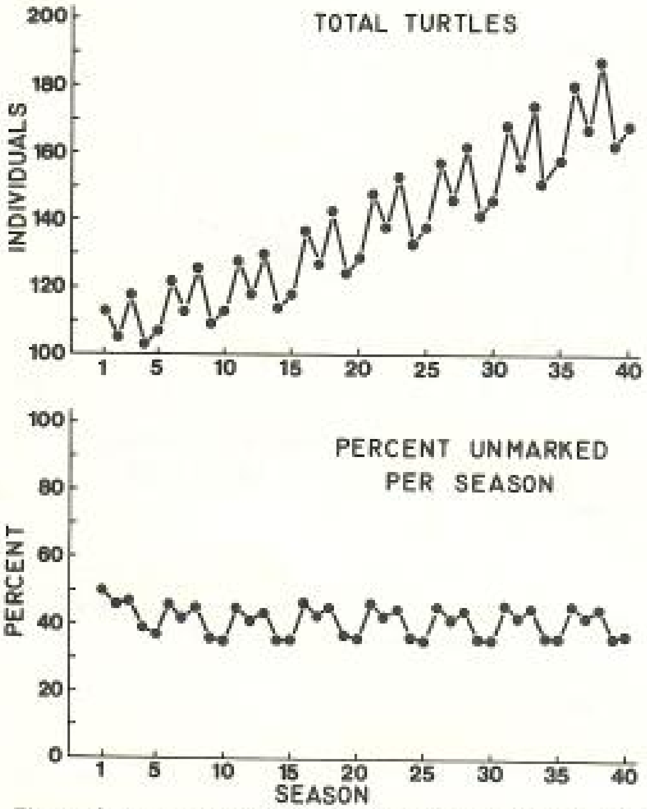

Figure 6. A simulation of loggerhead population behavior through 40 generations. The term "individuals" relates to the number of adult females observed on the nesting beach per season. Conditions are as follows: egg survival on a 5-year cycle (5 percent, 5 percent, 33 percent, 5 percent, 32 percent;) 1 percent juvenile survival; 10 years for age to maturity.

of the eggs) would be expected to exert a dramatic effect on nesting female numbers as soon as the first cohort of juveniles reached maturity. If, on the other hand, juvenile survival were 0.4 percent and age to maturity 15 years, a similar hatchery program would require 22 years for the population to double its original numbers and 16 years for each doubling time thereafter.

Population simulations are also useful for investigating intermittent recruitment into a population such as might occur from periodic predation on the eggs or other natural disasters that might befall eggs and young. In Figure 6, juvenile survival is 1 percent, age to maturity is 10 years, and survival of the eggs shifts on a 5-year cycle (5 percent, 5 percent, 33 percent, 5 percent, 32 percent). The resultant behavior of the model is meant to simulate the observed 2- and 3-year cyclical behavior of numbers of nesting females in natural populations. Note that the predictions fail to simulate observed behavior, corroborating a statement by Hughes (1974) that natural population fluctuations in numbers of nesting females are not logically caused by periodic variations in nesting success and juvenile survival. Specifically, the model is unable to simulate natural changes in numbers of adult females (Figure 2a) by changes in hatchling survivorship, and recruitment to the simulated adult population varies more than is observed in natural populations. A feeding or migratory strategy of the adults is the logical alternative explanation.

A significant fluctuation in the numbers of nesting females can be simulated with intermittent recruitment pulses, if such pulses are large and separated by several years of reduced egg survival, as might occur on a coastal island with periodic dieoffs of natural predators (raccoons). In Figure 7, juvenile survival is 1 percent, age to maturity is 15 years, and egg survival varies over a 10-year cycle (5 percent, 5 percent, 5 percent, 5 percent, 5 percent, 5 percent, 5 percent, 5 percent, 70 percent, 50 percent). A change in the recruitment of adult females of this magnitude would probably be observable in a natural population. An additional observation from this simulation is that total numbers of nesting females are actually increasing through time, even though population numbers exhibit decreasing trends which last for 7 years at a time. A 4-year study of a population such as this could indicate either dramatic increases or catastrophic declines in population numbers, depending on which year the study is initiated. The need for long-term population studies is apparent.

Conclusions

Marine turtles may prove to be unique among wildlife species, in that a management decision by one man may not become apparent in the turtle population until an entire human generation has passed. Present-day changes in population numbers of nesting loggerheads at Cape Romaine National Wildlife Refuge, South Carolina, may be reflecting predator management policies of the 1950s (S. Hopkins personal communication). Little Cumberland Island has maintained an expensive, time consuming hatchery program since 1965, but no measurable effect has yet to appear. The question is what, if any, these efforts and activities have had on population numbers. Predictive simulation models are one way to suggest management and research approaches to populations with unusually long time lags.

Data from the Little Cumberland nesting survey have been used to derive a preliminary population model that simulates long-term population responses to changes in recruitment. The strength or usefulness of the model depends upon the reliability of the data upon which it is built. Some parameters, such as remigration rate, are approximations. Others, particularly age to maturity and juvenile survivorship, are entirely unknown and can only be surmised at the present time. Inspite of its uncertainties, the Little Cumberland model provides predictions that can be tested against real data and focuses attention on needed areas of research. How closely this model approximates the actual Little Cum-

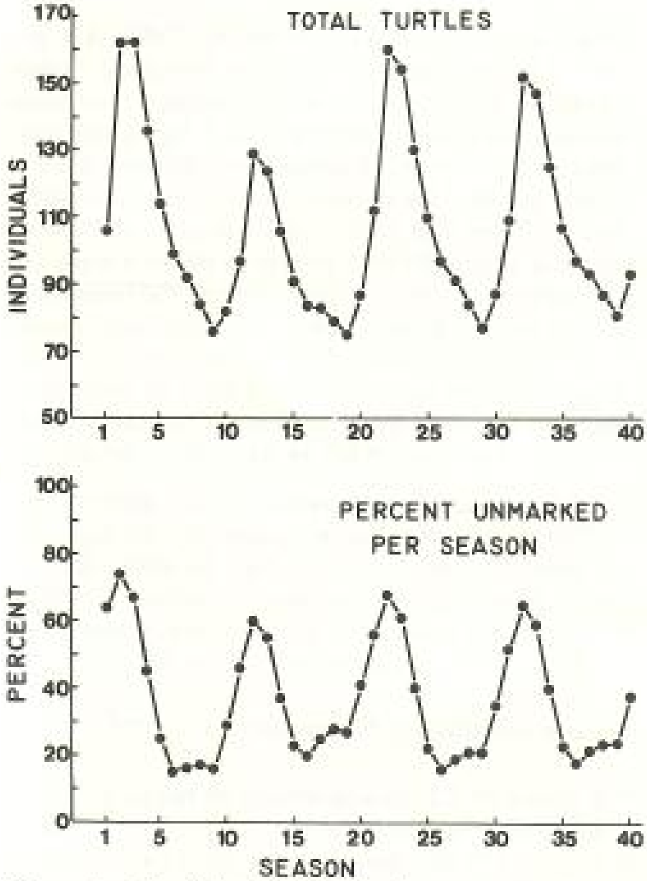

Figure 7. A simulation of loggerhead population behavior through 40 generations. The term "individuals" relates to the number of adult females observed on the nesting beach per season. Conditions are as follows: egg survival on a 10-year cycle (5 percent, 5 percent, 5 percent, 5 percent, 5 percent, 5 percent, 5 percent, 5 percent, 70 percent, 50 percent); 1 percent juvenile survival; 15 years for age to maturity.

berland population, or other sea turtle populations, remains to be seen.

Every effort should be made to derive life table information from existing, long-term population studies. The results could revolutionize the application of population models as tools for the management and protection of sea turtle populations throughout the world. Population parameters, particularly those which have been approximated, must be discussed and challenged by the various groups involved in long-term population studies. Only in this way will there be developed a sense of confidence concerning population models and their predictions.

Most population data have been collected from nesting female turtles and hatchlings. These data will become increasingly reliable with the continuing development of persistent flipper tags. In contrast, juvenile loggerheads, with carapace lengths of 50 to 90 cm, represent a critical life history stage about which almost nothing is known. These young animals represent the majority of carcasses found dead on U.S. beaches; most of them are presumed drowned in trawl nets. Population studies of juveniles, though requiring expensive boat time, would be worth the investment in terms of increased management expertise and understanding. Growth rates, age to maturity, and a knowledge of juvenile population stocks are critical unknowns, blocking all present attempts to model population behavior over multiple generations with realism. Quantitative studies of juvenile populations should receive the highest priority, if realistic population models are to be realized in the near future.

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Appendix I. Procedures for calculating remigration, survivorship, and fecundity values appearing in Table 1 and Figure 4

1. A year of reproductive maturity runs from nesting season to nesting season. A neophyte, by definition, nests at the beginning of her first year of maturity.

2. A cohort of neophytes (Table A1) will remigrate according to the following intervals and frequencies: 1-year (3 percent), 2-year (56 percent), 3-year (31 percent), 4-year (7 percent), 5-year (3 percent). Only 49 percent of neophytes will remigrate; predicted numbers of remigrating neophytes are reduced to 49 percent of maximum values. Seventy percent of remigrants will remigrate again; predicted numbers of remigrating remigrants are reduced to 70 percent of maximum values. Figures in Table A1 are summed by rows to generate column A, Table 1.

3. Column B, Table 1, is derived by multiplying values in column A by 38.9 percent, the predicted annual recruitment rate:

$$\text{Recruitment rate} = \frac{1{,}000}{2{,}574}$$

= 38.9 percent (from column A, Table 1).

There will be 389 neophytes in a seasonal nesting population of 1,000 adult female loggerheads.

4. Survivorship (column C, Table 1) is calculated from Table A2. It is predicted from observed remigration intervals and frequencies that 44 percent of the total population of adult nesting females will nest each season.

Remigration interval	*Remigration frequency*		*Proportion observed annually*		*Annual nesters*
1-year	3%	×	1.00	=	3%
2-year	56%	×	.50	=	28%
3-year	31%	×	.33	=	10%
4-year	7%	×	.25	=	2%
5-year	3%	×	.20	=	1%
			Total annual nesters	=	44%

Total population values (column A′, Table A2) are derived by dividing seasonal values (column A, Table A2) by 44 percent. The percent mortality (loss from reproductive population) experienced during each year (column A″, Table A2) is derived by comparing changes in total numbers for all pairs of consecutive years (column A′, Table A2). Sixteen years of predicted annual mortality were arbitrarily chosen to derive a mean annual survival rate of 13 percent. Due to the constraints of observed remigration intervals and frequencies placed on a theoretical cohort of neophytes, the model appears to require approximately 7 years to stabilize; it begins to lose stability after 23 years because of small numbers of individuals left in the original cohort.

5. Annual mortality, averaged and adjusted (column D, Table 1), is taken to be 13 percent, the mean for 16 years of column A″ (Table A2). To reflect the observed lower remigration rate (49 percent) of neophytes, annual mortality is increased during the first 5 years, according to the following formula:

$$\text{Annual mortality} = 13 \text{ percent } (1.13^{6\text{-years of maturity}}).$$

The choice of 1.13 as a multiplier of annual mortality is arbitrary. The objective is to reduce in numbers a cohort of 389 neophytes during the first 5 years of reproductive maturity, such that total surviving individuals approximate numbers of individuals in column A (Table 1) on a year by year basis.

6. Survivorship within a cohort of 389 neophytes (column C, Table 1) is generated by applying appropriate annual mortality rates (column D, Table 1). To satisfy the model, seasonal nesting totals (column B, Table 1) should be approximately 44 percent of total population size (column C, Table 1).

7. A Little Cumberland Island turtle lays an average of 2.5 clutches per season and 120 eggs per clutch. Fecundity (column E, Table 1) is derived by multiplying seasonal nesting totals (column B, Table 1) by 300 eggs per turtle.

Table A1. Iterative procedure for predicting remigration of a cohort of 1,000 neophytes

Years	*Iterations*							*Total individuals*
0	1,000							1,000
1		15[a]						15
2		274[a]						274
3		152[a]	6	5				163
4		34[a]	3	107	3			147
5		15[a]	1	60	64	3		143
6			—	14	36	57	3	110
7	2			5	8	32	56	103
8	43	2			3	7	31	86
9	24	40	2			3	7	76
10	6	23	34	2			3	68
11	2	5	19	30	1			57
12		2	4	17	27	1		51
13			2	4	15	22	1	44
14	1			2	3	13	20	39
15	17	1			1	3	11	33
16	10	15	1			1	3	30
17	2	9	13	1			1	26
18	1	2	7	12	1			23
19		1	2	7	10	—		20
20			1	2	6	9	—	18
21	—			1	1	5	8	15
22	7	—			1	1	4	13
23	4	6	—			—	1	11
24	1	3	5	—			—	9
25	—	1	3	4	—			0
							Predicted population total	2574

Note: Remigration figures reduced to 49 percent of maximum for neophyte remigrants (a) and 70 percent of maximum for all other remigrants.

Table A2. Procedure for calculating survivorship of a cohort of 389 individuals

Years of reproductive maturity	A *Seasonal nesting population*	A′ *Total population*	A″ *Annual mortality during year (percentage)*	D *Annual mortality averaged and adjusted (percentage)*	C *Numbers of survivors of 389 cohort*
0	1000				389
1	15			24	296
2	274			21	234
3	163	370		19	190
4	147	334		17	157
5	143	325		15	134
6	110	250		13	116
7	103	234		13	101
8	86	195	17	13	88
9	76	173	11	13	77
10	68	155	10	13	67

Table A2. Procedure for calculating survivorship of a cohort of 389 individuals (cont.)

Years of reproductive maturity	*A* *Seasonal nesting population*	*A′* *Total population*	*A″* *Annual mortality during year (percentage)*	*D* *Annual mortality averaged and adjusted*	*C* *Numbers of survivors of 389 cohort*
11	57	130	16	13	58
12	51	116	11	13	50
13	44	100	14	13	44
14	39	89	11	13	38
15	33	75	16	13	33
16	30	68	9	13	29
17	26	59	13	13	25
18	23	52	12	13	22
19	20	45	13	13	19
20	18	41	9	13	17
21	15	34	17	13	14
22	13	30	12	13	13
23	11	25	17	13	11
24	9	20		13	9
25	0	0		100	0

Note: By definition, all remaining individuals die during the twenty-fifth year of maturity.

Status of Sea Turtle Populations

Historical Review

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Historical Review of the Decline of the Green Turtle and the Hawksbill

Few wild species of vertebrates have played a more persistently important role in the European exploration and settlement of the western hemisphere and parts of Asia than has the green turtle, *Chelonia mydas*. Found in all tropical and temperate seas (between 35° N and S latitudes), the green turtle was readily exploited to supply protein (meat, calipee, calipash, eggs) to early explorers and coastal settlers (Carr 1956). It was netted or harpooned on the grass and algae-covered shoals, submerged banks, and in coastal estuaries, and females were captured in large numbers when they came ashore in nesting aggregations. This behavioral phenomenon of gathering together in hundreds or thousands to nest made the green turtle a ready source of fresh meat before mechanical refrigeration was invented. Turned on its back on the beach or in the hold of a boat, the turtle could be kept alive for weeks on end, if kept in the shade away from the heat of the sun (Carr 1956). The nesting aggregations also gave the mistaken impression the marine turtle was a superabundant, inexhaustible source of meat.

Quite the contrary, when those same numbers of turtles are dispersed over the entire range of the population, spread over the migratory routes, the turtle grass feeding flats, and across the shallow estuaries where green turtles grow to maturity, it soon becomes apparent that this species is not so abundant (Ross 1978). Thousands of marine species are more plentiful. Under the pressure of systematic commercial exploitation, a number of populations have become extinct, and most of those remaining are depleted and in danger of disappearing.

The Green Turtle

To understand historically what happened to the green turtle in most parts of the world, it is necessary to examine in detail what happened to 1 or 2 populations.

Possibly the largest green turtle rookery that ever existed was located in the Cayman Islands, West Indies.

One of the first accounts of this rookery is found in the narrative of Christopher Columbus's fourth and final voyage to America. On 10 May 1503, while sailing from Panama to Hispaniola, Columbus's ships came, ". . . in sight of two very small and low islands, full of tortoises, as was all the sea about, insomuch that they look'd like little rocks, for which reason those islands were called Tortugas . . ." (Lewis 1940; Carr 1956). It is interesting to note the green turtles were on the islands during the daytime, a phenomenon that occurs today only in the western Hawaiian Islands.

Spanish, French, and English ships sporadically began to visit the renamed Cayman Islands to capture turtles, but it was not until the mid-1600s that the rookery was systematically plundered. In 1655, the British colony in Jamaica needed meat, so the admiral dispatched one of his ships to the Caymans to acquire turtles (Long 1774; Lewis 1940). From that date on, the rookery was under constant pressure as the British fleet was victualled with Cayman turtles, and Jamaica was supplied with fresh meat and eggs. The laying season, from May through September, and the migratory routes used by the multitude of turtles to reach the island were well known to sailors. It is reported the number of migrants was so great that when,

"The greater part of them emigrate from the gulph of Honduras . . . it is affirmed, that vessels, which have lost their latitude in hazy weather, have steered entirely by the noise which these creatures make in swimming, to attain the Cayman isles . . . In these annual peregrinations across the ocean they resemble . . . herring shoals . . . Thus the inhabitants of all these islands are, by the gracious dispensation of the Almighty, benefited in their turn; so that, when the fruits of the earth are deficient, an ample sustenance may still be drawn from this never failing resource of turtle, or their eggs, conducted annually as it were into their very hands . . ." (Long 1774).

By 1688, a total of 40 sloops from Jamaica were engaged full time, year-round in bringing turtles from the Caymans to Jamaica (Lewis 1940). The turtles were turned on the beach during the summer nesting season, and during the rest of the year they were captured among the shoals and cays along Cuba's south shore. One of these sloops could be filled with 30 to 50 nesting females in as little as a single night, but it usually took 6 weeks if the turtles had to be pursued to the feeding grounds off Cuba. This fleet of turtlers returned upwards of 13,000 turtles a year to Jamaica.

By 1711, turtles were becoming sufficiently scarce that a law was enacted prohibiting the collecting of turtle eggs on any island belonging to Jamaica. Although the Cayman Islands were under Jamaican jurisdiction, the law was never enforced there or for Cayman eggs returned to Jamaica (Long 1774). In 1730, green turtles were reported to supply the principal meat eaten in Jamaica (Catesby 1731–43). Forty sloops were still engaged in supplying the Jamaica market with turtles, and permanent settlers on the Caymans made their living by turtling.

Green turtles were in danger of becoming extinct in the Cayman Islands by the late 1700s. Only a few nested there each year (Lewis 1940; Carr 1952), rather than the huge aggregations that formerly crawled ashore night and day during the summer. Most turtles were captured among Cuba's southern cays. The fishery supported only 8 or 9 boats that carried the catch to Jamaica.

By 1840, the Cayman Island turtles were so near extinction the islanders were forced to sail to the Miskito Cays off Nicaragua to make their catch (Lewis 1940). The Cayman nesting population was extinct by 1900. Only immature green turtles were found feeding in the shallow water around the islands. The Cayman turtle fishery depended entirely on greens brought from the Nicaraguan coast, from which the vessels seldom returned without a full catch. The Cayman fleet consisted of 12 to 17 schooners in the 1940s, each of which could hold approximately 200 turtles (Rebel 1974). The fleet produced an annual catch of 2,000 to 3,000 Nicaraguan green turtles, more of it exported to the United States than to Jamaica.

To supply newly constructed abattoirs and freezing plants in Bluefields and Corn Island, Nicaragua began large-scale commercial exploitation of green turtles in 1970. An average of 10,000 turtles were processed in these plants each year, and the Miskito Cays turtle population declined drastically, as documented in the survival of females returning to its Tortuguero, Costa Rica, rookery (Bjorndal 1980; see also Nietschmann, this volume).

It took just over a hundred years from the time the Cayman Island rookery first came under systematic, wholesale exploitation in the 1650s until it was destroyed and no longer significant as a commercial source of turtles in the late 1700s. It took another century to kill the few remaining females that matured and straggled ashore to lay eggs, but by 1900, green turtle nesting on the Caymans was a thing of the past. As the population disappeared, the fishery moved first to the coast of Cuba and then to Nicaragua, where it exploited and endangered another population which has its rookery in Costa Rica.

Similar depletion and extinction has occurred wherever commercial exploitation of green turtles replaced a subsistence take, or where turtles were exploited for an international market (IUCN 1975; Ross 1978).

In the early 1800s, the Halifax and Indian river estuaries on the east coast of Florida, United States, contained many green turtles in spring and summer. The population supported a commercial turtle fishery (Audubon 1926; Carr and Ingle 1959). In 1886, 1 fisherman landed 2,500 greens using 8 nets (Wilcox 1896). Only 738 turtles were landed in 1890 despite the 168 nets attended by 24 fishermen. In 1895, 519 turtles were landed, and by 1900 the Halifax-Indian river fishery was finished for lack of turtles (Rebel 1974).

In Bermuda, green turtles were caught in nets, harpooned, and captured when they came ashore to nest. By 1620 they had become sufficiently rare for the Bermuda assembly to pass an act prohibiting the killing of turtles less than 18 inches (45.7 cm) in width or length (Garman 1884; Carr 1952, 1967; Rebel 1974). The turtle fishing continued and the rookery aggregations became extinct, but two boats were still able to capture 40 turtles a day (Garman 1884). Fifty years later, no turtles at all nested in Bermuda and only 20 to 60 immature turtles were netted annually (Rebel 1974). In 1970, 25 immature turtles were captured.

Similarly, nesting populations in the Dry Tortugas, Florida, were extirpated within a hundred years of the initiation of commercial exploitation. Other populations have been severely depleted or have become endangered.

In Sarawak, Malaysia, the green rookeries on Talang Talang Besar, Talang Talang Kechil, and Satang islands have long been exploited for their eggs by the local Muslims, although the adult turtles have not been systematically killed (Harrisson 1962, 1967). Government records from egg collecting leases show a steady decline from the 1930s when more than 2,000,000 eggs were collected each year until the mid-1960s when only one-tenth that number was being laid (Figure 1). During the period of Japanese occupation, 1941 to 1945, adult turtles were eaten and Talang Talang Kechil was used as a bombing target, but the decline cannot be attributed solely to cause-and-effect during this 5-year period. Throughout the history of egg exploitation on the Sarawak turtle islands, virtually 100 percent of the eggs have been collected. During at least the 1960s and 1970s, a tiny fraction of the eggs (less than 1 percent) has been hatched and the hatchlings released in an attempt to restock the resource (Chin 1970, 1975). This token effort has been insufficient to stem the continuing decline, for during the 1970s the number of eggs laid has continued to decrease and has never exceeded 300,000 a year (de Silva, this volume). It is another example of commercial exploitation endangering a green turtle population, and in less than a hundred years.

Declines of populations can be even more dramatic under some circumstances, as demonstrated by the recent commercial exploitation of the green turtles in the northern end of the Gulf of California (Felger, Cliffton, and Regal 1976). Prior to 1970 that population had been exploited primarily by the Seri Indians, who harpooned turtles hibernating on the bottom. These adults were taken "as needed" and accounted for an

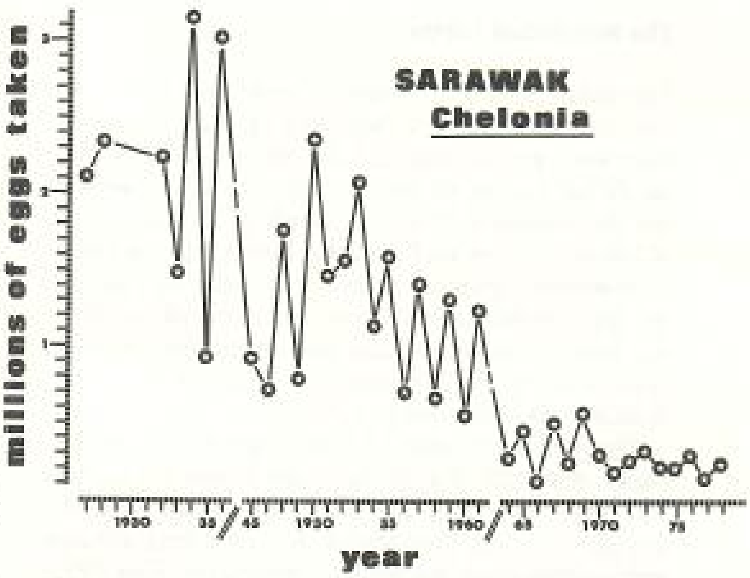

Figure 1. Decline in Sarawak *Chelonia mydas* population as reflected in the numbers of eggs collected for sale each year (Chin 1969, 1970, 1975; de Silva 1979; Harrisson 1962, 1967).

estimated 25 percent of the animal protein in the Seri diet. Then Mexican skindivers accidentally discovered the hibernating turtles in the winter of 1972–73 and immediately began scouring the bottom for all the turtles they could find. During the 1974–75 season, divers were averaging 5 turtles/hr of diving time. Five boats were capturing 80 turtles a week. By 1978, the winter dormant population was already so depleted as to be endangered (Felger and Cliffton, personal communication, 1978).

Most green turtle populations in the Atlantic Ocean, Mediterranean Sea, Indian Ocean, and Pacific Ocean are depleted or endangered as a result of direct exploitation or incidental drowning in trawl nets (IUCN 1975). The only populations not now declining, and which seem not to be threatened with extinction, are those that nest on Europa, Tromelin, and Glorious Isles in the Mozambique Channel; and on Raine Island, Australia. The Surinam population may also be safe, but recent increases in the numbers of shrimp trawlers operating in those waters will increase losses due to incidental drownings and may threaten the turtles, as might the present exploitation of the rookery for eggs.

While green turtles and their eggs are hunted primarily for human consumption, in the last 25 years the adults have come under increasing exploitation for leather (though not to the same extent as olive ridleys, *Lepidochelys olivacea*). The major international markets for meat and soupstock are the Federal Republic of Germany, the United Kingdom, and Japan (Mack, Duplaix, and Wells, this volume). The major consumers of leather are France, Italy, and Japan.

The Hawksbill Turtle

Hawksbill turtles, *Eretmochelys imbricata,* have been variously exploited for thousands of years as one culture after another coveted the horny scutes of their shells for making tortoiseshell jewelry and objects of art (Deraniyagala 1939; Holbrook 1842; Carr 1952). While this tortoiseshell trade has been the prime object of hawksbill exploitation, the species also is hunted for its eggs, leather, and for immature specimens which are stuffed, lacquered, and sold to tourists. In some regions the turtles are eaten, but in others their meat is poisonous (Deraniyagala 1939; Carr, this volume).

The hawksbill turtle is found in all tropical seas between about 30° N and S latitudes, where the water is less than 16-m deep and reefs, shoals, and estuaries are present. The hawksbill is less of a long-distance migrant than other species of marine turtles (Carr 1952; Carr, Hirth, and Ogren 1966; Pritchard 1979). Most hawksbill populations tend not to concentrate their nesting efforts into a few localized rookeries. Instead, nests are dispersed along many kilometers of undisturbed beach, including rookeries of other species of sea turtles. This dispersed nesting habit probably has saved many populations from extinction, since turtle fishermen largely have been unable to concentrate their efforts on rookery aggregations. Instead, they have been forced to intercept the few nesters they could find and to net or harpoon the rest of their catch on the feeding grounds. At the same time, the lack of rookery concentrations has hampered efforts to accurately document the conservation status of hawksbill populations. Population declines are not immediately reflected in fewer females returning to one or two beaches where their numbers can be counted. Frequently one of the first signs of overexploitation is a reduction in the numbers of adults, or even their elimination, leaving a population consisting of immature turtles (Carr 1952).

Government records of tortoiseshell imports and exports may reveal declines in local populations (Japanese Tortoise Shell Association 1978; Mack, Duplaix, and Wells, this volume), but often they do not do so. Turtle fishermen may be catching fewer adults, but supplementing their catch with more juvenile turtles. Government statistics rarely indicate the numbers of hawksbills taken, only the weight or value of scutes. Turtlers may also be traveling to new or more distant fishing areas to fill their catch, or staying away longer to capture the same number of turtles as in previous years (De Celis, this volume; Frazier, this volume). When these things happen, government records of the amount of tortoiseshell traded may remain relatively unchanged for years, or even increase temporarily, despite depletion of local turtle stocks. To complicate things further, government statistics often do not distinguish between raw scutes and worked shell products (Mack, Duplaix, and Wells, this volume).

During the 1930s and 1940s, hawksbills were given a temporary reprieve, especially in the Caribbean, as plastics replaced many of the utilitarian uses of tortoiseshell (Carr 1952; Carr, Hirth, and Ogren 1966; Rebel 1974). Eyeglass frames, pocket combs, and the backs of hand mirrors are seldom fabricated from genuine tortoiseshell even today, but the use of hawksbill shell for the manufacture of luxury items, jewelry, and art objects, enjoyed a resurgence in the 1950s that is continuing to the present. Of even greater concern is an enormous increase in volume of raw and worked tortoiseshell traded in the last 2 or 3 years (Mack, Duplaix, and Wells 1979).

Most populations of hawksbills are depleted or endangered (I.U.C.N. 1975). Small, but relatively dense rookeries (unusual for the species) exist on Cousin Island, Seychelles; Aziz Island, People's Republic of Yemen; Masirah Island, Oman; Shitvar and Lavan islands, Iran; in the Suakin Archipelago, Sudan; Nangka and Belitung islands, Indonesia; and on the islands of the Torres Straits, Australia. What may well have been the largest hawksbill rookery in the world, on Chiriqui beach, Panama, has been severely depleted as a result of commercial exploitation.

Tortoiseshell remains a much sought-after commodity, and hawksbill populations are under heavier exploitation pressure than ever before. Kilogram for kilogram, tortoiseshell is more valuable today than elephant ivory, and the last 5 years has seen the volume of the international trade in scutes increase dramatically (Mack, Duplaix, and Wells, this volume). For example, Indonesian exports, after increasing from less than 10,000 kg a year between 1971 and 1977, jumped to 219,585 kg in 1978 alone (Mack, Duplaix, and Wells, this volume). Exports from India, the Philippines, and Thailand also increased, as they did from a number of the Latin American countries. Imports into Taiwan soared from less than 3,000 kg in 1974 to over 128,000 kg in 1978. Japan's imports were generally less than 40,000 kg prior to 1969, then fluctuated between 40,000 and 92,000 kg a year from 1970 and 1973, and have since been about 42,000 to 47,000 kg a year (Mack, Duplaix, and Wells, this volume). Japan and Taiwan are the 2 largest consumer-importers, accounting for 75 percent to 80 percent of world production each year.

Simple economics suggests the tortoiseshell trade will yield reluctantly, if at all, to conservation efforts that would curtail or eliminate it. The rate of increase in the price of tortoiseshell makes it a good investment. However, cultural values may transcend economic considerations in some countries. For example, in Japan, tortoiseshell is used primarily in the artisanal production of hairpins, jewelry, and art objects that have great significance in Japanese cultural tradition (Japanese Tortoise Shell Association 1978). As a consequence, Japan can be expected to continue importing tortoiseshell regardless of any consideration of the need to conserve the wild resource.

During the 1973 conference in Washington, D.C., that drafted the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), considerable debate surrounded the placement of various species on Appendix I. Such placement prohibits commercial trade, allowing only exchange of specimens for scientific or conservation purposes (King 1974). Not all delegations initially agreed on whether or not particular species were being threatened by commercial trade, and that was the subject of the debate. However, negotiations led to unanimous agreement on the inclusion or deletion of some species, and compromises on many. The only major dispute which reached the point of being recorded as a formal objection in the summary record of the conference was the placement of the hawksbill, *Eretmochelys imbricata,* in Appendix I.

During the discussion of this species, Japan argued against any curtailment of trade. After the assembled delegations had examined the evidence, they seemed to unanimously agree that commercial trade in tortoiseshell should be eliminated. Rather than stand alone against the majority, Japan did not speak out further. Instead, a representative of the Japanese delegation persuaded Panama (a major Latin American exporter of tortoiseshell to Japan) to lodge the objection (personal observation). Until approached by the Japanese delegation, Panama had supported protection for the hawksbill. Panama ratified the CITES in 1978 without reservations. During 1979, it was continuing to export hawksbill scutes. When Japan joins the CITES, it almost certainly will lodge reservations (i.e., announcing nonacceptance of certain restrictions) on the hawksbill and other sea turtles and will continue to export these species regardless of what happens to the wild populations.[1] Green turtles[2] and the other species of sea turtle are also protected by being on Appendix I of the CITES. To date, over 50 nations have joined the CITES. Two of those nations—France and Italy—have taken reservations on sea turtles and are importing all the sea turtle leather and tortoiseshell they can buy. It is clear they are more interested in protecting their commercial interests than in conserving wild species. This is particularly distressing since no definite evidence exists that any wild populations of green or hawksbill or other species of sea turtle have ever been returned to abundance after depletion through overexploitation. The historical trend points toward depletion, endangerment, and extinction. If consuming nations are unwilling to cooperate with their CITES partners and the producing nations in avoiding threat to wild species resulting from uncontrolled exploitation, there seems little hope of conserving marine turtles for this and future generations of man.

1. Japan ratified the CITES in May 1980 and took reservations on the hawksbill, green turtle, olive ridley turtle, estuarine crocodile, 3 species of monitor lizard, musk deer, and fin whale.

2. Because green turtles are still abundant in Australia, where exploitation for international commerce is not occurring, that population of green turtle was not on Appendix I of the CITES. It was on Appendix II, which requires export permits from Australia before importation into another CITES nation is allowed. In 1981, all populations of green turtles were placed on Appendix I at the request of Australia when it was discovered Mexico was exporting greens with false documentation they claimed they originated in Australia.

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Historical Decline of Loggerhead, Ridley, and Leatherback Sea Turtles

ABSTRACT

The distribution of nesting populations of *Caretta caretta*, *Lepidochelys olivacea* and *Dermochelys coriacea* is reviewed. Populations that are known to have declined in numbers and populations that appear to be threatened are identified.

Each species has a large proportion of the individuals concentrated in a very few nesting populations. The total number of populations and the number of large populations is small.

A major identifiable cause of population decline is excessive commercial exploitation. Commercial exploitation must be reduced while management programs are being devised.

Introduction

This review is difficult to present because there is very little historical information on populations of these species with which present populations can be compared. A further problem is the taxonomic confusion between *Caretta* and *Lepidochelys* which, until recently, led to many misidentifications. (Nishimura 1967 for discussion) Also, even rough estimates of population size are lacking from the literature; many early reports only record presence and absence data. Another problem is the large amount of useful recent information that is hidden away in obscure unpublished reports. I would therefore urge all turtle researchers to publish their reports and include estimates, no matter how rough, of population sizes.

The Loggerhead (*Caretta caretta*)

This species is an omnivorous turtle which is often reported in temperate waters (Brongersma 1971). Juveniles and subadults disperse into major oceanic circulations although Hughes (1974b) suggests that the availability of benthic feeding areas may limit recruitment. Loggerheads often show a less rigid site fixity

Table 1. *Caretta caretta* nesting sites

Location	*Approximate number of females/yr*	*Reference*
Southeast U.S.A.[a]	6000–	
Cape Sable	25,000[b]	Lund 1974
Merrit Is., Hutchinson Is., Jupiter, Cumberland Is., Cape Romain		Carr & Carr 1978
Cuba	—	Bacon 1973
Honduras	—	Bacon 1973
Quintana Roo	500[b]	Marquez 1976
Santa Marta, Colombia	400	Kaufman 1973
Turkey	—	Carr 1952
Cyprus	—	
Cape Verde Islands	—	Schleich 1979
Almadies, Senegal	—	Cadenat 1949
Tongaland, South Africa	500[b]	Hughes 1974a, b
Paradise Island, Mozambique	300	Hughes 1974a, b
Fort Dauphin, Malagasy Republic	300	Hughes 1974a, b
Masirah Island, Oman	30,000	Ross 1979
Honshu, Japan	—	Nishimura 1967
Kyushu, Japan		Nishimura 1967
Mon Repos, Australia	200?[b]	Bustard and Limpus 1971
Wreck Island, Australia	1000	Limpus, personal communication
Capricorn and Bunker Islands, Australia	1000[b]	Bustard 1972

— No data.

a. Loggerheads nest on many small beaches along this coast, only larger sites listed.

b. Beaches with some protection.

than *Chelonia* and some nesting aggregations are strung out over kilometers of coastline (Carr and Carr 1972).

Table 1 shows nesting sites of *Caretta*. The southeastern United States location consists of numerous small nesting sites; only the more prominent are listed. A complete listing is found in Dodd (1978). Most nesting populations are of the order of 1,000 females per year. Exceptions are the unusually large population in Oman (30,000) and the populations in the Caribbean and Mediterranean, most of which are reduced to 100 females or less. Only nesting locations in the United States, Australia, Mexico, and South Africa are protected.

Loggerhead populations throughout the world are under severe pressure from local exploitation. Loggerhead meat is a favored item in the Mediterranean, Africa, and South America. Other pressures come from the taking of eggs and accidental capture in commercial shrimp trawls.

Populations which are known to have declined are Honduras (Parsons 1962; Bacon 1973), the Mexican populations of Quintana Roo (Márquez 1976), and the nesting population of Colombia (Kaufman 1973; Ramirez 1976).

Numerous other populations are subject to heavy predation but there are no comparative data to assess the effect. In the southeastern United States accidental catch in shrimp trawlers is estimated to remove 4,000 to 12,000 turtles a year from the population (Ross, unpublished). Most mortality is of subadult turtles. There has been considerable loss of nesting habitat to coastal development, but the remaining populations are protected by the Endangered Species Act. In Cuba, loggerheads are caught at sea for commercial use although nesting turtles are protected. Recent evaluations of the nesting populations suggest they are declining (Abascal 1971). In the Mediterranean the remaining populations are small and subject to disturbance and exploitation. Brongersma (1971) reported an annual catch of 1,000/yr at the Azores, mostly subadults that may be derived from the U.S. population. Similar levels of exploitation are reported from Cape Verde Islands (Schleich 1979), and the eggs of the small nesting population there are often taken.

Capture of loggerheads for food is extensive in West Africa (Carr 1952) and Mozambique (Hughes 1971, 1972). The situation in Japan is unclear, but Nowak (1974) reports extensive exploitation and disturbance are causing the population to decline. Nishimura (1967) reports extensive killing of females and taking of eggs.

Although *Caretta* remains abundant, it is clearly under pressure from local exploitation and accidental capture. Those populations which are undisturbed (for example, Masirah) reach large size. The small size of most populations may well be a result of continual pressure.

Populations afforded protection have tended to increase, for example, Tongaland (Hughes 1974a), Cumberland Island (Richardson, Richardson, and Dix 1978). This may indicate a more resilient life history strategy than other sea turtles, and some recent results confirm this. Hughes (1976) suggests many loggerheads nest only once, and annual recruitment is high. Richardson et al. (1978) have similar data from Cumberland Island, United States. More research is urgently needed to establish life history parameters of all sea turtles.

The anomalous absence of nesting grounds of *Caretta* in the central and western Pacific is unexplained. Hirth (1971a) reported loggerheads from Tonga and Fiji, but nesting is not reported.

The Olive Ridley, (*Lepidochelys olivacea*)

The olive ridley is the most extreme example of the strategy of aggregated nesting. This species nests in huge concentrations on a few days each year at a very restricted number of locations. For example, it is likely that the nesting grounds in Pacific Mexico and Central America support all the ridley turtles in the entire East Pacific. The biology of this species is reviewed by Márquez, Villanueva, and Peñaflores (1976).

Sixteen large nesting grounds of the olive ridley are listed in Table 2. Smaller nesting populations of a few hundred individuals are reported from Venezuela (Nowak 1974), Senegal (Miagret 1977), Angola (Nowak 1974), Oman (Ross 1979), Malaya (Moll, personal communication) and New Britain (Pritchard, personal communication). The population estimates shown indicate the nesting populations before recent extensive exploitation and in many cases are greatly reduced at present. Several populations are known to have virtually collapsed in recent years and are cause of great concern. Three populations in Mexico—Tlacoyunque, Mismaloya and Chacahua—have been greatly reduced in numbers since 1977 (Felger and Cliffton 1977; Anonymous 1979). A fourth, Escobilla, is reported to be currently collapsing (Anonymous, 1979). However, good estimates of population size are not available. The apparent cause of decline is exploitation of nesting female ridleys for an industrial commerce in turtle leather and turtle meat. Contributing factors to the disastrous effect of this exploitation appear to be an inadequate population model from which capture quotas are calculated and the disproportionate influence of the businessmen who control the turtle export trade.

Recent evidence from tag returns shows that these populations disperse southward to the coasts of Panama and Ecuador. Green and Ortiz Crespo (this volume) reports very heavy exploitation of these migrating ridleys in Ecuador. There is no rational program or control of this fishery. These populations are therefore being overexploited throughout their range and their future is in jeopardy.

A population of ridleys in Orissa province, India, estimated at 150,000 (Anonymous 1976) was reported not to be present in 1977 following heavy exploitation for food (Davis, Bedi, and Oza 1978). However, Kar and Bhaskar (this volume) reports that 150,000 females nested in 1979. On the west coast of India the large diffuse nesting population of ridleys is subject to heavy predation of eggs and many thousands of nesting females are killed (Whitaker 1977; Valliappan and Whitaker, 1975).

Ridleys are caught in substantial numbers in Madagascar (Hughes, this volume). Selm (1976) reports that the available nesting area on Sandspit and Hawkes Bay beaches in Pakistan is being reduced by building development. Schulz (1975) considers the accidental take of ridleys in shrimp trawlers a serious danger to the Suriname population, and recent coastal development at Ostional Beach in Costa Rica may pose problems for the ridleys nesting there.

The only large, unassailed ridley population is at Playa Nancite in Costa Rica. This beach is subject to occasional egg poaching, but the level is low. Recent overtures from the ridley exploiters in Mexico to begin operations on this beach are thought to have been rejected by Costa Rican authorities. Dialogue between critics and proponents of turtle exploitation in Central America has recently begun.

Table 2. *Lepidochelys olivacea* nesting sites

Location	*Approximate number of females/yr (thousands)*	*Reference*
Mismaloya, Mexico	20–50[a]	Marquez 1976
Tlacoyunque, Mexico	20–50[a]	Marquez 1976
Chacahua, Mexico	20–50[a]	Marquez 1976
Escobilla, Mexico	50–100[a]	Marquez 1976
Nancite, Costa Rica	200	Hughes and Richard 1974
Ostional, Costa Rica	100	Hughes and Richard 1974
Eilanti, Surinam	1	Schulz 1975
West Africa	—	Carr 1952
Mozambique	1?	Hughes 1974a, b
Malagasy Republic	1?	Hughes 1974a, b
Hawkes Bay, Pakistan	1?	Selm 1976
Coramandel Coast, India	10?	Valliappan and Whitaker 1975
Orissa Coast, India	150	Anon. 1976
Burma	—	Smith 1931
North East Australia	1?	Bustard 1972
Trengganu, Malaysia	1	Moll, personal communication

— No data.

a. Estimated numbers up to 1974. These numbers are known to be greatly reduced in 1977–1979.

The Leatherback or Luth, (*Dermochelys coriacea*)

Dermochelys, the largest of the sea turtles, nests widely but often sparsely in tropical regions. Leatherbacks range to north and south temperate zones where they feed on a variety of soft-bodied marine organisms (Brongersma 1969). The species has been described as a temperate zone form with a tropical nesting range (Carr, personal communication).

Table 3. *Dermochelys coriacea* nesting sites

Location	*Approximate number of females/yr*	*Reference*
Matina, Costa Rica	500[a]	Carr, personal communication
Gulf of Uraba, Colombia	100	Mrosovsky, personal communication
St. Croix, Virgin Islands	30[a]	Dodd 1978
East Florida	25[a]	Carr, personal communication
Trinidad	400–500	Bacon 1971
Culebra, Puerto Rico	—[a]	Dodd 1978
Bigisanti, Surinam	300–400[a]	Schulz 1975
Silebache, French Guiana	6000	Fretey 1977
Dominican Republic	100?	Carr, personal communication
Tongaland, South Africa	70[a]	Hughes, this volume
Angola	—	Hughes, this volume
Ceylon	100?	Selm 1976
Phuket, Thailand	—	Polunin 1977
Indonesia	—	Suwelo 1971
Trengganu, Malaysia	1,000–2,000[a]	Siow 1974
Manus Island, Papua New Guinea	100?	Pritchard, personal communication
Solomon Islands	—	Pritchard, personal communication
Chacahua, Mexico	2000	Marquez 1978
Tierra Colorada, Mexico	3000	Marquez 1978
Macconi, Sicily	—	Bruno 1978

— No data.
a. Beaches with some protection.

Table 3 lists 19 known nesting beaches. Of these only 4 are larger than 1,000 females nesting each year. Many nesting populations are small (25 to 100 females/yr). Seven populations receive some protection. Ten of these populations, including the large populations in Mexico, have been first reported within the last 5 years.

Leatherbacks are caught and eaten in Peru (Hays and Brown, this volume) and the Caribbean (Carr, personal communication). Leatherback eggs are taken universally. In many areas this is a subistence activity, but in Asia it is highly organized on a large scale. Leatherbacks are caught in Arabia and India and rendered for oil which is used to treat boat timbers.

Populations which are known to have declined occur on the west coast of India (Cameron 1923; Kar and Bhaskar, this volume), Ceylon (Deraniyagala 1939; Selm 1976) and Thailand (Polunin 1977). The main reason appears to be excessive removal of eggs by people. The large population in Trengganu, Malaysia is subject to intense egg harvest. Nearly 100 percent of eggs laid are taken, but up to 15 percent of these are acquired by authorities for hatching and release (Siow and Moll, this volume). It is not clear whether the present management program is effective (Chua and Furtado 1979).

Other areas where there are problems of unknown extent are the Dominican Republic where subsistence take of eggs is high, Mexico where there are occasional large scale removal of eggs, and Peru where a local industry catches nonbreeding leatherbacks for meat. Anonymous (1975) reports widespread slaughter of nesting turtles and egg taking in Trinidad. Leatherbacks are reported to be taken in large numbers as incidental catch in commercial fishing operations in the Mediterranean and occasionally elsewhere. Fretey and Lescure (1976) express concern that legislated protection of the large nesting ground in French Guiana is not preventing large-scale poaching of leatherback eggs. Populations in Suriname, Florida and South Africa which do have adequate protection have increased in recent years (Schulz 1975; Hughes 1974a).

Discussion

From the preceding accounts several general points on the status of these sea turtles can be derived. Table 4 summarizes the information from Tables 1–3. There is a surprisingly small number of large populations of any species. This may reflect the incomplete information available. Several of the large populations were discovered recently: *Lepidochelys* at Nancite, Ostional and Orissa, India, and *Caretta* at Masirah. It is possible that future discoveries will add more large populations. However, for the present we can only proceed with the available information.

I have made no attempt to extend estimates of the number of females nesting each year to total population size estimates. Annual numbers fluctuate by factors of 5 to 20 from season to season for the various species. Examples are given in Hughes (1974b), Carr, Carr, and Meylan (1978), and Chin (1970). Therefore these numbers are only general indications, and a priority for research is to refine them. Although the estimates of nesting females are crude or absent in many cases, it is clear that there are surprisingly small numbers of *Caretta* and *Dermochelys* known at present.

The most striking point from Table 4 is the degree

Table 4. Summary of the available data on populations of *Caretta caretta*, *Lepidochelys olivacea*, and *Dermochelys coriacea*. Population estimates are not based on firm data and the record of known populations is incomplete. The very concentrated and vulnerable nature of these species is demonstrated.

Species	Large populations 1000 ♀/yr +	Total ♀/yr[a]	Percentage of individuals in 4 largest populations	Populations: Protected	Populations: Reduced	Populations: Threatened
Caretta caretta	2	41,000	93	5	3	5
Lepidochelys olivacea	5[b]	518,000	97	4	3	6
Dermochelys coriacea	4	14,325	84	7	3	5

a. Populations for which estimates are not available were assumed to have 100 individuals (*Caretta* & *Dermochelys*) or 1000 individuals (*Lepidochelys*).

b. Three formerly large populations in Mexico are greatly reduced and are omitted. See Table 2 and text.

to which the numbers of turtles are concentrated in a very few large nesting populations. Between 84 percent and 97 percent of the females of each species are accounted for in the 4 largest nesting grounds currently known. This is an astounding degree of concentration and brings into focus the fact that much of our past research has concentrated on a very small proportion of each species.

The number of populations that receive effective protection is small, particularly when compared with the number of populations threatened with exploitation. In many cases those populations that are effectively protected are not the large populations.

Doubt is sometimes expressed that turtle populations have actually declined. Even with the scarce information available I have still been able to show that 3 populations of each species have suffered serious reduction in numbers. There are probably other populations that have disappeared or that persist in greatly reduced numbers about which we have no data.

The cause for the declines is unambiguous. In every documented case it is large-scale exploitation by man that has led to drastic reduction in numbers. For this reason, turtles now being intensively exploited are listed as threatened. The exact form of human activity leading to population reduction varies for each species. Loggerheads have been reduced by hunting for food for both local market and export consumption. The olive ridley has been decimated by commercial exploitation for its leather in the Americas. In India it is the large scale commerce in turtle meat to big cities which is critical. Leatherbacks seem most affected by the intense exploitation of their eggs. Accidental capture in commercial fishing operations is a problem for all species. In all cases, the extension of commerce in turtle products beyond the immediate subsistence needs of the local people has been followed by reduction of turtle numbers. It can be argued that I have only demonstrated loose correlations which may not be causal. They may only be correlations, but they are compelling ones and certainly sufficient to cause concern. They merit intense further study and cannot be dismissed.

The question arises, what action can we take to ensure that these demonstrably vulnerable animals do not disappear? To effectively manage sea turtles we need to know as a minimum, population sizes, age structure, and reproductive output. When these parameters are known rational management can be planned. A model for such treatment is the paper by Márquez and Doi (1973). The authors recognize the need to make assumptions about some parameters because real data are not available. The assumptions can now be seen to be unrealistic, and the practical application of their results is limited. Nevertheless, the technique is exemplary.

It is quite clear from recent changes in the accepted knowledge of sea turtles that we do not have adequate data for any species. The green turtle *Chelonia mydas* is the most extensively studied sea turtle. In recent papers estimates of the number of nests laid by a green turtle in one season were 1 to 3 (Carr, Carr, and Meylan 1978; Schulz 1975) rather than early figures of 3 to 7 (Hirth 1971b; Hendrickson 1958.) The age at maturity is now thought to be 15 to 50 years (Balazs 1979, Limpus 1979) not 5 to 10 years as previously (summarized in Hirth 1971b). Hughes (1976) has challenged a number of previous ideas of the total reproductive output of loggerheads. Uncertainty abounds, which is the very reason for this conference. There are indications that these factors are different and largely unknown for other species. We do not have enough correct information to manage sea turtle populations today.

There is one indisputable fact: when sea turtle populations have been exploited, they decline; when they have been protected, they increase. The political realities in developing nations and pressure from the commercial vested interests make complete protection an unpalatable and perhaps an impossible goal. We must ensure that the necessary compromise is based on caution and what little good data we have. I believe that the correct strategy for preventing the extinction of sea turtles is to limit exploitation to the lowest take that is compatible with the real social needs of indigenous people who eat turtle products. This may give us the time to do the research that is necessary to achieve sustainable management policies worldwide.

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Sea Turtles of the Pacific Coast of Mexico

The west coast of Mexico once provided food, protection, and nesting beaches for one of the largest and most diverse assemblages of sea turtles in the world. Their history spans earth ages while their decimation spans but a few decades. In a rapidly developing country, social, political, and economic concerns seemingly outweigh biological realities. Of millions of sea turtles that occurred on the Pacific coast of Mexico, only a few hundred thousand remain. The sea turtles of the Pacific coast of Mexico are on a rendezvous with extinction.

The Pacific coast of Mexico and offshore islands still provide important breeding grounds for the green, ridley, and leatherback turtles. While many green and olive ridley turtles remain in Mexican seas all year, others migrate thousands of kilometers to feeding grounds in Central and South America (René Márquez, personal communication; Green and Ortiz, this volume). Five species of sea turtles are native to the Pacific coast of the Americas; some range as far north as the United States (Stebbins 1966).

The following is a species-by-species account of the present status of the sea turtles of the Pacific Coast of Mexico. Our approach is heuristic; we compare the more recent quantitative information with the older qualitative knowledge that predates heavy exploitation. Our quantitative information was compiled from existing literature, the Mexican Fisheries Department (PESCA), and 5 years of our fieldwork. Qualitative information was collected from our ethnobiological fieldwork along the Pacific Coast of Mexico and existing literature.

The Leatherback (*Dermochelys coriacea*)

The leatherback is called *Laud, De Altura, or Del Canal* in southern Mexico, and *Siete Filos* in the northwest. Its nesting beaches are known from the states of Michoacán, Guerrero, and Oaxaca. The recently discovered rookery at Tierra Colorado, Guerrero, may be the largest for this species in the world, with an estimated 500 females nesting per night during the season (René Márquez and Peter Pritchard, personal communication). This breeding population was discovered in 1976, when a shipment of many thousands of eggs was confiscated en route to Mexico City. The Tierra Colorado nesting beach does not have sufficient protection.

The greatest nesting densities at Tierra Colorado occur in December and January, following the peak breeding season of both the ridley (July through October) and the green turtle (October through November). Leatherback nesting outside the Tierra Colorado area seems to coincide with green turtle nesting activities (most leatherback nesting in Michoacán occurs in October and November). These nestings may be females migrating towards the Tierra Colorado beach. Pritchard (1973) reports similar behavior for leatherbacks in Surinam.

In 1978 the eggs sold for 10 to 12 pesos (US $0.52) each in Mexico. Generally egg poachers wait for the turtle to lay her eggs. However, on beaches being protected by Mexican marines, egg poachers are known to kill turtles in order to hurriedly remove the eggs. Nesting animals are also killed for their oil, which is used in skin lotion and for medicinal purposes (for example, as a remedy for respiratory disorders). The meat is of negligible value.

These pelagic animals are uncommon visitors elsewhere along the Mexican coast. They are occasionally seen in the coastal areas of Sinaloa, the Gulf of California, and the Pacific coast of Baja California and the United States. Dead, stranded leatherbacks are occasionally seen along the shores of the Gulf of California (e.g., near El Golfo, Sonora, in March 1977, Cliffton, Felger, and Nabhan; Puertecitos, Baja California Norte, in November 1980, Brian Brown).

No male leatherback has been positively identified in the northern part of the Gulf of California. The Seri Indians, who revere the animal's spirit power, and Mexican fishermen at Kino Bay, Sonora, recall having encountered less than 2 dozen of them during the past 4 to 5 decades.

The Pacific Hawksbill (*Eretmochelys imbricata squamata*)

The hawksbill is called *Carey* in Mexico. It was once common along the Pacific coast of Mexico. Nesting may have occurred in scattered localities south of the desert coast of Sonora. Today it is rare, and there are no known nesting beaches for it on the Pacific coast.

Tortoiseshell has been traded along the coast of Mexico since ancient times. During the Spanish colonial era the shell was traded between coastal Indians, such as the Seri and those from Baja California, and Spaniards (Del Barco 1980; Hardy 1829). In the late nineteenth and early twentieth centuries, the hawksbill was abundant and heavily exploited, particularly in the southern part of the Gulf of California (Townsend 1916). Twenty years ago it was still common (Caldwell 1962).

Older fishermen from the Gulf of California region also tell of an abundance of hawksbills only 20 to 30 years ago. They say that the increase in price of tortoiseshell has doomed this creature. Hunting activities were concentrated in La Paz and Concepcion Bay on the east coast of Baja California, and the Infiernillo Channel on the Sonora coast north of Kino Bay. Seri Indians say that large hawksbills were frequent visitors into the Infiernillo Channel but are now seldom seen.

Mexican fishermen from the east coast of Baja California told us that 30 years ago the crew of a single fishing canoe (1 harpooner and 2 or 3 men paddling) could capture 5 to 7 hawksbills in 1 night (3 to 4 hours' work) in calm seas. They sold the tortoiseshell to local prisons, where the inmates were famous for working the material into combs, pendants, rings, and other ornaments. One fisherman told us of a hawksbill from Concepcion Bay weighing 100 kg which yielded 5 kg of tortoiseshell. A large population was reported from the Tres Marias Islands which may have been a major breeding ground (Parsons 1962).

Today, even though the hawksbill is rare, the fishermen consider it fair game regardless of size. When one is taken it is carefully cleaned and the meat eaten. It is then stuffed and sold as a curio to North American or Mexican tourists, or kept in the fisherman's home as a trophy. During the past 6 years we have seen about a dozen hawksbills captured by Seri and Mexican fishermen in the Kino Bay region, and 3 in a single season from the Michoacán coast. Only one showed adult characteristics.

The Pacific Loggerhead (*Caretta caretta gigas*)

The Pacific loggerhead is called *Perica* in Sonora and *Javelina* in Baja California. No nesting beaches are known for this species on the Pacific coast of Mexico. Though now relatively rare, it is occasionally taken incidentally in shrimp trawls in the Gulf of California and on the Pacific coast of Baja California. Shrimpers say that loggerheads are sighted floating on the surface of waters 20 to 60 m deep. They also enter the shallow bays, channels, and estuaries of northwestern Mexico.

The Seri Indians recognized 2 ethnospecies of loggerheads in their region, indicating greater diversity and abundance in the past (Felger and Edward Moser, unpublished notes). Mexican fishermen often refer to the loggerhead as *caguama mestiza* (sea-turtle half-breed), a designation given to any turtle that does not fit readily into their folk classification.

The loggerhead is generally not worth as much money as the green turtle. Although the fresh meat is considered "rank" by Sonoran epicures, it is palatable when prepared as *machaca* (meat which is salted, dried, shredded and fried). It has less meat in relation to body weight than does the green turtle. Juvenile loggerheads are stuffed and sold as curios by the fishermen.

No loggerhead taken in the Kino Bay region has been found with eggs in any stage of development. In recent decades there has also been no confirmed capture of a sexually mature loggerhead. The largest one we have seen, an immature male, weighed 65 kg.

According to the Seri and Mexican fishermen, large loggerheads once occurred in the Gulf of California. During the summer months lobster divers in the midriff island region of the Gulf of California sometimes encounter these turtles resting underwater among rocks along shallow lava reefs called *tepetates*. One diver saw 9 loggerheads during 1 summer. He estimated the largest animal to weigh 90 kg. During October and November 1976, Seri Indians harpooned 6 loggerheads in the Infiernillo Channel. It is considered unusual nowadays to see so many in such a short time.

Cliffton found 2 torpid (probably overwintering) loggerheads at 15-m depths, 1 in the Infiernillo Channel in March 1978, and the other off Margarita Island at Magdalena Bay, Baja California Sur, in February 1979. Unlike most overwintering green turtles, which have thick epizoic algae on their carapaces, the 2 loggerheads were heavily covered with bryozoans and associated invertebrates.

Mexican fishermen say that the loggerhead occurs at the Tres Marias Islands, the Revillagigedo Islands, and the Pacific coast of Baja California. They say that it does not occur on the Pacific coast of southern Mexico, and we have not seen it in that region. However, there are reports of loggerhead rookeries in Panama (Cornelius, this volume), and they also occur in northern Chile (Hays and Brown, this volume).

The Olive Ridley (*Lepidochelys olivacea*)

In Mexico, the smallest and most prolific Pacific Ocean sea turtle is called *Golfina*. The Nahuatl Indians call it *chiwanini* (the little one). The ridley is sought after for its quality leather, eggs, and meat. The most economically valuable sea turtle in Mexico, the ridley is the prime target and an easy catch for Mexico's industrialized turtle fisheries because it gathers in huge numbers during the breeding and nesting season.

The most dramatic feature of its life history is the simultaneous nesting of as many as hundred of thousands of turtles, known as the *arribazón* (great arrival), *arribada* (arrival), or the *moriña* (homecoming). The arribadas used to occur once during each lunar cycle of the nesting season, June through November, with peak nesting lasting 5 to 6 days in August, September, and October. The arribadas often follow strong and persistent south winds (in 1979 2 small arribadas occurred at Maruata Bay and Colola, Michoacán, when strong south winds signaled the daylight emergence of 30 to 100 females). After the nesting season, the turtles return to feeding grounds in Ecuador, Central America, and Mexico (René Márquez, personal communication).

The major olive ridley rookeries in Mexico were El Playón de Mismaloya, Jalisco; Piedra del Tlacoyunque, Guerrero; and Bahía Chacahua, La Escobilla, and El Moro Ayuta, Oaxaca. Nesting also occurred in the states of Sinaloa, Colima, Michoacán and Baja California Sur (Márquez, Villanueva and Peñaflores 1976).

According to a report by the National Marine Fisheries Service (1976), an average of 137,000 ridleys nested in the largest arribadas of 3 major beaches in the years 1968, 1969, and 1970, with considerable year to year variation. However, reliable informants in these areas say there was not as much variation in numbers of nesting turtles as indicated by the Fisheries report. Indeed there were tens of thousands of ridleys nesting at La Escobilla, Oaxaca, in 1969 (Antonio Suarez, personal communication), whereas the publication reports only a few hundred. It is apparent that the estimates presented in the report do not include all the arribadas from those years. Therefore, we use these estimates to calculate the lower limits of the adult female ridley populations of western Mexico prior to 1969. We make this calculation as follows:

$$N = (x)(m)/(p)(t)$$

Where: N *equals* the estimated total number of adult female turtles in the Mexican populations in 1969; x *equals* the average number of female turtles in the largest arribadas at the 3 nesting beaches (La Escobilla, Piedra de Tlacoyunque, and El Playón de Mismaloya) in 1968, 1969, and 1970 (x = 137,000); m *equals* the average remigration period (m = 1.3 years; Márquez et al., this volume); p *equals* the proportion of females nesting in each arribada (p = 0.6) [This proportion was used because in the past there were more arribadas than the average number of clutches laid by a turtle per season—each female did not participate in each arribada (Márquez et al., this volume)]; and t *equals* the proportion of all olive ridley nesting in Mexico that occurs at these three beaches (t = 0.5)(Márquez, Villanueva, and Peñaflores 1976). Therefore:

$$N = \frac{(137{,}000)(1.3)}{(0.6)(0.5)} = 593{,}667 \text{ female turtles.}$$

In the early 1970s, these 3 beaches were the site of approximately one-half of the olive ridley nestings in Mexico (Márquez, Villanueva, and Peñaflores 1976).

Thus, assuming a 50:50 sex ratio, at the lowest limits, there were approximately 1,185,000 adult (including males) olive ridleys in the breeding populations of Mexico in 1969.

During the peak of ridley turtle exploitation, the late 1960s, the harvest far exceeded any damage natural mortality could do (or that natural recruitment could make up for). By adding the number of turtles harvested over a short period of time to our 1969 population calculation we can estimate a population level that predates heavy exploitation.

The reported take of olive ridleys in the 5-year period to 1969 was approximately 27,800 metric tons (Mexican fisheries records as reported by Márquez, Villanueva, and Peñaflores 1976). This represents almost 700,000 individuals, most of which were females (based on Márquez's unpublished data from San Augustinillo, Oaxaca, 1977: $\bar{x}$ = 40.9 kg/turtle). This is an underestimation.

For catch data given by Márquez, Villanueva, and Peñaflores (1976) for 1968 alone, our calculation ($\bar{x}$ = 40.9 kg) yields 316,127 adult turtles. However, the fisheries records of this period have underestimated total catch. Carr (1972) states that more than 1,000,000 olive ridleys were landed in Mexico during 1968. Using this proportionality (the actual take being 3 times larger than the reported take), at least 2,000,000 olive ridley turtles would have been landed during the 5 years prior to 1969. Antonio Suarez, an undisputed expert on ridley harvest data in Mexico, corroborates this figure (Antonio Suarez, personal communication). The estimate of approximately 1,185,000 adult turtles in the breeding populations in 1969 coupled with 2,000,000 turtles killed in the 5 preceding years yields a conservative estimate of 3,185,000 olive ridleys in the seas of western Mexico in the mid-1960s.

We estimate the pre-1950 population size of olive ridleys in this area by another method. If the 3 major olive ridley nesting beaches in Mexico had the density of turtles that our informants claim (approximately one nesting turtle per square meter) there were on the order of 10,000,000 adult turtles prior to the recent intensive predation and destruction of habitat. This calculation is probably conservative considering that actual reported nesting densities of large ridley populations in western Costa Rica are 14 nests/m^2 (Cornelius, this volume) and that all nesting beaches are not included in the calculation.

For the past 15 years 3 human forces have affected the olive ridley in Mexico: the Mexican government's sea turtle program, industrialized sea turtle fisheries, and poachers. In the 1960s, Mexico's sea turtle program was heralded as a conservation model for the world. However, it has shown signs of weakness as seen in the following translation from Tecnica Pesquera (1970:7–8):

The obstacles that the Mexican turtle program is encountering (funding and organization) and the increased clandestine exploitation of eggs, meat, and turtle skin during the closed season are causing Mexican and foreign biologists to worry over the fate of the Pacific ridley turtle, Lepidochelys olivacea, which is intensively exploited.

Until a short time ago, it was believed that the survival of the species was guaranteed by the program of breeding and protection established by the Mexican government, and by the precautions taken to insure rational exploitation. The situation now seems less promising, however, and could be said to be very disturbing.

Mexico's answer to the pleas for rational exploitation was the industrialized sea turtle fishery, developed by Antonio Suarez Gutierrez. He began by selling Oaxaca ridley skins to the European markets. By 1969 Mexican law allowed exploitation of sea turtles only by those equipped to utilize the entire animal. Suarez's company had one of the only legitimate processing plants in Mexico. Prior to Suarez's entry into the business, it was common practice to utilize only a portion of the hide for the leather trade. The rest of the animal was discarded.

Overshadowing both industrialized fishing and government protection programs are the poachers. They take millions of eggs and countless thousands of animals each year. Suarez said that despite his well organized protection of the Oaxaca beaches, the poachers took about 1 million eggs from La Escobilla in 1979. Sr. Suarez claimed that he championed the sea turtles' cause in Mexico by combating the poachers in Oaxaca. Of the 3 major olive ridley rookeries in Mexico, only the Oaxaca beaches still have arribadas. Suarez claims this as a testimonial to his practices. However, his theories are based on the effects of exploitation. In 1976, the Mexican Department of Fisheries estimated a total population of 485,000 olive ridleys breeding off the Pacific coast (Márquez, Villanueva, and Peñaflores 1976). Suarez disagreed openly with this figure in June 1979, when he stated, "The ridley cannot be in danger of extinction if we (Mexico and Ecuador) have taken 400,000 turtles in 2 years (1977–78)" [This probably includes turtles that nest in Costa Rica and feed in Ecuador (see Cornelius, this volume)].

In fact there is no biologically sound formula for the continued exploitation of Mexico's ridleys. The huge breeding populations at El Tlacoyunque, Guerrero; El Playón de Mismaloya, Jalisco; Sinaloa; Michoacán; and Baja California Sur have crashed. The Oaxaca population is severely depleted and is showing signs of collapse.

In 1977 the size (58,000 female ridleys in the largest arribada) and the frequency of arribadas (only 2 per season) was one of the latest indications of the downward trend. In 1977, Suarez's company, PIOSA (Pesquera Industria de Oaxaca), took 70,000 ridleys (90 percent of them gravid) from this population, and 58,000 in 1978. At a meeting with Suarez in Mexico City in 1979, Peter Pritchard said, "Then in fact, the largest part of the arribada is taken each year."

Since then, with Suarez's approval, the government quota for capture of olive ridleys was cut in half. Observers at La Escobilla estimated that 36,000 female ridleys participated in the largest arribada in the 1979 season. PIOSA took 24,500 of them. There is little doubt that Suarez's protection of the Oaxaca nesting beaches has postponed the total collapse of this population. However, coupled with the uncontrolled exploitation in Ecuador, an estimated 100,000 ridleys harvested per season (Green and Ortiz, this volume; Antonio Suarez, personal communication), these great populations seem doomed.

Much of the industrialized fisheries protection program is based on the incubation of ovaductal eggs. Calcified eggs are taken from the ovaries of slaughtered gravid females, and less developed eggs are discarded. The calcified eggs are then transplanted to artificial nests along the beach or placed in styrofoam boxes with sand. Some of the problems with this method are: low hatch rates due in part to unskilled handling techniques (7 to 22 percent in 1977, Oaxaca; Antonio Suarez and others, personal communication), unnatural temperature regimes during incubation, and the absence of natural environmental stimuli that might be important if imprinting is required.

The East Pacific Green Turtle (*Chelonia mydas agassizi*)

The East Pacific green turtle is called *Caguama negra* or *Caguama prieta* in northwestern Mexico, and *Sacasillo* in Oaxaca. This species is vanishing from all its major feeding grounds in the Gulf of California and the Pacific Coast of Baja California. The last major nesting sites for the species in North America are 2 nearly adjacent beaches at Maruata Bay and Colola, Michoacán, nearly 3,000 km from the northern feeding grounds (Figure 1). Our tag returns indicate that the turtles traverse the Mexican coastline in their migrations, as well as travel to distant feeding grounds in Central and South America (Instituto Nacional de Pesca, unpublished data).

This species once provided coastal peoples with a major source of protein. Today, the meat is of very high commercial value in northern Mexico (100 pesos or US $4.44/kg, liveweight). The eggs are illegally collected and sold in Mexican cities. There is a popular belief that consumption of sea turtle eggs enhances virility.

The green turtle is the only Pacific turtle with both major feeding and breeding areas in Mexico. The green turtle section is divided into 2 subsections: the northern feeding grounds and the southern breeding grounds.

The Green Turtle's Northern Feeding Grounds

Earlier in the century the green turtle was prevalent throughout the Gulf of California. It was abundant along the coasts and in the large bays, great saltwater lagoons, and deltas of Baja California, Sinaloa, and Sonora. It even entered the Colorado River, traveling upstream some 80 km to the Cocopa Indian village of El Mayor (Felger and Rea, unpublished notes). In these places the green turtle grazed on eelgrass (*Zostera marina*), ditchgrass (*Ruppia maritima*), marine algae (Fucales, Gelidiales, and Ulvales), white mangrove leaves (*Laguncularia racemosa*), and marine invertebrates (Felger and Moser 1973; Felger, Moser, and Moser 1980). Isolated groups of green turtles occurred along the rocky shores and bays of Nayarit, Jalisco, Oaxaca, and Chiapas, and it was abundant around the Revillagigedo and Tres Marias Islands. These were the major historic feeding grounds of the green turtle in western Mexico (Parsons 1962).

> *An indication of their former abundance on the Pacific coast is found in the report of the visit of the* Albatross *to San Bartolome, or Turtle Bay in April 1889, when a remarkable catch of 162 green turtles, many of large size, was made in a single haul of a 600-foot-long seine. Half as many again were believed to have escaped from the seine before it was beached* (Parsons 1962:73).

On the Pacific coast green turtles were first heavily fished at the turn of the century in Baja California (O'Donnell 1974). An estimated 1,000 live turtles/month were sent to San Diego, California, from Scammon's Lagoon. By the 1930s, the market for fresh sea turtle meat in the United States dwindled but found added vigor in the border towns of Tijuana, Mexicali, Nogales, and the major cities in Baja California and Sonora (O'Donnell 1974). Demand for green turtle meat within Mexico grew steadily as the meat became equated with increased physical vitality and stamina, or virility.

In 1947, Jose León, Enrique Alverez, and Rafael Valenzuela were returning to Kino Bay, Sonora, and anchored at an abandoned Seri Indian camp on the shore of the Infiernillo Channel. Using a gasoline lamp and harpoon, they drifted into the canal that night in search of green turtles. In 4 hours the fishermen captured 9 green turtles whose total weight was 1.2 metric tons, an average of 133 kg per animal. The large turtles were preferred because it was easier to salt and dry the meat of a few big turtles than many smaller ones. The meat was sold for 50 centavos/kg, but salting and drying is a laborious process, and the turtles were readily sold alive for 10 to 30 pesos each.

Since ancient times the Seri Indians of the Sonora

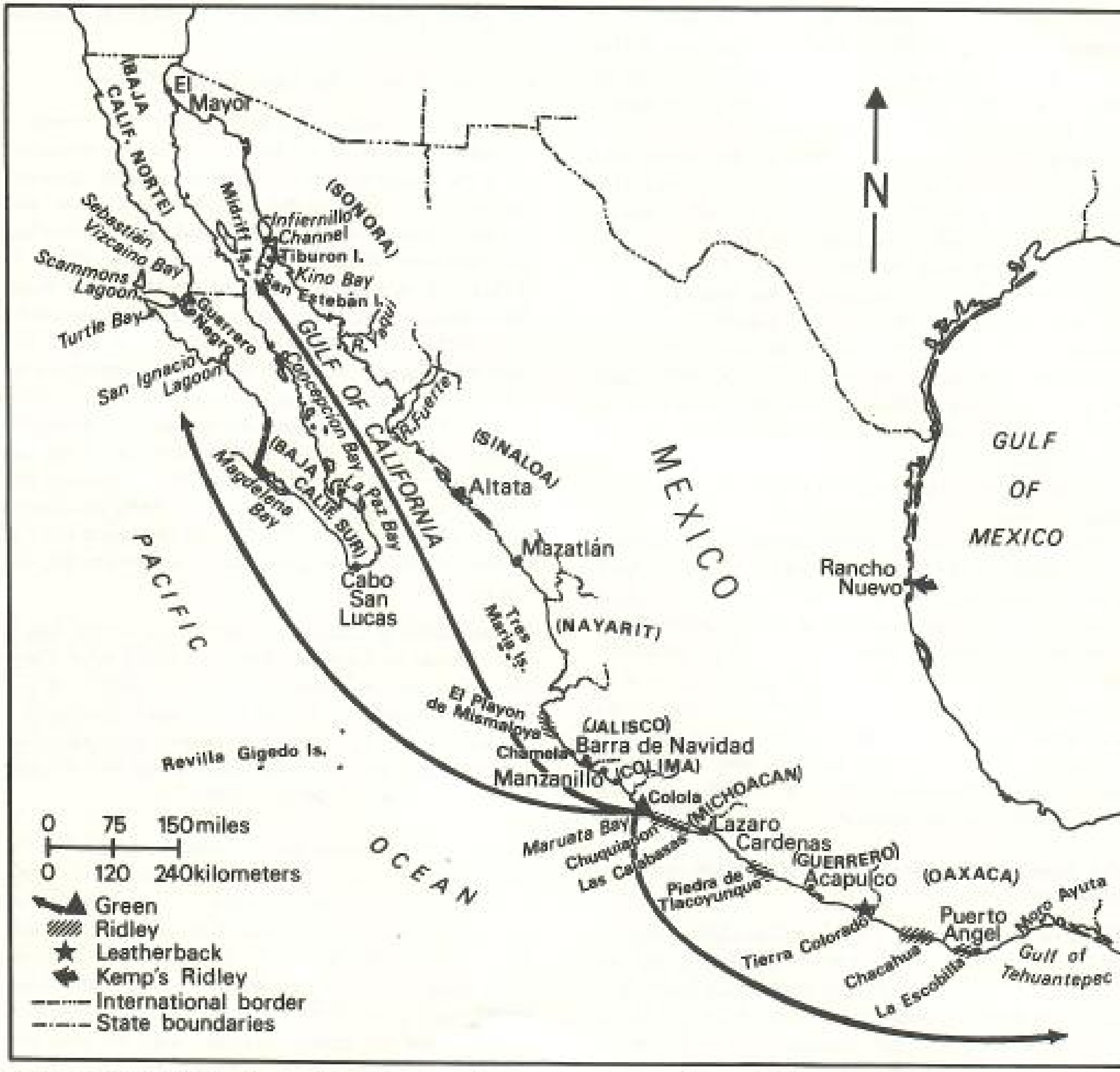

Figure 1. Map of Mexico showing the major sea turtle nesting beaches of the Pacific coast. Arrows leading away from Maruata-Colola indicate general migratory path of green turtles returning to feeding grounds. The arrow to Baja California is hypothetical since there are no tag returns from the Pacific coast of Baja California.

coast have hunted sea turtles in the northern part of the Gulf of California (McGee 1898; Smith 1974; Felger, Cliffton, and Regal 1976; Felger, Moser and Moser 1980). Certain groups of Seri Indians depended upon the abundance of large green turtles the year round. Their knowledge of marine turtles is rich and reveals detailed biological observations. The Seri name 7 ethnotaxa of green turtles while the Mexican fishermen from Kino Bay name 5 (Felger and Edward Moser, unpublished notes; Cliffton and Felger, in prep.). Today both the Seri and the Kino Bay fishermen see only 2 of these ethnotaxa.

In the 1950s, Chui Montaño, a Seri Indian, was enticed by a Mexican fish buyer to hunt green turtles commercially. In those days Chui could drift lazily with the current through the Infiernillo Channel and singlehandedly harpoon and boat 12 to 18 large (70 to 100 kg each) green turtles a day. He sold them for 10 pesos apiece.

Once a fixed price per turtle was set, the fishermen stopped hunting large turtles because more smaller ones, each at the same price as a large turtle, could fit in their boats. The catches were made entirely with harpoons until cloth tangle nets were introduced in the early 1960s. The nets reduced the investment of human energy. Despite the relatively small size of these nets (100-m long), an average of 22 green turtles/day was caught with little effort. In 1965 the price was set at 1 peso/kg of live turtle. Once again the pressure on large turtles was increased.

In the 1960s the Seri readily adapted their *pangas* (6- to 7-m plank boats) to accommodate powerful outboard motors (25 to 50 h.p.). They combined ancestral knowledge and skill (the use of harpoons 7- to 10-m long) with modern techniques (monofilament turtle nets 160- to 200-m long) to virtually extirpate the remaining green turtles from their region by the late 1970s. In 1965, Guadalupe Lopez, the best Seri turtle hunter, could harpoon 5 metric tons of green turtle a week within 50 km of his home at El Desemboque. As larger turtles became scarce the Seri simply caught more juveniles (18 to 25 kg) at rates of 25 to 30 turtles/*panga*/day. There were 10 to 12 Seri *pangas* in operation in those days. Seri turtle hunting efficiency was demonstrated soon after we tagged and released 13 adult and subadult green turtles in the Infiernillo Channel in March, 1977. The Seri proudly returned 7 of the tags by May 1977.

In 1975 compressor diving was introduced as a new technique for hunting sea turtles in the Gulf of California. Mexican divers from Kino Bay accidentally discovered sluggish, overwintering green turtles off the south shore of Tiburon Island while hunting lobsters (Felger, Cliffton, and Regal 1976). These turtles were present in surprisingly large numbers, lying motionless at depths of 10 to 30 m. Exploitation of the overwintering populations quickly became a cottage industry. By the winter season of 1975 5 turtle boats or *pangas* were landing 4 to 5 metric tons of turtles/week at Kino Bay from late November through early March ($\bar{x}$ = 29.0 kg/turtle, S.D. = 8.31, n = 161). In 1975 it took 5 boats of fishermen with diving equipment to catch as much turtle as 1 boat of Seri Indians with harpoons in the 1960s.

One after another of these overwintering sites were located and depleted. The fishermen then began to exploit more distant areas in the northern part of the Gulf of California. By winter 1979–80 Kino Bay divers traveled 3 times the distance and invested many times the hunting effort but obtained smaller catches. The rapidly rising cash value of these increasingly rare animals provided ample incentive to the hunters.

Southern Breeding Grounds of the Green Turtle

The major nesting beaches were located on the sparsely inhabited mainland coast of Michoacán. Today the only remaining major nesting site for the green turtle on the Pacific coast of North America is Colola-Maruata Bay, between the Río Tikla and Río Balsas, Michoacán. Other less important nesting beaches may occur on the Pacific coast of Baja California Sur near Todos Santos and western Chiapas (Pritchard 1979). Green turtles also nested at the Revillagigedo and Tres Marias Islands (Parsons 1962).

Maruata Bay was used by British privateers while raiding Spanish shipping lanes near Acapulco and Manzanillo. They replenished stores of fresh meat by capturing green turtles which abounded in the area, and obtained fresh water at the perennial river which flowed into a deep estuary and out to sea. William Funnel, mate to Captain Dampier, wrote on 22 November 1704, "Here we watered our ship and found in a small river a great many large green turtles, the best I ever tasted" (Dampier 1906, *in* Peters 1956:21).

In August 1950 Peters (1956:22) journeyed into the "isolation and comparative primitiveness" of Maruata Bay and made the following observations 2 months prior to the peak nesting:

The evidences of their activity were everywhere . . . In a half mile stretch between two stringers I counted 472 such tracks (nesting turtles), which would indicate 250 individual turtles . . . Many turtles returned to the ocean via the track they made so I'm sure my estimate is not high.

By extrapolating these nesting densities over the entire 3-km length of beach, we estimate that there were on the order of 900 turtles nesting at Maruata Bay within several days of Peters' observations. (The tracks may remain for 2 to 5 days during this time of year which is the rainy season). In contrast, we estimate that only 600 turtles nested at Maruata Bay during the entire 1979 season. Furthermore, nesting green turtles are no longer common in August.

Native (Nahuatl Indian) informants claim that 500 to 1,000 green turtles a night nested at Colola only 10 years ago during the heaviest nights of nesting. At first these claims seemed to be impossible; they were saying that there were 10 to 20 times as many turtles in 1970 as there were in 1977. That would be approximately 25,000 females nesting in Michoacán yearly, possibly 150,000 adult turtles (males and females) in the population, assuming a 3-year remigration period and a 50:50 sex ratio. Informants who have hunted for more than 25 years in the northern feeding grounds of the Gulf of California and the Pacific coast of Baja California report a similar decrease in the abundance of green turtles in their area.

According to the Instituto Nacional de Pesca, in a 5-year period from 1966 through 1970, 4,618 metric tons of green turtle were landed on the Pacific coast of Mexico (Márquez, Villanueva, and Peñaflores 1976). We calculate that this represents approximately 125,000 turtles, adults and subadults [36.5 kg average weight (Caldwell 1962)]. While 125,000 is an impressive figure insomuch as there are not that many green turtles left in Mexico's seas, it is an underestimation of the total number of turtles landed during that period. Until the mid- to late-1970s there were no roads to the major nesting beaches in Michoacán. Meat and the skins were taken out by boat or plane, and many fishermen in these underdeveloped areas never reported their catches. Carr (1972) indicates that the fishery records for this period represent about a third the number of turtles landed. In other words, about 375,000 green turtles were taken in that 5-year period, of which at least half were adults.

The number of green turtles nesting each year in Michoacán fluctuates dramatically, as it does elsewhere in the world (Carr, Carr, and Meylan 1978). For example, 7 to 30 turtles nested per night at Colola during October and November 1977, as compared to 50 to 150 per night on the same beach in October and November 1979.

We estimate that there are now between 5,114 and 8,523 adult female green turtles in the Michoacán breeding population. We make this calculation as follows:

$$y = (u)(r)/(n)(s)$$

Where: y *equals* the number of adult female green turtles in the Michoacán population, n *equals* the number of clutches they lay per season (n = 4, Márquez *et al.*, this volume), s is the average number of eggs per clutch (s = 66, Márquez et al., this volume; and our data), u *equals* the average number of eggs laid per season at Colola and Maruata Bay (u = 750,000, estimated average from 1977–79), and r is the average remigration period (r = 1.8 years, Márquez, et al., this volume, for the lower limit; and r = 3.0 years for the upper limit because it is so common for the green turtle elsewhere in the world).

For the past 15 years the Nahuatl people have increased their population and settlements on the coastal plain encompassing the green turtle breeding grounds. Their slash and burn agriculture in the nearby hills greatly increased the rate of erosion. This, coupled with a hurricane in 1970 resulted in the near destruction of the estuary at Maruata Bay, changed the course of the river (now a dry arroyo for most of the year), and reshaped the western beach.

As international markets for sea turtle leather expanded in the 1960s and 1970s, so did human predation on the green turtle rookeries in Michoacán. Fishermen from Colima, Jalisco, and Guerrero began capturing breeding turtles with nets and by pouncing on mating pairs (a hunting technique called *al brinco*).

At first the Nahuatl Indians gazed upon this carnage in disgust. They even killed an occasional outside fisherman because they equated the wholesale slaughter with a threat to their own commercial interests. Beginning in the early 1970s, a market for sea turtle eggs was introduced to the Nahuatl. They were offered 20 pesos per 100 eggs. They claimed that each night 15,000 to 20,000 eggs were collected at Maruata Bay, 70,000 eggs at Colola. The people became "rich" overnight, and settlements around the nesting beaches increased rapidly.

In 1974 President Luis Echeverria's administration expanded the development of fishing cooperatives along the Pacific coast. The Nahuatl were given, on loan, new boats, motors, and nets to increase the production of coastal fisheries. However, the young men who organized the Pomaro fishing cooperative of Maruata Bay turned their new found technology on the green turtle. On Cliffton's first visit to Maruata Bay in August 1976, he witnessed the illegal capture of 40 to 80 green turtles a day. Most of the animals were drowned in shark nets set directly in front of the nesting beaches. Though of low quality, the hides were stripped from the animals to be sold for 50 pesos each (US $2.20). The carcasses were thrown into the sea.

Government control in this remote area was nonexistent until Mexican marines were sent to protect the Colola beach in 1977. The marines collected nearly 50,000 sea turtle eggs, and protected them in a hatchery. However, they were relieved of their duty prior to the hatch-out, and within weeks the entire hatchery was destroyed by pigs and dogs.

In 1977 Suarez's company, IPOSA (Industria Pesquera Occidental), a subsidiary of PIOSA, began exploiting the breeding green turtles in Michoacán. In 1978, IPOSA began full-scale processing of male and female green turtles legally captured by the Pomaro fishing cooperative in Maruata Bay. The majority of the animals were drowned in shark nets set by the fishermen. The incubation of oviduct eggs, which has had poor results in Oaxaca for the ridley, had no success when eggs were taken from turtles dead for some hours, then transported in trucks for 6 hr to the IPOSA plant in Barre Navidad, Jalisco (Figure 2). Regional fisheries inspectors described the operation as "scandalous" and prohibited the use of shark nets and the capture of any more female turtles. The final tally for the season was 500 female and 10,000 male green turtles taken in Michoacán and Jalisco by IPOSA (Antonio Suarez, personal communication). These figures do not include losses to poachers for 1978 that probably figure in the hundreds of female green turtles. After analyzing the IPOSA catch data for 1978 which indicated a 20:1 male-to-female sex ratio for the green turtle, Suarez decided that there was an abundance of still exploitable male green turtles.

For good reasons, the male sex ratios appear higher in the breeding grounds. Nahuatl fishermen can capture male green turtles in the breeding grounds all year. Tagging data indicate that the male turtles wander hundreds of kilometers to and from the breeding beaches (male green turtles tagged at Colola were recaptured

Figure 2. Carapaces, bones, and entrails of female green turtles from Colola-Maruata at the IPOSA plant awaiting conversion into chicken feed, July 1978.

in Chamela, Jalisco within 2 weeks of release). The males are extremely active during the breeding season in comparison with the females. Offshore from the nesting beaches in rocky areas (20 to 60 m deep) they feed on crabs, jelly fish, sponges, hydroids, algae, and debris washed down from the rivers. Fishermen in the feeding and breeding grounds describe male green turtles as "skinny." A few tag returns indicate that some of the males return to mate annually. In rut they are almost completely beyond any concern for self-preservation and are extremely vulnerable to fishermen hunting them *al brinco*.

The females spend their internesting periods in semimoble aggregations within a few hundred meters of the nesting beach in shallow water (1- to 6-m deep). Consequently, they are infrequently captured by the Nahuatl Indians who traditionally fish for the male greens in the offshore areas previously described.

The new coastal highway reached Maruata in 1978, passing within 200 m of both major nesting beaches. Virtually overnight a viable commerce in green turtle contraband sprang up, supplying meat to Sonora and Sinaloa markets, already depleted of their once abundant local reserves. Members of the Pomaro fishing cooperative soon discovered it was far more profitable to sell to the smugglers than to IPOSA.

Since the 1978 season, the Mexican Government has tried two methods to gain control of the green turtle fisheries. In 1979 a closed season was declared for the nesting beaches. However, the fishing cooperative continued to catch turtles and sell them to smugglers. We estimate that 2,000 female and 1,000 male green turtles were illegally taken at Colola and Maruata Bay in 1979.

In 1980 the Government changed strategy and established a quota of 250 male turtles a month throughout the season (September through December) for the Pomaro cooperative. The setting of a quota has greatly changed the attitudes of the co-op members. No longer do they sell to poachers or take nesting turtles. Indeed, for the first time they have begun to accept the green turtle recovery program.

The East Pacific green turtle recovery program, designed and implemented in 1978 by the Arizona-Sonora Desert Museum and the Instituto Nacional de Pesca, began with the release of over 70,000 hatchlings. It would be extremely difficult to control poaching on the Michoacán coast which now has open access from land, sea, and air. The 6 marines stationed at Colola, without a vehicle, could not be expected to control the contraband. Consequently, to combat poachers coming from towns on the Colima border, we saturated the remote sections of beach with egg collectors loyal to our cause.

In 1979 Suarez was convinced that the East Pacific green turtle was endangered and began actively to support their protection. With the addition of his financial support in 1979, 326,000 eggs were recovered and transplanted to protected hatchery-corrals at Colola and Maruata Bay by the Nahuatl men, women, and children. Most of the eggs were *Chelonia*, but there were also several thousand *Lepidochelys* and *Dermochelys*. In the decade prior to 1978 virtually the entire reproductive efforts of the green, ridley, and leatherback turtles at Maruata Bay and Colola were destroyed by man and his domestic animals.

The hatcheries at Colola and Maruata Bay have been set up to follow as closely as possible the natural pathways of the turtle's life history tactics by transplanting the eggs into a corral situated on the native beach. When the hatchlings emerged they were collected around a small kerosene lamp. Within a few hours they were released on diverse sections of the beach to avoid the build up of predatory fish (e.g., *Nemastistius*, rooster fish; *Coryphaena*, dolphin; and *Caranx*, jack). The hatchlings were allowed to crawl to the sea so as not to interfere with possible imprinting.

Conclusions

In the late 1970s a spirit of cooperation was reached among the Mexican government, commercial interests, local people, and the international sea turtle conservation community. It was agreed that conservation efforts are best served by open communication, honesty, and mutual respect. Yet these successes seem negligible when compared to losses to poachers. The mania for green turtle meat in Sonora and Sinaloa, and the demand for all sea turtle eggs in Mexico and leather for the luxury trade continue to drive the prices up, cultivating corruption at local levels.

In recent years a philosophy of "rational exploitation" has emerged in Mexico, and relies on modern processing to make maximum use of natural resources. Suarez and others involved in legal exploitation are strong adherents to this point of view. They see the sea turtle situation as influenced by a triangle of factors: socioeconomic, political, and biological. Consistant with the concept of rational exploitation, Suarez said, "The surest way to drive a species to extinction [in Latin America] is to give it total protection." He felt that a total moratorium on sea turtle hunting in the past benefited those operating outside of the law and crippled those wishing to work in compliance with it. This is why he insisted that, "You must exploit something, even a token quota, to maintain control of the fishery." This philosophy has been at odds with most international conservation activities.

Márquez (1976) proposed that the major breeding beaches of Mexico should be made into National Reserves. Organization of a private citizen's committee to fund research and conservation programs for sea turtles in Mexico seems a logical step to the protection of these magnificent animals. Excessive take, poaching and loss of habitat have brought the sea turtles of Mexico to the brink of extinction. The social and economic pressures that have led to this ecological disaster need to be assuaged by setting new priorities in the very near future. We believe that Mexico's sea turtles can probably still be saved.

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Status of Sea Turtles Along the Pacific Coast of Middle America

ABSTRACT

The current status and distribution of sea turtle populations, historical trends, manner of exploitation and conservation and research programs are described for each of the 6 countries of Middle America. Five species, listed in order of their estimated relative abundance, are: olive ridley (*Lepidochelys olivacea*), green turtle (*Chelonia mydas*), loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), and hawksbill (*Eretmochelys imbricata*). The olive ridley is the most abundant turtle in El Salvador, Honduras, Nicaragua, and Costa Rica. Large synchronous nesting emergences (*arribadas*) of this species occur in Costa Rica and formally occurred in Nicaragua and Panama. The green turtle is the most abundant species in Guatemala. Unusually large numbers of loggerheads apparently comprise the majority of Panama's turtle population. All countries either have had in the past, now have or are preparing protective legislation for sea turtles and/or their eggs. Costa Rica's populations are the best known, but basic inventories of nesting beaches are needed in all countries to fill gaps in knowledge of population status, distribution, reproductive potential, and level of exploitation. The commercial overexploitation of eggs, inadvertent mortalities from shrimping operations, egg predation by domestic animals, and general inadequacy of regulatory mechanisms are all, to some degree, factors contributing to the decline of sea turtle populations in Middle America.

Introduction

This report discusses the current status of sea turtle populations along the Pacific Coast of Middle America. Each of the 6 countries—Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama—is treated separately in the following general manner: physical description of the coastline, status and distribution of the populations, threats to survival, protective measures, and conservation/research programs.

Except for Mexico and Costa Rica, very little infor-

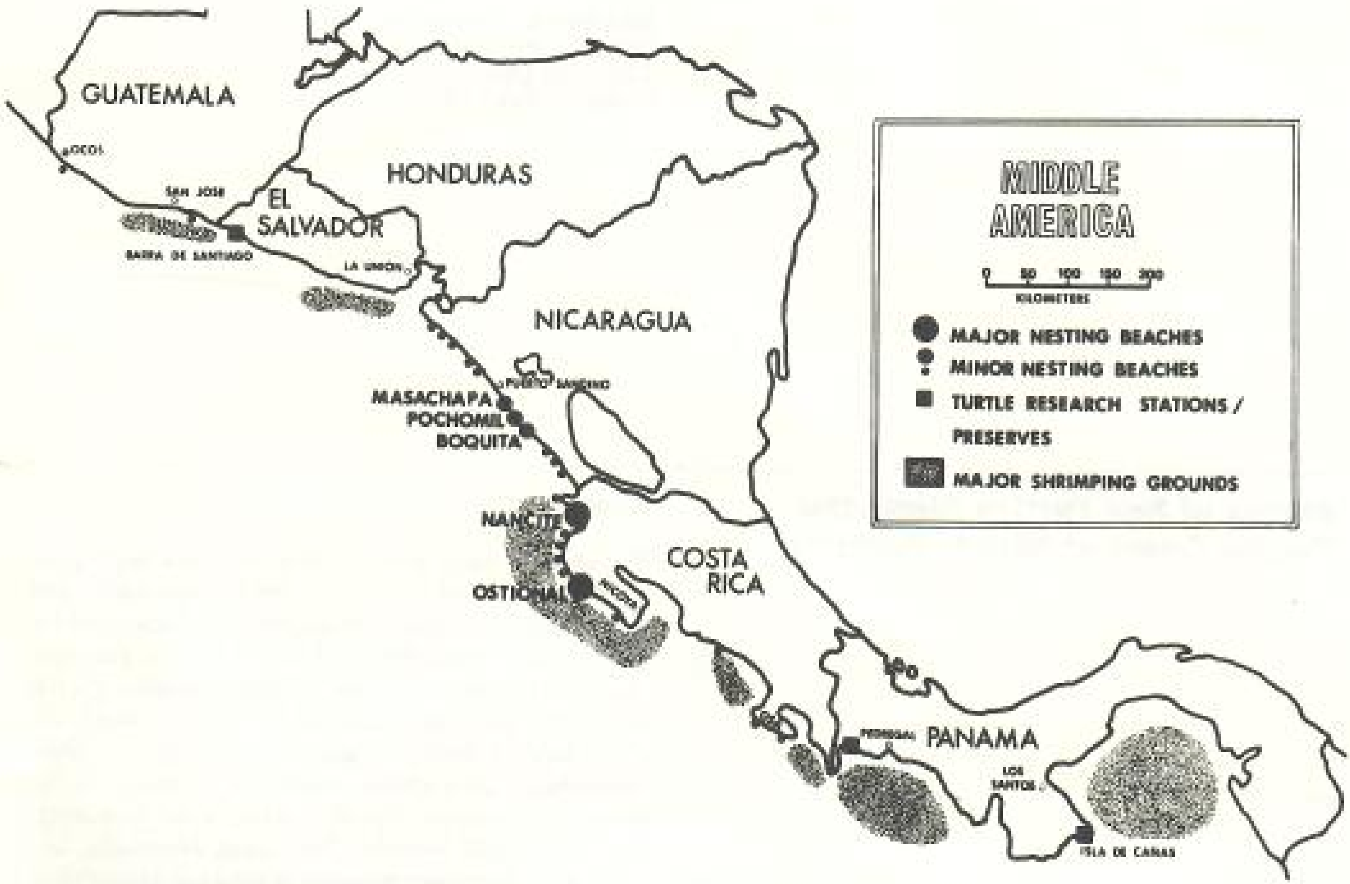

Figure 1. Map of Middle America showing the location of marine turtle nesting beaches, research stations, reserves, and major shrimping grounds.

mation has entered the turtle literature for the East Pacific region. It was necessary, therefore, to rely extensively on information solicited from those acquainted with the current situation in each country. This was especially important regarding the effectiveness of existing legislation.

Guatemala

Guatemala's Pacific coastline of about 250 km is straight and open with no natural harbors and relatively shallow offshore waters. The long stretches of black sand beaches are broken by 7 estuaries between its river borders with Mexico and El Salvador.

Probably less is known about the sea turtles in Guatemala than anywhere else in Middle America. Published information is typically incidental to other studies. Coe and Flannery (1967) listed both the meat and eggs of the *parlama (Chelonia mydas)* as a food item in the southwestern coastal villages near Ocós. The barrier beaches fronting the Chiquimulilla Canal (La Rosario, Las Lisas, El Hawaii) harbor a sizable population of green turtles (Figure 1). At least 20 individuals a night have been observed along a 15-km stretch during the nesting season of September and October (Herman Kihn, personal communication). Olive ridleys are present in fewer numbers.

The past 20 years have witnessed a steady decline in Guatemala's turtle populations. This can be attributed to two factors: commercial harvests of eggs and the incidental catch of subadult and adult turtles in shrimp trawls. There is no demand for turtle skins or meat.

Although Carr (1961) found olive ridley eggs common in the markets in 1959, human exploitation probably did not adversely affect turtle populations until access to the remote southeast coastal region improved. With increased contact with the more populated highland interior, poaching and marketing have become vigorous businesses in areas where turtles nest. Eggs can be purchased at the nesting beaches for 50 cents a dozen by coastal families or 2 for 25 cents by tourists. In the large cities the price rises to $1.50 a dozen in the open markets and 2 for 50 cents in bars and restaurants (anonymous communication at request of informant).

The shrimp fishery, which began in the late 1950s, has expanded considerably causing an increase in the incidental catch of turtles. Approximately 150 to 200 carcasses wash ashore in southeast Guatemala annually (anonymous communication). Their undecomposed and nonmutilated condition upon stranding implicated the shrimp fleet that patrols the entire coast in water less than 70 m. The center of the fishery is from San José to the Salvadorean border. Until recently, most turtles were returned to the sea. Serious consideration is now being given to developing a market for these incidental catches (Kihn, personal communication).

At present, the capture and commercial use of all sea turtles is prohibited by law (Bacon 1973; Kihn, personal communication), although the law is widely ignored in the case of eggs. In 1976, the government attempted to limit the harvest of eggs (James Richardson, personal communication). It is likely that commercial use has now returned to total exploitation. A hatchery was established on the southeast coast five years ago but is now unattended (Kihn, personal communication).

El Salvador

El Salvador has a 300-km coastline, about half of which fronts a narrow coastal plain. The south central plain widens to 30 km around the 2 major estuaries, Estero Jaltepeque and Bahia Jiquilisco.

Four species of sea turtles are known to utilize Salvadorean beaches: *golfina (Lepidochelys olivacea)*, *tortuga (Chelonia mydas)*, *baul (Dermochelys coriacea)* and *carey (Eretmochelys imbricata)* (Victor Rosales and Manuel Benítez, personal communication). Preliminary results of a government survey indicate the olive ridley and hawksbill are the most abundant and rarest, respectively. Dispersed nesting occurs from July through December on all sandy beaches.

Coastal fishermen report nesting has decreased abruptly in recent years (Benítez, personal communication). Few people kill nesting turtles, and there exists only a small craft industry in hawksbill shell. El Salvador appears to be the only country in Middle America where beach destruction and alteration are serious threats to nesting habitat. Construction of tourist facilities near the high tide line causing beach erosion and general pollution of the shoreline are blamed (Benítez, personal communication). Most exploitation centers, however, around a well-organized domestic egg trade. In three markets, 18,956 eggs were sold during September to December 1978 (Zelaya 1979). The high price of $2.50 to $3.00 a dozen was indicative of their scarcity.

Many turtles, mostly olive ridleys, are entangled by nets of the shrimp fleet that operates in nearshore waters from Estero Jaltepeque to the mouth of the Gulf of Fonseca (Benítez, personal communication). Observations of government personnel and coastal fishermen suggest a direct relationship between degree of shrimping activity and numbers of dead turtles stranding.

Although El Salvador offered nesting turtles some protection in the early 1970s, no legal instrument currently regulates the use and conservation of fisheries and wildlife (Serrano 1978; Benítez, personal communication). The civil code, in fact, considers all wildlife as *propriedad feudal*. Neither has the country ratified any international conventions on natural resource conservation. Responsibility for marine resources are jointly held by the Division of National Parks and Wildlife and the Fisheries Resources Service. Considerable effort has been made to rectify the situation, beginning with a study of coastal areas appropriate for national parks and marine biological reserves (Serrano 1978).

During 1978, Legislative Decree 427 (December 1977) prohibited the hunting, selling, buying, exporting and consumption of all marine turtles and their eggs. The law had a rather short lifespan, expiring after 1 year. During the time the law was in effect, fewer eggs were sold openly in the markets. Poaching at the beaches was uninterrupted, however, and most bars and restaurants continued selling eggs with few restrictions.

The Fisheries Resources Service established hatcheries at four locations in 1975. Beginning in 1978, the program was expanded and a cooperative effort between the Ministry of Agriculture (with assistance from the U.S. Peace Corps), Ministry of Education, University of El Salvador and the commercial fishing cooperative at Barra de Santiago (ACUARIO) resulted in adoption of a more scientific approach to the collection of eggs, identification of nesting turtles and care of transplanted nests (Rosales, personal communication).

El Salvador has initiated an ambitious study of their sea turtle populations. The absence of protective legislation, lack of a strong conservation ethic in the general populace, and insufficient funding and direction will make their effort difficult.

Honduras

Honduras has only a 65 km-long contact with the Pacific Ocean at the head of the Gulf of Fonseca, which it shares with El Salvador and Nicaragua. It also has jurisdiction over several nearshore, largely uninhabited, islands. The perimeter of the shallow gulf has only a few narrow and uncompacted sand beaches.

In spite of the apparent unsuitability of the gulf's shores for marine turtle nesting, most early information of Middle America's west coast populations has come from Honduras (Carr 1952). Carr (1948) reported green turtles, hawksbills, and olive ridleys in the market places of the capital, Tegucigalpa, and observed ridleys nesting on several islands in the gulf.

Recent estimates of the ridley population in Pacific Honduras are placed at 3,000 nesting individuals (Jonathan Espinoza, personal communication). They are common throughout the gulf from July through December with a peak in September and October. Most nesting activity is concentrated in the areas of Punta Ratón and Playa Cedeño (Paul Purdy, personal communication).

A noticeable decline in numbers of nesting turtles has been observed (Espinoza, personal communication). At the time of Carr's visits, egg collecting, conducted primarily by Salvadoreans, occurred on the islands from August through November. They were transported to La Union, El Salvador for sale. Ridleys probably suffered the most from such collecting, but nests of hawksbills were likely poached also. The sale of turtle eggs in local and countrywide markets and coastal restaurants is still a lucrative business for people residing near nesting beaches. It is estimated that at least 90 percent of all eggs are removed for the commercial trade (Purdy, personal communication). There is no exploitation of turtles for meat, oil or leather.

The National Fishing Law (1959) prohibits the capture of turtles and the taking of eggs, although there is little effort to enforce the regulation (Purdy, personal communication). Resolutions to prohibit the sale of turtle eggs are submitted annually to the congress but have never been approved (Espinoza, personal communication).

There is no developed shrimp industry in Pacific Honduras as few shrimp of commercial size are produced in the Gulf of Fonseca. The estuaries are excellent nursury grounds for many species of finfish, however, and a subsistence cast net and set net fishery probably takes turtles occasionally.

Sea turtle conservation and management is the responsibility of the Department of Wildlife and Environmental Resources, created in 1974. No biological reserves exist, although several are planned (Aguilar 1978). Some effort has been made to protect certain nesting beaches and operate artificial hatcheries but these have not been very successful (Espinoza and Purdy, personal communication).

Nicaragua

Nicaragua's 300-km shoreline on the Pacific is composed of 3 physiographic regions. Sand beaches suitable for sea turtle nesting are found in all regions.

Five species reportedly frequent the beaches of Pacific Nicaragua (Nietschmann 1975; Reynaldo Arostegui, personal communication): ***paslama** (Lepidochelys olivacea)*, ***tortuga tora** (Dermochelys coriacea)*, ***tortuga caguama*** or ***falso carey** (Caretta caretta)*, ***carey** (Eretmochelys imbricata)*, and ***tortuga verde** (Chelonia mydas)*. The olive ridley is the most common species but relative abundances of the others are unknown. Known nesting areas by political departments are as follows: Chinandega—Potosí, Padre Ramos, Jiquilillo and Corinto; Leon—Peneloya, Salinas Grandes, El Tránsito and Puerto Sandino; Managua—Masachapa and Pochomil; Carazo—La Boquita and Casares; Rivas—El Astillero, Ostional and Brito (Figure 1). The most important beaches are in the departments of Managua, Carrazo and Rivas. The 20-km stretch between Masachapa and Pochomil and El Astillero Beach are well known sites for mass nesting olive ridleys and are the focus of year-round nesting by other species (Nietschmann and Arostegui, personal communication). Ridleys nest from September through November but are observed in nearshore waters during the remainder of the year.

Local people claim the ridley used to nest in much larger numbers, and that the size and frequency of mass arrivals are diminishing. Nesting turtles are rarely killed except by an occasional coastal family for fresh meat, and few are accidentially caught and killed in shrimping operations (Nietschmann 1975). Rather, the observed decline is traced to overexploitation by egg collectors. Total removal in a traditional, well-organized and legal manner occurs during August and September. Egg collecting is banned during October and November. Weak surveillance, however, permits continual exploitation, especially from Masachapa to La Boquita (Arostegui, personal communication). A small number are eaten by coastal dwellers while the vast majority are transported to the major cities and sold in the open markets, supermarkets, bars, and restaurants. Large shipments are also exported to other Middle American countries. Nietschmann (1975) reported 500,000 sent to Guatemala. El Salvador imported 568,000 eggs in 1975 and 648,000 in 1976 from Nicaragua (Arostegui, personal communication). Assuming an average clutch of 100 eggs and 2 nests a season, this represented the repoductive effort of 2,840 females in 1975 and 3,240 in 1976.

The apparently low rate of capture in shrimp nets may be due to the inability of boats to drag close to shore. Shrimpers operate along the entire coast but because the nearshore shelf is poorly known and rocky, most trawling takes place at depths greater than 20 m (Gross 1971). This probably reduces contact between trawlers and turtles near nesting beaches.

The protection and scientific study of sea turtles falls under the jurisdiction of the Department of Wildlife, created in 1956. It was not until Legislative Decree 625 was published in May 1977, however, that capture and hunting of all wild animals, including sea turtles, for commercial gain was prohibited (Salas 1978). This legislation also prohibited for 10 years the exportation of olive ridley eggs. It is poorly enforced and exporters are able to circumvent its intent (Arostegui, personal communication). The new revolutionary government that came to power in 1979 has "expressed a concern for the protection and appropriate use of the country's renewable natural resources" (Arostegui, personal communication).

From 1959 until 1976, a hatchery was operated at Pochomil during the nesting season of the ridley. In 1975, 38,250 eggs, representing 425 nests, were transplanted. No information is available on percent hatch, but even if a 100 percent success rate were achieved, this attempt could only restore a very small portion of that lost through the egg trade. The only scientific study of Nicaragua's turtle populations was conducted by Bernard Nietschmann in 1972 at the beaches of Masachapa and La Boquita (Nietschmann, personal communication).

Costa Rica

The 575-km coastline of Costa Rica is broken by a series of peninsulas and gulfs. from its northern border with Nicaragua to the tip of the Peninsula of Nicoya, a multitude of cobblestone and compacted beaches have formed. Around the perimeter of the Gulf of Nicoya to the Peninsula of Osa, the coastal plain broadens and long beaches are broken intermittently by rock headlands and large estuaries. The precipitous nature of the northwest coastline returns at the Peninsula of Osa.

At least 4 species of turtles nest along the Pacific coast. They are: *lora* or *carpintera (Lepidochelys olivacea)*, *tora* or *verde (Chelonia mydas)*, *baula (Dermochelys coriacea)* and *carey (Eretmochelys imbricata)*. The loggerhead *(caretta caretta)* may nest around the Peninsula of Osa since it is reportedly common in Panama.

Ostional and Nancite beaches are well known for their large mass nesting populations of olive ridleys. Other beaches in Guanacaste Province used extensively by various species but not approaching the numbers at Ostional and Nancite are: Coloradas, Cabuyal, Matapalo-Zapotal, Langosta-Tamarindo, and San Miguel-Coyote (Richard and Hughes 1972). Except for Savegre and Matapalo beaches south of Puerto Quepos, only scattered nesting is recorded between the Nicoya and Osa peninsulas. Heavy nesting occurs on the long exposed beaches of the Osa, particularly Piro-Madreigal and Llorona-Sirena (Richard and Hughes 1972; Christopher Vaughan, personal communication) (Figure 1).

Leatherbacks nest sporadically along the length of the coast. Total numbers are small (Cornelius 1976). Local people claim the leatherback is more abundant during the dry season months of December to May. This nesting chronology coincides with reports from El Salvador, where leatherbacks nest in November and December after other species have finished (Benítez, personal communication).

The green turtle is locally common although far less abundant than ridleys. The nesting season is prolonged, possibly extending the year around (Cornelius 1976). The appearance of numerous moribund subadults on the northwest Guanacaste coast during 1972 (Cornelius 1975) suggests that Costa Rica's green turtles may be resident, or that juveniles participate in seasonal movements.

Hawksbills are more often seen in shrimp trawl catches than nesting on the beaches. Coastal people recognize the name *carey* and can reasonably describe the species.

Egg poaching is a time-honored tradition. Ostional has been the primary egg supplier to the markets of Guanacaste and the Central Highlands. At least 60,000 eggs left Ostional during a 3-day period in 1970 (Doug Cuillard, personal communication). Because of a surprisingly low hatching rate of eggs at arribada beaches (Hughes and Richard 1974) a controlled harvest of ridley eggs was proposed in 1977. This project was subsequently denied following a lively newspaper debate.

Wherever villages are situated on or near nesting beaches natural predation is augmented or replaced by domestic animals. Dogs destroy almost every nest along the Peninsula of Osa during certain times of the year (William Rainey, personal communication). At Ostional, pigs consume large quantities of eggs with the ironic result of instilling an undesirable flavor to the flesh. Guards were placed at Ostional in 1979 for the first time and have been successful in reducing the loss to domestic animals as well as stopping human poaching (Douglas Robinson, personal communication).

Large numbers of turtles are caught by shrimp trawlers most often along the coast of Guanacaste Province (Figure 1). Islas Negritos, Punta Guiones, Cabo Velas and the Gulf of Papagayo are cited by shrimpers as areas with high incidental catch rates. It is likely that turtles are also taken in the other major shrimping grounds in the open Colorados Bay and the Dulce Gulf. The Gulf of Nicoya is a declared nursury ground and shrimp trawling is prohibited in the upper reaches (Gross 1971).

Estimates of catch rates differ among shrimp captains and range from 600 to 2,000 annually by the fleet of 61 trawlers (Eduardo Lopez, personal communication). Most turtles captured are olive ridleys and many of these are females with shelled eggs. Catches of up to 45 in 1 haul, with averages of 4 to 5 per haul are also reported. Other estimates reach upwards of 200 juveniles and adults taken daily in late spring and early summer (B. Couper in communication with J. D. Richard).

Those that arrive on deck alive and some of the dead are returned to the sea. This mortality is probably the cause of the relatively large numbers of carcasses observed on Costa Rican beaches. Seventy-three green turtles and 2 ridleys in varying stages of decomposition were counted along 6 km of beach over a 75-day period in 1972 (Cornelius 1975). Ten ridleys, 3 greens and 1 hawksbill were observed on the same beach in August 1977 (Rainey, personal communication). The latter count was thought to represent 10 day's deposit.

During the late 1960s and early 1970s, the Costa Rican press reported foreign fishing vessels of unknown nationality operating off the Guanacaste coastline. Turtles, mostly ridleys, were shot on the beaches and transported to a "mother ship" which remained outside the country's territorial waters. This activity ceased shortly after news articles appeared.

The protection and management of sea turtles and their habitat in Costa Rica are the dual responsibility of the Executive Direction of Fisheries and Wildlife Resources and the National Park Service. Probably nowhere in Middle America has a framework for the conservation of renewable natural resources been established so concretely as in Costa Rica. This is fortunate for sea turtles, as nowhere on the Pacific side of the isthmus are there larger populations.

The legal basis for the protection of sea turtles is contained in the broad Wildlife Conservation Law (No. 4551), prohibiting the commercial exploitation of animals and their products for both the domestic and export markets. For a species to be covered it must first be declared either endangered or threatened (López 1978). The taking of sea turtles and their eggs is prohibited on the beach and in the territorial waters. It remains legal to land turtles killed on the high seas and to import them from foreign countries (Anonymous 1978). This applies to the domestic green turtle fishery on the Caribbean. No permits have been granted, or perhaps requested, for capture of sea turtles on the Pacific coast since 1977 (Fernando Víquiz, personal communication).

The government of Costa Rica, though maintaining the excellent attitude toward natural resource conservation initiated by two previous administrations, has been less generous with funding as a result of a governmentwide budget-tightening process (José Rodriquez, personal communication). No additional protection can be expected in the immediate future but neither will there be any relaxation of present laws. A law to permit Caribbean turtle fisherman to operate closer to nesting beaches was recently vetoed by the President.

Sea turtles have long been the subject of interest and scientific research in Costa Rica. Most field studies have been directed at the West Caribbean populations nesting in northeast Limon Province (Carr and Giovannoli 1957; Carr and Ogren 1959; Carr and Hirth 1962; Carr, Hirth, and Ogren 1966).

Except for a few notes on solitary nesting olive ridleys in Guanacaste and Puntarenas provinces (Carr 1961; Caldwell and Casebeer 1964), little was known until recently of the Pacific coast sea turtles. In 1970, Richard and Hughes (1972) conducted a low level aerial reconnaissance of Costa Rica's shores. In the Pacific, major nesting beaches of the olive ridley were discovered, each having over 100,000 turtles aggregated offshore. Both Nancite beach, within Santa Rosa National Park, and Ostional beach, located 90 km to the south, host periodic mass nesting emergences (variously called *arribada*, *salida de flota*, or *cardumen*) from mid-summer through December (Hughes and Richard 1974). Smaller arribadas sometimes begin as early as April at Ostional, where the University of Costa Rica has maintained a field station for nine years (Robinson, McDuffie, and Cornelius 1973).

Two- to three-hundred-thousand ridleys participate in the arribadas at Nancite and Ostional. Each mass emergence lasts 3 to 10 days, with daylight nesting sometimes observed. These 2 beaches are the most important sites of ridley reproduction in the western hemisphere, if not in the world. The adults suffer little intentional human exploitation since consumption of turtle meat is, to some extent, culturally unacceptable on the Pacific. Until recently, these populations were considered fairly secure because of the natural isolation of the major nesting beaches, legislated protection within Costa Rican waters, and the likelihood that they were distinct from ridleys nesting in Mexico.

The over-harvest and eventual demise of the Mexican fleets will force that industry to locate a new supply. Contact between Costa Rican officials and the Mexican turtle industry has been made. This event together with the development within the past 3 years of a massive commercial harvest of ridleys in Ecuador has left Costa Rica's population highly vulnerable.

Panama

Very little of Panama's sinuous and island-studded coastline of 1,100 km is unsuited for sea turtle nesting (Figure 1).

Five species reportedly occur in the coastal waters and beaches of Pacific Panama. In order of their relative abundances, they are: *tortuga cahuama (Caretta caretta)*, *tortuga mulato (Lepidochelys olivacea)*, *tortuga verde (Chelonia mydas)*, *tortuga canal (Dermochelys coriacea)* and *carey (Eretmochelys imbricata)* (Argelis Ruiz, personal communication). The green turtle nests very little although it is frequently observed in coastal waters. Although no systematic inventory has been conducted of these populations, the loggerhead is considered to be by far the most abundant. Nowhere else along the Middle American coast is the species common, and in most countries it is listed only because of Carr's (1952) broad range description. It may be common in Colombia (Green and Ortiz, this volume).

Panamanian officials have identified 12 important nesting beaches on the Pacific coast. The reproductive season for all species is from May to December (Nicholas Real, personal communication). Turtle populations have decreased drastically in the last 10 years. At least 30 beaches were formerly known to host large nesting aggregations. These were called *arribadas* but whether the term was used in the sense of mass emergences such as now occurs in Costa Rica and Mexico or whether it was a qualitative expression of large numbers of solitary nesters is unknown. In either event, the sizes of the populations at each of the 12 remaining beaches are not as large nor is the nesting process as prolonged.

There is no industry established in Pacific Panama for the exploitation of sea turtles. This is in contrast to the Caribbean coast, where several companies are involved in the importation, exportation, and transshipment of stuffed juveniles and hawksbill shell. From 1964 to 1976, over 96,000 kg of shell were officically exported from Panama (Vallester 1978). This represented approximately 55,670 hawksbills, most originating from Bocas del Toro and San Blas provinces.

Coastal villagers of the Pacific are permitted a small number of turtles for their own use, and egg consumption exists on a small scale but is illegal. The Panamanian shrimp fleet, largest in Middle America, reportedly releases the majority of the turtles caught incidental to their activities in the gulfs of Chiriquí and Panama (Real, personal communication).

The National Direction of Renewable Natural Resources (RENARE) has the principal responsibility of managing and protecting the country's wildlife, including sea turtles. Partial protection is now afforded the green turtle, loggerhead, and olive ridley by Executive Decree 23 (January 1967) and a closed season from 1 May to 30 September was declared by Executive Decree 104 (September 1974). A proposal to bring the leatherback and hawksbill some protection will soon become law (Vallester 1978; Real, personal communication). As elsewhere in Middle America, insufficient funds make strict vigilence of the beaches difficult, and the laws are often ignored.

There are now no sea turtle studies underway, but a program to identify nesting areas and mark populations is planned (Real and Ruiz, personal communications). In 1975, a biological reserve was established at Isla de Cañas along the coast of Los Santos Province where thousands of loggerheads, olive ridleys, and leatherbacks reportedly nest on 70 km of beach. At present, 2 additional turtle reserves have been established at Playas de la Barquete, Chiriquí Province and on the Caribbean at Playas Largas-Isla Bastimentos, Bocas del Toro Province. An artificial hatchery program has been in operation since 1975 at Islas de Cañas. The program was expanded in 1979, and egg transplants are expected to reach 65,000 (Real, personal communication). Guards patrol the beaches and are making an effort to eliminate the hordes of feral dogs that destroy up to 90 percent of the nests.

Conclusions

Undoubtedly, the total number of sea turtles in the East Pacific was once many times what it is today. The large concentrations seen off the Middle American coast as recently as the mid-twentieth century (Oliver 1946), were probably still largely unaffected by human exploitation.

Destruction and modification of nesting and feeding habitats have not been a significant factor adversely affecting sea turtles in Middle America, with the possible exception of recent events in El Salvador. Neither have these populations suffered from large-scale exploitation for meat, leather, oil, or tortoiseshell. That some populations of ridleys, which nest in Middle America, are endangered by such activities on their feeding grounds in Ecuador is now evident, however. Nesting turtles are rarely killed by coastal residents of the Pacific, as most do not consider the meat very good. In general, the Pacific coast populace do not have a strong marine component of their culture, except for the consumption of turtle eggs. This contrasts sharply with the Caribbean side of the isthmus, where sea turtles have traditionally been an important dietary item.

The regionwide population decline is likely the result of 2 factors, working in concert or alone depending on the specific locale. Poaching of eggs is a lucrative commerce in all 6 countries, regardless of protecting legislation. Nicaragua's diminished populations can be traced easily to the tremendous drain of eggs from the nesting beaches. Predation by domestic animals is normally associated with human poaching. Certain beaches of Costa Rica and Panamá are especially susceptible to this form of destruction.

The second major factor adversely affecting the region's sea turtles is the inadvertent mortality caused by the relatively new shrimping industry. This fishery began in 1941 in northern Mexico, but did not spread to the tropical East Pacific until the early 1950s. General development proceeded slowly, with Panamá and Costa Rica the first to exploit the extensive white and pink shrimp grounds (Gross 1971). In 1958, Costa Rica expanded considerably, and El Salvador began harvesting what has become the most productive grounds along the isthmus. Development of commercial fisheries in Nicaragua and Guatamala followed. The fishery operates throughout the year, with white shrimp and pink shrimp taken in the wet and dry seasons, respectively.

The incidence of moribund turtle strandings seems to be highest in Guatemala, El Salvador and Costa Rica where shrimping operations are fairly close to shore and overlap major turtle nesting areas. Nicaragua's small fleet may trawl far enough offshore to alleviate the problem. Panamá's large fleet probably kills more turtles than suspected as its grounds in the bays of Chiriquí and Panamá coincide with important nesting beaches. Studies of the incidental catch problem in the southeast United States, report subadults rather than gravid females as the primary group affected (Anonymous 1978). Both juveniles and adults, including females with eggs, are reported in the trawls in Middle America.

All 6 countries have or are preparing some legislated protection for sea turtles and eggs. The lack of means of enforcement, however, is the plight of well-intentioned but financially restricted governments. Protection of all beaches from egg poachers is impossible, even given multiple increases in funding for vigilence. A policy of permitting coastal communities to harvest reasonable numbers of eggs for their own use, while directing most law enforcement effort at the few beaches which supply the bulk of the commercial trade seems appropriate for each country.

Basic inventories of nesting beaches have yet to be conducted in most countries, resulting in obvious gaps in knowledge of distribution, relative abundances, nesting seasons, etc. As some populations appear to be resident, studies of nonreproductive activities are possible. With international funding and consultation from experienced turtle researchers, several countries, notably El Salvador, Nicaragua, and Panamá, appear prepared to undertake such investigations.

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Status of Sea Turtle Populations in the Central Eastern Pacific

ABSTRACT

Data relating to research, exploitation and conservation of sea turtles in Colombia, Ecuador, and the Galápagos Islands are presented. Data for Colombia are restricted to personal communications. In Galápagos, extensive data have been gathered continuously for 4 years, especially on the east Pacific green turtle, *Chelonia mydas agassizi.* There is no current research in mainland Ecuador, but results of earlier investigations by the authors are given. The east Pacific green turtle, *Ch. m. agassizi,* the Indo-Pacific hawksbill, *Eretmochelys imbricata* and the Pacific leatherback, *Dermochelys coriacea,* have been reported from all 3 regions. The Pacific loggerhead, *Caretta caretta,* has been reported only from Colombia and the Pacific ridley, *Lepidochelys olivacea,* only from Colombia and mainland Ecuador. Exploitation in Colombia is for domestic consumption and in the Galápagos Islands is at a subsistence level. In mainland Ecuador there is heavy commercial exploitation of *L. olivacea*; possibly as many as 100,000 will be killed by the end of 1979, and their meat and skins exported, mainly to Japan. Efforts to curtail this exploitation are described in detail, and suggestions for future research and conservation are made.

Introduction

For the purposes of this paper, the Central Eastern Pacific is defined as Colombia and Ecuador (including the Galápagos Islands). The aim is to update our knowledge of the status of sea turtles in these regions, especially in regard to exploitation, conservation and research. The data for Colombia are from personal communications only; neither author has first-hand knowledge of the status of the sea turtles in this region. Data for the Galápagos Islands are gleaned from the senior author's current research program at the Charles Darwin Research Station on Galápagos sea turtles. The data for mainland Ecuador are derived from 2 independent investigations; one by the senior author for the National Fisheries Institute (INP), Guayaquil, and

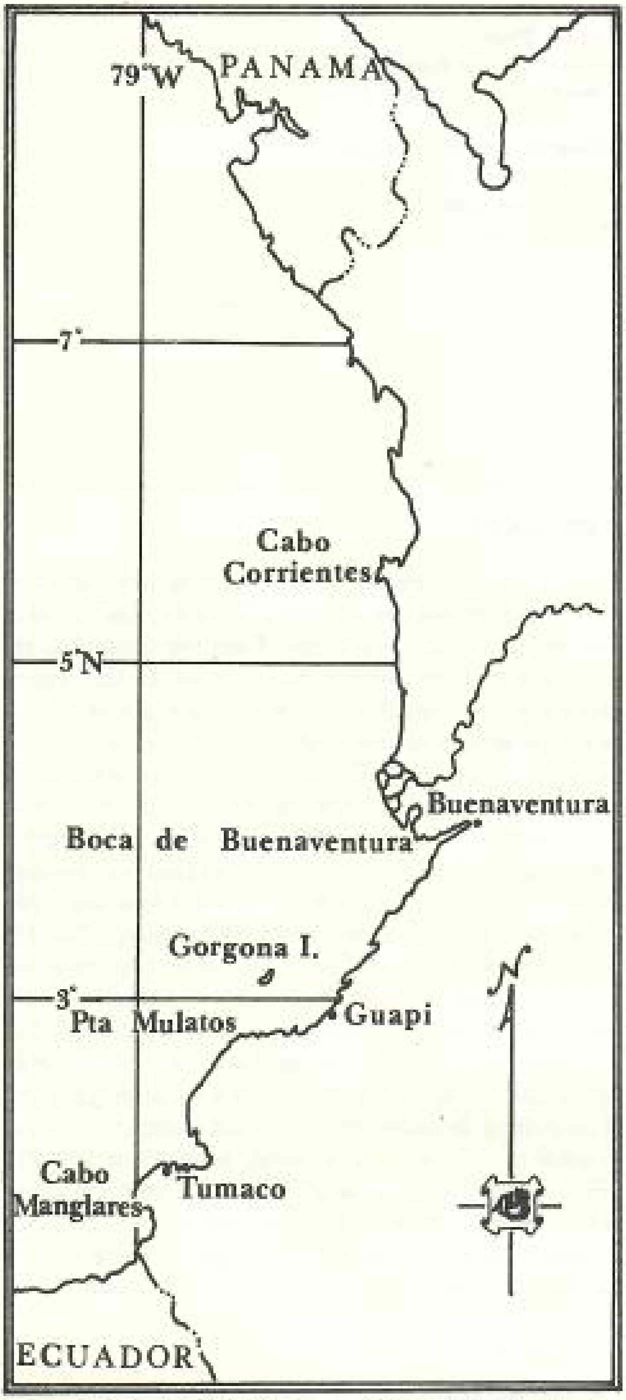

Figure 1. Map of the Pacific coast of Colombia showing the location of some of the areas mentioned in the text.

the other by the junior author for the Ministry of Agriculture and Livestock (MAG), Quito.

Colombia

Most efforts to contact the various Colombian bodies concerned with turtles proved fruitless. This, together with the paucity of turtle literature for this region, has left us very much in the dark as to the real state of affairs. The following account is based on information received by the senior author in letters from Henry von Prahl and Felipe Guhl from the Universidad de los Andes, Bogotá, and a single recapture of a Galápagos-tagged green turtle. Figure 1 shows the location of some of the areas mentioned below.

Species Present

The following species have been reported:

	English Name	*Local Name(s)*
Chelonia mydas agassizi	East Pacific green	Tortuga de mar, Caguama
Eretmochelys imbricata	Indo-Pacific hawksbill	Tortuga fina, Carey
Dermochelys coriacea	Pacific leatherback	Tortuga bufeadora
Caretta caretta	Pacific loggerhead	Tortugaña de mar, Tortuga
Lepidochelys olivacea	Pacific (olive) ridley	—

The only record we have of *Ch. m. agassizi* in Colombia is of a female tagged in Galápagos and recaptured in the Boca de Buenaventura (Green, unpublished data). The local name given for this specimen is *caguama*, which is also the common name used in Colombia for the Atlantic loggerhead, *Caretta caretta* (Kaufmann 1971). Von Prahl reports *E. imbricata* from the Guapi, Mulatos, and Sanquianga estuaries and on the *Pocillopora* reef off Gorgona Island, and *D. coriacea* from near Gorgona Island. According to Guhl, *C. caretta* is the most common species present around Gorgona Island. Von Prahl reports it also from southern Colombia near Tumaco and the Guapi, Sanquianga and Satinga estuaries. It thus appears to be the most common species present. The Pacific ridley, *L. olivacea*, has been observed in Colombia, but its abundance is unknown to us.

Exploitation

According to Von Prahl and Guhl, there is no international market. *C. caretta* and *Ch. m. agassizi* are caught for local consumption, and hawksbill shell is often used in craftwork. All 5 species are occasionally taken accidentally in shrimp and fishing nets.

Nesting

The nesting situation is unknown to the authors.

The Galápagos Islands

The Galápagos Archipelago straddles the equator and lies approximately 1,000 km off the coast of mainland Ecuador. It consists of 17 major islands, volcanic in origin, with a total land area of approximately 8,000 km^2 (Wiggins and Porter 1971). The 2 seasons, a hot, wet season between December and May, and a cool, dry one between June and November, are influenced by 3 major ocean currents, themselves influenced by the tradewinds (cited by Wellington, 1975). These climatic factors possibly affect the distribution of the sea turtles in Galápagos.

Research

THE PAST

Prior to 1970, very little work of a scientific nature had been done on Galápagos sea turtles, although they are mentioned in the journals of several earlier visitors to the islands. Slevin (1905–06 California Academy of Sciences Expedition) was one of the first to record them on a scientific basis. He skinned numerous green turtles, took measurements of their flippers and noted the stomach contents. His collection is preserved in the California Academy of Sciences, San Francisco.

During the breeding seasons of 1970 through 1975, Dr. Peter Pritchard, Miguel Cifuentes, and Judy Webb tagged 867 nesting females and 1 male (Pritchard 1971a, 1971b, 1972, and 1975; Cifuentes 1975). In addition, Pritchard made extensive surveys of the shoreline of most of the islands in order to determine the extent of nesting within the Archipelago (Pritchard 1972 and 1975). In September 1975, the senior author initiated a year-round research program which has just entered its fifth consecutive year.

THE PRESENT

The three main objectives are to determine the status of sea turtle populations in Galápagos; to collect enough scientific data on which to base recommendations for future management policies both in Galápagos and mainland Ecuador; and to incorporate Eucadorian university students into the program with the aim of extending, with their help, the research to mainland Ecuador.

Apart from monitoring the nesting beaches and thus gathering data only on nesting females and only during the nesting season, feeding grounds are also visited at intervals throughout the year. Here both males and immatures as well as females are caught with nets or by hand.

In addition, a study of the effects of a scarabeid beetle, *Trox suberosus*, on the nesting success of *Chelonia mydas agassizi* was made this year by Karin Allgöwer (1979).

The present research program has produced data on breeding cycles, multiple nesting, reproductive potential, hatching success, clutch size, incubation periods, migration, interisland movements, feeding potential, etc. In addition, extremely important data were gathered on growth rates of immatures in the wild. Some of these results are incorporated in the text below.

Species Present

The following species have been reported:

	English Name	*Local Name*
Chelonia mydas agassizi	East Pacific green	Tortuga negra
Eretmochelys imbricata	Indo-Pacific hawksbill	Carey
Dermochelys coriacea	Pacific leatherback	None

Chelonia mydas agassizi is the most common species and exists in large numbers. It is known locally as *tortuga negra* or black turtle (referring to the dark color of the carapace) in order to distinguish it from a rare yellow form, the yellow turtle or *tortuga amarilla*, of unknown scientific status, but considered by Pritchard (1971a and 1972) to be a sterile mutant of the black form. A more detailed description of this rare yellow turtle will appear in a future paper (Green, in prep.).

Eretmochelys imbricata is encountered occasionally but *D. coriacea* has been sighted only 3 times and is by far the rarest of all 3 species present. Figure 2 shows sightings of *E. imbricata* and *D. coriacea* by local inhabitants, visiting yachtsmen and scientists.

Nesting

Chelonia mydas agassizi is the only species that nests in the Galápagos Islands. These islands are probably the most important nesting area in the Central Eastern Pacific and perhaps even the whole Pacific South America for this species.

Turtles nest on most of the islands within the Archipelago. Six of the most important beaches, which correspond to the study sites, are shown in Figure 2. A total of 3,784 mature females and 10 mature males have been tagged from these nesting beaches since 1970.

Although eggs have been laid in every month of the year, a distinct season occurs between December and May, with a peak in February. This corresponds to the hot or wet season.

Quinta Playa, a 2-km-long beach on southern Isabela, is probably the most important single nesting beach in Galápagos. The maximum number of nests laid in any one night on this beach were 23, 20, 45, and 18 for the 1976, 1977, 1978, and 1979 seasons, respectively. For these same seasons, the total numbers of different nesting females recorded on this beach were 315, 308, 610, and 300, respectively.

Table 1 gives the percentage hatch (referring to the total number of hatchlings) and the percentage emergence (the number of hatchlings actually reaching the surface) for Las Salinas, Baltra, and Quinta Playa, Isabela, for the years 1976–79; and Bahía Barahona on Isabela, Las Bachas on Santa Cruz, Espumilla on James, and Bartolomé for 1979.

The low hatching and emergence rates for Quinta Playa are mainly due to nest destruction by feral pigs and egg predation by a scarabeid beetle, *Trox suberosus*. This beetle has also been found preying on turtle nests on nearby Bahía Barahona and on Bartolomé, and nests of the Galápagos land inguana, *Conolophus subcristatus*, on South Plaza Island (Howard and Heidi Snell, personal communication). As far as we are aware, there is no record in the literature of this beetle's attacking turtle nests in other parts of the world.

The extremely low hatching and emergence rates of 1.88 percent for Espumilla are almost entirely due to feral pigs, which in 1979 totally destroyed most of the nests laid. Of 122 nests marked, only 8 resulted in hatchlings, and 5 of these had also been attacked by pigs. These results do not include 7 other marked nests which were partially destroyed by pigs and several other marked nests swamped by high tides, for which the hatching and emergence rates are unknown.

Feeding Grounds

The most important feeding grounds for the green turtles in Galápagos appear to be the algae beds in the western islands of Isabela and Fernandina. Stomach analyses and underwater observations have shown that these green turtles eat at least 15 different species of algae.

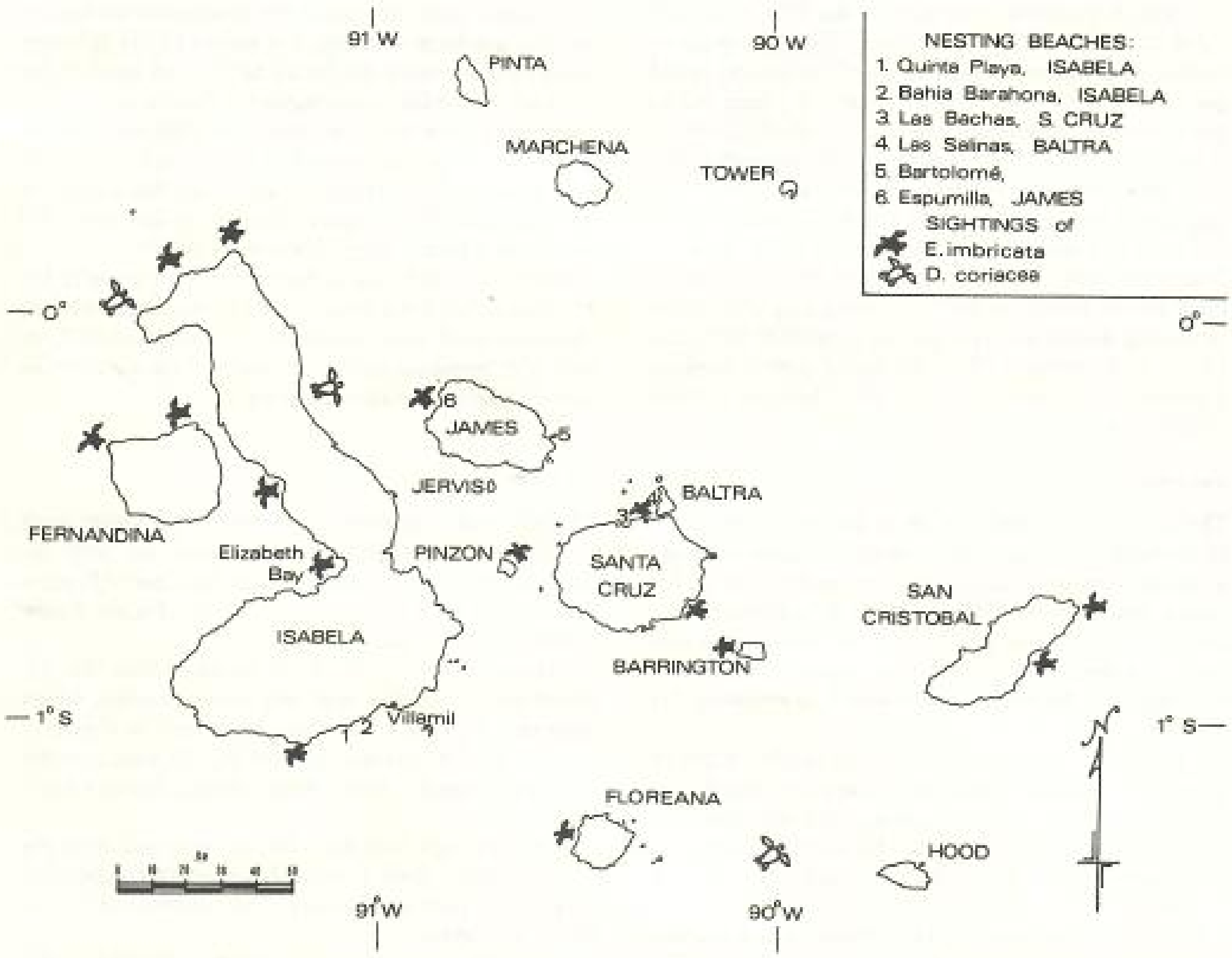

Figure 2. Map of the Galápagos Islands showing the principal nesting beaches of the east Pacific green turtle *Chelonia mydas agassizi*, and sightings of the Indo-Pacific hawksbill, *Eretmochelys imbricata*, and the Pacific leatherback, *Dermochelys coriacea*.

Table 1. Comparison of percentage hatch and percentage emergence of the east Pacific green turtle, *Chelonia mydas agassizi*

Year	*Nesting beach*	*Number of nests marked*	*Number of eggs*	*Percentage hatch*	*Percentage emergence*
1976	Las Salinas, Baltra	94	8198	72.12	69.66
	Quinta Playa, Isabela	120	9651[a]	38.63	37.82
1977	Las Salinas, Baltra	21	1842	52.23	49.67
	Quinta Playa, Isabela	101	8018[a]	43.73[b]	40.47
1978	Las Salinas, Baltra	38	3334[a]	70.97	69.77
	Quinta Playa, Isabela	40	3385[a]	43.46	41.18
1979	Las Salinas, Baltra	22	1688	71.09	69.91
	Quinta Playa, Isabela	67	5363[a]	48.69	47.70
	Bahía Barahona, Isabela	69	5643[a]	74.23	72.92
	Las Bachas, Santa Cruz	22	1687	80.44	78.42
	Espumilla, James	122	9709[c]	1.88	1.88
	Bartolome	15	1142	50.00	47.20

Note: This comparison is based on observation of 731 natural nests on several different beaches in Galápagos between 1976 and 1979.

a. Samples include nests where the original clutch size was impossible to determine due to total destruction of the nest and where the percentage hatch and the percent emergence were therefore both zero. In these cases the mean clutch size for the respective beach is added for each nest destroyed in order to determine the total number of eggs in the sample.

b. A pig totally destroyed one nest while the hatchlings were in transit to the surface. The emergence rate was zero. The mean number of hatchlings per nest for Quinta Playa 1977 was added to the total in order to determine the total number of hatchlings in the sample.

c. In all 122 nests it was impossible to determine the original clutch size. Therefore the mean of 188 clutches laid on the other 5 beaches during 1979 ($\bar{x}$ = 79.58 eggs per clutch) is used to determine the original number of eggs in the sample.

Population: Resident vs Migratory

Recaptures indicate that some of the green turtles tagged on the local feeding grounds, especially immatures and virgin females, are present there year round. In addition, several females tagged on the nesting beaches were recaptured on these feeding grounds well after the season had ended. On the other hand, from these same beaches there have been 17 international recoveries (Peru, 7; mainland Ecuador, 4; Colombia, 1; Panama, 3; and Costa Rica, 2) of Galápagos-tagged female green turtles. It thus appears that part of the Galápagos population is resident and part is migratory. What percentage of the resident part consists of late departures from the previous nesting season or early arrivals for the next is unknown. Without more recapture data it is not possible to say what proportion is truly resident and what migratory, or even to give a worthwhile estimate of population size. The subject of migration of Galápagos green turtles will appear in a future paper (Green and Pritchard, in preparation).

Growth Rates

Recaptures of immatures on the feeding grounds have furnished some important data on growth rates of immatures in the wild. This topic will be the subject of a future paper (Green, in preparation) but results can be summarized by saying that growth rates are extremely slow. For example, 11 immatures with straight carapace lengths ranging from 46 to 59 cm showed a mean growth rate of only 0.53 cm/yr over periods of 4 to 33 months. These slow growth rates will certainly have to be taken into consideration when planning future management policies.

Exploitation and Conservation

There is very little exploitation in Galápagos at present. By law, only local inhabitants are allowed to fish for turtles and only on a subsistence basis. This privilege is rarely exercised in Galápagos because turtle meat is not highly esteemed, and because there are so many cheap foods available. Since the Galápagos Islands are a National Park, all nesting beaches are completely protected, even from locals, although the military on Baltra take up to six nesting females per season from the beaches on that island. However, because of the migratory habit of green turtles (see above), although protected in Galápagos, they are open to exploitation elsewhere.

The Future

Four research needs, for which adequate financing is crucial, must be met in the future.

RESEARCH REQUIREMENTS

First, the present research program needs not only to be continued but also to be expanded in order to include more nesting beaches and more feeding grounds. We are still ignorant, for example, of the total population size of the Galápagos green turtle. Second, the work on growth rates of turtles in the wild should continue. Third, a detailed study of the feral pigs is urgently required, with the overall objective of eradication. Fourth, the work on *Trox suberosus* should be continued in more detail and methods designed and tested for the prevention of egg predation.

FINANCIAL FEASIBILITY

Funds promised by the Ecuadorian National Fisheries Institute (INP) have not materialized; nor, it seems, are they likely to materialize. Unless funds become available immediately, the program is in grave danger of terminating. Present resources will allow research to continue only on a skeleton basis, and only for a few months more.

Mainland Ecuador

Research

Prior to 1978, the status of sea turtles of mainland Ecuador was unknown. From May to July 1978 the senior author, under the auspices of the National Fisheries Institute (INP), Guayaquil, made a survey of the mainland shoreline from the Peruvian border in the south to Rocafuerte in the province of Esmeraldas in the north, approximately 80 km south of the border with Colombia. This investigation also included several visits to turtle-processing factories and an analysis of their trade figures. In June of 1978, Drs. Fernando Ortiz-Crespo of the Catholic University and Galo Cantos of the Central University, both in Quito, were commissioned by the Ministry of Agriculture and Livestock (MAG) to investigate the activities of the turtle factories. Both investigations were carried out independently, and their respective reports reside with their respective ministries. Data from both reports have been used in this paper.

Due to lack of time and, later, lack of funds, the senior author's investigation terminated in Rocafuerte. Turtles are said to occur north of this point, for example, in La Tola and probably as far north as the border with Colombia.

Species Present

The following species have been reported:

	English Name	*Local Name(s)*
Chelonia mydas agassizi	East Pacific green	Numerous
Eretmochelys imbricata	Indo-Pacific hawksbill	Carey, peinilla
Dermochelys coriacea	Pacific leatherback	Numerous
Lepidochelys olivacea	Pacific ridley	Tortuga verde

Chelonia mydas agassizi, *E. imbricata* and *D. coriacea* all occur in small numbers from the Gulf of Guayaquil in the south to at least Rocafuerte and probably to the Colombian border in the north. In addition, *Ch. m. agassizi* and *E. imbricata* are found as far south as the border with Peru. Of these three species, *Ch. m. agassizi* is the most frequently encountered, and *D. coriacea* the least.

The Pacific ridley, *L. olivacea*, is the most common species and occurs in fairly large numbers from Anconcito, in the province of Guayas, to Esmeraldas and probably even farther north. This species is migratory in Ecuadorian waters and tends to remain farther offshore than the other species. Isla de la Plata (a small island 30 km from the mainland) and an area 30 to 50 km out to sea from Esmeraldas are the two areas where it is the most abundant.

There is no evidence at present for the occurrence of the Pacific loggerhead, *Caretta caretta*, in Ecuador.

Nesting

Chelonia mydas agassizi, *E. imbricata* and *D. coriacea* all nest in small numbers along most of the Ecuadorian coast but are more commonly found nesting between Manta and Cojimíes in the province of Manabí. Figure 3 shows the northern and southern nesting limits of these 3 species as they are known at present. For *Ch. m. agassizi*, the limits are Costa Rica Island near the Peruvian border to the south, and a small beach just north of Atacames in the province of Esmeraldas to the north. This same small beach is also the northern limit for *E. imbricata*; its southern limit is Ayampe in the province of Manabí. For *D. coriacea*, the southern limit is Rio Chico in the province of Manabí, and the northern limit is a beach 14 km south of Esmeraldas, the northernmost record in Ecuador for any species. These limits do not take into account nesting which may take place in the extreme north of Ecuador between Rocafuerte and the Colombian border.

There is at present no authentic nesting record for *L. olivacea* in Ecuador.

The season starts in December and ends in April or May, with a peak in February. Though shorter, this basically coincides with the Galápagos nesting season.

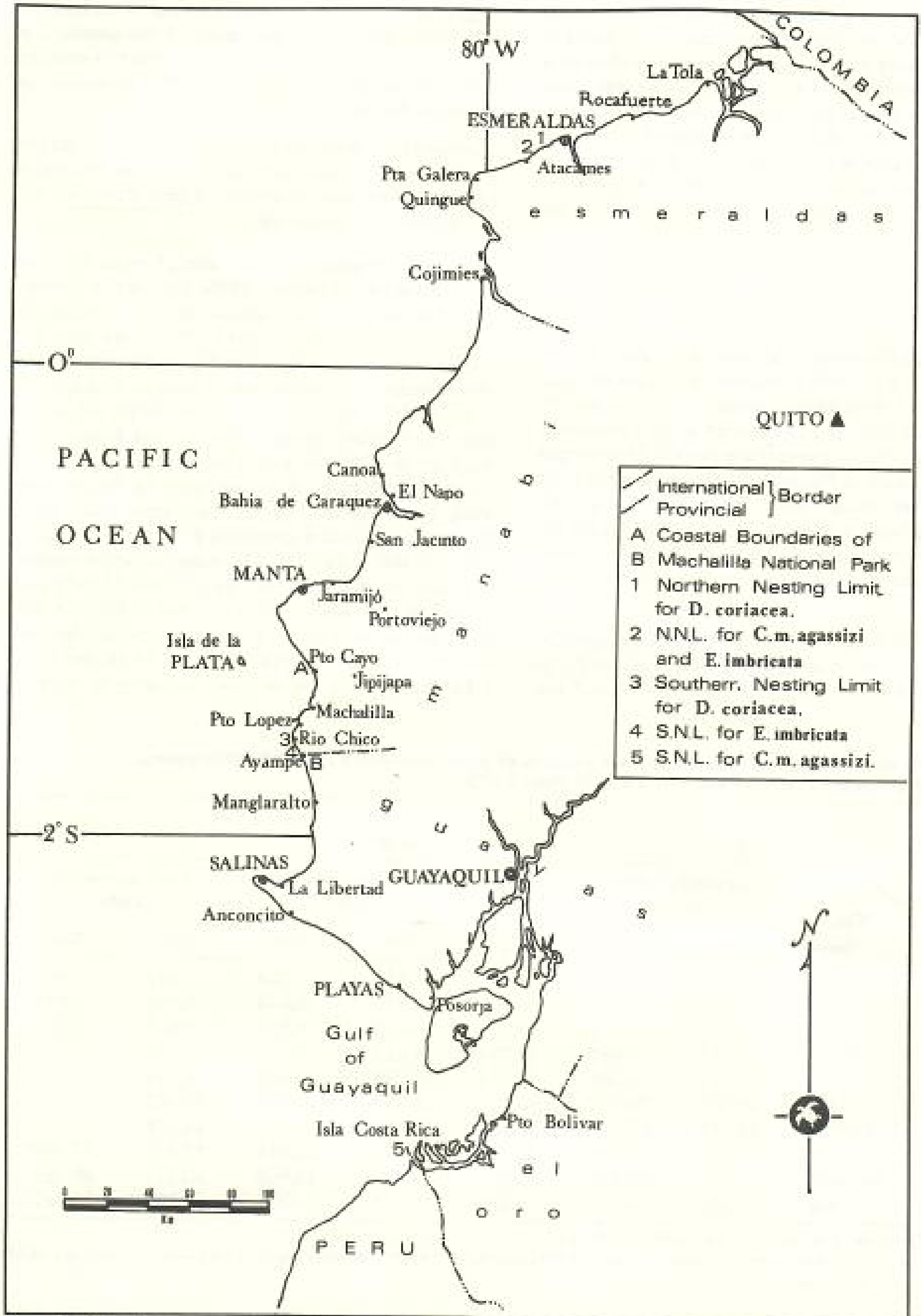

Figure 3. Map of the coastal region of mainland Ecuador showing the known nesting ranges of the east Pacific green turtle *Chelonia mydas agassizi*, the Indo-Pacific hawksbill, *Eretmochelys imbricata* and the Pacific leatherback, *Dermochelys coriacea*.

Since the senior author's survey was started after the nesting season had virtually finished, it is difficult to give an accurate estimate of the abundance of nesting females, although based on reports by local inhabitants, the numbers are certainly low. For example, the continuous 14-km stretch of beach between El Napo and Canoa in the province of Manabí, certainly one of the higher density nesting beaches, could only boast 10 turtles of all species per night during the peak of the season.

Exploitation

Chelonia mydas agassizi. This species is taken in very small numbers for local consumption and accidentally in shrimp or fishing nets all along its range, especially around Santa Rosa and La Libertad in the province of Guayas. Varnished carapaces are often sold in certain tourist spots such as Playas in the Guayas province. As with the other two species which nest in Ecuador, the numbers of nesting females are so low that local inhabitants do not bother to patrol the beach, although they will take both nesting females and eggs if encountered.

Eretmochelys imbricata. Being rarer than *Ch. m. agassizi*, it is taken less often and usually only incidentally in shrimp or fishing nets. The meat is not eaten, and the eggs only on the rare occasions they are encountered. The only commercial exploitation of this species is in certain tourist spots such as Playas, where varnished carapaces and plastrons, or even stuffed juveniles, can be found for sale.

Dermochelys coriacea. Being the rarest of all 4 species present, it is the one least taken. Nesting females or eggs are taken only on extremely rare occasions. It is not exploited commercially.

Lepidochelys olivacea. Although some, for example near Santa Rosa and La Libertad in the province of Guayas, are taken for local consumption, the vast majority are caught for export. This makes *L. olivacea* the only species of marine turtle found in Ecuadorian waters that is commercially exploited on an international level.

Since 1970, at least 6 companies (Neptuno, Expromar, Exporklore, Inexpac, Shayne, and Songa) have been involved in the exportation of turtle products, mainly in the form of frozen meat for human consumption and salted skin for the leather trade. Table 2 gives the annual exportation of turtle (*L. olivacea*) meat and skin since 1970. The maximum and minimum estimates of the corresponding numbers of turtles involved as presented in this Table and in Tables 3 to 5 are based on the following: 3 companies said they obtained on average 4.54 kg (10 lbs), 4.54 kg, and 5.45-6.81 kg (12 to 15 lbs) of meat, respectively, from an

Table 2. Six companies'[a] combined annual exports of skins and meat of the Pacific ridley, *Lepidochelys olivacea*, from Ecuador, 1970 to June 1979

	Skins			*Meat*				
		Estimated number of turtles			*Estimated number of turtles*		*Total number of turtles*	
Year	*Weight (kg)*	*Min.*	*Max.*	*Weight (kg)*	*Min.*	*Max.*	*Min.*	*Max.*
1970	0	0	0	2,398	352	528	352	528
1971	0	0	0	30,165	4,430	6,644	4,430	6,644
1972	0	0	0	45,124	6,626	9,939	6,626	9,939
1973	8,425	4,212	4,681	28,759	4,223	6,335	4,212	[b]
1974	32,703	16,351	18,168	114,053	16,748	25,121	16,351	[b]
1975	32,602	16,301	18,112	59,837	8,787	13,180	16,301	[b]
1976	49,556	24,778	27,531	137,223	20,150	30,225	24,778	[b]
1977	110,150	55,080	61,194	122,198	17,944	26,916	59,476[c]	67,788[c]
1978	161,070	80,535	89,483	62,967[d]	9,246	13,869	80,535	89,483
1979[e]	139,900	69,950	77,722	3,230[d]	474	711	69,950	77,722

a. Neptuno, Expromar, Exporklore, Songa, Shayne, and Inexpac.

b. Maximum estimates in these cases impossible to determine because details of which companies exported both skins and meat and which the meat only, were not available.

c. See Table 3.

d. This meat is from turtles already butchered for their skins and so does not alter the total number of turtles involved which is estimated from the weight of the skins.

e. Figures are for the first 6 months only.

Source: Figures by courtesy of the Instituto Nacional de Pesca, Guayaquil and Ing. Tuly Loor, Subsecretaria de Recursos Pesqueros.

Table 3. Six companies'[a] combined monthly exportation of *Lepidochelys olivacea* products from Ecuador, 1977

	Skins			Meat							Total number of turtles	
		Estimated number of turtles			Weight from companies exporting meat only	Estimated number of turtles (meat only)		Carapaces	Heads	Claws	(skin only + meat only)	
Month	Weight (kg)	Min.	Max.	Total weight (kg)	(kg)	Min.	Max.	Number of turtles	Number of turtles	Number of turtles	Min.	Max.
January	3,083	1,542	1,713	15,282	4,037	593	889	1,110	108	250	2,135	2,602
February	4,100	2,050	2,278	29,043	4,059	596	894	0	0	0	2,646	3,172
March	8,903	4,452	4,946	15,801	2,268	333	500	0	0	0	4,785	5,446
April	10,119	5,060	5,622	24,521	9,752	1,432	2,148	0	0	0	6,492	7,770
May	23,289	11,645	12,938	22,087	6,804	999	1,499	0	0	0	12,644	14,437
June	9,517	4,759	5,287	8,459	3,016	443	664	0	0	0	5,202	5,951
July	16,213	8,107	9,007	0	0	0	0	0	0	0	8,107	9,007
August	5,293	2,647	2,941	506	0	0	0	0	0	0	2,647	2,941
September	1,089	545	605	499	0	0	0	0	0	0	545	605
October	7,265	3,633	4,036	0	0	0	0	0	0	0	3,633	4,036
November	17,466	8,733	9,703	0	0	0	0	0	0	0	8,733	9,703
December	3,813	1,907	2,118	6,000	0	0	0	0	0	0	1,907	2,118
Totals	110,150	55,080	61,194	122,198	29,936	4,396	6,594	1,110	108	250	59,476	67,788

a. Neptuno, Expromar, Exporklore, Songa, Shayne, and Inexpac.

Source: Figures supplied by courtesy of the Instituto Nacional de Pesca and the Direccion General de Pesca, Guayaquil.

average sized turtle. Hence, the minimum number of turtles is estimated by using 6.81 kg per turtle, and the maximum number by using 4.54 kg per turtle. Two of these companies said they obtained 1.8 kg and about 2 kg of skin per turtle and so again both minimum and maximum estimates are given. These weights are slightly lower than those determined by Márquez, Villanueva, and Peñaflores (1976), who obtained average weights of 7.27 kg and 2.5 kg for the meat and skin, respectively, from 14 adult *L. olivacea* each weighing approximately 40 kg. Since there is less variation in the weights of skin per turtle than the weights of meat per turtle, estimates of the corresponding number of turtles based on the former are more accurate. Some companies export both the skin and the meat from the same turtle and others only the meat. Therefore estimates from companies exporting the meat only are added to the estimates from the skins to give the total number of turtles involved. In cases where companies export both, if an estimate from the skins exceeds the estimate for meat, it indicates that the company has a surplus of meat or stock in deep freeze. It will be seen later that this concept of stock is a stumbling block for any attempts at legislative control.

It can be seen from Table 2 that there has been a marked increase in the exportation of both skins and meat since 1970. Although exportation of skins started in only 1973, the demand from the leather trade has been so great that this has proved the most profitable and hence most heavily exploited of all the sea turtle products. Table 3 presents the combined monthly exportation figures of turtle products of the 6 turtle companies for 1977. Table 4 presents the combined monthly exportation figures of the 3 surviving companies (Neptuno, Expromar, and Exporklore) for the first 6 months of 1978. Although only these 3 companies are still involved with sea turtle products, the amount of skins, some 107,714 kg, exported in the first 6 months of 1978, was almost as high as that for the whole of 1977, which in itself was double that for 1976. By the end of 1978 this 107,714 kg had increased to 161,070 kg—representing a minimum of 80,535 turtles.

The figures for 1979 are even more alarming. During the first 6 months of this year, 139,900 kg of skins (some 70,000 turtles) were exported. Judging by the 1977 figures (Table 3) and the 1978 figures (Tables 2 and 4), exportation could well reach the 200,000 kg mark by the end of the year. In other words, around 100,000 adult *L. olivacea* may be butchered in Ecuador during 1979 for the luxury goods trade. According to René Márquez (personal communication), only 150,000 to 200,000 female ridleys nested in Pacific Mexico this year (1979). How many will nest there next year?

Table 5 shows that most of the turtle products exported during 1977 were destined for Japan and Italy, both nonsignatories of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (see below).

Table 4. Three companies'[a] combined exports of skin and meat of the Pacific ridley, *Lepidochelys olivacea*, January to June 1978

	Skins			*Meat*			*Total number of turtles*	
		Estimated number of turtles			*Estimated number of turtles (meat only)*		*(skin only + meat only)*	
Month	*Weight (kg)*	*Min.*	*Max.*	*Weight (kg)*	*Min.*	*Max.*	*Min.*	*Max.*
January	6,189	3,094	3,438	0	0	0	3,094	3,438
February	9,302	4,651	5,168	0	0	0	4,651	5,168
March	9,647	4,823	5,359	0	0	0	4,823	5,359
April	9,904	4,952	5,502	0	0	0	4,952	5,502
May	35,632	17,816	19,796	4,000[b]	587	881	17,816	19,796
June	37,040	18,520	20,578	58,967[b]	8,659	12,988	18,520	20,578
Totals	107,714	53,856	59,841	62,967[b]	9,246	13,869	53,856	59,841

a. Nepruno, Expromar and Exporklore.

b. This meat is from turtles already butchered for their skins and so does not alter the total no. turtles involved which is estimated from the weights of the skins.

Source: Figures by courtesy of the Direccion General de Pesca and the Instituto Nacional de Pesca, Guayaquil.

Ridleys are most abundant, and hence most exploited, in Ecuadorian waters between April and June (see Tables 3 and 4 but note that there will always be a slight delay between catch and exportation). During two visits by the senior author to the Neptuno factory in Jaramijó (province of Manabí) on 31 May and 2 June 1978, totals of 390 and 1,003 *L. olivacea* respectively, were brought in for processing. In early June the ridleys start to move north. Several caught in Ecuador bore tags from Mexico and Costa Rican nesting beaches, and so it is assumed that the ridleys return there for the nesting season which starts in Mexico in June (Márquez 1976)

Conservation

The Past

When Ecuador became the eighth signatory of the Convention on International Trade in Endangered Species of Wild Fauna and Flora in 1976, the Department of National Parks and Wildlife, under the auspices of the Ministry of Agriculture and Livestock, was designated the Management Authority responsible for all legislation regarding marine turtles in Ecuadorian waters. Unknown to the Ministry of Agriculture and Livestock, both the General Fisheries Management (DGP) and the National Fisheries Institute (INP), subsidiaries of the Ministry of Natural Resources, were continuing to allow various companies to export turtle products. The Ministry of Natural Resources was not cognizant of the signing of the Convention by Ecuador.

In 1977, the senior author and others, including Craig MacFarland, who was then the Director of the Charles Darwin Research Station, Galápagos, wrote several reports and letters to the Ministries of Agriculture, Natural Resources, and other responsible bodies, informing them of the exploitation. More letters, reports, memoranda and several meetings in 1978 led to the independent investigations of the authors mentioned above.

Their reports and recommendations were discussed in July in Quito at a meeting of all interested parties, including representatives of the government bodies concerned, conservationists, and the factory owners. Basically there were two factions. One faction wanted to follow the advice of the authors and close the factories immediately, at least until further research, such as a periodic census of *L. olivacea* populations, had been conducted and quotas had been fixed. Ortiz and Cantos (1978) suggested that the turtle companies, in their own interest, should sponsor this research. In addition this faction maintained that Ecuador, being a signatory to an international convention, had an obligation to fulfill.

The other faction opposed closure of the factories and maintained that, because *L. olivacea* is migratory, if Ecuador did not utilize this resource someone else would and referred to the continued harvesting of these turtles by Mexico. In addition, because there is less demand internationally for the meat than for the skin, several factories had a meat surplus or stock. It was proposed that these factories be allowed to export this stock since the turtles were already dead. This could lead to some problems because the stock could be augmented illegally. Realizing this, Ortiz and Cantos (1978) had previously recommended that there be regular inspection of the factories, especially to establish that the amount of stock quoted on invoices agreed with the amount still in the refrigerators.

Any possible friction between the two government bodies had already been somewhat forestalled by the very diplomatic proposal of Ortiz and Cantos (1978) that a joint, interministerial commission be formed between the Ministry of Agriculture and Livestock, and the Ministry of Natural Resources; this commission would deal with all aspects of the turtle problem, including centralization of data, legislation, and control.

The results of the meeting were disappointing, for no definite line of action was taken one way or the other.

The Present

The present situation with regard to the turtle factories is a stalemate. No definite action has been taken thus far and so this species is still being exploited on an international level and on a greater scale than ever. However, there has been a recent change in government and it seems that personnel of the Subsecretaría de Pesca of the new government are more receptive to conservation measures. Visits by the junior author in September 1979 to Mauricio Dávalos, the new Minister of Natural Resources and to Ing. Tuly Loor, the new Subsecretaría of Fisheries Resources resulted in the 1979 figures being put at our disposal and sincere promises to fully investigate and act upon the turtle problem.

There is no intention and indeed no need to curtail the present level of exploitation of *Ch. m. agassizi* and *L. olivacea* in areas such as La Libertad in the province of Guayas, nor the negligible taking of nesting females and eggs of *Ch. m. agassizi, E. imbricata* and *D. coriacea* in other areas.

Due to financial and administrative difficulties, all efforts by the senior author to establish a tagging program on the mainland beaches to determine the status of the 3 species known to nest in Ecuador have so far proved fruitless.

On the brighter side, in September 1979 a new National Park was declared. The 35,000 ha Machalilla National Park in the province of Manabí is the first to include any coastline of mainland Ecuador. It stretches from Ayampe in the south to Puerto Cayo in the north (Figure 3), with approximately 43 km of coastline. Although turtle nesting and hence exploitation on the beaches is negligible in this area, the new Park will offer complete protection for any turtles that do nest there. Even more significantly, the Park also includes Isla de la Plata, an important feeding area for the migratory *L. olivacea*. In addition, Park boundaries extend 2 nautical miles out to sea. Even if turtles are caught outside these limits, they cannot be disembarked inside the Park. This means that places such as Puerto Lopez, an important unloading area in the past, can no longer function as such.

The Future

Providing the law can be enforced, Machalilla National Park will provide some protection for the persecuted *L. olivacea*, and this in itself will have an immediate

Table 5. Destinations of six companies'[a] skin and meat exports of the Pacific ridley, *Lepidochelys olivacea*, from Ecuador, 1977

	Skins				Meat				Total number of turtles	
Country of destination	Total weight (kg)	Price in US $ per kg	Estimated number of turtles Min.	Max.	Total weight (kg)	Price in US $ per kg	Estimated number of turtles Min.	Max.	(skin only + meat only) Min.	Max.
Japan	67,000	4.18	33,500	37,222	1,000[b]	1.00	147	220	33,500	37,222
Italy	25,000	8.00	12,500	13,889	0	—	0	0	12,500	13,889
Panama	7,000	4.29	3,500	3,889	0	—	0	0	3,500	3,889
Hong Kong	2,000	8.50	1,000	1,111	0	—	0	0	1,000	1,111
United States	0	—	0	0	81,000[b]	3.02	11,894	17,841	[b]	[b]
Companies exporting meat only	0	—	0	0	30,000	[c]	4,405	6,608	4,405	6,608
Totals	101,000	$\bar{x}=5.22$	50,500	56,111	112,000	$\bar{x}=2.99$	16,446	24,669	54,905	62,719

— No data.

a. Neptuno, Expromar, Exporklore, Songa, Shayne, and Inexpac.

b. Companies exporting this meat to Japan and the United States had already butchered the turtles for their skin and so these turtles are excluded from the total number of turtles.

c. Prices not known.

Source: Figures by courtesy of the Instituto Nacional de Pesca, Guayaquil.

bearing on the exportation of ridley products. Even so, efforts must be redoubled in an attempt to reach a favorable conclusion regarding the activity of the turtle factories.

Population censuses of ridleys are urgently required. It is also of vital importance to establish a tagging program on the beaches similar to the one in Galápagos in order to determine the size of the nesting populations of *Ch. m. agassizi, E. imbricata* and *D. coriacea,* as well as to gather nesting data and details of migration. This research will provide the necessary scientific background on which to base recommendations for future management policies of sea turtles in mainland Ecuador.

Here there is another ray of hope—or rather 10; 10 Ecuadorian students from the University of Guayaquil were trained on the Galápagos nesting beaches in 1979. It is hoped, should funds become available, that some of these students will pioneer the much needed research on their own mainland shores.

Summary

Species Present

Chelonia mydas agassizi, E. imbricata and *D. coriacea* are present in all three regions. *Caretta caretta* occurs in Colombia but has not been recorded from either the Galápagos Islands or mainland Ecuador. *Lepidochelys olivacea* occurs in mainland Ecuador and Colombia, but not the Galápagos.

Nesting

The situation in Colombia is unknown to us. *Chelonia mydas agassizi* nests in both the Galápagos Islands and mainland Ecuador whereas *E. imbricata* and *D. coriacea* nest only on the mainland.

Exploitation

In Colombia, as far as we are aware, *Ch. m. agassizi* and *C. caretta* are taken only for local consumption. The carapace of *E. imbricata* is often used in craftwork. In mainland Ecuador, although there is exploitation of *Ch. m. agassizi* for local consumption and occasional use of *E. imbricata* in the tourist trade, by far the main exploitation is of the migratory *L. olivacea* for the international market. All species are also caught accidentally in shrimp and fishing nets in both Colombia and mainland Ecuador. Exploitation in Galápagos is virtually nonexistent.

Research and Conservation

The situation in Colombia is unknown to us. Intensive research has been conducted in the Galápagos Islands for 4 consecutive years. Because they are a National Park there is total protection of sea turtles. Research in mainland Ecuador was limited to the 2 independent investigations by the authors. The new Machalilla National Park will offer total protection for sea turtles, but it includes only a very small proportion of the coastline of mainland Ecuador.

Providing that the local consumption and accidental capture of *Ch. m. agassizi, E. imbricata, D. coriacea* and *C. caretta* are maintained at present levels, populations of these species should not decline. Hence, conservation and legislative measures are not of great urgency except to protect nesting females. In the case of the Pacific ridley, *L. olivacea,* however, if the exploitation in mainland Ecuador continues on its present scale, it will not be a question of whether this species will become seriously threatened with extinction, but when. Protection measures are needed now.

Acknowledgments

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Status of Sea Turtles in the Southeastern Pacific: Emphasis on Perú

Introduction

Two species of marine turtles, *Chelonia mydas* and *Dermochelys coriacea,* were reported to occur along the coast of Perú. A preliminary survey of marine turtle populations was conducted from January to June 1979. The study area covered approximately 1,750 km along the Peruvian coast. The information on Chile was obtained from published literature and, consequently, is minimal.

Species Present

The following 5 species of sea turtles were found to occur along the southeast Pacific: *Chelonia mydas, Dermochelys coriacea, Lepidochelys olivacea, Eretmochelys imbricata* and *Caretta caretta*. The East Pacific green turtle (*Chelonia mydas agassizi*) is the most abundant species in Perú. They are locally known as *tortuga* or *tortuga blanca.* Its distribution is along the entire coastline and into Chile to Isla Desolación (52° S). This is the most southern report of a marine turtle.

Along the Peruvian coast, leatherbacks (*Dermochelys coriacea*) are reported 3 to 4 hours out to sea, being sighted closer to the coast in the central Departments of Lima and Ica. They are generally referred to as *tinglada, tortuga galápagos,* or *dorso de cuero.* According to the late Dr. Donoso-Barros (1966), they are frequently encountered in Chile; the southern limit of their distribution is the Island of Chiloe.

The olive ridley (*Lepidochelys olivacea*), referred to as *pico de loro* is uncommon in central Perú. It may be common in northern Perú where a nest of eggs was found. Donoso-Barros (1966) mentions them as relatively frequent in northern Chile and, consequently, they may also appear in southern Perú. The olive ridley prefers protected waters, especially the warm waters to the north, and can be found as far south as Talcahuano, Chile.

The hawksbill (*Eretmochelys imbricata*) is rarely found. Only 5 carapaces were recorded from northern Perú;

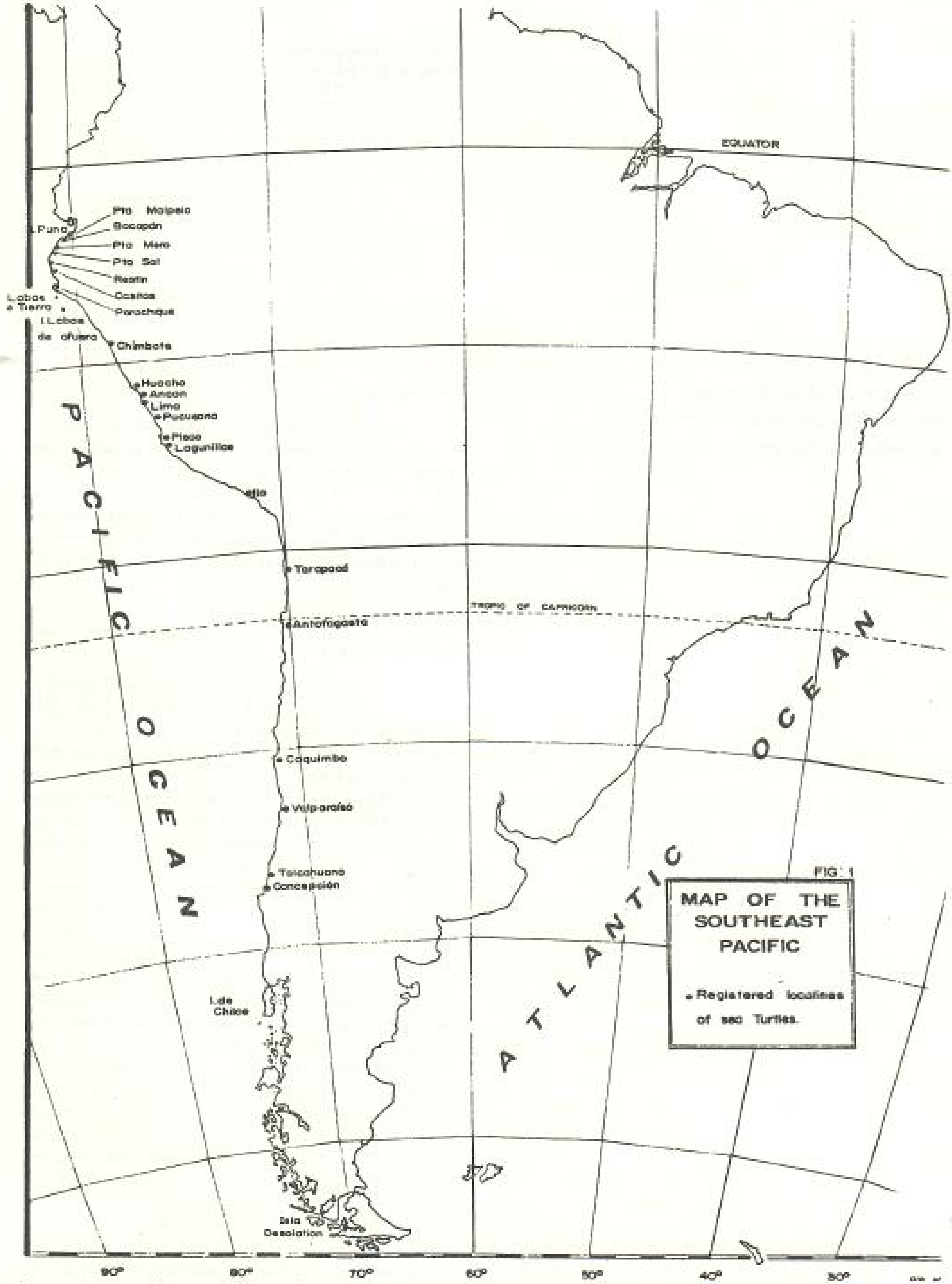

Figure 1. Map of the southeast Pacific showing registered localities of sea turtles.

the last was encountered farther south at 4°30'S. This is the first documented evidence of their presence. As of yet, no specimens are known for Chile.

The loggerhead (*Caretta caretta*) has been cited by Donoso-Barros (1966) as relatively abundant along the coast of Tarapaca, northern Chile, where its meat is consumed. It is known as *tortuga boba*. Mention has been made for Perú, but documentation is lacking. An evaluation of the southern coastline would most likely reveal the occurrence of loggerhead (*Caretta caretta*) since it is abundant in northern Chile.

Feeding

Green turtles were frequently sighted feeding in offshore areas in significant numbers (at least 6 turtles). These feeding areas were common along the northern Peruvian coast. The locations where *Chelonia* was sighted most frequently were characterized by rocky outcroppings with an abundance of algal growth associated with rocky intertidal zones. Green turtles were also found in shallow bays and offshore island beaches (Isla Lobo de Tierra). Locations along the northern Peruvian coast where green turtles were feeding regularly were Bocapan, Punta Mero, Punta Sal, Restin, Casitas, Parachique, Islands of Lobos de Tierra and Lobos de Afuera, Pisco (Jaguay), and Lagunillas (Figure 1).

Stomach contents from 39 green turtles caught in Pisco were analyzed. Some of these turtles had been on their backs for several days, and only residues of their diet were encountered. Data for analyzed stomach contents in Table 1 indicate the occurrence of food content but does not reveal the quantity. Likewise, Paredes (1969) analyzed the contents of 20 Peruvian *Chelonia* stomachs. Algae were found to occur in 100 percent of the samples, jellyfish in 60 percent, fish in 60 percent, and various molluscs in 50 percent.

During interviews in the north, octopi were mentioned as part of the varied diet of green turtles. Only 3 stomach samples from *Chelonia* caught in northern Perú were analyzed, 1 of which contained an octopus.

Fishermen report that leatherbacks are present from December to March feeding on the jellyfish which occur off the coast in large quantities during the summer season. They are believed to follow the jellyfish, indicating that these leatherbacks are on a feeding migration.

Distribution

The greatest number of marine turtles are captured in the port of Pisco, next to the Paracas Reserve. The catch is mainly green turtles and, to a much lesser degree, leatherbacks. The olive ridley is taken on occasion. During the summer months of December to April, there is an increase in the green turtle population. Leatherbacks are said to be most plentiful from December to March.

Measurements of 416 green turtles were taken. The straight carapace length (SCL) was recorded (Table 2). The captured population was found to be 89 percent immatures (80 cm and below) and 11 percent mature individuals (above 80 cm). Southern Perú may well be considered a developmental habitat since immatures comprise the majority of the population. No hatchlings were encountered.

Of the 416 green turtles, only 27 males were encountered with secondary sexual characteristics (elongated tail). The SCL of males varied from 65 to 92 cm, with the average being 84 cm.

Measurements were taken of 4 hawksbill carapaces. The SCL ranged from 30.5 cm to 41 cm. Six olive ridley carapaces ranged from 47.5 cm to 72 cm. At Pucusana 115 leatherbacks were measured. Mean carapace length was 135 cm with the carapace length varying from 112 cm to 168 cm. At Playa Naranjo, on the Pacific coast of Costa Rica, 18 nesting leatherback measurements ranged from 128 cm to 151 cm (Cornelius 1976). These data indicate that the East Pacific leatherback is mature at a smaller size than the Atlantic leatherback, which has a reported mean carapace length of 158 cm (Pritchard 1971). Considering 130 cm to be the size at which Pacific leatherbacks reach sexual

Table 1. Stomach content analysis from 39 *Chelonia mydas agassizi*, ranging from 51.5–89 cm straight carapace length

Stomach content	*Number of samples*	*Percentage occurrence*
Molluscs: mainly *Nassarius*, *Mytilus* and *Semele*[a]	25	64
Algae: macrocystis, *Rhodymenia*, and *Gigartina* predominate[a]	20	51
Annelids: polychaetes only[a]	19	49
Jellyfish and amphipods[b]	12	31
Fish (eggs included): sardine and anchovy	9	23
Distichlis (salt grass)[c]	7	18
Crustaceans[a]	5	13
Plastic bags[d]	9	23

Note: In addition to the 39 turtles mentioned in Table 1, 3 more were analyzed which contained empty stomachs and were not included in the data.

a. Majority derived from mesolittoral zone.

b. The amphipod *Hypenia medusarum* is commensal to jellyfish and was encountered in various stomach contents.

c. These turtles are feeding in the vicinity of the mouth of the Rio Chico so it is most probable that the *Distichlis* is being carried out.

d. Floating plastic bags may resemble jellyfish; reflects degree of pollution.

Table 2. Straight-line carapace lengths of 416 *Chelonia mydas*

SCL (cm)	*Number of Chelonia mydas*	*Average SCL (cm)*
≤ 50	26	46.7
51–60	122	55.7
61–70	148	65.6
71–80	75	76.1
> 80	45	84.4
Total	416	65.7

Table 3. Tag returns from Perú

Tag number	*Sex*	*Year tagged in Galápagos*	*Year recovered at Pisco*
Z 1582	F	1977	1979
Z 1948	F	1978	1979
Z 2047	F	1978	1979
Z 2298	F	1978	1979
Z 2482	F	1978	1979
Z 2739	F	1978	1979
376	M	—	1979
3578	F	1970	1978

— No data.

maturity, 71 percent of the measured Peruvian population were mature while 29 percent were immature individuals.

Nesting

Many northern beaches appear suitable for nesting. Fishermen report sea turtles nesting sporadically along the coast, more frequently in past years than in the present.

On one occasion evidence of nesting was recorded. At Punta Malpelo (3°30'S), on the south of the Rio Tumbes, a nest of 80 eggs was found which had been transplanted from their original site by local fishermen. One egg contained an embryo measuring 2.3 cm and identified as *Lepidochelys olivacea*. The remaining eggs showed no signs of development. The mean of the measured eggs was 4.3 cm in diameter.

The nesting season is apparently from December to February. Fishermen commented that 3 to 4 years ago more turtles nested in the area. During this past season other nests were reported, but due to extremely high tides all evidence had been erased. Nesting along this beach appears to be infrequent though not uncommon.

The coast of Punta Malpelo is a long stretch of white sand composed mainly of quartz and feldspar. The slope of the beach is gradual. Approximately 50 m above the high tide mark driftwood mounds up and, beyond that, there are mangroves. This beach is being developed. Breeding tanks for shrimp hatcheries are going to be built, as are beachside hotels.

South of Punta Malpelo we occasionally found turtle tracks which indicated nesting activity in this area. The local fishermen stated that turtle nests were seldom disturbed and that there had been more nesting in the past. Nesting seems to have declined due to recent development along this section of the coast.

There is no evidence that sea turtles nest in southern Perú. Turtle dealers report that the few olive ridleys captured usually bear unshelled eggs. Older fishermen of the area refer to turtles nesting, or rather coming ashore, at Caucato, above the Pisco River. Today this beach is subject to intense human disturbance.

At the University of Luis Gonzaga in Pisco, there are 5 preserved marine turtle eggs. These were found in a butchered female 6 years ago, species unknown. Other than this, no evidence of nesting exists.

Commensalism

Many green turtles bear barnacles of the species *Chelonibia testudinaria* on their carapaces. Occasionally, barnacles of the genus *Lepas* are also found on the tough leathery skin between the plastron and carapace.

The crab *Planes cyaneus* is found on the basal section of the tail of *Chelonia mydas agassizi*. These crabs are recovered when the turtle is captured at sea. Schweigger (1964) refers to an old fisherman's tale of a relationship between a crab and a turtle; the crab rides the turtle when it is ready to submerge to the depths.

Currents and Migrations

The coast of Perú is bordered by a continental shelf. The widest part, approximately 105 km, is located in the north at Pimentel (9° S); the narrowest part is at Punta San Juan in the south (15° S). The continental shelf inclines to depths of more than 3,000 m.

Currents flowing along the coast are responsible for the upwelling known to supply Peruvian waters with rich nutrients. This upwelling creates good feeding habitats for marine turtles.

By July, *Chelonia mydas* has left its nesting grounds in the Galápagos Islands for its feeding grounds (Green, this volume). The distribution of part of this *Chelonia* population is reflected by tag recoveries from Perú. The 7 tag returns from Perú reveal that *Chelonia mydas* nesting in the Galápagos have migrated as far south as Pisco, 13°5'S, (Table 3), a distance of 2,300 km. The recoveries are too few to indicate whether a large portion of this population regularly migrates to Perú.

Part of the feeding population in Perú may have migrated from the nesting population on Puna Island, southern Ecuador (3° S).

During years of increased water temperatures there seems to be a direct relationship with an increase in the sea turtle population. Catch statistics, which are not very reliable for exact numbers but do reflect the relative proportions, indicate that during the years 1972, 1975, and 1976 there was an increase in the catch (Figure 2). These were years of the phenomenon known as *El Niño*, which occurs when the equatorial current pushes warm waters farther south than normal.

In Figure 2 the high catch in 1978 may reflect the fact that the Ministry of Fisheries is now more concerned about marine turtles than in past years. Stricter control in declaring the poundage caught has been enforced since the enactment of the Ministerial Resolution in 1977 protecting sea turtles. To date, catch statistics are still not specific as to species.

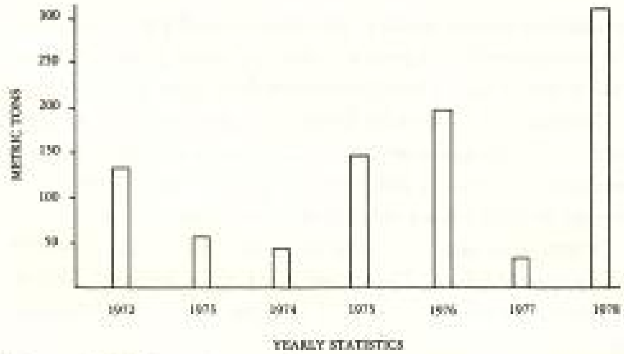

Figure 2. Catch statistics of marine turtles according to mass (metric tons).

Legislation

In January 1977, the Ministerial Resolution, No. 01065, was enacted. Through it, protection is provided for the green turtle and the leatherback. It prohibits hunting of all leatherbacks, and only *Chelonia mydas* 80 cm or above are allowed to be taken. Only at one port was this resolution found to be enforced. It is now being enforced at Pisco where the greatest number of turtles is caught. The responsibility of enforcement is on the captain of each port.

In October 1978, 167 leatherback carapaces were found in a canyon near the port of Pucusana. They were captured during the summer months (January to March). A conservative estimate of the catch per season is 200 leatherbacks. As stated by Pritchard (1972) and Frazier (1979), central Perú has the largest known leatherback fishery in the world. Most appear to be adult and subadult and thus represent a considerable number of reproductive and near reproductive individuals.

Green turtles along the northern coast are incidently caught in fishing nets and shrimp trawlers. If the turtle is not consumed by the fisherman, he sells it to a turtle buyer who generally passes by every few days. This buyer will sell the meat at a central market. Main markets in the north are La Cruz, Piura, and Chiclayo. Meat is occasionally transported frozen to Lima.

In southern Perú there is a more sophisticated turtle traffic where fishermen have nets specially designed to catch turtles. They are made with 59 cm^2 mesh and function as tangle nets. In the area of Pisco there are approximately 7 to 10 boats dedicated to the capture of turtles, going out on 2 to 3 day ventures. The turtles are sold to the *tortuguera*—a woman whose business is buying and selling turtle products. The green turtles are surreptitiously transported ashore during the night and early hours of the morning and slaughtered as the sun rises.

During the height of the season (December to April) there may be up to 70 green turtles lying on their backs, in the shade, waiting to be butchered. During this season, the average catch was 10 to 30 turtles per day. The family begins work around 4:30 A.M. and by 7:30 A.M. the meat is ready to be sold at the market. At Pisco, turtle meat sells for $2 per kg, which is half the market value of beef.

The entire turtle is utilized. The meat, liver, kidneys, heart, esophagus, and head are consumed. The fat is boiled to extract the oil which is believed to be a remedy for bronchial problems such as asthma. The hides of the front and hind flippers are salted and sold to a leather company in Lima. The blood is believed to fortify the body and is drunk soon after decapitating the turtle. The carapaces are used for artistic purposes, for feeding dishes for pigs and ducks, and for bowls to salt fish in. The calipee, which is so highly esteemed in other parts of the world, is of no use to Peruvian consumers. At seaside restaurants in Pisco, turtle meat is openly advertised. The meat is also transported to several first class restaurants in Lima. All turtle products are consumed within the country and are of no consequence for exportation.

Conclusion

The following 5 species of marine turtles are present in the southeastern Pacific: *Chelonia mydas*, *Dermochelys coriacea*, *Lepidochelys olivacea*, *Eretmochelys imbricata*, and *Caretta caretta*. Perú's highly productive coastal waters are an important feeding ground for immature green turtles and also may be an important feeding area for the East Pacific leatherback turtle.

An extensive tagging and recovery program is necessary to further establish what breeding populations supply these migrants in Perú. If adequate protection is given at the breeding grounds, a moderate scale exploitation program may also be conducted with the immature green turtles. The Reserve of Paracas should be proclaimed a "turtle sanctuary," thus providing partial protection of important feeding grounds.

Leatherbacks should be given total protection until further investigations are conducted with these poorly studied turtles. In addition to adults, we also find juvenile leatherbacks which are rarely seen elsewhere.

Further analysis of marine turtle stomach contents is recommended. This may lead to a greater understanding of the ecology of marine turtle populations in Perú.

Acknowledgments

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Hawaii, Oceania, and Australia

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Status of Sea Turtles in the Central Pacific Ocean

Except for the Hawaiian Archipelago, sea turtle populations in the Central Pacific Ocean and other areas of Polynesia have not been systematically surveyed and only limited information exists on their occurrence and present survival status. This report will summarize and review what is known for a number of locations within the region, specifically the Hawaiian Archipelago, Line Islands, Phoenix Islands, Cook Islands, American Samoa, Western Samoa, Tokelau, Tuvalu, Wake, Johnston, Howland, and Baker (Figure 1). While the information for most of these areas is clearly inadequate, there is nevertheless evidence to indicate that the numbers of turtles have declined within historical times. At those islands with indigenous human populations, the traditional conservation systems that served to protect turtles and other marine resources from overexploitation have deteriorated considerably, and in some cases vanished altogether. Three interrelated factors contributing to this breakdown have been the introduction of money economies, the decline of traditional authority, and the imposition of new laws and practices by colonial powers (Johannes 1978). In Polynesian societies, sea turtles are known to have played an important role in certain religious ceremonies, in mythology and art, in the production of implements and medication, and as high protein food sources generally reserved for chiefs and priests (Buck 1932; Emory 1933, 1947; Emory, Bonk, and Sinoto 1968; Kalakaua 1888; Pukui and Elbert 1971).

Of the islands covered in this report, only the ones under United States jurisdiction currently have governmental regulations for sea turtles. Under the U.S. Endangered Species Act, all sea turtles at these U.S. areas are fully protected.

Status

Hawaiian Archipelago (United States)

Three species of sea turtles occur in Hawaiian waters, the green turtle, *Chelonia mydas*, the hawksbill, *Eret-*

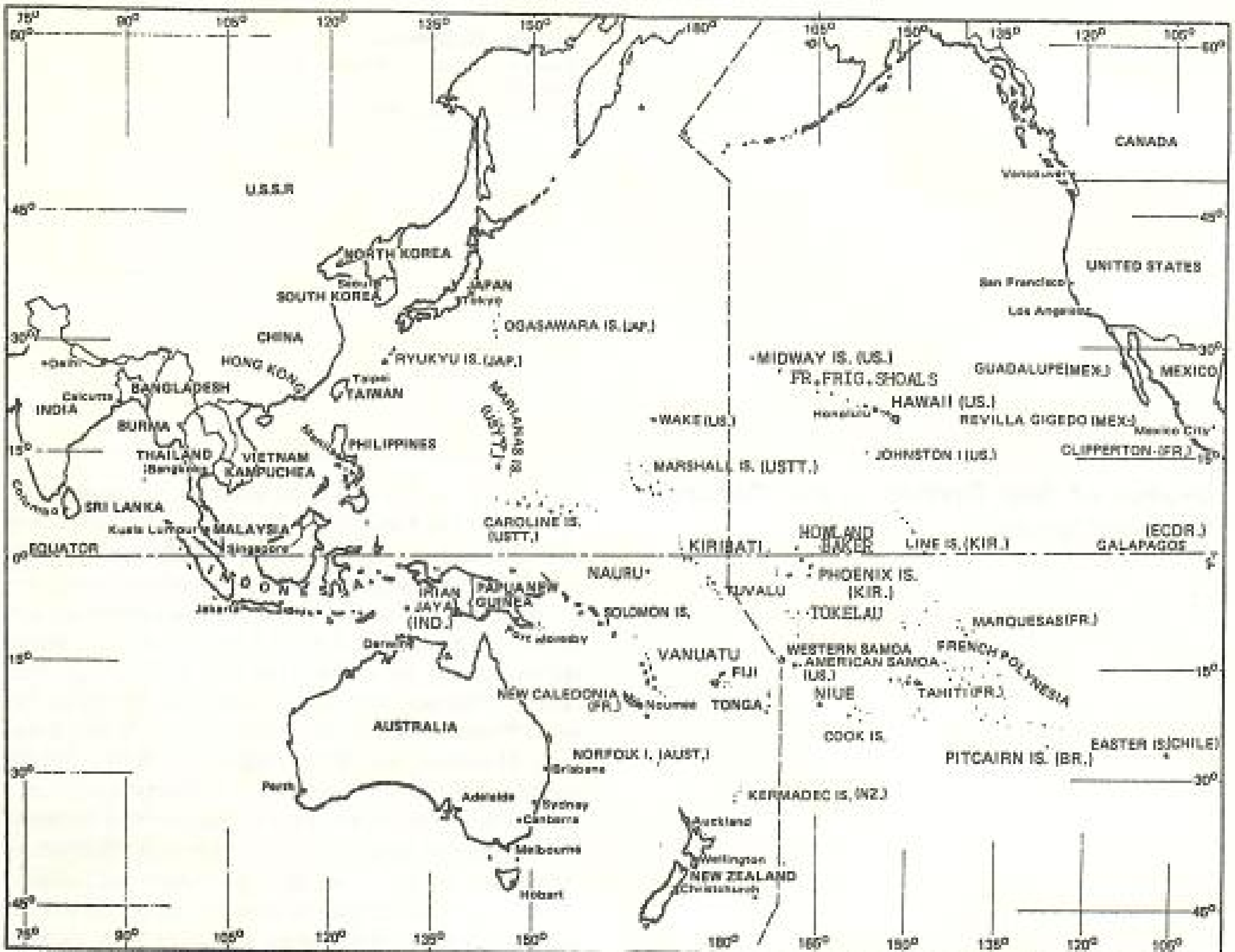

Figure 1. Map of the Central Pacific Ocean.

mochelys imbricata, and the leatherback, *Dermochelys coriacea*. The olive ridley, *Lepidochelys olivacea*, and the loggerhead, *Caretta caretta*, have been recorded, but only as rare visitors.

The Hawaiian hawksbill population is small and only known to occur in coastal waters of the 8 main and inhabited islands at the southeastern end of the 2,450-km-long archipelago. Several nestings have been documented on the island of Hawaii where black volcanic sand beaches are utilized. A single nesting has also been recorded on the island of Molokai (Ernst and Barbour 1972).

Leatherbacks are regularly sighted in offshore waters at the southeastern end of the archipelago, but nesting does not take place. During August 1979, at least 10 leatherbacks ranging from 60 to 120 cm in carapace length were sighted in pelagic waters to the northwest of the Hawaiian Archipelago between 40° to 43°N and 175° to 179°W (G. Naftel, in litt.).

Green turtles are by far the most abundant of Hawaiian sea turtles, with mixed aggregations of adults and immature individuals larger than 35 cm residing in coastal waters throughout the archipelago where they feed on several kinds of benthic algae. In excess of 90 percent of all nesting occurs on 6 small sand islands at French Frigate Shoals (23°45'N, 166°10'W), a 35 km long atoll situated in the middle of the archipelago. Tagging has demonstrated that long-distance migrations to this site are periodically undertaken by adults from numerous resident foraging areas, all of which are within the Hawaiian chain (Figure 2; Balazs 1976a, 1979). Hawaiian green turtles therefore appear to be genetically isolated from other populations in the Pacific. Systematic monitoring of the breeding colony at French Frigate Shoals was initiated in 1973 and has continued during each subsequent year. The number of females nesting annually has been found to fluctuate considerably, with the range extending from 94 in 1976 to 248 in 1978 (Figure 3). No population trends are apparent for the 7-year study period. The production of hatchlings since 1973 has ranged from approximately 12,500 in 1976 to 32,900 in 1978. Predation

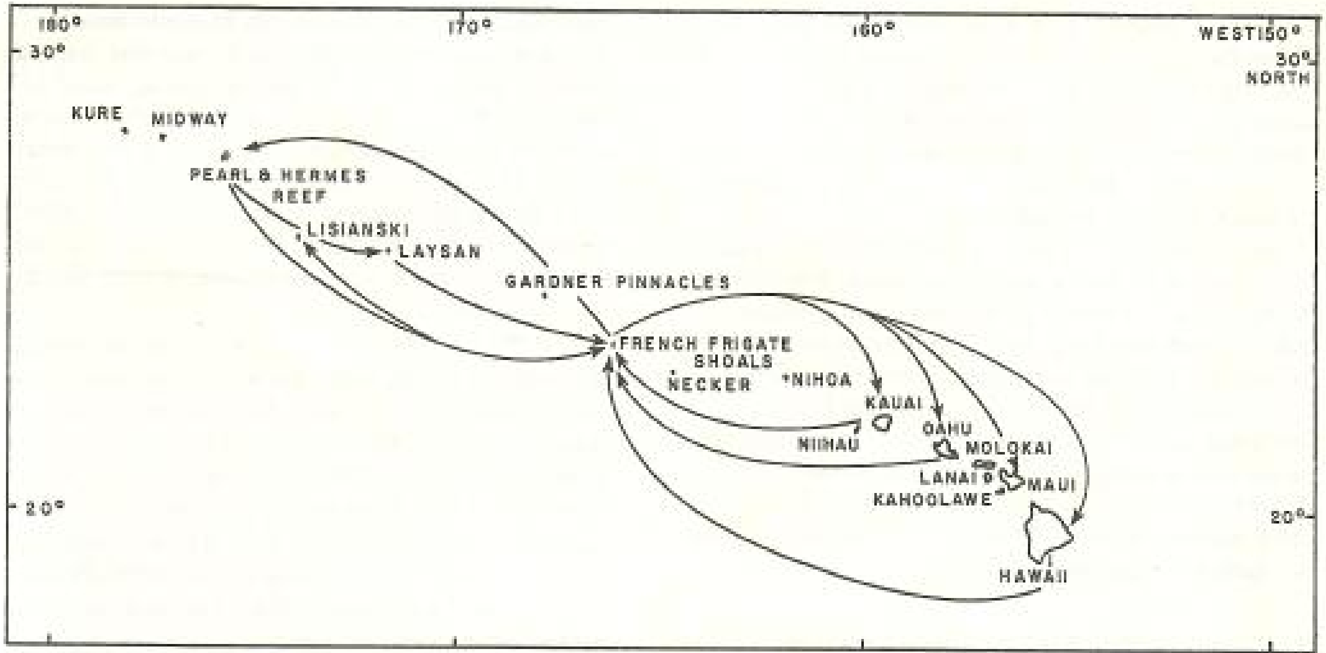

Figure 2. Documented migrations of adult green turtles in the Hawaiian Archipelago.

on eggs does not take place at French Frigate Shoals, and predation on hatchlings appears to be minimal. However, predation by tiger sharks (*Galeocerdo cuvier*) on both adults and immature turtles throughout the chain may be substantial (Balazs 1979). Prior to 1973, the annual breeding colony at French Frigate Shoals was incorrectly estimated by previous workers to contain as many as 2,600 to 5,200 turtles (Hendrickson 1969; Amerson 1971).

Hawaiian green turtles exhibit the rare behavioral trait among sea turtles of coming ashore to bask or rest, but only at certain undisturbed sand beaches or rock ledges in the uninhabited Northwestern Hawaiian Islands (Wetmore 1925; Balazs 1976b; Eliot 1978; Lipman 1978). This behavior provides access for the tagging of males as well as females, both at the breeding grounds and at a number of resident foraging areas. However, caution is being exercised in these research activities so that normal behavioral patterns will not be adversely affected.

Large numbers of green turtles were commercially exploited in the Hawaiian Archipelago until 1974 when the State of Hawaii adopted a protective regulation banning this activity. In 1909 all of the Northwestern Hawaiian Islands except Midway were designated as a Bird Reservation, which in 1940 became known as the Hawaiian Islands National Wildlife Refuge. However, the exploitation of turtles in these areas, particularly at French Frigate Shoals, periodically continued until at least 1969 (Amerson 1971; Balazs 1975a). Of concern at the present time is the well-documented, drastic decline of the foraging and basking aggregations in the Northwestern Hawaiian Islands at Laysan Island, Lisianski Island and, to a lesser extent, at Pearl and Hermes Reef. Furthermore, the forthcoming development of various commercial fisheries in this segment of the chain represents a potential threat to the remaining aggregations. Terrestrial areas in the Northwestern Hawaiian Islands are under review by the Fish and Wildlife Service for designation as Critical Habitat under the U.S. Endangered Species Act (Dodd 1978; see also Balazs 1978).

Johnston Atoll (United States)

Johnston Atoll is located at 16°45'N, 169°31'W and

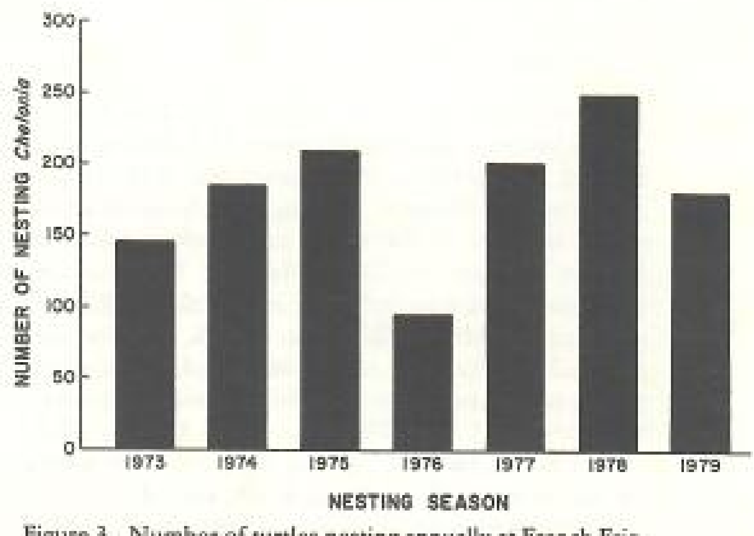

Figure 3. Number of turtles nesting annually at French Frigate Shoals.

contains 4 islands, 2 of them completely man-made. From the late 1950s until 1962, nuclear weapons' testing was conducted over the atoll. The area is administered by the Nuclear Defense Agency, but is now used prinicpally as a storage site for chemical munitions (Inder 1978). Johnston is concurrently managed as a National Wildlife Refuge.

Both immature and adult green turtles are regularly seen foraging in shallow waters, but nesting is not known to take place. Courtship behavior and possibly sustained copulation have, however, been periodically reported by resident personnel. Numerous species of algae occur within the atoll (Buggeln and Tsuda 1966), including *Caulerpa racemosa, Codium arabicum* and *Gelidium pusillum* which are known food sources of green turtles (Balazs 1979). Large sharks that are probably tiger sharks have been observed attacking and feeding on turtles (C. Cecrle in litt.).

Wake (United States)

Wake is an inhabited atoll located at 19°18'N, 166°35'E that is administered by the U. S. Air Force. Both immature and adult green turtles are regularly observed foraging in the lagoon and along the outside perimeter of the atoll. Nesting has never been recorded.

Howland and Baker (United States)

Howland (0°48'N, 176°38'W) and Baker (0°13'N, 176°28'W), 2 low coral islands, were designated National Wildlife Refuges in 1974 and are now uninhabited. Turtles were reported to be "abundant" in the waters around Howland by residents present in May and June of 1935 (Bryan 1974). No information on turtles exists for Baker. Feral cats, which are known in some areas to be predators of hatchlings and eggs, are present on both of these islands.

Line Islands

All of the Line Islands are low coral islands and atolls. The Northern Line Islands consist of Kingman Reef, Palmyra and Jarvis, under the jurisdiction of the United States; and Washington, Fanning and Christmas under the jurisdiction of the newly independent nation of Kiribati (formerly the Gilbert Islands). The Southern Line Islands are also under the jurisdiction of Kiribati and consist of Malden, Starbuck, Vostok, Caroline, and Flint, all of which are now uninhabited. Information on sea turtles exists only for the following locations.

- *Palmyra (5°53'N, 162°05'W).* From 1958 to 1965, green turtles were periodically seen in shallow waters at the eastern side of the atoll. On one of these occasions a group of 11 adults was observed foraging together (P. Helfrich and J. Naughton, personal communication). Similar observations have also been made during recent years (M. Vitousek, personal communication).There are no reports of nesting. Algal collections at Palmyra have included *Pterocladia*, a known food source of green turtles (Dawson 1959; Balazs 1979). The atoll is now used as a copra plantation and has a small resident human population. Along with Midway and Wake, the U.S. government is considering Palmyra as an international storage site for nuclear wastes.
- *Jarvis (0°23'S, 160°01'W).* A low level of nesting, apparently involving green turtles, was recorded along the western coast of Jarvis by residents present in August of 1935 (Bryan 1974). The island was designated a National Wildlife Refuge in 1974 and is now uninhabited. Feral cats are present on the island.
- *Fanning (3°52'N, 159°20'W).* Turtles were reported to "abound" at Fanning in the 1850s (Burnett 1910, quoted by Wiens 1962). The atoll has been continuously inhabited since 1852 and used principally as a copra plantation. A small number of turtles are regularly sighted in the lagoon, and a low level of nesting still takes place. The residents capture turtles whenever possible.
- *Christmas (1°59'N, 157°30'W).* When Captain James Cook discovered uninhabited Christmas atoll in late December of 1777, between 200 and 300 green turtles were captured during the 8-day visit (Beaglehole 1967). Turtles were taken both in the shallow lagoon and on the beaches, with weights ranging from 20 to 90 kg. Publicity resulting from Captain Cook's visit caused numerous whaling vessels to stop at the atoll for provisions (Bryan 1942). Green turtles were still abundant in 1838 (Tresilian 1838, quoted by Wiens 1962). Christmas has been inhabited and used as a copra plantation since 1902. Nuclear weapons' testing was conducted over the atoll by the British from 1956 to 1958, and by the United States in 1962 (Inder 1978). In 1975 a visitor noted that some nesting was still taking place, but no details were available (D. Crear, personal communication).
- *Vostok (10°06'S, 152°23'W).* In June of 1965, Clapp and Sibley (1971a) saw several turtles in the waters surrounding Vostok, but no signs of nesting were found. M. Vitousek (personal communication) was informed that numerous turtle tracks were seen on the beaches during a visit made in recent years, but no details are available. Vostok is only 1.2 km^2.
- *Malden (4°1'S, 154°58'W).* No evidence of turtles has been found during several recent visits to Malden (E. Vitousek, personal communication).
- *Caroline (9°58'S, 150°14'W).* Dixon (1884) reported that turtles were seen at Caroline, but not in great numbers. No turtles were seen by Clapp and Sibley (1971b) during a 2-day visit in June 1965.

Phoenix Islands

The Phoenix group is under the jurisdiction of Kiribati and consists of 8 low coral islands and atolls. Only Canton is now inhabited.

- *Canton (2°50'S, 171°43'W).* Green turtles nest along the northern, eastern and western shores of Canton throughout the year, but greater numbers are present during October and November (Balazs 1975b). The total annual number of nesting females using the atoll may involve as many as 200 turtles. Large populations of ghost crabs (*Ocypode* spp.) and hermit crabs (*Coenobita perlitus*) are present and probably prey heavily on hatchlings. It is not uncommon for nesting females and hatchlings to become disoriented and travel inland where they die of hyperthermia. Adult males and females in groups of up to 40 individuals have been observed foraging close to shore in water less than 50-cm deep (J. Hass, in litt.). Algal collections from Canton have included *Caulerpa racemosa, Codium arabicum, Gelidium pusillum,* and *Pterocladia* (Dawson 1959).
- *Enderbury (3°07'S, 171°03'W).* Green turtles nest along Enderbury's western and eastern shores (Balazs, 1975b; J. Keys, in litt.). King (1973) listed this island as one of the most important nesting sites for green turtles in the Central Pacific. Two Korean fishing vessels were wrecked on the island during recent years.
- *Phoenix (3°43'S, 170°43'W).* Turtle bones were found on Phoenix during a visit in 1924 and nesting was presumed to take place (Bryan, 1942). Feral rabbits are present on the island.
- *Birnie (3°35'S, 171°31'W).* During a low-altitude overflight of the Phoenix group in January 1978, the author found the beaches of Birnie to be covered with turtle tracks. Birnie is the smallest island in the Phoenix group (0.5 by 1.25 km) and the only one that has never been inhabited or mined for guano.
- *Hull (4°30'S, 172°10'W).* Green turtles nest along the northeastern and southeastern shores of Hull (Balazs 1975b; J. Keys, in litt.). When the U.S. Exploring Expedition visited this atoll in August 1840, a Frenchman and 11 Tahitians were found to have been stationed there to catch turtles (Wilkes 1845). In May 1974 large numbers of dead fish and an adult male green turtle were found washed ashore from inside the lagoon. The cause of this mortality could not be determined.
- *Sydney (4°27'S, 171°16'W).* Turtle tracks have been observed on Sydney's northwestern shore (Balazs, 1975b). Evidence of trespassing by crewmembers of foreign fishing vessels has been found on this atoll during recent years.
- *Gardner (4°40'S, 174°32'W).* Turtle tracks have been observed on Gardner's southwestern shore (Balazs 1975b). Evidence of trespassing has also been found on this atoll.
- *McKean (3°36'S, 174°08'W).* No information on turtles exists for McKean. Several foreign fishing vessels have been wrecked on the island.

American Samoa (United States)

American Samoa consists of the mountainous volcanic islands of Tutuila and the Manua group (Ofu, Olosega, Tau), and Swains and Rose Atoll which are of coral origin. Approximately 94 percent of the Polynesian inhabitants reside on Tutuila (port city—Pago Pago). Rose is the only uninhabited island in the group. Certain terrestrial areas, including Swains and Rose, are under review by the Fish and Wildlife Service for designation as Critical Habitat under the U.S. Endangered Species Act (Dodd 1978).

- *Tutuila (14°16'S, 170°40'W)* and *Manua group (14°10'S, 169°35'W).* Green turtles and hawksbills occur in the waters surrounding these islands, but apparently only in small numbers. There is some indication that the hawksbill is the more abundant species. Occasional nesting on isolated beaches is thought to take place (Coffman 1977; S. Swerdloff, W. Pedro and R. Wass, personal communication).
- *Swains (11°03'S, 171°05'W).* Green turtles and hawksbills are known to nest at Swains (Swerdloff, personal communication). Turtle eggs were observed being gathered by the native inhabitants during July and August 1963 (Pedro, personal communication). The atoll is only 2 km in diameter.
- *Rose Atoll (14°33'S, 168°09'W).* Green turtles, and probably some hawksbills, nest on the islets (Rose and Sand) at Rose Atoll. An account in the 1800s stated that large numbers of turtles nest during August and September, and that numerous sharks prey on the hatchlings (Graeffe 1873, quoted by Hirth 1971a). On 7 October 1970, Hirth (1971a) counted 35 and 301 nesting pits of varying age on Sand and Rose Islets, respectively. Fishermen in Pago Pago confirmed that the peak nesting season is August and September.

On a low-altitude overflight in October 1974, 75 adult turtles were counted within the lagoon (P. Sekora, personal communication). During a 5-day visit in May 1976, only 3 adults and 1 immature green turtle were observed, and no nesting took place (Coffman 1977). During a daytime visit on 29 March 1978, Coleman (1978) recorded 1 recently excavated pit on Rose and 4 that he estimated to be 1-month old. Other older pits were noted, as well as a single adult green turtle in the lagoon and the rib bones of a turtle on Sand Islet. Numerous black-tipped sharks (*Carcharhinus melanopterus*) 20- to 40-cm long were present.

Direct observations of predation on hatchlings by rats have been made during recent years (Swerdloff, personal communication), but the extent and significance are unknown. Mayor (1921) was the first author to record rats at Rose. Hirth (1971a) stated that Rose Islet "swarms with rats (possibly *Rattus exulans*)." Coleman (1978) found that rats were "extremely abundant" and thought that black rats (*Rattus rattus*) might be present.

Following the recommendations of Hirth (1971a), Rose Atoll was designated a National Wildlife Refuge in 1974 (see also Rockefeller and Rockefeller 1974).

Western Samoa

Western Samoa is an independent nation consisting of 2 large islands of volcanic origin (Savaii and Upolu) and several offshore islets. The islands are located between 13° to 15°S and 168° to 173°W. Approximately 72 percent of the 152,000 Polynesian inhabitants reside on Upolu Island.

Green turtles and hawksbills occur in the surrounding waters of both Savaii and Upolu. The green turtle has been reported by fishermen to be the more abundant (Hirth 1971a). It is uncertain whether this species nests in the area. Hawksbills are known to nest, but now only on the offshore islets of Namua, Nuutele, and Nuulua located at the western end of Upolu. The nesting season extends from October to June, with most activity occurring in January and February. Nesting tracks counted by Witzell (1972a) suggest that not more than 45 females use these beaches each season. The number of hawksbills is believed to have declined considerably, due mostly to human exploitation of eggs and nesting females (Witzell 1972a, 1972b, 1974). The coasts of both Upolu and Savaii were reported to have abounded with turtles in the early 1800s (Williams 1837).

In 1971 a hatchery project was initiated by the Fisheries Division and 2 U.S. Peace Corps volunteers in an attempt to replenish the hawksbill population. This effort has continued until the present time. During each nesting season as many freshly laid eggs as possible are transferred from the 3 islets and reburied at a protected facility on the adjacent mainland shore of the Aleipata district. Hatchlings are held for up to 3 months in concrete tanks before being released into offshore waters. Marginal scutes have been notched for identification purposes. Hatchery data for the years 1973 through 1975 are as follows (from Anonymous 1974, 1975; A. Phillip, O. Gulbrandsen and T. Poutoa, personal communication):

Year	*Eggs collected*	*Eggs hatched*
1973	*4,656*	*3,257 (70 percent)*
1974	*6,231*	*4,951 (79 percent)*
1975	*5,159*	*2,460 (48 percent)*

This restocking effort has been considered at least a partial success by fisheries personnel because several marked immature turtles have been found for sale on Upolu (Anonymous 1975). Educational programs have also been periodically conducted to inform the populace of the need to conserve sea turtles (Witzell 1972b, 1974).

Based on the advice of an FAO sea turtle consultant, plans were prepared for a ranching industry in which hawksbill hatchlings would be grown to a size suitable for stuffing and export to Japan (Banner 1971). However, raising the turtles for more than a few months was not found to be feasible. Difficulties encountered included the need to frequently change the sea water in the rearing tanks, the presence of disease which caused serious tissue necrosis, the turtles' constant biting of one another, and the absence of a suitable, inexpensive food (Witzell 1972a; Anonymous 1974).

Tokelau

Tokelau is a New Zealand dependency consisting of three atolls (Atafu, Fakaofo, Nukunonu) located between 8° to 10°S and 171° to 173°W. The total Polynesian population is 1,600.

Hirth (1971a) reported that green turtles and, to a much lesser extent, hawksbills nest in Tokelau during September and October, but that their numbers were rapidly declining. In 1977, 1 of the remaining nesting sites was along the southern portion of Taulagapapa Islet at Nukunonu Atoll (N. Walton, personal communication).

Tuvalu

Tuvalu, formerly known as the Ellice Islands, is a newly independent nation comprised of 9 coral islands and atolls located between 5° to 10°S and 176° to 180°E. From north to south, the group consists of Nanumea, Niutao, Nanumanga, Nui, Vaitupu, Nukufetau, Funafuti, Nukulaelae, and Niulakita. The total Polynesian population is estimated to be 9,000. The capital of the group, Funafuti Atoll (8°30′S, 179°10′E), is 18 by 25 km and contains 30 islets (Inder 1978).

Hedley (1896), quoted by Wiens (1962), stated that "the green turtle was the only one found at Funafuti," but no additional information was provided. Carr (1965) listed the atoll as a minor green turtle nesting area, while Hirth (1971b) included it among important nesting sites in the western hemisphere. No other information on turtles is known to exist for Funafuti or other members of the group. However, in 1972 an intense tropical cyclone struck Funafuti and deposited an 18-km-long rampart of coral rubble along the atoll's southeastern outer reef (Maragos, Baines, and Beveridge 1973). The impact of this new formation on available nesting habitat could be substantial.

The coinage of Tuvalu includes a $1-piece displaying the green turtle. Furthermore, the commemorative stamps issue in 1976 features a leatherback and the uninhabited atoll of Niulakita. This would suggest that leatherbacks either nest or are sighted in the area.

Cook Islands

The Cook group, a self-governing state associated with New Zealand, consists of 15 volcanic islands and atolls located between 9° to 23°S and 156° to 167°W. The islands of volcanic origin include Rarotonga, Aitutaki, Atiu, Mitiaro, Mauke, and Mangaia, while the coral atolls, most of which are in the northern portion of the group, include Palmerston, Suwarrow, Pukapuka (not to be confused with Pukapuka in the Tuamotu Archipelago), Nassau, Manihiki, Rakahanga, Penrhyn (Tongareva), Manuae, and Takutea. There are approximately 18,000 Polynesian inhabitants, 54 percent of which live on Rarotonga. Information on the occurrence of turtles exists for the following locations.

- *Palmerston (18°04'S, 163°10'W).* Powell (1957), quoted by Weins (1962), indicated that green turtle eggs were "fairly plentiful" at Palmerston and that both turtles and eggs were frequently used for food by the 85 inhabitants. Carr (1965) considered Palmerston to be a major Pacific nesting site for green turtles. Although Hirth (1971b) included the atoll in a list of important nesting sites in the western hemisphere, it was stressed that the number of turtles involved was unknown and that the situation warranted immediate research attention.

In 1977 each family on the atoll had a tradition of raising 15 hatchlings in floating cages for 1 to 3 months before releasing them as a restocking effort (S. Kavakana and D. Brandon, personal communication). This practice apparently started in the 1950s following recommendations offered by Powell (1957). However, other reports in 1977 indicated that, instead of being released, many of the turtles were gutted, injected with formalin, and sent as curios to relatives in New Zealand. From 1972 to 1977 a decline in the number of nesting turtles was observed by the inhabitants, thereby prompting the local Island Council to prohibit the use of spearguns (T. Wichman, personal communication). Approximately 4 to 5 turtles are sent from Palmerston each year to the market in Rarotonga where the meat is not readily accepted by the residents and sells for only US$0.45 to 0.90 per kg. Large shells, however, bring US$50.00 or more in the growing tourist trade. Hatchlings were reported to be present at Palmerston in January (Brandon 1977), but the range of months in which nesting takes place is unknown.

Prior to 1862 Palmerston was uninhabited. In that year an Englishman (William Marsters) and 3 women from Penrhyn settled on the atoll and founded the colony that now exists (Bryan 1942).

- *Pukapuka (10°53'S, 165°49'W).* Green turtles and some hawksbills nest on one of the uninhabited islets at Pukapuka. Turtles and eggs that are taken from this location must be shared among the native inhabitants of the atoll (D. Clark, personal communication).
- *Manihiki (10°25'S, 161°01'W).* Green turtles, and possibly some hawksbills, nest at Manihiki. The natives take both the turtles and eggs for food. Hatchlings are also raised for a few months and preserved with formalin for shipment to relatives in New Zealand (T. Wichman, personal communication).
- *Rakahanga (10°02'S, 161°05'W).* Both Carr (1965) and Hirth (1971b) list Rakahanga as a nesting site for green turtles. Gill (1876), quoted by Wiens (1962), stated that "Several species of turtle—loggerhead, hawksbill, green turtle, etc.,—are very plentiful on Rakahanga in the breeding season." Although loggerheads (as well as leatherbacks) have occasionally been sighted in the Cook Islands (Brandon, 1977), this is the only known report of nesting. The northwestern point of Rakahanga is named Te Mata i Pahonu and relates to sea turtles.
- *Penrhyn (9°0'S, 157°59'W).* Green turtles and some hawksbills are known to nest at Penrhyn and forage in the adjacent waters. During 1976 between 40 and 50 turtles of unknown sizes were taken principally for their shell. A few were sent to Rarotonga, but most were used for trading with Japanese, Korean, and Taiwanese fishing vessels that illegally visit the atoll (Brandon 1977 and personal communication).
- *Suwarrow (13°15'S, 163°06'W).* Brandon (1977) lists Suwarrow as a nesting site for turtles, but no details are provided. One of the islets is named Turtle Island. Only one person lives on the atoll.
- *Manuae (19°16'S, 158°58'W).* In May of 1975 the Cook Islands' Government donated Manuae for use as the first World Marine Park (Allen 1975; see also Shadbolt 1967). However, questions of ownership of the atoll have prevented this action from being carried out. Manuae is listed by Brandon (1977) as a nesting site for turtles, but details are not provided.
- *Takutea (19°49'S, 158°18'W).* Takutea is also listed as a nesting site for turtles by Brandon (1977), but again no details are provided.

From 1974 to 1977, studies on the rearing of green turtles as a village industry were conducted at Rarotonga with financial support from the South Pacific Commission (Baird 1975; see also Powell 1957; Anonymous 1972). As part of this project, laboratory experiments were also carried out at the University of the South Pacific in Fiji (Raj 1975). The findings of this work were similar to those made in Western Samoa, in that problems of disease and a suitable, inexpensive food supply could not be resolved (Brandon 1977, Balazs 1977, Anonymous 1978).

Recommendations

The survival status of sea turtle populations occurring in the areas covered by this report can be enhanced through implementation of the following recommendations.

1. Where appropriate, island governments should attempt to reinforce the traditional conservation systems that formerly served as a buffer for sea turtles. The absence of governmental regulations for most of the areas covered makes it imperative that some protective action be undertaken, but in close consultation with native inhabitants.

2. Known rookeries should be intensively monitored during the peak period of at least 1, but preferably several, nesting seasons to determine the number of females present. As a minimum, this should include Rose Atoll, Enderbury, Birnie, Palmerston, Penrhyn, and the offshore islets of Namua, Nuutele, and Nuulua in Western Samoa. Tagging with durable tags (see Balazs, this volume) should be carried out as an integral part of this work to gain some insight into the occurrence of international migrations, hence shared usage of resources.

3. Based on the results of Recommendation 2, and in harmony with Recommendation 1, governments should be encouraged to designate certain islands and their surrounding waters as sea turtle sanctuaries. This would be a relatively uncomplicated undertaking in the Phoenix group and Southern Line Islands where most of the islands are currently uninhabited and unused by man.

4. The illegal landings on uninhabited islands by foreign fishing vessels should be investigated by an international task force. Such violations constitute a worldwide problem and usually involve the theft and destruction of natural resources that include sea turtles.

5. A comprehensive appraisal should be undertaken of the 9-year-old hawksbill hatchery in Western Samoa. The results of this little-known conservation experiment may be of considerable value to worldwide efforts aimed at saving endangered hawksbill populations.

6. The predation on hatchlings by rats at Rose Atoll should be quantified and control methods implemented if the conditions warrant.

7. Military agencies of the U.S. government administering islands covered in this report should undertake a thorough investigation of the aggregations of sea turtles occurring at such sites. This would include Johnston Atoll, Kingman Reef, Wake, and Midway in the Northwestern Hawaiian Islands. Any plans for the storage of nuclear wastes and other highly toxic substances on Pacific islands should include a careful evaluation of the potential impact on both nesting and foraging aggregations of turtles.

8. The Hawaiian Islands National Wildlife Refuge should encompass a substantial amount of surrounding marine habitat to serve as a buffer against the forthcoming development of commercial fisheries.

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From 11 to 14 December 1979 a workshop on sea turtles in the Pacific islands was to be jointly held by the South Pacific Commission and the U. S. National Marine Fisheries Service in Noumea, New Caledonia.

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Marine Turtles of the South Pacific

The turtles of the Pacific Ocean have received extensive coverage in many fine presentations at this symposium. This paper will discuss the turtles of those islands and territories not specifically covered by other contributors. The area thus included comprises part of Melanesia (New Caledonia, the Solomons, New Hebrides, and Fiji), and southern Polynesia (New Zealand, the Kermadec Islands, Tonga, French Polynesia, Pitcairn and Henderson, and Easter Island).

New Caledonia

It has long been known that green turtles (*Chelonia mydas*) abounded in the waters and islands of the d'Entrecasteaux Reefs, north of New Caledonia. For example, William Billings, master of a sailing vessel that ran aground on the reefs in September 1856, recorded the presence of many turtles, one of which reportedly weighed 600 pounds (273 kg). The nesting season was supposed to take place from July to December. Eight turtles caught were reported to have an *average* weight of 5 cwt (254 kg). The turtles apparently basked both on land and in water, as do Hawaiian green turtles; Billings reported that "the Master turned twenty-seven one morning without wetting his feet, and he counted eighteen more asleep in six inches [15 cm] of water. . ." (Billings, in Chimmo, 1856).

Although the islands in the d'Entrecasteaux Reef system are visited at least annually by weather station personnel, no literature seems to have been published recently on the turtles there. However, in December 1979 I was part of an aerial survey group that overflew the reef at low altitude, and we confirmed that the 4 islands large enough to have scrub or tree cover in their interior (Isles Surprise, Le Leixour, Fabre, and Huon) were still attracting large numbers of turtles; the beaches and dunes of these islands gave the appearance of being nested to capacity. No turtles were seen on the land at the time of our survey, but many were seen in the adjacent shallow waters, and they appeared to be green turtles.

On 10–11 February 1980 the French Navy ship *La Dunkerquoise* visited Huon Island, which was then estimated to be 3 km in length (including the elongate sandbanks), a maximum of 200 m wide, and with only 12 of the 200 ha surface covered with vegetation (a single species of creeper). Turtle nesting density was impressive; 20 ha were used for nesting, of which a single 50 by 50-m sample contained approximately 140 nest pits, about 25 percent of which were 48 hours old or less. Evidence of much hatchling emergence was visible, and about 15 dead and decaying adult turtles were seen on land. The density of tracks of adult turtles along the shoreline averaged about 25 distinct departures every 100 m (only counting tracks estimated to be 24 to 48 hours old). Clutch sizes, reported as 60 ± 20, were surprisingly small.

Calculations based on these figures suggest $25 \times 60 = 1{,}500$ emergences over the entire 6-km perimeter of the island over a 2-night period. The numbers of nests in this same period calculated from the area mentioned above would be $35 \times 4 \times 20 = 2{,}800$. Actual observations during a 4-hour period 1 night revealed only about 50 nesting emergences. It therefore appears likely that the nests and tracks had accumulated over more than 24 to 48 hours; but still the island, together with its 3 neighbors in the d'Entrecasteaux Reef system, constitute the most important turtle nesting area among all the oceanic islands of the Pacific.

The reported average size of the turtles was very large—carapace length approximately 1.4 m, width approximately 0.9 m. These dimensions are entirely compatible with Billings' report of an average weight of 5 cwt, but even so this size is similar to that of the record size known for a green turtle, and is greatly in excess of the average size of any known population. It will be interesting to obtain confirmation and to salvage the dead specimens on the island.

The hawksbill is well-known in New Caledonia, and is probably ubiquitous on the reefs that virtually surround the island. On the Isle des Pins, at the southern end of New Caledonia, we were informed by a local fisherman that the loggerhead, locally known as *grosse tête* (big head), was in fact the commonest species; the presence of this species was confirmed by a photograph of an adult nesting and a young specimen, about 30 cm in length, in the Noumea aquarium.

A fourth species, that would appear to be the olive ridley, was familiar to some informants; it was reported to be rare. No one seemed to be familiar with the leatherback; this species avoids coral reefs, and would not be expected anywhere in New Caledonia except as an accident.

In the Loyalty Islands, a dependency of New Caledonia, our aerial survey in December 1979 revealed significant turtle nesting activity on the smaller islands in the northern and northwestern part of the Uvea atoll complex. By far the best nesting was on the island of Beautemps-Beaupré, where the more northern beach was literally covered with turtle tracks: this island is the only emergent point of a separate atoll system northwest of Uvea. It was not possible to determine the species responsible for the nests.

Turtle nesting in New Caledonia is concentrated in the summer months (November to March).[1] The sea turtles in New Caledonia receive considerable protection under the provisions of Ordinance No. 220 of 3 August 1977, adopted by the New Caledonia Territorial Assembly. This ordinance prohibits any collection of turtle eggs, or any marketing of turtle meat, mounted turtles, or shells. All species are totally protected during the nesting season (November to March, inclusive). Application may be made for special permission to take turtles during these times for scientific purposes or for Melanesian traditional feasts and ceremonies. Between 3 August 1977 and 22 August 1979, permits were issued for the taking of 77 turtles for traditional purposes during the closed season.

On Lifou Island, we were informed that only the chief can eat turtle meat, although he can authorize certain clans to eat the meat approximately once a year. The turtles were reported to be very abundant and virtually unhunted. Both the hawksbill and green turtle were present in the lagoon of Uvea. Melanesian traditional law is still respected, and turtles are essentially private property of certain clans, which provides for considerable protection.

Solomon Islands

A recent report by McKeown (1977) gives a great deal of valuable data on turtle nesting in the Solomon Islands.

The green turtle is thought to be the commonest species in the Solomons, although aggregated nesting does not seem to take place there. They are most commonly seen in the Roviana-Marovo Lagoon System; at Ontong Java Atoll; and in the Reef Islands, notably Nupani Atoll. Sporadic breeding has been reported from October to February at Kerehikapa; Oroa Island, Makira; Lilika Bay, Santa Ysabel; and the Hele Bar Islands, New Georgia. As with green turtles in the Bismarck Islands, the green turtles in the Solomons are apparently never colonized by barnacles.

Carapace lengths of 4 adult females ranged from 78 to 89 cm; weights from 84 to 95 kgs (means 85 cm and 89.78 kg). Mean clutch size for 5 clutches was 84.6 but the range was great—45 to 156.

Green turtles in the Solomons are subject to rather intensive pressure by local people, who catch them principally for special feasts. McKeown reports 22 caught

1. But Billings (op.cit.) refers to a somewhat earlier nesting season.

in Baola in November 1976 for a feast, and 39 in Samasodu in July 1977; formerly, according to the Samasodu people, 100 was not uncommon for a day's catch. The turtles are caught by tangle nets, spearing, diving and holding while the turtles are sleeping, shooting with bows and arrows, with nets baited with pawpaw, on the nesting beaches, and by hook and line, using pawpaw as bait.

The hawksbill is the commonest nesting species in the Solomons, but although still ubiquitous, populations have declined considerably; even religious groups (such as the Seventh Day Adventists) who do not eat turtles will kill hawksbills for their shells, and considerable volumes are exported from the Solomons. Numerical data on the volume of this trade are scarce, but exploitation is clearly excessive; despite rising prices and greater hunting effort, traders found that the quantities of shell offered them decreased steadily. In July 1977, the price of turtle shell on Wagina Island, a center for the industry, was $6.50/lb (about $14.30/kg).

Hawksbills are known to nest on many beaches in the Solomons, but the most important is Kerehikapa, a horseshoe-shaped island about 4-km long in the Arnavon Group. Straight carapace lengths of nesting hawksbills there varied from 68 to 93 cm, although 1 female caught while copulating measured only 61 cm. Weights ranged from 42 to 77 kg; average values were 80.5 cm and 66 kg (N = 40). Nesting is almost always nocturnal; only 1 diurnal nesting was witnessed, although many local people claimed that this habit was common in former times, as it still is on many of the Torres Strait Islands. Some cases of renesting have been reported, though surprisingly few in view of the extent of beach coverage; of 91 individuals tagged at Kerehikapa, 4 were seen to come back to lay another clutch, at intervals of 13, 15, 17, and 28 days. Sixty-six hawksbill nests were unobserved during this period, so there may in fact have been more renesting than this.

The mean incubation period for 164 nests was 64 days. Clutch size varies from 75 to 250 eggs, the latter being apparently the largest clutch on record for any turtle—or indeed reptile—species: mean was 137.53. Nesting is year-round at Kerehikapa, though there may be an indistinct peak in June–July.

The leatherback turtle nests on numerous isolated beaches in the Solomons, preferring those that are located near river mouths, having a reefless approach, and being composed of black sand. Nesting takes place in the November–January season. The taking of this species is illegal (Regulation 17 of the 1972 Fisheries Regulations), but nevertheless, nesting animals are frequently butchered, and their nests raided.

The loggerhead is very rare in the Solomons, but it is recognized by villagers in many areas, and the identification has now been confirmed by McKeown, who had the opportunity to examine a skull and a live specimen. Nesting in the Solomons by this species is unknown.

The olive ridley is known only from 3 individuals from the Solomons, 2 of which were a mating pair caught off northern Guadalcanal near Honiara in February 1976. The third individual was a juvenile found at Makira in July 1977.

A hawksbill turtle tagged while nesting on Santa Ysabel in December 1976 was caught on the reef at Fishermen's Island, Papua New Guinea, in March 1979 (P. Vaughan, personal communication). This journey of at least 1,800 km represents the longest reported movement of a hawksbill turtle.

Additional information on sea turtles in the Solomon Islands, including proposed population models for both the green turtle and the hawksbill, is given by McElroy and Alexander (1979).

New Hebrides

The turtles of the New Hebrides are in need of study. However, there is evidence that about 200 turtles were caught at Mota Lava, near the northern end of the New Hebrides system, in the first 6 months of 1979, and Reef Island nearby is an important green turtle nesting ground. The following information on sea turtles in the New Hebrides is taken from the report by McElroy and Alexander (1979).

The species named as nesting in the group are the green and hawksbill turtles. Information on the leathery turtle indicated that it occurs in some parts of the group but no nesting beaches were known. The green and hawksbill turtles are common in the extensive reefs and shallow areas of the group.

The most important nesting area in the group is at south Malekula Island. Important mainland nesting of greens occurs at South West Bay, and particularly Lambobe beach. Small numbers of hawksbills also nest here. A rough estimate of the numbers nesting each year is from 40 to 120 turtles. The Maskelynes form a group of offshore islands off the southern coast of Malekula where turtles are particularly plentiful. Regular nesting of both species also occurs within the group, particularly at Seior and Laifond islands. Sakau and 2 small islands close to Akam are used occasionally. Purposeful fishing at sea accounts for most turtles captured. The people of the Maskelynes group are reported to be the best fishermen in the New Hebrides. Estimates indicate a yearly catch here of 60 to 120 turtles, about evenly spread between both species. Other notable areas for nesting turtles were southeast of Epi, and in the north amongst the Torres group. Whenever found, nesting females and eggs are usually taken.

The nesting season for both species extends from

September to early January. The general picture gained indicated that nesting on main (populated) islands was still common. Hunting and fishing pressure was extremely localized and never intense. The lack of strong fishing pressure coupled with a small population and minimal developments along the coasts of the group, indicates that the normal nesting pattern of these 2 species in the group is virtually unchanged.

Though there is negligible trade in tortoise shell from the New Hebrides, in recent years turtles and turtle eggs have been appearing more frequently in the markets of Santo and Vila. Legislation has been passed (Joint Rules No. 7 of 1974) to prohibit the taking or selling of nesting turtles or their eggs. Thus islanders who catch turtles at sea can still use these for food.

These regulations were found to be poorly understood and little known despite a recent article in the New Hebrides News. However, the situation still seems to be good. The major long-term threat to turtles in the group is increased human predation brought about by the continuing population explosion.

Fiji

Turtles of Fiji are currently being studied by M. Guinea of the University of the South Pacific at Suva; but until these results are published, the principal source of information is Bustard (1970). The 2 most plentiful species in Fiji, as elsewhere in the South Pacific, are the hawksbill and the green turtle. The leatherback is also reported to nest in Fiji, though very rarely (Bustard 1970). A very low level of nesting of this species takes place on the southeastern coast of Vanua Levu (M. Guinea, personal communication). This is the most easterly record of nesting of *Dermochelys* in the Pacific Islands. Both Bustard and Guinea report that either the loggerhead or the olive ridley, or both, are occasionally found in Fiji, and Hirth (1971) saw a shell of the loggerhead at Malake Village, Fiji.

Some of the salient points regarding sea turtles in Fiji reported by Bustard (1970) are as follows:

1. Turtles feed in the passage between Taveuni and Vanua Levu but rarely nest in the area.

2. No significant nesting occurs on Qamea.

3. Hawksbill nesting on Matagi is now reduced to about 1 nesting per week.

4. Some nesting takes place on Nanuku Levu, mostly by greens, but numbers are now very depleted.

5. Reasonable levels of hawksbill nesting were observed on Nanuku Lailai.

In December 1979 I found carapaces of half-grown hawksbills offered for sale in some numbers in the market in Sigatoka, on the south coast of Viti Levu.

In theory, sea turtles in Fiji are well protected by the Fisheries Act. Turtle eggs enjoy total protection; turtles less than 18 inches (46 cm) in length are also protected; and there is a completely closed season during the nesting months of November to February. Fijian law also requires that "no person shall harpoon any turtle unless the harpoon is armed with at least one barb of which the point projects not less than 3/8 inch [0.95 cm] from the surface of the shaft, measured at right angles to the long axis of the shaft." Prosecutions are sometimes made under the turtle laws, but basically violations are frequent and not even clandestine. Moreover, feral mongooses eat the eggs, or the baby turtles before they reach the sea.

Some of the salient points in the report of Hirth (1971) on marine turtles in Fiji are as follows:

1. Species known: Green (Vonu Damu, Vonu Loa, Mako Loa, Ika Damu); Hawksbill (Taku). Loggerheads and leatherbacks are present but extremely rare.

2. Hawksbills are fairly common in north loop of Great Astrolabe Reef in Kadavu, and nest there, the season peaking in January. Some green and hawksbill turtles nest in the southern Lau group. The largest nesting sites are likely to be the Yasawa Islands, the Mananutha Islands, and the Lau Islands.

3. Some kraals of green and hawksbill turtles are maintained for the benefit of tourists. In one such kraal on Vinivandra Island, hawksbills grew to 15 to 17 cm in 2 years.

4. Green turtles are caught in feeding pastures off north-central coast of Viti Levu; 80 were caught in October. The turtles subsist largely on red and green algae.

5. Many hawksbill curios are sold in Suva shops and in the market. Demand increases as tourists increase. Green turtle meat is erratically available in the market and in first class hotels.

6. Export of raw tortoise shell was proscribed as of September 10, 1969 to encourage local manufacture of curios and other products. In 1969, 137 kg of turtle shell were exported (88 kg of hawksbill shell); in 1968, 270 kg (78 kg hawksbill).

New Zealand

The leatherback turtle is fairly regularly encountered in New Zealand waters. McCann (1966a) reported this species to be seen most often in northern waters, but that it had been recorded as far south as Otago and Foveaux Strait. Subsequently, McCann (1966b) listed the following localities for leatherbacks in New Zealand: Bay of Islands, passing Cape Brett (1892); between Bay of Islands and Mangonui (1894); New

Plymouth (1895); Palmer Head (ca 1930); Doubtless Bay (1924); Mayor Island (1939); off Cape Brett (1939); Pukerua Bay (1948); Waitarere Beach (1954).

Other records cited by Eggleston (1971) include a sight record for Foveaux Strait, off Saddle Point, on 20 February 1970; this is the southernmost known record for the species. Also, a specimen was sighted off Cape Palliser on 12 December 1969; and a specimen washed ashore at Gillespie's Beach, South Westland, in 1969.

Some more recent records that came to my attention on a visit to the National Museum (formerly the Dominion Museum) in December 1979 were as follows: Wairarapa Coast (26 May 1976; specimen mounted for National Museum); Poison Bay (15 February 1972); Three Stones Bay, 24 km north of Kennedy Bay (5 February 1970); Mangonui, north of Kaitata 46 m depth, 2.4 km offshore (2 April 1973) drowned by trawler; near mouth of Conway River (1 April 1970); near Raglan (23 January 1973); Ariel Reef, 11 km off Gisborne Coast (24 February 1975); Coromandel Coast (April 1971).

Fordyce and Clark (1977) gave the following records: Jacksons Bay, Westland, 4 October 1975; Great Barrier Island, Northland, 4 April 1976; Kaikoura, 3 specimens fouled in crayfish pot lines, March-April 1977; and Adderley Head, Banks Peninsula, 27 March 1977.

The green turtle is very rare in New Zealand waters. Specimens reported by McCann (1966b) were as follows: Kawau Islands, Hauraki Gulf (carapace 872 by 685 mm); Hauraki Gulf (1911); Waikato River, Taupiri (1936); Great Exhibition Bay, south of Parengarena Harbour (1895) "nearly three feet long"; and Ninety-mile Beach (January 1949, carapace 775 by 525 mm).

In addition to these records, the *Nelson Evening News* of 23 March 1971 illustrates an immature green turtle caught in 59 m in Tasman Bay by a trawler; and the *Christchurch Press* of 3 January 1948 reported a 36 kg green caught on a set line at Whangaparaoa, near Auckland.

The hawksbill is even rarer than the green turtle in New Zealand waters. McCann (1966b) reports on 3 specimens: an adult (90 cm in carapace length) taken at Muriwai Beach on 21 June 1949; a juvenile taken at the same location on 29 August 1956; and a specimen of unrecorded size taken at Ninety-mile Beach, about 18 km north of Waipapakauri, on August 15, 1956. The 1956 Muriwai Beach specimen contained fragments of barnacles, cephalopods, *Vellela*, *Salpa*, and pteropods.

Robb (1973) reported that a live hawksbill was found on Piha Beach, near Auckland, in August 1970.

A live turtle found at Uretiti Beach, 25 cm in length, was identified as an *Eretmochelys* in an article in the *Northern Advocate* of 23 July 1973, but the identification was corrected to *Caretta* in the 9 August 1973 issue of the same newspaper.

The available literature confuses the loggerhead and the olive ridley in New Zealand waters, but the photographs in McCann (1966b) make it clear that both species occur, although *Caretta* is probably much more common. The specimen 610 by 560 mm in size, 25 kg in weight, with enlarged ova present, and with 7 costal scutes on one side and 8 on the other, was clearly a *Lepidochelys olivacea*. On the other hand, the illustrated specimen caught at Whenupai in 1956, which exhibited 5 pairs of costal scutes and a carapace measuring 500 by 446 mm, was clearly a *Caretta caretta*.

Other *Caretta* in New Zealand include the following: a 33 cm immature washed up at Flat Point, 64 km from Masterton, in August 1966, reported in the *Wairarapa Times-Age* (29 August 66); a 72 kg specimen caught 3 km off the Wairarapa Coast in March 1973, and released the next day at Castlepoint Beach (*Wairarapa Times-Age*, 2 March 1973); and a juvenile netted by a Greymouth fishing boat in January 1975 (*Greymouth Evening Star*, 10 January 1975).

The possibility exists that *Caretta* may occasionally nest on the extreme northern beaches of New Zealand. Very small specimens, 8 to 10 cm long, are found on occasion, for example, 3 specimens taken at Ninety-mile Beach, 1 in 1949 and 2 in 1952, reported by McCann (1966b); these specimens ranged from 86 to 97 mm in length. Another specimen in this size range was caught on East Beach in July 1973 (*Northland Age*, 7 September 1973).

McCann (1966b) observed correctly that, although these specimens were indeed very small, they were probably around 6-months old rather than hatchlings; and the fact that they were caught in late winter would correlate with their having hatched about 6-months before. It might be concluded that the specimens had hatched on beaches in Queensland, Australia, and had reached New Zealand by passive drifting during the ensuing months. Nevertheless, an article in the *Northland Age* (27 July 1973) concludes that "marine turtles must occasionally breed on the coast of the Far North (of New Zealand)," based on the evidence not only of the very small loggerheads occasionally found in the region, but also on reports of "strange tracks like those made by turtles" in Spirits Bay and Ninety-mile Beach; and a report by Mrs. Peter Nilsson that turtle tracks had definitely been seen on several occasions in late summer leading from the sea to the sandhills of Tom Bowling Bay, adjacent to Spirits Bay at the extreme northern tip of New Zealand.

Kermadec Islands

Oliver (1910) reports that green turtles may be found feeding in substantial numbers between January and

March near Sunday Island, in the Kermadec Islands, north of New Zealand at a latitude of about 30°S, although no breeding occurs there. A 1908 photograph in the Archives of the National Museum in Wellington, New Zealand, shows an immature green turtle from the Kermadec Islands. Parsons (1962) postulated that these turtles might be derived from the colony that nested on Vatoa Island, the southernmost of the Fiji Group where Captain Cook found numerous nesting turtles. However, I am informed that there is no longer a nesting colony of green turtles on Vatoa, and in any case, it is dangerous to assume that a feeding population of green turtles is necessarily derived from the geographically closest nesting population.

Tonga

The only available information on the sea turtles of Tonga is unpublished; it appears in the reports of H. F. Hirth (1971) and Wilkinson (1979). Since this information is not generally available, some quotes are presented below.

According to Hirth, 3 species of marine turtles are found in the Tonga Islands: the green turtle (local names: Fonu, Fonu Tu'a'uli, Fonu Tu'akula, Fony Tu'apolata, Tuai Fonu); hawksbill (bonu Kolaa), and loggerhead (Tu Fonu). The vernacular names vary from village to village. Some fishermen have additional names for the color phases and various sizes and sex of each species. The green turtle definitely nests on islands in the Ha'apai group, chiefly on the uninhabited ones. The consultant was unable to determine whether the other 2 species nest in the Kingdom.

Interviews all lead to the conclusion that most marine turtles are found in the Ha'apai group and that the period of nesting is in the summer (November to February) with December being the peak month for oviposition.

Turtles, especially green turtles, can be caught throughout the year in the Ha'apai group as well as in the Tongatapu group.

Tongans eat turtle meat and eggs. Eggs are eaten by the inhabitants of the nesting beaches and no eggs are found in markets in Tongatapu. Turtle meat itself is rarely sold in the market in Nuku'alofa because turtles are usually butchered and sold on the beaches as soon as they are landed.

Green turtles (some loggerheads and rarely hawksbills) are caught on the feeding pastures off Tongatapu Island. One of the best pastures is north of Nuku'alofa and east of the islands of Paloa, Alakipeau, Tufata, and Atata. The most common method of capture is by spear gun. Occasionally, nets are set and only very seldom are special turtle fences bulit. The latter method, however, was common a couple of decades ago (see current turtle regulations). Fences are seldom used now because turtles are rarely seen on the feeding pastures close to the shore. According to the best turtle divers, females are more common than males on the grass flats. Turtles can be caught all year on the pastures, and some turtle fishermen claim that the best months are from November to March when the "grass" is especially lush. Furthermore, again according to the local fishermen, the grass goes through cycles when it is very lush and then sparse. Divers also state that green turtles smaller than "plate-size" (about 25 cm in carapace length) are not seen on the feeding pastures.

Three men, working from a small boat and diving all day for turtles on the Nuku'alofa pastures will call it a "very good day" if they manage to get 2 or 3 green turtles. The most common method of catching turtles in the Ha'apai group is with nets. These usually have a 12-inch mesh. A few fishermen chase turtles with motorboats and after the reptile becomes tired or has been chased into shallow water, a man jumps overboard and catches the turtle by hand.

Turtle grass pastures (*Syringodium isoetifolium* and *Halodule uninervis*) encompassing at least a square mile, are found off the coast of Nukunukumotu. These spermatophyte pastures, along with those in Fiji, are the best the consultant has seen on the survey, although it should be emphasized that he did not make extensive surveys for pastures throughout the South Pacific.

According to some fishermen, a few turtles (the species are not known) still occur in the lagoon but they are not so abundant as in former days. The consultant could not determine the extent of turtle fishing in the lagoon at the time of writing these comments, but he is of the opinion that turtling here would be very unprofitable. In some areas the water is extremely polluted.

Fishermen on Pangaimotu Island used to keep adult turtles in a kraal feeding them with turtle grass (*Syringodium* and *Halodule*) which washed up on the beach. They declared that the turtles ate this grass readily, and the consultant saw large amounts of turtle grass of both species washed up on shore in October.

The consultant examined the stomachs of 2 green turtles caught during the week of 19 October on the feeding pastures in the main channel off Nuku'alofa and both were full of *Syringodium*. One stomach also contained a few pieces of *Halophila ovalis*. The Tongan name for turtle grass, as well as for algae, is *limu*.

Since green turtles are caught regularly on the feeding grounds off Tongatapu (but do not nest on Tongatapu) and since green turtles are known to nest in the Ha'apai group—it may be that there is a nesting-feeding migration between the 2 groups. The consultant dissected 2 adult green turtles (caught on the feeding pasture off Nuku'alofa during the week of 19 October) and both contained hundreds of small developing eggs which appeared to be about 1 month away from

Table 1. Tongan names of marine turtles and their English and scientific equivalents

Tongan name	*Equivalents*
Fonu Koloa	Hawksbill (*Eretmochelys imbricata*)
Tuangange	Probably olive ridley (*Lepidochelys olivacea*), but may possibly be the Indo-Pacific loggerhead (*Caretta caretta gigas*).
Ika ta'one Hulemui	Males of the green turtle; different size, color. (*Chelonia mydas*)
Tu'a polata Tu'a 'uli Tongotongo Aleifua Tufonu	Females of the green turtle (*Chelonia mydas*). Different names due to size variation, age variation as well as color variation. Possibly the black turtle (*Chelonia agassizi*) is included here.

being shelled. Both turtles also possessed large amounts of fat which might indicate a premigratory condition.

The information from Wilkinson (1979) is as follows.

The hawksbill nests on the following islands: Kelefesia, Tonumea, Telekitonga, Lalona, Telekivava'u, Lalona, Telekivava'u, Fetokopunga, Nukufaiva, Meama (near Fonoifua), Fonuaika, Tokulu, Nukulai, Luanamu, Kito, Fetoa, Putuputua, Limu, Uonukuhahake, Tofanga, Uonukuhihifo, Luangahu, Hakauata, Tatafa, Luaheka, Nukutula, Nukupule, Meama (near Nukupule), Niniva (uninhabited), and Nukufaiau. One additional uninhabited island which is a probable hawksbill nesting site is Lekeleka.

The turtles are known to nest on 3 inhabited islands: Mango; 'Uiha, Liku side, and Ha'ano, Muitoa.

The Tongan names of the different marine turtles in Ha'apai and the English and scientific names which fit descriptions of the Tongan names are presented in Table 1.

Of the 10 Tongan names for marine turtles, 8 of these describe *Chelonia mydas* (the green turtle) with possibly 1 of the names describing *Chelonia agassizi* (black turtle). This is reasonable, however, since *Chelonia mydas* is really a combined species name for a number of yet unnamed races of the green turtle. There are small differences in color, head, flipper size, and overall size between these unnamed races.

Fishermen from the Ha'apai islands were asked whether they had seen (and not just heard it from others) any of the other turtles nesting besides the fonu koloa (hawksbill). The *tu'a 'uli*, one of the names describing the female green turtle (*Chelonia mydas*) has been seen nesting by fishermen from Tungua, 'O'ua and Ha'afeva islands (also the *aleifua*, the green turtle). Islands where the green turtle has been seen nesting include 2 uninhabited and 1 inhabited island: Nukufaiva, Fetoa, and Mango Island.

The most common and least common turtle names were asked of the fishermen. Almost consistently they mentioned the tu'a 'uli as being the most commonly caught, which is what we have observed as well. Many said the *fonu koloa* (hawksbill) was not the least common turtle in Ha' apai, so apparently the population is not down to its most critical level as yet. *Tuangange* (ridley) and *tu'a kula* (*Chelonia* sp.) were often mentioned as being the least common and maybe the black turtle. This is what was expected since no ridleys have been seen, nor their shells at the market or on the boats.

According to fishermen, nesting begins very sparsely in October, increases in November and reaches a peak in December-January, slackens off quickly, and nesting probably ceases sometime after the middle of January.

In the Vava'u group the composition of the turtle population is the same as identified in the Ha'apai group: tungange, most likely the Pacific ridley *Lepidochelys olivacea;* aleifua, probably the green turtle *Chelonia mydas;* fonu koloa, the hawksbill *Eretmochelys imbricata;* tofunu, possibly *Chelonia agassizi.* In discussions with fishermen, it was found that the main egg-laying season is from November to January, although the gathering of turtles on the sea, off the nesting sites, begins as early as October.

The main nesting islands are in the southwestern area. They are Fonua'one'one, Fangasito, Folifuka, Foeata, and Maninita. These islands are relatively accessible and all should be declared seasonal breeding sanctuaries. Fishermen admit the islands are visited by people and that eggs are taken. In the long term, this practice could be disastrous for the turtle population in Tonga. Enforcement of sanctuary regulations should not be difficult if a fisheries station and regulatory staff were stationed at Vava'u.

Turtle nesting is reputed to occur on Malinoa Island off Tongatapu. Nowhere else, on or around Tongatapu, do turtle nesting areas presently exist, mainly due to human predation and interference.

French Polynesia

French Polynesia includes several far-flung archipelagoes, including the Society Islands (Isles de la Société), the Marquesas (Iles Marquises), the Tuamotu Islands (Archipel des Tuamotu-Gambier), the Austral Islands (Iles Austral), and Rapa. The most commonly encountered turtle in French Polynesia is the green; the hawksbill is reported to be almost extinct, and other species are unreported.

Society Islands

Green turtles are reasonably plentiful in the Society Islands. The principal nesting islands, as in Micronesia, are uninhabited or only seasonably inhabited by man. One such island is Mopelia, locally renowned for turtle nesting. According to Eggleston (1953) and Legand (1950), the peak of the nesting season is around November. Nevertheless, by continental standards the nesting colony is small; it is considered a good week in which a dozen turtles nest. Parsons comments on some locally initiated conservation measures that have taken place, including a program of protection of the young turtles and their eggs. Regulations allow the local people to "head-start" the turtles in corrals in the lagoon, and to send a turtle to the Papeete Market for each one they release.

Hirth (1971) gives the following information for turtles in the Society Islands: The most common sea turtle in the area is the green turtle (French: Tortue; Tahitian: Honu). One of the principal nesting grounds is Scilly. Other important nesting sites are Mopelia, Bellinghausen, Tupai, and some of the Tuamotu atolls. The peak nesting season in Scilly, Mopelia, Bellinghausen, and Tupai is October through December. Reports indicate that some turtles can be found throughout the year off Scilly. The hawksbill turtle is sometimes taken by fishermen. There is 1 authentic record of a leatherback caught in a seine. On 24 September, the consultant counted 20 green turtles in the water around Mopelia (but there were no tracks on the beach), and 42 around Scilly, including 12 in a village kraal. He also noticed fresh tracks and nests on Motu Honu (Islet of Scilly).

Many males and some gravid females are speared as they mate off the nesting beaches on the atolls. Tahitian fishermen report a sex ratio in favor of males. The turtles sold in Papeete market in September were mostly males. Green turtle meat is considered a delicacy and sells for about $3 per kg in the Papeete market but there is no market for eggs. A few cured shells are sold in tourist shops at $25 each but the demand is insignificant.

There are no regulations in French Polynesia concerning marine turtles.

Stomachs examined by the consultant were chiefly empty but a few contained a little green algae and one harbored a long piece of plastic. During his limited survey, the consultant did not find any extensive algae beds or grass flats.

Fisheries Department records indicate that between 1953 and 1967 from 24 (1954) to 262 (1962) turtles caught at Scilly were sold annually in the Papeete market.

Further information on green turtles in the Society Islands was provided by Anon (1979). This paper reports that the principal nesting island, Scilly, was declared a "protected area" on 28 July 1971, with a family appointed to watch over the nesting turtles. Nesting takes place primarily from September to December, but with significant year-round nesting. There is significant predation of hatchlings by frigate birds (by day) and hermit crabs (by night).

The Scilly green turtle breeding colony was studied and tagged intensively in 1972 and 1973 and, after several years' hiatus, operations were resumed in 1979. 364 female turtles were tagged and measured in 1972, and 42 more in 1979. The population has dwindled considerably in recent decades; only 20 to 30 years ago, it was reported that 100 to 150 turtles could be turned in a single night. The fact that such numbers not only could be, but were, turned resulted in a decline to the point where today about 20 nest on a typical night on the islet of Motu Rahi, 5 to 6 on Motu Honu, and 8 or 9 throughout the rest of the atoll. It was also reported that, with the decline in numbers, average size of the turtles had declined, carapace lengths now typically lying between 93 and 97 cm, with the maximum 106 cm. Maximum weight was now 175 kg although a few years earlier, turtles weighing over 200 kg were supposed to have existed.

These weights, although not so mentioned in the report, are unusually high for Pacific green turtles, especially when remembering that the green turtles nesting on the mainland Pacific coast of Mexico at Colola, Michoacan, average only 77.32 cm and 57.36 kg (females) and 72.68 cm and 43.19 kg (males) (Cliffton, unpublished data). The rather large size may well correlate with the extensive transoceanic migrations of this population. In the Atlantic, the transoceanic migratory green turtles of the Brazil-Ascension Colony are among the largest known anywhere in the world. Similarly, some extensive migrations to points hundreds or thousands of kilometers to the west have recently been reported for the Scilly green turtles. These recaptures of tagged turtles (Anonymous 1979), are summarized in Table 2. It should be noted that the turtles were kept in captivity for up to 4 months before re-

Table 2. Recaptures of green turtles (*Chelonia mydas*) tagged on Scilly Island, Society Islands, French Polynesia

Number	*Sex*	*Carapace length*	*Tagging date*	*Recapture date*	*Location of recapture*
18	F	101 cm	30 Apr. 1972	9 Aug. 1972	Vavau Is., Tonga
26	F	102 cm	30 Apr. 1972	26 Jul. 1972	Rabi, Fiji
39	F	93 cm	30 Apr. 1972	14 Sept. 1973	Maskeline Is. (New Hebrides)
103	F	99 cm	5 Dec. 1972	15 Jan. 1975	New Caledonia
138	F	88 cm	5 Dec. 1972	Jul. 1974	Malekula, New Hebrides
151	F	86 cm	5 Dec. 1972	15 May 1975	Baie de Gomen, New Caledonia
173	F	98 cm	5 Dec. 1972	Oct. 1973	Anatom, New Hebrides
180	M	103 cm	5 Dec. 1972	3 Oct. 1974	Kandavu Is., Fiji
181	F	102 cm	5 Dec. 1972	15 Oct. 1974	Kandavu Is., Fiji
1330	M	102 cm	5 Dec. 1972	1 Aug. 1974	Druadrua Is., Fiji

lease. They were fed on green plants during captivity and released in the lagoon.

The recapture of 2 male turtles at great distances is very interesting. These and D. Green's recaptures of male Galapagos green turtles in mainland South America are the only recorded instances of long-distance migrations by male turtles.

Similarly, the reports of a male and female, released on the same day and in the same place, and recaptured almost 2 years later within a few days of each other at Kandavu Island, Fiji, is of great interest, although no definitive interpretation can be given at this time.

Tuamotu Archipelago

The scattered literature suggests that green turtles occur throughout the Tuamotu Archipelago. Beaglehole and Beaglehole (1938) reported on green turtles at Pukapuka Island (not to be confused with Pukapuka Island in the Cook Islands). The turtles there are commonly taken on the beaches or are seized in the lagoon by swimmers, who tie a rope around a foreflipper and pull the turtle ashore. At Pukapuka, a turtle is considered the property of the entire community, as is common in many unspoiled Pacific Island cultures, and a public feast is held when a turtle is brought ashore. One native offered the Beagleholes the observation that "it is only in recent times, since people have taken eggs of turtles from the nest, that turtles have been dying out," although in many other areas of the Pacific the eggs are sought even more assiduously than the turtle itself, and apparently always have been.

More recent information from Manihi atoll, also in the Tuamotus, by Hirth (1971), suggests that a fairly sophisticated turtle-ranching program has been developed by local people. Turtle eggs are collected and hatched, and the young turtles are raised in village kraals for later consumption. The turtles, fed on coconut meat and fish, reach a length of 50 to 71 cm in 3 to 3.5 years—a much more rapid rate of growth than seems to operate in the wild.

Very few data are available on turtles in other parts of French Polynesia. Turtles are apparently rare in the Marquesas, where capture of a turtle is now so infrequent that it is considered a special occasion. The Marquesas, Austral, and Gambier Islands all have rocky coasts with very few beaches, and turtle stocks appear to be very limited, although a hawksbill was reported from the southern Marquesas in 1978, and another in 1979.

Pitcairn and Henderson Islands

There is no information available to me on turtles in these islands; certainly there is no evidence that occurrence of turtles around these islands is anything more than sporadic.

Easter Island

The only available information on the turtles of Easter Island of which I am aware is the following paragraph in Harrisson (1971):

The hitherto neglected marine turtles around Easter Island may turn out to be of special importance. Some remarkably detailed petroglyphs, carapaces retained as heirlooms, and discussion with informants suggest that at least three species, possibly four, visit the beaches and sheltered bays, for food and/or nesting. Wonderfully well-made stone towers were erected along sections of the coastline and are still called turtle towers—though they have not been used in living memory. Again there are strong indications that in the past turtles were not indiscriminately slaughtered but respected, but those sanctions have not operated since the island went Catholic in the last century. Turtle visitors are now much more scarce and irregular.

Tom Harrisson did not mention the species he identified in his paper, but in a letter dated 27 March 1971, he informed me that "at least the ridley, hawksbill and green come up there," and in a subsequent letter (12 May 1971), he wrote as follows:

I am almost certain that four species have been reported and are well known to the islanders, who are extremely good naturalists, especially so as there is no resident fauna and they are extremely interested in the birds and reptiles that come in from the ocean, as they did themselves centuries ago.

Keep in close touch and remember this Easter Island thing could be very interesting indeed: this is the only piece of land a turtle can come up on or breed in 2,000 miles of tropical ocean. Please do not pass this word around to everybody else; I would like to have that little bit of territory for my old age.

This is all the information I could find on Easter Island turtles. Tom Harrisson's old age, alas, did not come to pass, so the area seems to be wide open for investigation. If the nesting by the ridley is confirmed, this would be of great interest; ridleys do not normally frequent remote or isolated midoceanic islands.

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Marine Turtles of Micronesia

The islands of Micronesia comprise 1 of the 3 great groups of Pacific Oceanic Islands. They are almost all located north of the Equator, being situated east of the Philippines and southwest of the Hawaiian Islands. The boundaries of Micronesia are almost identical to those of the U.S. Trust Territory, with the exception that Guam, an unincorporated territory of the United States, is not part of the Trust Territory, while the Gilbert Islands (part of the independent Kiribati), and the independent Nauru are considered part of Micronesia. Nukuoro and Kapingamarangi Atoll, though included in the Trust Territory, are culturally considered to be part of Polynesia. Moreover, the northern Marianas Islands have recently achieved Commonwealth status with the United States. The islands are all small and distances between them are large. Micronesia occupies an area equal to that of the United States, yet the land area is only half that of Rhode Island. Bryan (1971) calculates the total number of islands in Micronesia as 2,203. The 1973 population was 114,973 (excluding Guam), with an annual growth rate of 3.6 percent. The total land area is only 1,851 km².

Geologically the islands are all of volcanic origin, but differing age and subsequent weathering, subsidence, and coral formation have given them a very varied physiognomy. As a first-order approximation, the eastern islands are typically low atolls, often composed of many dozens of small, narrow islands surrounding a large central lagoon. The westernmost islands contain much weathered limestone and reach much higher altitudes. The highest islands, such as Ponape, attract an exceedingly high rainfall, with consequently lush vegetation. Shoreline vegetation throughout the Territory shows certain dominant species, such as coconut palms (*Cocos*), *Pandanus*, *Messerschmidtia*, *Portulaca*, *Sida*, and *Scaevola*.

Species Present

The hawksbill (*Eretmochelys imbricata*) and the green turtle (*Chelonia mydas*) are present throughout Micronesia and are widely recognized animals among those familiar with marine life in all districts. Nearly everywhere the green turtle is the more plentiful species, although in the Palau Lagoon area the hawksbill appears to be more common.

Two other species have been recorded on rare occasions. The olive ridley (*Lepidochelys olivacea*) was first recorded in Micronesia by Falanruw, McCoy, and Namlug (1975), who observed a mating pair in M'il Channel, northwest of Yap, on 30 November 1973. These authors also recorded a small (29 cm) *L. olivacea* from Lamotrek, in the eastern Yap District. Cushing (1974) reported 5 *L. olivacea* that were caught accidentally by long lines and plankton nets between 13 and 20 September 1974, in the southern Palau District (0° to 4°N, 131° to 137°E). In addition, I saw an immature stuffed *L. olivacea* for sale in a souvenir shop on Saipan in April 1976 that was said to have been locally caught and preserved.

The leatherback (*Dermochelys coriacea*) is reported occasionally in Micronesia, although it appears to be encountered only in deep water and has never been reported nesting in Micronesia. McCoy (1974) mentioned a very young leatherback, 69.4 cm in carapace length, that was captured near Satawal, in the eastern Yap District, on 2 September 1972. The turtle was tagged and released. McCoy also mentioned a leatherback caught at Woleai in 1971 that was captured and consumed by local people. I also have an unidentified newspaper cutting describing a large leatherback (444 kg in weight, 2.167 m in total length) caught by 2 Kapingamarangi fishermen off Parem Reef, Ponape Island.

Conservation Laws and Jurisdictional Background

Three completely different legal systems prevail concurrently in the Trust Territory: traditional law, vested in the hereditary chiefs; Micronesian law, as elaborated by elected delegates to the Micronesian Legislature; and U. S. federal law. As far as turtles are concerned, traditional law reflects patterns of hereditary ownership of the turtle resource, and the need for permission to be sought from traditional owners before turtles can be exploited. Micronesian law, as reflected in the Trust Territory Code (Title 45, Section 2) prohibits the capture of hawksbills less than 27 inches (69 cm) long, or green turtles less than 34 inches (86 cm) long (although only recently has the code differentiated between the 2 species). In addition, turtles are totally protected by Trust Territory law during the months of 1 June to 31 August and 1 December to 31 January, inclusive. They may also not be captured on the nesting beaches.

Federal law at present offers total protection to the hawksbill turtle, which is listed as an endangered species. The green turtle is listed as a threatened species, with certain populations, namely those of Florida and Pacific Mexico, being listed as endangered. The Department of the Interior Regulations recognize and permit the continuation of certain patterns of traditional subsistence use of turtles in the Trust Territory.

Traditional ownership patterns are still respected to a large extent in Micronesia, and flagrant violations of these rights may lead to protest or sanctions of one kind or another. The Trust Territory Code, however, is not widely respected; hawksbills, for example, tend to be chased and caught whenever seen, whatever their size or whatever the season of the year, and the nests too are frequently raided. The green turtle has traditionally been collected on nesting beaches in many parts of Micronesia, especially in the Yap District, and no attempts have been made to enforce that section of the Trust Territory Code that prohibits such activities.

Little attempt is made to enforce the Endangered Species Act in the Trust Territory, and the law is ignored throughout Micronesia. Indeed, some question exists as to whether provisions of the Endangered Species Act even apply in the Trust Territory, but most legal opinions now hold that it does; for purposes of import and export of listed wildlife, the Act specifically refers to the Trust Territory as having the status of a State of the Union. Reluctance to enforce federal endangered species law in the Trust Territory probably stems from several considerations:

1. The Trust Territory has for years had but a single American conservation officer, based in Palau, to whom local people have made clear that his life may be in danger if he insists on rigorous enforcement of turtle protection laws.

2. The United States has been sensitive to charges of colonialism in thrusting conservation laws passed in Washington, D.C. on peoples leading traditional subsistence life-styles in remote islands on the far side of the world.

3. The Trust Territory is not a permanent political entity, and in the years to come the various districts will be electing whether or not they wish to remain associated with the United States. The United States has not deemed it politic or appropriate to thrust unwelcome conservation obligations upon people who would be likely to reject them totally on reaching political independence.

A loophole that has resulted from the wording of the Endangered Species Act, which considers the Trust Territory to have the status of a state, is that products of the hawksbill turtle hand-carried by tourists entering Honolulu from the Trust Territory can no longer be confiscated. Such transportation of products is legally simply a case of carrying personal effects across state lines, unless it can be proven that the material is post-Act in origin.

Palau District

The hawksbill is more abundant than the green turtle in the Palau District, or is at least more conspicuous in the more accessible areas such as the Palau Lagoon. Douglas Faulkner, the underwater photographer, reports that hawksbills may be seen virtually every day in the Palau Lagoon by a competent scuba diver, and immature hawksbills are also reported to be numerous in the Kayangel Lagoon at the northern end of the Palau system. However, Robert Owen, conservation officer for Micronesia from 1949 to 1978, reports a gradual but steady decline in abundance. Natural predators are relatively few, and no natural egg predators have been reported, but the turtles are eaten by crocodiles (*Crocodylus porosus*), and the human pressure on eggs is intense—estimated at 80 percent by Jim McVey, who conducted a head-starting program for hawksbills in Palau in the early 1970s. Adult turtles too are highly persecuted. Hawksbill meat is eaten locally, but the economic pressure on the species is definitely from the shell trade. Tourism in the islands increased about 300 percent with the advent of regular air service in the early 1970s; a large proportion of tourists in Palau are from Japan, which of course offers no legal impediments to the free importation of hawksbill products.

The hawksbill turtle nests on small beaches on limestone islands in the Palau Lagoon. The principal nesting months are July and August, but some nesting takes place in June and September, and a few may nest in any month of the year. Their nesting site fidelity is reported to be strong, and they nest at approximately 15-day intervals, 2 or 3 times in a season. Favored islands include Eomogan, where Jeff June of the Peace Corps saw 3 turtles nesting in 1 night in late August 1975, and Ngerugelbtang Island, where the turtles often walk the length of a long spit before reaching a nesting area safe from tidal inundation. Other islands sometimes used for nesting include Aulong, Ngeangas, Ngobadangel, Unkaseri, and Abappaomogan.

Green turtles are not often seen in the Palau Lagoon, but achieve substantial populations in the northern and southern extremes of the Palau District. Richard Howell, district fisheries officer on Truk, reported that about 10 years ago he found fully mature green turtles to be plentiful in the Ngaruangl Lagoon, at the northern tip of the Palau complex. Villagers from Kayangel could catch 5 in 30 to 60 minutes. The turtles were resident there year-round, feeding on the large strands of turtle grass present especially on the western edge of the reef. Howell reported seeing only 1 male turtle in the area. Nesting (probably by greens) takes place on the barely exposed Ngaruangl Island, since natives of Kayangel returned from the lagoon with fresh eggs. Raids on the turtles were sporadic, and could be made only during calm weather. The turtles were only used by Kayangel people for special occasions, although they were also used for trade with villagers on northern Babelthaup.

Green turtles also nest in small numbers on Honeymoon Beach, Pelelieu Island, and, on 1 occasion, a female was seen inside the reef on Morei Island. However, the best green turtle beaches by far in the Palau System are on the southern islands of Merir and Helen Reef, located many kilometers to the south; coordinates are 4°19′N, 132°19′E for Merir, and 2°48′ to 3°01′N, 131°44′ to 131°51′E for Helen Reef. Merir now unfortunately has a small permanent settlement, numbering 7 people in 1976. Even such a small group of people can cause havoc to the turtle population on such a tiny island. Helen Reef, whose single emergent point of land, Helen Island, is too small for permanent settlement, still has heavy pressure on its marine resources, especially by pirates, the majority of whom come from Taiwan. When caught, they may be jailed in Palau for variable periods of time. Another serious problem for turtles in the outlying islands is that the crew of the government field trip vessel, far from being a positive force for law enforcement, take advantage of their subsidized trip to Helen Island, Merir, and other turtle islands to gather as many turtles as they can for themselves, which can be taken back to markets for personal profit.

There is an extensive folklore and legend regarding turtles in Palau. For example, the disovery of the approximately 2-week nesting cycle for both the green and the hawksbill turtles is attributed to a chance discovery described as follows:

"A young couple arranged to spend the night on a remote beach on Pelelieu Island. They used the girl's grass skirt as a pillow, and after making love, went to sleep. When they woke the next morning, there were turtle tracks on the beach and a nest right beside them but, to their great embarrassment, the grass skirt had disappeared. Nevertheless, they decided to repeat the rendezvous two weeks later, and, just before they fell asleep, noticed a large turtle crawling ashore with the remains of the grass skirt still attached to a front flipper."

This story is a favorite subject of Palauan story boards.

Yap District

Chief informant on sea turtles in the Yap District is Mike McCoy (this volume), formerly of the Peace Corps and now chief fisheries officer for Ponape and associate of the Yap Institute of Natural Sciences. McCoy's 1974 paper "Man and Turtles in the Central Carolines" is

Table 1. Summary of turtle sightings by aerial survey region, Guam, Fiscal Years 1975 through 1979

	Region												*Total sightings*	*Number of months*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*		
FY 1979	4	1	1	1		1	6	2	43	31	18	77	185	12
FY 1978	6	3	1	9		6	14	3	10	1	15	15	83	12
FY 1977	0	3	1	1		4	1	5	10	0	8	8	41	2
FY 1976	7	5	6	6		35	8	14	44	10	12	42	189	9
FY 1975	14	5	18	3		23	11	9	37	16	6	143	285	6
Total	31	17	27	20		69	40	33	144	58	59	285	783	41
$\bar{x}$/Region	6	4	6	4		15	8	8	31	12	13	59	—	—

Source: Molina, unpublished report.

one of the most valuable sources available on human attitudes to turtles in Micronesia. To avoid duplication, reference is made to McCoy's paper herein for information on turtles in the Yap District.

Marianas District and Guam

Hendrickson (in manuscript) quoted the following information, received from Isaac I. Ikehara, chief of the Guam Division of Fish and Wildlife, regarding the available information on sea turtles in Guam in 1968:

Green turtles and hawksbills are reported to occur in Guam waters. They apparently nest on the island beaches, but only sporadically; eggs were harvested more commonly during the time before the second World War, in many areas of the island, especially on the northern and southern ends (Tarague, Ritidian, Uruno, Orote, Cocos Island, Asiga Beach, and other localities).

It appears from local residents that sea turtles are a rarity on the local market and the consultant found none on three of his visits. Skin divers occasionally bring them back but they are not considered a normal commercial item although red turtle meat is reputed to sell at $0.75 (US) per pound. There is no export of turtle products from Guam. In 1968 there were reportedly two divers specializing in turtles each catching three or four turtles on a good day.

There is apparently no legislation protecting sea turtles or regulating the catch in any way, but there are some good catch statistics. All sizes from 15 lb. to 400 lb. are taken, but the informant estimates that the average size is around 60 lb. (the type most likely to be taken by divers). No special feeding grounds have been identified.

Harry Kami, enforcement officer for the Guam Fish and Wildlife Division, made a number of flights over the Guam coast during the last couple of years, and saw sea turtles—sometimes in concentrations of 40 or 50 individuals—off the northern coast of Guam, between Ritidian Point and Pati Point. Kami also sometimes saw 3 or 4 turtles off the coast near Inarajan Bay, on the southeast coast, and said that turtles formerly nested on Cocos Island, off the southwest coast, although the island was now too intensively visited for nesting to take place.

The north coast of Guam, near which the turtles were seen, was under Air Force control, and was rather little visited. However, despite the presence of a good beach, little nesting took place here. Factors that lessen the suitability of this beach for nesting may include the shallow reef (only 1 m submergence by high tide), and the presence of dense vegetation above the high tide line on the beach. Most of the turtles seen off Guam were of adult size, and indeed appeared to be very

Table 2. Summary of turtle sightings by month, Guam, Fiscal Years 1975 through 1979

	Month												*Total sightings*	*Number of flights*
	J	*A*	*S*	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*M*	*J*		
FY 1979	12	3	6	6	7	12	18	52	24	14	20	11	185	24
FY 1978	7	6	10	4	16	17	7	5	0	3	4	4	83	24
FY 1977	23	—	—	18	—	—	—	—	—	—	—	—	41	4
FY 1976	—	20	28	24	20	42	16	10	7	22	—	—	189	18
	—	—	—	—	—	—	45	44	32	46	54	64	285	12
Total	42	29	44	52	43	71	86	111	63	85	78	79	783	82
$\bar{x}$/Month	14	12	15	13	14	24	22	28	16	21	26	26	—	—

Source: Molina, unpublished report.

large from an aircraft at 65 to 80-m altitude; but mating pairs had not been seen.

Kami found 1 green turtle nest on the east coast of Guam between Ylig Bay and Togcha in 1974. Because of the extensive human use of this beach, the eggs were moved and, while reburying them, several incomplete nests were found.

Dr. Lucius Eldredge informed me by letter (dated 12 July 1976) that Dick Randall of the University of Guam Marine Laboratory reported 6 recent turtle nests on June 26, 1976, at the north edge of Sella Bay on the southwest coast of Guam.

A recent unpublished report by Molina includes the results of 5 years of aerial surveys of turtles around Guam. The following section is extracted from this report:

The island of Guam was divided into 12 survey regions (Figure 1). Marine turtles have been sighted within every survey region (Table 1) and during all months of the year (Table 2). Region 5 has not been censused due to military restriction. Two flights were made each month in all cases. A total of 783 marine turtles have been sighted around Guam on 41 aerial surveys made during the past 5 years. Far more turtles were sighted within region 12 (Pati Pt.-Ritidian Pt.) than in any other (Table 1). Approximately 74 percent of the observed turtles were seen within regions 8 to 12. The most probable explanations for this distribution are the low levels of development and fishing pressure in these areas.

Marine turtle abundance appears to peak twice during the year (Table 2). In general, these peaks coincide with the winter (December to February) and late spring (May to June) months. This also loosely correlates with Guam's "dry," tradewind season which usually lasts from December to June. It is unclear at the present time whether or not the turtles are mating during the entire period, yet it seems likely. The time of nesting is also unclear. However, reports from local fishermen indicate that nesting occurs around June.

Reports have been made of larger than usual numbers of turtles visiting Guam about every 3 years. The last of these visits happened in 1976, and is reflected in our aerial survey data (Table 2). Another visit was expected this year. Again, our data show the winter increase in numbers.

Since it is difficult to make positive species identifications on turtles from a moving airplane, we have no reliable estimate of the species composition of Guam's marine turtle community. However, it is generally regarded that Chelonia mydas *is by far the major component.*

Human interference with nesting turtles is a serious problem at Tarague Beach. The majority of the problem lies with the friends and relatives of the Tarague landowners who use the beach for "4-wheeling" and who actively hunt for turtle eggs. Since Tarague Beach is privately owned and enjoys military isolation, there may be a good chance

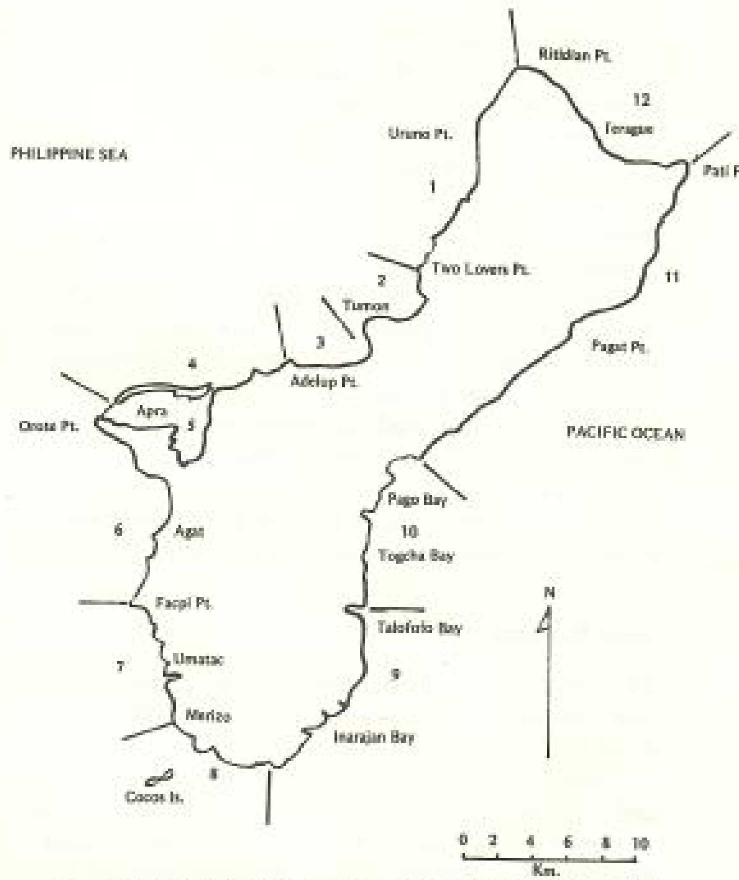

Figure 1. The island of Guam with its 12 aerial survey regions.

of controlling this problem, especially if the area could be designated as a marine turtle sanctuary. If it is not already too late, Tarague Beach may be Guam's only hope for such a valuable natural resource. Mr. Castro appears to be pro-turtle conservation and has offered to do what he can in cooperation with our office to help protect these animals.

Turtle meat is occasionally sold in Guam, but is very expensive—although it can on occasion be purchased with U.S. government food stamps at Perez Market. There are no laws protecting turtles in Guam at the present time, and some opposition to establishing local laws because turtles protected in Guam may well be caught in the Trust Territory. However, because Guam is an unincorporated territory of the United States, federal law unquestionably applies, and hawksbills should already have legal protection. The green turtle too should soon receive nominal protection.

Very few Guamanians are expert at spearing sea turtles, with the exception of a few old-timers, and nets are never used nowadays for catching turtles.

North of Guam, the Northern Marianas Islands stretch in a slightly curved elongated chain. Few turtles appear to nest anywhere in the Marianas; to a large extent this may reflect shortage of nesting beach, most of the uninhabited islands having no beach whatsoever. Saipan has several kilometers of beach on the west coast, but the area is rather extensively developed with hotels and other beach facilities, and few if any turtles nest there. However, dense patches of turtle grass within a few meters of the beach suggest good feeding habitat for green turtles. Rota has several beaches, and Tinian 2 small, marginal ones, but I have no evidence that these are used by nesting turtles.

Stuffed turtles are for sale at several locations on Saipan. In a handcraft shop on Beach Road, 13 stuffed green turtles (half-grown to maturity) were for sale; also 3 hawksbills and 1 olive ridley. The turtles were reportedly all locally caught.

Turtles are being caught in increasing—and now rather large—numbers in the northern Marianas. The turtles were captured by divers for sale to hotels and gift shops, and 1 diver could easily catch 4 or 5 turtles in a day (Ben Sablan, personal communication).

Truk District

The islands of the Truk District lie to the east of the Yap District. Truk itself is composed of a large lagoon, roughly circular in shape, about 40 miles in diameter. The lagoon is fringed by a reef, broken in several places and reaching above sea level to form small, low islets, principally in the northern and southeastern sections. Most of the human inhabitants, who numbered 20,105 in 1970, however, do not live on the reef islands, but rather on several mountainous, large islands near the middle of the reef. The other islands of the Truk District—the Lower and Upper Mortlocks, to the southeast; the Hall Islands to the north; and the so-called Western Islands of Namonuito, Palap, Puluwat and Pulusuk—are low atolls.

Although only 2 days were spent on Truk during the survey reported here, I was able to learn a good deal regarding sea turtles in the District, through the kindness and efficiency of Mr. Richard Howell and Mr. Tawn Paul of the Fisheries Office. Informants for turtles in the outer islands were Mr. Casian Orik (Western Islands), Mr. Marion Henry (Mortlocks), and Mr. Appo Pius (Truk Lagoon).

Three species of sea turtles are recognized in the Truk District: the leatherback (locally called "mirang"); the green turtle ("winimon") and the hawksbill ("winichen"). The leatherback is seen only occasionally and always in deep water; there are no nesting records in the area. The other 2 species are both widespread, but the green turtle is generally more plentiful than the hawksbill.

The hawksbill is found principally in the Truk Lagoon and in the Mortlocks. On the northern fringe of the Truk Lagoon, hawksbills nest in small numbers on the islands of Holap, Tora, Ruac, Lap, Ushi, Onao, Tonelik, Pis, Alanenkobwe, Lemoil and Falalu. The largest of the islands, Pis, has human inhabitants, and turtles nesting there are likely to get killed. Mr. Pius informed me that the casual nesting in this area (perhaps 1 or 2 turtles per night on each beach during May to October) had not diminished perceptibly during the last 50 years. In the Lower Mortlocks, Marion Henry reported casual hawksbill nesting in all 3 atolls (Etal, Lukunor, and Satawan), but not commonly on the inhabited islands (Kutu, Mor Satawan and Ta in Satawan atoll; Etal Islet; and Lukunor Islet).

The tiny island of East Fayu, about 100 km north-northwest of the Northeast Pass leading out of the Truk Lagoon, is an important one for green turtle nesting. About 6 or 7 turtles are reported to nest here each night during the season, which begins remarkably early (February), and lasts until about June. The island is elongate, less than 2-km long, and has a sandy beach with a deep water approach all around. The rights to the turtle resource are vested in the people of Nomwin Atoll, a few kilometers to the east. A few green turtles (1 to 3 per night) are also reported to nest on Fanang Islet, at the eastern end of Nomwin Atoll, and on a few tiny islets in adjacent Murilo atoll. A few also nest on northern Murilo Island.

Turtle nesting has not been reported in the Western Islands, all of which are inhabited. However, the people of Pulusuk, and also of Puluwat and Pulap (Tamatam Islet) take advantage of the March-April tradewinds to travel to Pikelot, in eastern Yap District, to collect turtles. This journey may be made 3 or 4 times during the 2-month period, and a typical catch is about 20 turtles, which are collected on the beach during a stay of 1 or a few nights. The eggs are also collected. It was estimated that about 30 turtles nest each night at Pikelot; however, from data obtained in the Yap District, I believe this to be a distinct exaggeration. Turtles were reported to be diminishing in Pikelot, but holding their own in the Hall Island–East Fayu region.

In the Truk Lagoon both species of turtle are found (mostly adults) and are about equally common; however, only the hawksbill is known to nest. Rather few turtle fishermen are operating, and the turtles are obtained by spearing. A turtle can be obtained on demand within 24 hours by certain fishermen. Reportedly, the hawksbills are killed for use of their shell, which is sold in souvenir shops; however, I did not see any for sale at the time of my visit.

In the Truk District, it was reported to me that the green turtle often weighs 300 to 350 lbs. (136 to 159 kg), and occasionally 400 lbs. (181 kg), and usually laid 80 to 120 eggs. The hawksbill weighed 100 to 150 lbs. (45 to 68 kg) and laid 110 or more eggs (maximum observed: 152). There is no reason to question the accuracy of these figures. I was also informed that *both* species eat seagrass and algae. When I questioned an informant (Appo Pius, a fisherman of 50 years' standing) on this, he appeared absolutely certain that stomachs of the hawksbill as well as the green contained such plant material, even when I pointed out that in most parts of the world the hawksbill is carnivorous.

Ponape District

The Ponape District is situated to the east of the Truk District. Ponape, the District Headquarters, is a large (129.04 square-mile), centrally located island, which is highly elevated, reaching an altitude of over 2,500 feet. Rainfall is heavy, and vegetation lush. The island is roughly circular in shape and is surrounded by a barrier reef penetrated by about twenty entrances. There are some sizeable offshore islands, including Sokehs, Langer, Parem, Mwahnd Peidi, Mwahnd Peidak, Takaiu, Dehpehk, and Temwen. The population of the island was estimated to be 14,520 in 1970.

Kusaie is the second largest single island of the Ponape District; it has an area of 42 square miles, an altitude of 2,064 feet, and a 1970 population of 3,743. It is situated approximately 300 miles east-southeast of Ponape.

The other islands of the District are all atolls. Mokil (population 1970, 411) and Pingelap (population 849) lie between Ponape and Kusaie. The atolls of Ant and Pakin lie close to the west coast of Ponape; Pakin had a population of 36 in 1973; Ant had 10. Oroluk atoll, which had a population of 42 in 1935, none in 1948 or 1970, but since mid-1973 inhabited by about 18 people, lies west-northwest of Ponape. Southwest of Ponape are the atolls of Ngatik (population 442) and Nukuoro (population 420). Far to the southwest, nearly 500 miles from Ponape, is the atoll of Kapingamarangi, inhabited by 432 people in 1970, but with a permanent overflow population now living on Ponape, and a few others on Oroluk.

I spent 5 days on Ponape, where my chief informant was Ben Sablan of the Fisheries Department. Valuable information was also received from Alan Millikan, the District Fisheries Specialist, and David Fullaway, the chief Forestry Officer.

Populations of sea turtles around Ponape itself appear to be relatively insignificant and very little nesting, if any, takes place. Indeed, Ponape has very few sandy beaches. Turtles used to provide an important source of food to the people of Kapingamarangi, but they are now rarely seen in that area (Niering 1963). Nesting does not take place on Pingelap and Mokil, but Mokil has a shallow lagoon in which small green turtles (less than about 50 cm long) are easily seen and caught. Ben Sablan observed 5 such turtles on an underwater survey of the 15.5 km² Mokil Lagoon in 1974.

Around Kusaie, Sablan found 31 green turtles and 6 hawksbills during a 3-day underwater survey in August 1973; nesting, however, appears to be sparse at best.

No details are available for nesting on Ngatik, but Sablan reports some nesting on the eastern islets of Peina, Bigen Karakar, Jirup, Bigen Kelang, Piken Mategan, Dekehnman, and Wat. Two green turtles were seen in the water during an underwater survey in September 1973.

Green turtles have been seen around Ant Atoll and it is rumored that daytime nesting occurs; but this needs confirmation.

Green turtles appear to be rather plentiful around Nukuoro, where Sablan counted 52 (but no hawksbills) during an October 1973 underwater survey. Nearly all were of adult size and were relatively inactive. They probably nest on the island, but there is no evidence of high-density nesting. Sablan also saw 3 green turtles underwater in Pakin.

Apparently the only nesting ground of importance in the Ponape District is the atoll of Oroluk, which once boasted as many as 19 islets, but apparently all but Oroluk Islet itself, at the extreme northwest of the atoll, have now disappeared. The District Administrator of Truk reported to me that he had seen green turtles nesting by daylight on Oroluk, on the lagoon side of the island, during a helicopter visit in November 1964. The island was uninhabited at that time, and the turtles reportedly showed no fear of the observers. Turtles in Oroluk are considered to have a split nesting season (December to January and June to July), and this may have been the original rationale for the split closed season throughout the Trust Territory. It is estimated that between 9 and 15 turtles nest on Oroluk on the average night, with up to 20 on a very good night. The local people, about 18 in number and resident on the island since mid-1973, catch a substantial proportion of the nesting turtles.

In a memorandum dated February 3, 1976, Sablan described the findings of a July 1975 visit to Oroluk. The islanders reported that since they first settled on the island 2 years ago, the number of turtles nesting had dropped considerably. This may well have been due to excessive predation, although Sablan also recorded the following human disturbances to the nesting beach during the night he was on the beach: 1) very active human activities until the early morning; 2) several campfires maintained until midnight; 3) copra operation with outboard motor until 9:00 a.m.; 4) ship generator and lights on until morning. However, at West Fayu in the Yap District, the tagging and hatchery crew in 1972 found that the turtles continued to nest even though a wrecked cargo ship containing 300 Toyotas was being salvaged on the island with extensive lights, noise and other disturbance by the salvage crew every night. The ship had spilled 600 tons of oil and was not completely defueled until more than 6 months after the wrecking.

Marshall Islands District

The Marshall Islands comprise a widespread District at the eastern end of Micronesia. With the exception of a few small isolated reef islands, such as Jemo, the Marshalls are comprised exclusively of atolls, most of which are made up of a few to many dozens of islets. The atolls are roughly aligned along 2 parallel axes, the northeastern being the Ratak Chain and the southwestern the Ralik Chain. None of the islands reaches a height of more than a few meters above sea level, and the total land area of the District is only 180.82 km^2. The human population, numbering 20,206 in 1970, is widely distributed, but only the atolls of Majuro, Kwajalein, and Ailinglapalap have more than a thousand people.

Bryan (1971) lists Taongi, Bikar, Taka, Jemo, and Erikub as the only atolls or islands that have never had human populations, while the people of Bikini and Enewetak were displaced after the second World War when these islands were used for atomic weapons testing. Rongerik is listed by Bryan as having 6 people in 1935 and 1948, but as being uninhabited in 1970; this island was used temporarily by the displaced people of Bikini, but proved unsatisfactory. The Marshall Islands are well described by Anonymous (1965), while excellent maps and directories to names of islands are provided by Bryan (1971).

Only Kwajalein and Majuro were visited during the present survey. However, much useful information on turtles elsewhere in the Marshalls was provided by Ben Sablan on Ponape, who was formerly resident in the Marshalls; by Major Ron Barnett and Rev. Elden Buck on Kwajalein; Jim Hiyane, the agricultural officer on Ponape; George Balazs in Hawaii; and Jobel Emos, a janitor at the Kwajalein Missile Range.

Bikar Atoll

The atoll of Bikar, one of the northernmost of the Marshalls, is generally thought to have the highest concentration of breeding green turtles in the District. The atoll is composed of several islets, the named ones being Jabwelo and Almani on the east, Bikar on the south, and the sandbank of Jaboero between Bikar and Almani. Bikar is the largest with an area of 0.063 $miles^2$.

Bikar has been thus described (Anonymous 1956): "Sea birds of many kinds are abundant, but the outstanding feature is the great number of turtles that come ashore to lay eggs on Bikar Islet." Fosberg (1969) recounted his experiences with the turtles of Bikar as follows:

On the night of August 6, a few baby black turtles were seen hurrying toward the sea. They were being attacked by large red hermit crabs (Coenobita perlata) *and by rats* (Rattus exulans). *The hermit crabs bit through the carapace, the rats through the plastron. Almost all of the female turtles that visited Bikar Atoll, well over 300 in the seven nights, August 5–12, came ashore on Bikar Islet. One set of tracks and a pit were noted on Jaboero Islet, a few on the south part of Almeni Islet, but none on Jaliklik Islet, which is rocky and has no loose sand.*

Judging by the numbers given in an earlier part of this paper, it is possible that the "over 300" turtles is a misprint for "over 30."

From the large numbers of tracks seen, the relatively light nesting observed and the observations on hatchlings, it appears that the season on Bikar reaches its peak probably around June and July.

In 1958 Bikar Atoll and Pokak (Taongi) Atoll, which lies to the north of it, were set aside as preserved natural areas by administrative decree by the then District Administrator, Maynard Neas. It is hoped that this protection may be strengthened, as clearly Bikar is the principal turtle nesting area in the Marshalls and should be kept as a stocking area for the rest of the archipelago.

Hendrickson (in manuscript) was able to visit Bikar on 2–3 July 1971 and made the following observations:

The consultant visited Bikar Atoll and all 3 of its islets judged suitable for green turtle nesting (Bikar, Arumeni and Jaboerukku). These are the only vegetated islets in the atoll, the remainder being barren bars and banks which are presumably swept by high wave action. The timing of the visit was particularly favorable, being at the end of a 7-day period of diminishing tides during calm weather. This left a series of high tide marks on the clear areas of beach where rocks had not confused the wave wash pattern and, for the most part, it was possible to identify the night on which recent beach ascents had been made by nesting turtles, by noting the particular high tide mark where the track ceased to be evident. It was possible to say with some confidence that 39 turtles had ascended the beaches during the preceding 6 days (78 tracks, half ascending, half descending). Thirty-five of the 39 turtles had used the beach on Bikar Islet, 1 had ascended the Arumeni and 2 had ascended Jaboerukku. One of the 35 tracks on Bikar was a hawksbill track (not ridley); all others were presumed made by green turtles (loggerheads have not been reported from the area).

Hendrickson made some calculations of the possible size of the nesting population on Bikar, concluding that the order of magnitude of the population was 711 sexually active adult female turtles in the Bikar breeding population. From these figures, he reasoned that "even the most favorable interpretation of the data available (granting the assumptions made) allows consideration of a population of only small size, not constituting an exploitable wild resource of any significant magnitude."

Jemo Island

Jemo is an isolated, tiny island situated at 10°8'N, 169°32'E, located between the atolls of Ailuk and Likiep. The land area of Jemo is only 1.55 km². The turtles on Jemo were described as follows (Anonymous 1956): "Many turtles visited Jemo to lay their eggs. Jemo was formerly tabu for most of the year, being regarded as a bird and turtle reservation. Only during one month in the year were these animals hunted and their eggs taken."

Fosberg (1969) visited Jemo from 18 to 22 December 1951 and observed tracks corresponding to the nesting of 22 turtles during the past several days.

The Rev. Elden Buck of Kwajalein informed me that a boat from Likiep sometimes brings 10 to 15 turtles for sale on Ebeye. These turtles were presumably caught on Jemo, which is the closest turtle island to Likiep. Likiep itself has few turtles, according to Ben Sablan on Ponape. Further confirmation of the presence of nesting turtles on Jemo was provided by several informants during my survey.

Arno Atoll

Green turtles nest occasionally on the sandy beaches of Arno Atoll, but they are scarce and of no commercial importance (Hiatt 1951). Ben Sablan reported that nesting on Arno takes place on the islet of Ine, in the south and southwest.

Erikub Atoll

Erikub is an uninhabited atoll composed of 16 islets lying just south of the inhabited atoll of Wotje. Jim Hiyane, the agricultural officer on Ponape, informed me that he had seen turtles nesting on Erikub, and estimated that 6 or 8 turtles nested nightly. He mentioned that people from Wotje go to Erikub for copra, coconut, crabs, etc., and often picked up turtles when there, but did not go specifically for turtles.

Jobel Emos on Kwajalein confirmed that turtles nested on Erikub and pinpointed the northwestern islets of Enogo and Loj as being the most favored for nesting. Emos claimed that nesting on Erikub was year-round, but that the turtles were usually exploited during summer months because of the prevailing calm water at that season. He said that the Wotje people, when they caught a female turtle on Erikub, would tether it in shallow water so that it would attract males, which were captured as they mounted her. Emos' estimate was that 3 or 4 turtles nest nightly on Erikub.

On Kwajalein, the Rev. Buck showed me a photograph of a boatload of over twenty turtles that had been brought in from Erikub and Bikar for sale on Ebeye, the islet where the Marshallese workers on the Kwajalein Missile Range reside.

Taka Atoll

Taka is an uninhabited atoll lying very close to, and southwest of, the inhabited atoll of Utirik. It has five islets, the largest of which is Taka itself (2.5795 km²). According to the Rev. Buck, people from Utirik collect turtles and turtle eggs on Taka, but further details are not available.

Ebon Atoll

Ebon is the southernmost of the Marshall Islands. It is a roughly circular atoll composed of 22 islets, by far the largest of which is Ebon itself, an elongate island that makes up the southern side of the atoll; it is about 10-km long and has an area of 2.804 km². Bryan (1971) lists the 1970 population of Ebon as 480—substantially reduced from the 1935 and 1948 censuses. Ebon has a reputation for abundance of food of all kinds, and although no definite information on turtle nesting is available, it is considered to be the best area for catching turtles in the water. The turtles are nearly all of adult size and are caught with nets. Each night 2 to 4 can be caught. Rev. Buck said that if a turtle on Ebon is captured in a certain place, the next night it is often found that another turtle has moved to the same spot.

Kwajalein Atoll

Kwajalein is the largest atoll in the Marshalls, and reputedly the largest in the world. Ninety-three islets are listed by Bryan (1971). The islets of Kwajalein (at the southern tip) and Roi and Namur (now connected by a runway and called Roi-Namur) are devoted exclusively to U.S. military uses. The Marshallese residents live on Ebeye, a small and highly overcrowded islet a short distance north of Kwajalein, on the eastern edge of the atoll. Most of the other islets are very small, and in some parts the bounding reef is without islets for distances of 15 to 25 km.

Major Ron Barnett on Kwajalein gave me considerable information on turtle observations on Kwajalein. Turtles are often seen around Kwajalein Islet, and between Kwajalein and Ebeye. A few turtles appear to be extraordinarily static in range; a certain green turtle is reported to have resided at a certain coral head (known as K5) off the lagoon shore of Kwajalein for 2 to 3 years, and is very familiar to skin divers. Green turtles are also seen on the ocean side of Kwajalein at the end of the runway, where they scavenge for the kitchen scraps that are thrown in each day. They are usually of less than mature size. One turtle that I saw feeding on the kitchen scraps of Kwajalein, however, appeared to be of adult size.

No records are available for turtle nesting on Kwajalein, and indeed there is a shortage of good beaches. However, much of the atoll is poorly studied and a

Marshallese informant on Kwajalein informed me that turtles do nest sometimes on the islands at the northwestern end of the atoll.

Major Barnett, in a letter dated 16 July 1976, reported that on July 10 a green turtle had been found nesting on the ocean side of Bigej Island, about 19 km north of Kwajalein Islet.

Ujelang Atoll

Ujelang or Ujilang, is an elongate atoll about 20-km long located at the western extreme of the Marshalls, being closer to Ponape than to the population centers of the Marshalls. It had a small native population of about 40 people (plus 12 non-natives) in 1935. It was uninhabited in 1948 according to Bryan, but this is presumably in error, since Helfich (in manuscript) reports that the Enewetakese people displaced by atomic tests were settled on Ujelang in 1947. The 1970 population, according to Bryan (1971), was 281.

Ujelang is listed by Carr (1965) as a "minor nesting beach" for the green turtle. The source of this information was not quoted, but Carr informs me that he based this record on an observation made by the crew of a U.S. Naval vessel anchored off Ujelang one night in 1962. Baby green turtles were attracted to the lights of the ship in very large numbers—although at this point it is not possible to ascertain whether the numbers represented only 1 or 2 successful nests, or whether there were numerous nests erupting simultaneously. Two of these hatchlings were transmitted alive to Carr. Phil Helfich, in a brief manuscript, reports on an interview with Chief Johannes, chief of the exiled Enewetakese people on Ujelang: "Chief Johannes indicated that turtles nested all around the island Ujilang. Ujilang is the island which has been occupied by the Enewetakese since 1947, and it is difficult to visualize that they did not decimate the nesting turtle populations, because Ujilang is such a small island."

None of the informants on my survey had any information about turtles on Ujelang. The island is extremely remote and is not often visited. This would appear to be a priority for future studies.

Enewetak Atoll

Enewetak is a rather large, almost circular atoll in the western Marshalls. According to Bryan (1971), it is composed of 44 islets, has a land area of 2.26 miles^2 and had 128 people in 1948, but none in 1970. However, according to one writer (Anonymous 1972), 100 people, mostly civilians, live on Enewetak. Another report (Anonymous 1975) gives 1947 as the year in which the 136 Enewetakese residents were transferred to Ujelang; the island was used for nuclear tests between 1948 and 1958. Since 1954, the University of Hawaii has operated the Mid-Pacific Marine Laboratory on Medren Island, Enewetak, which is financed almost completely by the U.S. Energy Research and Development Administration.

Helfich (in manuscript) quotes Chief Johannes of Enewetak, who lived on the atoll until 1946, as reporting turtle nesting (up to 1946) taking place from May through August on the islets of Alice, Bell, Runit (Yvonne), Glen through Keith, Leroy, Wilma, and Vero. The last 2 islands had the best nesting areas. Another islet by the name of "Vikai" was reported by Johannes to have abundant nesting turtles, but no island of this name is shown on available maps of Enewetak.

At the present time there appears to be little turtle nesting on Enewtak. However, George Balazs has prepared reporting sheets for observations of turtles by scientists at the Mid-Pacific Marine Laboratory and others, and valuable information may eventually be forthcoming from this program.

Majuro Atoll

Majuro, the District Headquarters, is an elongate atoll approximately 30-km long. The southern rim of Majuro was originally composed of a single extremely attenuated island, Majuro, and a series of much smaller islands to the west. However, these islands have now been connected in order to provide vehicular access between the principal town (known as D-U-D, from its constituent and now coalesced islets of Carrit, Uliga, and Dalap) and the airport; and the blockage of the former passages between islets, with no provision for bridges or culverts, has led to substantial pollution problems in the Majuro lagoon.

Turtle nesting has not been reported on Majuro, although turtles are spotted in the waters of Majuro relatively frequently. Ben Sablan informed me that large turtles are seen resting near the Windward Islands of Majuro, and on an afternoon dive one summer he had seen more than 15 turtles, all females.

Jaluit

Jaluit is a large, irregularly shaped atoll, about 30-miles long from north to south. It is composed of 91 islets. Bryan (1971) gives the 1970 population as 881, substantially reduced from former years. Ben Sablan informed me that turtles nest in small numbers on Lijeron Islet, near the northern end on the west side of the atoll.

Aur, Maloelap and Likiep Atolls

Ben Sablan reports that turtles may be found on each of these atolls, but that in no case were they plentiful.

Bikini and Taongi Atolls

Although my informants did not mention these atolls, both were recorded by Hendrickson (in manuscript) as being second in importance only to Bikar among the Marshall Island turtle nesting atolls. Hendrickson obtained his information about Bikini from Mr. Robert Ward, a heavy equipment maintenance supervisor for the Bikini Atoll Rehabilitation Project. Additionally, the popular movie *Mondo Cane* made several years ago showed rather large numbers of dead green turtles on Bikini, though the interpretation made that these had been disoriented by radiation damage and had wandered into the interior of the island to die is somewhat questionable. I have seen dozens of dead green turtles inland from the nesting beach on Baltra Island, Galapagos. This island appears to lack the normal sea-finding (or land-fleeing) cues that enable a turtle to identify the proper heading for the ocean.

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Subsistence Hunting of Turtles in the Western Pacific: The Caroline Islands

ABSTRACT

The Caroline Islands comprise numerous low coral atolls and islands as well as high volcanic islands. Some of the remote coral islands are used by sea turtles, mostly the green turtle, *Chelonia mydas*, as nesting areas during the season which generally lasts from March to September. Green turtles, and to a lesser extent hawksbills, *Eretmochelys imbricata*, are found year-round in the lagoons of the high islands. The inhabitants of the coral atolls, the "outer islanders" have, for the most part, developed methods of capture and utilization exceeding those of the islanders residing in the administrative centers of Truk, Ponape, Yap, and Kosrae. However, population pressures, the emergence of a "money economy," and other factors have increased the pressures on turtles throughout the region. The decline in importance of traditional tabus and the preference for modern boats and motors over traditional canoes have led to the disappearance of the protective buffer these customs once provided. Turtles face increased harvesting, and there is a need for a conservation system to replace the original tabus. Any such system must be designed with the people in mind and worked out in partnership with them.

Stretching from 131° East to 163° East Longitude, the Caroline Islands comprise a series of both high volcanic and low coral islands and atolls placed in a rough line totaling 3,200 km in length. On the easternmost limit is the high volcanic island of Kosrae; the west is bounded by the small coral island of Tobi. The total land area does not exceed 1,193 km^2 of dry land. The lagoon area, on the other hand, encompasses 8,546 km^2 and a total of about 950 islands and islets. The ocean area inside the present political boundaries of the Federated States of Micronesia (Yap, Truk, Ponape, and Kosrae) and Palau exceeds 3.4 million km^2.

Within this vast expanse of ocean, sprinkled among the island chain are a few uninhabited atolls and single islands, all coralline in structure, which serve as nesting beaches for green and, to a lesser extent, hawksbill turtles. These islands are sometimes visited by islanders in canoes from nearby inhabited islands, or by the crew from a passing fishing vessel. Little is known of the nesting turtle populations or of their capacity to withstand exploitation.

The inhabitants of the Carolines arrived many centuries before the first Europeans. They had already developed cultures allowing exploration of remote parts of the Pacific. Whether voyaging for discovery or due to social pressures, they inhabited the islands and were well established by the arrival of the first Spaniards in the sixteenth century. Serious colonization by Europeans did not take place until the Germans discovered how valuable the islands were for copra and other commodities, including turtle shell. There are, however, no reports in the literature of the early explorers or commercial entrepeneurs that would suggest that the resource ever existed on the scale reported for the Caribbean. While turtles were most certainly seen and occasionally eaten by early visitors and inhabitants alike, we can only speculate on their numbers.

The Carolines had a series of various colonial masters interested in different goals. First the Spanish arrived with soul-saving religion, and guns to back them up. They met with less than resounding success. Two notable events were the slaying of the Spanish Governor and troops in Ponape during the late 1800s, and the supposed eating by natives of a priest and his followers left on Ulithi atoll about the same period. The Germans administered the area from their western Pacific headquarters in Rabaul, but only for a relatively brief time. Their rule was cut short by the first world war and the almost immediate occupation of the major islands by the Japanese in 1914. The area was given to Japan as a mandated area under the League of Nations and remained so until 1945, when the United States occupied the main islands. The United Nations then gave the United States control over the area known as Micronesia as a Strategic Trusteeship, and today it remains the last trusteeship under U.N. control. Political talks are progressing with the United States on the one hand, and the separate delegations from the Marshalls, Palau, and the Federated States of Micronesia on the other.

Turtles are occasionally seen around the main islands of Yap, Koror, Truk, Ponape, and Kosrae, usually in the water, and never for very long. The turtles, mostly *Chelonia mydas*, are to be found in the uninhabited islands far from the dusty streets, bars, and tin shacks of the administrative and population centers. The turtles concentrate their nesting activities on small islands such as Oroluk, Pikelot, West Fayu, Gaferut, and Helens Reef.

Oroluk atoll is located midway between Truk and Ponape. Until the late 1960s it was uninhabited, but today a small band of Polynesians from Kapingamaringi occupy the island with government consent and cause disruption to what once was regarded as one of the largest turtle nesting areas in the Eastern Carolines.

The island of Gaferut, containing 0.111 km^2, has been used as a resource island for many years by the people of Faraulep, and to a lesser extent by those from Woleai and Ifaluk. Gaferut is now seldom visited, due to the decline in the use of voyaging canoes by those islanders. Another factor was the tragic loss of most of the able-bodied men of Faraulep in their canoes during a typhoon in the 1950s. The island is sometimes visited by the governament field-trip ship from Yap, and occasionally passengers from Faraulep, Ifaluk, and Woleai take turtles to be carried to their home islands. The ship's visit is short, and the evening's take is usually never more than 8 or 10 green turtles. The island is visited in this manner perhaps 2 or 3 times a year. A unique feature of Gaferut is a reef extension on the northwest side of the island which contains a large, deep hole big enough to accommodate many large turtles. Turtles often stay in this natural hole during the day or days before nesting. The standard method of capture is to move silently to this depression and capture the turtles resting there. The island itself is heavily wooded and has a large population of sea birds, only 1 coconut tree, and no fresh water. This makes a rather inhospitable place for humans.

One recent visit to Gaferut was made by islanders in a canoe from Satawal who were returning home on a long sea voyage from Saipan in June 1979. The navigator of the canoe reported that the island was covered with tracks and nests. The canoe was heavily laden, and able to carry only 2 or 3 turtles on the continuation of its voyage. This points out the limitations placed on the taking of turtles by the traditional mode of conveyance: the voyaging sailing canoe. These canoes are capable of extended voyages of many hundreds of miles with capable navigators from the islands of Satawal, Puluwat, Pulap, Tamatam, and Elato. But the number of turtles taken is limited by the size of canoe (usually not exceeding 8.2 m in length) and by the winds encountered. This is in stark contrast to the government ship or stray Japanese or Taiwanese fishing vessel, which happen upon an island, with a capacity far exceeding that of the canoes.

The other important nesting areas in the central and western Carolines are the islands of Ulithi atoll. Traditional customs are still strong within the atoll, and the turtles are considered the property of the chiefs of Mogmog, the highest caste island in the atoll. Information about turtles from Ulithi is not readily available, but the relatively large numbers of nesting turtles reported on 2 small islands just outside the atoll warrant a close study. A program sponsored jointly by the Peace Corps and the Micronesian Mariculture Center in Palau failed dismally in Ulithi during 1973 due to a number of factors, not the least of which was the personality of the Peace Corps volunteer assigned to the project. The resultant bad feelings have probably lessened the chances for serious investigators to do any work at Ulithi for some time.

Thus, except for the relatively few outer islanders who still possess the skills of their ancestors in bulding and sailing the large voyaging canoes, the great majority of the Micronesian population in the Carolines does not have access to turtle nesting sites. From a conservationist's standpoint this may be desirable, because the number of people exploiting turtles is reduced to manageable numbers (3,000 vs 90,000). Nevertheless, the remoteness of the islands makes the work more difficult than one would first imagine.

The inhabitants of the Caroline Islands are essentially of 1 Micronesian stock. Like other inhabitants of the Pacific, they can be grouped generally into 2 distinct groups: those that inhabit the low coral islands and atolls, and those who farm the higher volcanic islands of the chain. The languages are different from island to island, with the western Yapese and Palauan languages being distinct from the Carolinian dialects spoken from Ulithi to Kosrae. Ethnically and linguistically the outer islands of Palau are linked to Ulithi and the central Carolines, although administratively they are under the control of the administrative center in Koror, Palau. The rest of the islands' inhabitants live within 1 of the 4 states of the Federated States of Micronesia: Yap, Truk, Ponape or Kosrae. In Ponape, 2 outer islands, Kapingamarangi and Nukuoro, are inhabited by Polynesians rather than Micronesians, and make up the only distinctly different ethnic group in the Carolines.

It is important to note the basic differences between the coral atoll inhabitants and those living on volcanic islands. The former are mostly fishermen and "people of the sea," while the latter tend to concentrate their activities in farming and gathering crops on the more fertile high islands. As would be expected, the level of knowledge of the sea and its fauna is greatest in the coral islands.

The people of the coral islands, for the most part referred to as "outer islanders" by expatriates, have the greatest knowledge of turtle behavior, except for the inhabitants of Palau. Palau, in the western Carolines, is unique for many reasons; this uniqueness extends to knowledge of turtles and fishing activities in general. The Palauans have developed relatively exacting bodies of knowledge for much of the reef fauna, turtles included. Scientists studying there have remarked on the level of general knowledge and abilities of Palauans around the reefs of their home islands. But on the other high islands of Yap, Truk, Ponape, and Kosrae the knowledge of the sea is not on a par with the "outer islanders" of those states.

In the outer islands, knowledge of turtle behavior is wrapped up in traditional beliefs, altered somewhat by the advent of western schooling, the outboard motor, and other introductions. Population pressures in these islands have forced migrations to the administrative centers and, in some instances, colonization of atoll islands not usually used for habitation. In general, however, population pressures are not as extreme today as in the Gilbert Islands during the 1930s when the British Administration forced migrations and resettlement from traditionally inhabited islands to previously uninhabited ones.

These pressures will increase, particularly in the outer islands; and it appears that neither government nor local institutions are aware of or concerned with the problem. For example, the island of Satawal in the central Carolines had approximately 275 inhabitants at the end of the second world war. In 1968 the population of this 350-acre island was about 390. By 1978 it had risen to over 550, or a density of over 1,000 people per square mile. Marriage on other islands, employment in the administrative center and other factors tend to conceal the real growth, but an average of 22 births and only 3 deaths a year is quickly moving the island towards dangerous overpopulation.

These increasing pressures, in the case of Satawal, put increased pressure on traditional sources of protein, including turtles. Voyages in the traditional canoes will be made more often in search of turtles and fish on the nearby nesting islands, and perhaps the not-too-distant future will see the introduction of larger motorboats for this purpose. Indeed, on Lamotrek Island, 64 km west of Satawal, an 8.2 m diesel-powered skiff was recently purchased with funds granted by the District Legislature. The vessel reportedly travels to the atoll of Olimarao in search of turtles, and occasionally to Satawal for trading and social visits.

Turtles have suffered and will continue to suffer under such pressures. The atoll of Oroluk, located in western Ponape and already briefly described, was uninhabited until the late 1960s. When the Kapingamarangi people petitioned the government to allow colonization, a stable population resulted on Oroluk. While the numbers are not great, from 10 to 20 persons at any one time, the effects have been startling. The island itself is the only one in a large atoll enclosing 419 km^2 of lagoon area. The island has been known as a nesting ground for years during the season from March to September. The inhabitants have built a stone holding-pen, and turtles are placed within the pen to await the government field trip ship which calls about 6 times per year. Until recently turtles were loaded aboard the field trip vessel for return to Ponape, where they were either sold or eaten in the Polynesian village there. The enforcement of the Endangered Species Act has put a stop to commercialization, but subsistence use is still allowed under Federal law.

While there are no figures available on the numbers of nesting turtles at Oroluk, the inhabitants complain of a decline in numbers, and estimates of nesting females per year range from 40 to 100 individuals. This is not a great number, considering that, at least by reputation, Oroluk is considered one of the better "turtle islands" in the Carolines.

Because the physical environment of the outer islanders consists of coral atolls, and since the turtles prefer the beaches of the atolls and low islands to those found on the higher volcanic islands, they have the most contact with nesting turtles. They also develop the skills necessary for catching turtles in the lagoons and from boats and canoes. In the past 30 to 40 years, outer islanders in the administrative centers on the high volcanic islands, principally Truk, Ponape and Yap, often have shared these skills with friends and relatives there. Thus, techniques for catching turtles have been developed in the high islands which were absent in the past. As travel between islands is made easier by government-subsidized shipping, the chance for such minor technology-transfer increases.

In addition to sharing their own techniques and knowledge of turtles, the Micronesians learned much from the Okinawans who were brought to the islands prior to the second world war. The Okinawans came as laborers in the sea-oriented enterprises run by the Japanese, and many were excellent divers. They showed the Micronesians how to dive for turtles resting under the coral ledges, and how to gaff them with hooks embedded in long lengths of bamboo. The hooks were released from the gaff but remained tied to a long length of fishing line which was in turn tied to a floating log or other float. Some turtles were undoubtedly lost as they struggled to drag the float, and lines became entangled in the coral. But for the most part the method became an effective and successful way to catch green turtles, particularly in Yap.

The knowledge of turtle behavior possessed by outer islanders is limited, however. For example, in 1972 I inquired of the elders of an island their determination of periods between nesting. Some swore that females nest only once a season, others that she nests up to 10 times. Because they captured every nesting female they saw, there was no way for them to be sure. In another instance, a turtle was spotted nesting on a remote atoll away from the inhabited island. I asked the men how long they thought it would take for the eggs to hatch, assuming we left them in the ground. Some ventured 10 days, others 25. Nobody really knew, however, for they always dug up every nest they encountered and had no means of determining the time required. It was not until work at the West Fayu turtle hatchery showed the local crew that 58 to 60 days were required, that they began to understand some of the basics of turtle behavior.

Pressures on the turtles of the Carolines have been rising at an accelerated pace during the past 10 years. The main reasons for this seem to be the furtherance of the "money economy" in Micronesia, and the relative ease with which fishermen are now able to procure outboard motors, boats, and the gear required to hunt turtles. Amazingly, tangle nets such as are used in some places in the Caribbean are not used in Micronesia, and for that reason I have always hesitated to show the classic movie on the Miskito Indians produced a few years ago. Clarity of the water might be one of the reasons why people have never used nets, but the unavailability of materials might be another. Since most materials are now available, I felt it better not to show the movie and introduce the concept, rather than trust to *Chelonia's* eyesight.

Other factors have combined to increase the pressures on turtles. In the case of West Fayu, it was the island's flora. Until after the second world war, there were no coconuts on the island, which limited the amount of time voyagers could remain to await the turtles. Shortly after the war, a major infestation of an unidentified insect killed many of the bushy trees on the island which had prevented coconuts from receiving enough sunlight to survive. People from Satawal then transported copra nuts to the island and planted much of the island in coconuts. The coconuts have been the single most important change on the island (not counting a wrecked 9,000 ton freighter full of Toyotas in 1971). Man can now increase the length of a stay to hunt turtles.

Another factor that has increased the number of voyages is the improvement in materials used in the manufacture of the traditional canoes. Until the middle 1950s pandanus sails were used exclusively on all canoes on Satawal Island in the central Carolines. The introduction of cotton canvas sails greatly increased the speed and performance of the canoes. Recently, the introduction of dacron sailcloth has lessened the voyage time even more. Other improvements and introductions, such as the magnetic compass, have meant a greater confidence in voyaging and a strong probability that many more voyages are undertaken now than in the past.

Many of these improvements, including introduction of motor boats on other islands, have occurred during the years since 1965. They have greatly increased the pressure on the turtle populations in all of the areas visited by inhabitants of the central Carolines, with the possible exception of Gaferut.

The motorboats, usually under 6.7 m in length and powered by 25 to 40 horsepower outboard motors, are used mostly in the administrative centers (the high islands). In Truk, for example, motorboats are used to chase the turtles on moonlit nights across the shallows, and harpoons are used to spear and retrieve them. Turtles captured in the higher islands, where varieties of seagrasses are found, tend to be smaller and more variable in size than those in the nesting areas of the outer islands.

In the outer islands, the turtles are most often captured while mating or on the nesting beaches. The people of Satawal Island, and to a lesser extent those of the westernmost islands of Truk, Puluwat, Pulap, Tamatam, and Pulusuk, go to West Fayu to capture turtles. During the day a close watch is kept for mating turtles within the lagoon. If mating turtles are spotted, a canoe races to the position. The men affix large hooks to strong lines and then place the hook in a notch in the end of a piece of bamboo or stick approximately 2-m long. The ends of the lines are then tied to a large boom carried on the canoes, or to the canoe itself. Two men are given the responsibility of swimming up silently behind the mating turtles with the hooks. They then swim under the mating turtles, and each man places a hook into the skin on the turtle's neck. A sharp watch must be kept for sharks which occasionally cruise around mating turtles and take nips out of their flippers. For the most part, the mating turtles are oblivious to what is taking place around them. The swimmers are usually successful in their attempts. Once the turtle is hooked it immediately sounds and a tug-of-war ensues, with the turtle usually losing. Often the equipment for this type of capture is not available when islanders on fishing voyages sight mating turtles. In this case, the men swim up to the unsuspecting turtles and grab them in a "full nelson" hold from the underside. The man's hands are then placed under the chin of the turtle and force its head back, minimizing the chances of being bitten. Other men then jump off the canoes with whatever ropes and lines are available, and attempt to tie the front flippers in a manner that will allow them to drag the turtle aboard. This is obviously a much more dangerous and less successful operation than the hook and bamboo pole method.

During moonlit nights on West Fayu, it is also possible to tether a previously captured female to a tree, and allow her to swim in the shallows around the island. The nesting beach is not more than 15 m wide, and the tether is fairly short. Men then climb into the trees near the water's edge and wait for her to attract males. Once the males are attracted, the men chase them down.

Pikelot Island is perhaps one of the best known and most visited turtle islands in the central Carolines. Canoes from Puluwat, Tamatam, Pulap and Pulusuk in the western part of Truk visit the island during the summer months to capture turtles to take to their home islands for consumption.

Canoes from Satawal also visit Pikelot, as it is traditionally owned by them, and administratively it is the easternmost island in Yap State. In 1978 canoes journeying to Pikelot returned to Satawal carrying 18, 10, and 11 green turtles on 9 March, 8 May, and 16 June, respectively. Another trip by 4 canoes to West Fayu returned on 31 May the same year and brought with them 11 captured turtles from that island. This number of turtles is considered average to good. The yearly fluctuations in the total number harvested varies considerably. These excursions usually last from 1 to 3 weeks, depending upon the winds, weather, and food supply. An important consideration for the voyaging canoes is the weather, for the turtle nesting season coincides with the typhoon season in the central Carolines, and is also the time of the most variable and fickle winds.

Reports from Pikelot in 1977 showed canoes from Puluwat averaging 4 turtles a night (all nesting females) during a week's stay in May of that year. The report, published in Guam, further noted that because of the number of tracks on the beach, the 28 individuals taken could have represented only a portion of the population. What was not understood, however, was that during the good weather experienced on the island, the tracks and nests could have been made over a 1- to 2-month period by a relatively small number of turtles.

The total number of nesting females on the beaches at West Fayu and Pikelot is probably not very large, but their presence provides the incentive for inhabitants of the nearby islands to continue making the large sailing canoes primarily for the purpose of transporting live turtles back to the inhabited islands. There is a good chance that without adequate stocks of turtles, the canoe voyaging tradition would suffer, and with it an important component of local society. Thus, while actual numbers of turtles harvested may not be large, perhaps averaging 30 to 70 a year per island for the 6 major islands involved (Satawal, Puluwat, Pulap, Tamatam, Pulusuk, and Lamotrek-Elato), the turtles contribute much to their overall cultural stability, reinforcing their independence from the outside. The estimated maximum contribution to the protein, perhaps 18 kg a person a year, is not nearly as important as this cultural role.

An important buffer provided for the turtles were the past tabus and ceremonies surrounding the taking and consumption of turtles. Canoe travel provided an additional buffer, and has continued in the face of the lifting of traditional religious tabus. While it cannot be shown quantitatively that many of the tabus formed such a buffer, it is my opinion that a substitute is required to restore the balance and to enable the relationships to continue to exist.

The taking of turtle eggs was not traditionally covered by tabus. The exploitation of this resource has continued unchecked on almost all islands where there is nesting in the Carolines. The comparison of 25 g of protein to a possible 150 kg needs no elaboration here. However, the local inhabitants' belief must be remembered that the sea has been, and always will be, an adequate provider for all things. In my discussions with various inhabitants, none expressed great concern over the taking of eggs or, when concern was expressed, it was always countered by a bird-in-the-hand philosophy.

In the population centers such as Truk and Yap, the taking of marine turtles is an occurrence best equated with deer hunting in the United States. Often the hunting of turtles is undertaken with a form of sport in mind and, although the turtle is eventually consumed, it does not figure as prominently in the lives of the inhabitants as it does in the outer islands.

It has been my continued belief that efforts at conservation should be made with the people of the area firmly in mind and that assistance should be given to enable them to better understand the resource. This is not an easy task for scientists and others who themselves know so little of the behavior of turtles in the Carolines. Yet, the challenge presented must be met in the very near future if turtles are to remain a viable part of the island ecosystem.

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Status of Marine Turtle Populations in Papua New Guinea

ABSTRACT

There are 6 species of marine turtles found in Papua New Guinea (PNG). These are the green turtle *Chelonia mydas*, the hawksbill turtle *Eretmochelys imbricata*, the leatherback turtle *Dermochelys coriacea*, the loggerhead turtle *Caretta caretta*, the Pacific ridley turtle *Lepidochelys olivacea*, and the flatback *Chelonia depressa*. There is also 1 record of the subspecies *Chelonia mydas agassizi* from PNG (Pritchard 1979).

Village surveys indicate that populations of marine turtles are slowly declining in most areas. This decline is attributed to many things but mainly to the breakdown in traditional practices, introduction of modern fishing methods, population increase, and the introduction of a cash incentive in modern villages. It is hoped that education and extension work will result in the setting up of Wildlife Management Areas to allow populations of marine turtles to recover. Internationally, Papua New Guinea participates in the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) which prohibits overseas exploitation of PNG marine turtle resources.

Introduction

Papua New Guinea is a recently independent country consisting of the eastern half of the island of New Guinea, including the Bismark Archipelago. The country is divided into 19 separate provinces, throughout which there are 717 spoken languages. The 3 main languages are English, Motu (spoken in Papua) and Pidgin (spoken in New Guinea).

Papua New Guinea has a rather unique biological resource. Of the 7 species of marine turtles alive in the world today, 6 are found in Papua New Guinea. Committed to the conservation of its natural resources, especially those of nutritional or cultural value to the people, the PNG government set up the Marine Turtle Project in 1977 to:

- ensure the survival of the marine turtle resource and its subsistence and cultural values for the coastal peo-

ple of Papua New Guinea;
- map the distribution and abundance of marine turtle species in Papua New Guinea;
- collect traditional information concerning the subsistence and cultural values of marine turtles;
- educate the village people on the biology of their marine turtle resource and the need for conservation.

Methods

Village surveys and the closely related education and extension work are the main tools used in Papua New Guinea in marine turtle conservation.

Surveys

Village surveys provide the bulk of the information presented in this report. Most provinces have been visited, except the Morobe, Northern, and Gulf Provinces. However, parts of New Ireland, Bougainville, New Britain, and Milne Bay need to be more thoroughly investigated. It is hoped to eventually cover the entire coastline of Papua New Guinea and the islands for the sake of completeness. However this is a major and expensive operation involving travel to thousands of villages, many of them remote, and money, manpower, and time are limiting factors.

Aerial surveys have been carried out rather sporadically since 1977, and have been a useful means of reaching the more remote villages and of obtaining a general indication of nesting and feeding areas.

Market surveys are currently being conducted in Daru and Port Moresby.

Education and Extension Work

Education plays an important role in conservation of marine turtles, and extension work is tied in with village surveys. In Papua New Guinea, the onus for conservation work lies with the landowners. They will be responsible for introducing and enforcing conservation measures in the villages. The Wildlife Division provides the legal means for villagers to do this through the system of Wildlife Management Areas. Educational aids aimed at village, government, and general public include posters, badges and stickers produced by Rare Animals Relief Effort (RARE) Incorporated and T-shirts which are used as a reward for tag recoveries.

This paper summarizes the results of surveys into the distribution and abundance of marine turtles in Papua New Guinea.

Results

The Green Turtle (Chelonia mydas)

The green turtle (*Chelonia mydas*) is the most abundant and widespread turtle found in Papua New Guinea and is the most heavily utilized by villagers for food. It is identified with a vernacular name in nearly all parts of PNG.

Green turtle meat is considered by far the most tasty turtle meat. Adults and subadults are hunted in preference to juveniles, as are females to males, because of their higher fat content. In most places turtles are used for village consumption, however in the Central Province most turtles find their way into Koki Market where a large adult fetches between US $90 and US $115. The main turtle hunters in the Central Province are the Hula people. In March this year, 133 adult green turtles passed through Koki Market at a cash value of US $9500. Of these, 113 were caught and sold by Hula village people.

In comparison, in the Daru area, where turtles are much more abundant, an adult green turtle fetches between US $15 and US $30 in the market. In March this year, 47 turtles were sold at a cash value of US $1,080. The greater hunting pressure in the Port Moresby area is a result of the greater need for money and the higher prices of turtle meat.

The green turtle is found around the entire coastline of Papua New Guinea (Figure 1). The highest concentrations occur on the uninhabited island groups; in areas inhabited by Seventh Day Adventists and others who do not favor turtle meat as food; and in protected areas.

UNINHABITED ISLAND GROUPS

There is an abundance of good nesting beaches and uninhabited islands around the coast of Papua New Guinea. In most village interviews, the people could name a nearly uninhabited island or deserted stretch of beach where turtles nest. Turtles are no longer found nesting on beaches or feeding on reefs in front of villages, due to overhunting. People now have to go farther afield to catch turtles. There are several uninhabited island groups in the Manus Province which are important breeding areas for green turtles. These are the Sabben Islands (6 islands which are traditionally owned by a clan at Bipi Island), the Los Reyes Islands (3 islands traditionally owned by several nearby islands), the Purdy Islands, and the Johnson Islands. Nesting coincides with the southeasterly winds, from May to August. Eggs and females are collected from these islands, but is usually within limits imposed by distance and weather and by the clans who own the turtles. There are also the Kaniet Islands and the Anchorites, 2 uninhabited and isolated island groups in the Western Islands and rarely visited by people.

SEVENTH DAY ADVENTIST AREAS

Seventh Day Adventists do not eat meat and that inclubes turtle meat. Most Seventh Day villagers follow

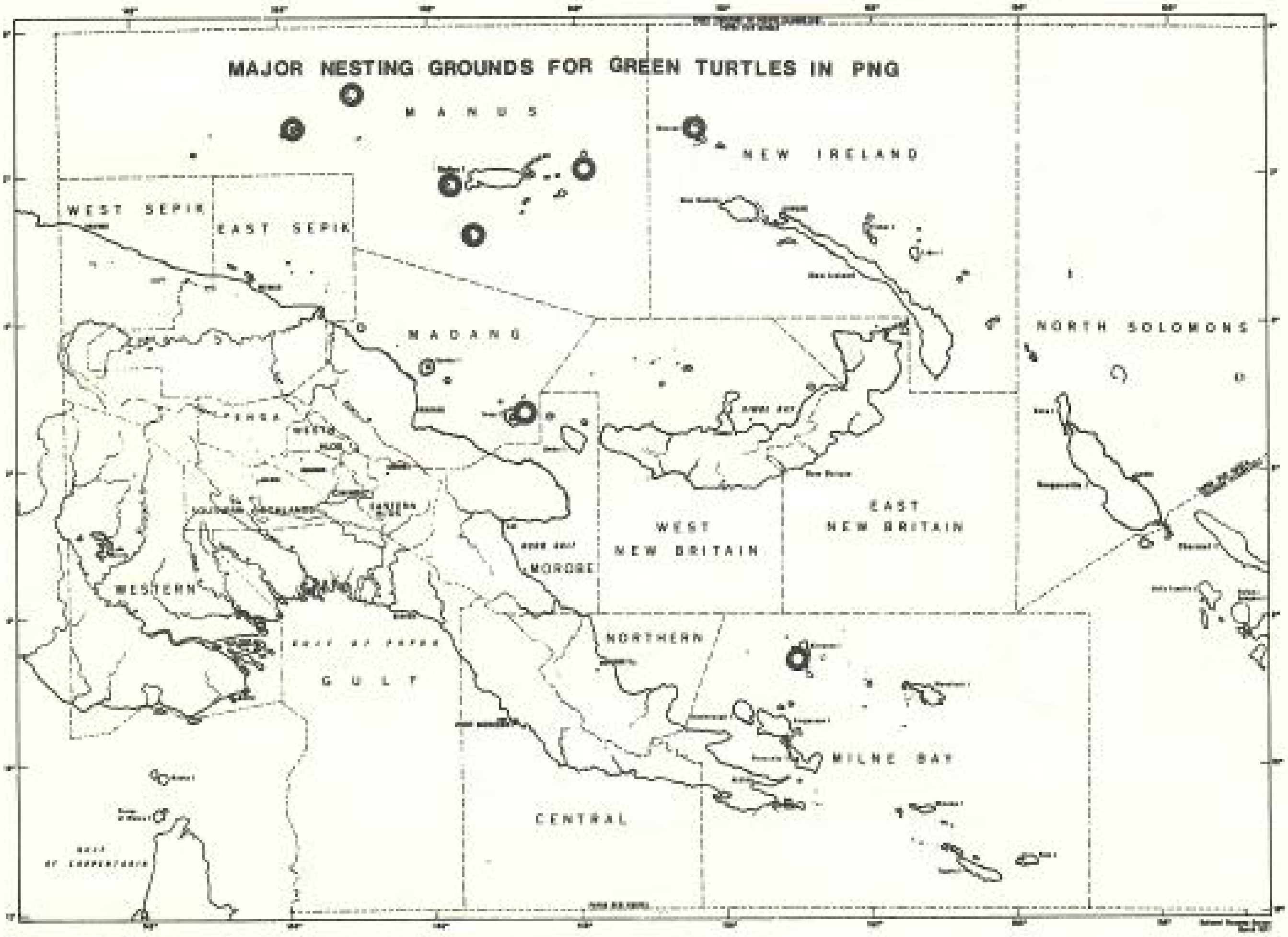

Figure 1. Major green turtle nesting grounds in Papua New Guinea.

this rule. In areas where this religion is established, villagers report a noticeable increase in the turtle populations over a period of 30 to 50 years at the most.

The Hermit Islands are an extremely isolated ring of coral islands, with a very small population (53 persons) who accepted the Seventh Day Adventist religion in the 1950s. Prior to that time they hunted and ate green turtles. There are 4 main turtle islands and turtles nest on all the islands from June to September: Pami, Makan, Planau, and Kocheran Islands.

The Ninigo Islands lie approximately 64 km to the west of the closest neighbor, the Hermits, and have a population of 567, spread over 6 islands, half of which are Seventh Day Adventists. Green turtles are not nearly so abundant here as in the Hermits, but are plentiful and nest on the uninhabited islands from May to September. Other important breeding areas for turtles occur on Lou Island in the Manus Province, and Mussau Island of the St. Matthias Group in the New Ireland Province. The people in both areas converted to the Seventh Day Adventist religion in the 1930s.

PEOPLE NOT FAVORING TURTLES AS A FOOD

In the Trobriand Islands, the village people are cultivators of yams, a very important foodstuff to them. Turtles are not eaten, as it is believed that eating turtle meat will ruin the magic of the garden, and the yams will die.

Only 1 or 2 villages hunt turtles. Turtles nest on a few beaches on Kiriwina Island but mainly on the outlying uninhabited islands, for example, Tuma, Munuwata, and Simlindon islands from March to April. Many turtles are also reported on the Luscany islands and reefs and Simsim Island.

A very large feeding ground of approximately 52

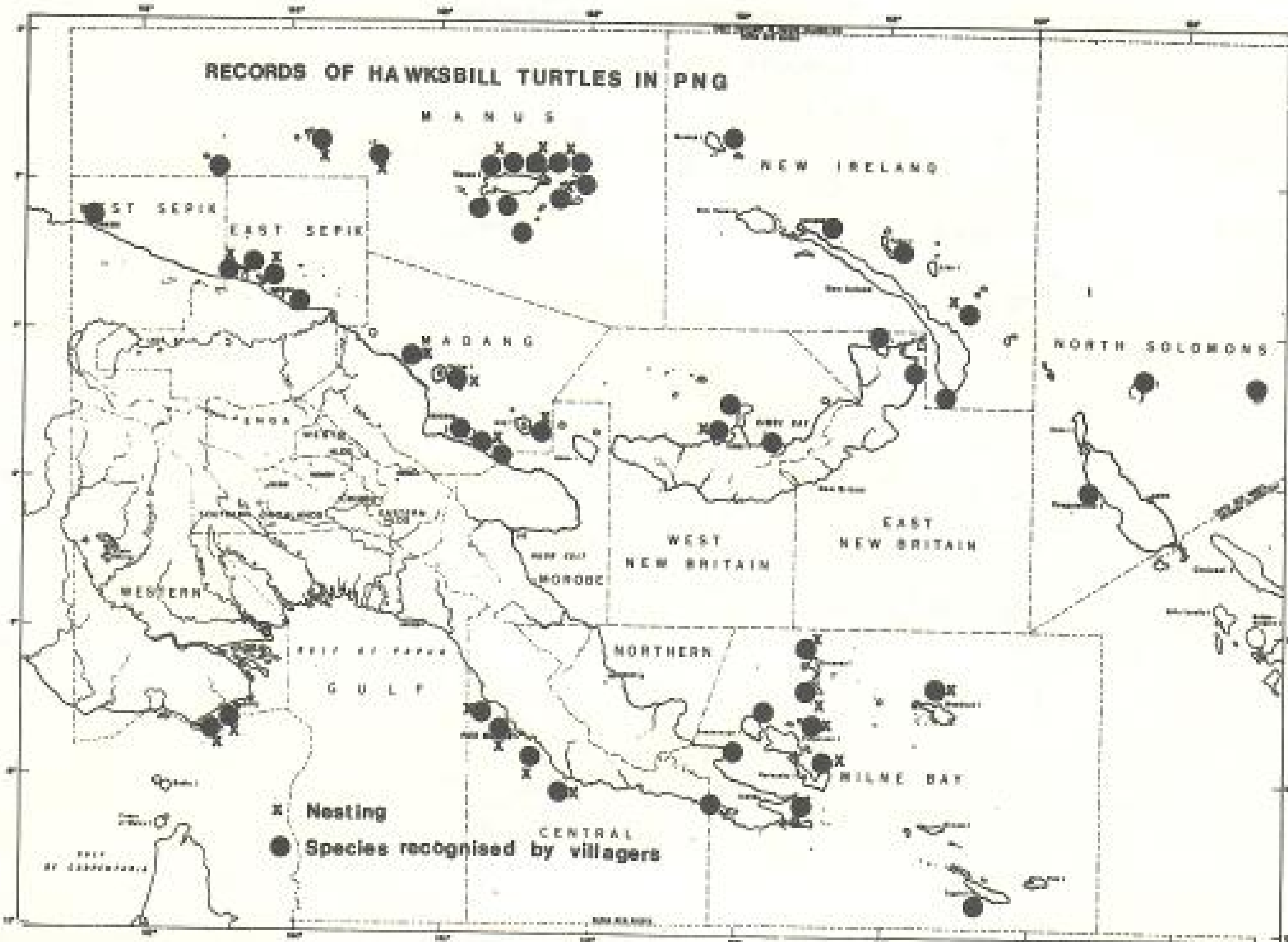

Figure 2. Records of the hawksbill turtle in Papua New Guinea.

km² lies between Losuia and Vakuta Island. It consists of sandy flats full of seagrass and occasional coral heads, with a mean water level of 5.8 m low tide. Many turtles are seen feeding here.

PROTECTED AREAS

The other main breeding area for green turtles occurs at Long Island. The major nesting beaches occur along the northwest of the island from Malala village to Sororo. Nesting is reported to occur year round, except during the rough northwest season from November to February. This area has long been exploited by passing fishing boats and government trawlers. Reports expressing concern over the harvesting rate were received by the Wildlife Division as early as 1974. Long Island has since been declared a Wildlife Management Area with restraints on taking nesting females during the months of May, June, and July. Also, outsiders are no longer permitted to go to the area and take turtles.

It is known that green turtle stocks on the Papuan side are shared with Australia, especially in the Torres Strait area. Turtles tagged in the Torres Strait are regularly recovered around the Daru and sometimes in the Gulf and Central Provinces. There is no evidence of shared stocks on the New Guinea side. All green turtles seen in PNG are of the subspecies *Chelonia mydas mydas*. There is a single record of *Chelonia mydas agassizi* in PNG from the Manus Province (Pritchard 1979).

The Hawksbill Turtle (Eretmochelys imbricata)

Hawksbills, almost as abundant and widespread as green turtles, are found wherever there are coral reefs. In some places they are even more abundant than the green turtle for example, Lou Island in the Manus Province and Kairuri Island in the East Sepik Province. Hawksbills are eaten when found, apparently with little ill-effect. Poisoning is uncommon (Carr, this volume),

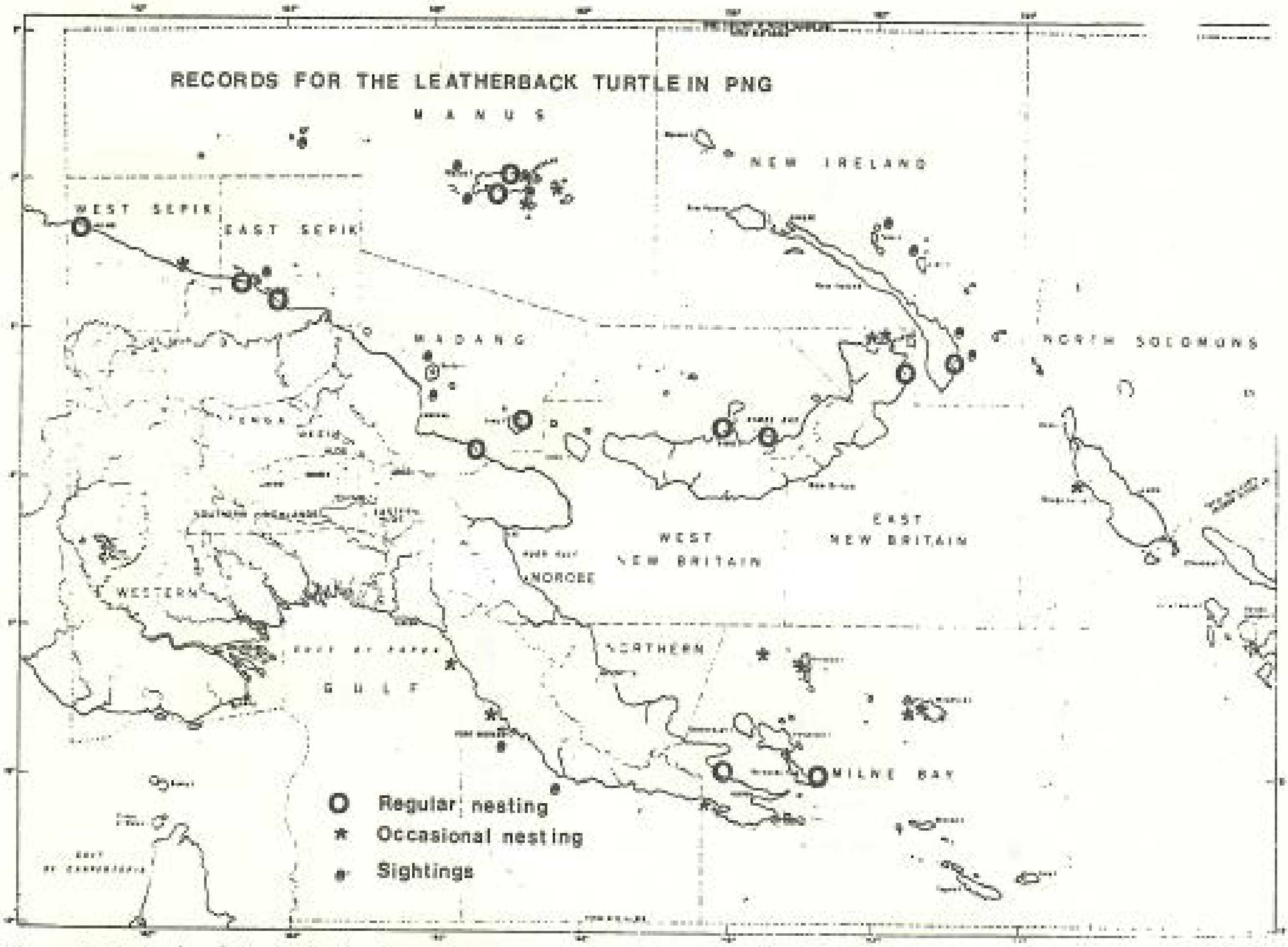

Figure 3. Records of the leatherback turtle in Papua New Guinea.

however in a recent incident on the Talasea Peninsula, 35 people were poisoned by eating hawksbill meat, and two children died.

Hawksbill shell is traditionally used to make combs, limesticks and jewelry and in some places, brideprice items. Shells are either kept as a decoration for the house or sold in the markets on the streets and in artifact shops to tourists. Apart from village use, there is one jeweler who specializes in tortoiseshell jewelry. Shells are bought in small quantities from the Marshall Lagoon area. There have been several incidents of illegal smuggling of hawksbill shells by Japanese tuna boats.

Nesting of hawksbills appears to coincide largely with that of green turtles (Figure 2). In the East Sepik Province, villagers report hawksbills nesting widely on the mainland and on small offshore islands from May to September. Raboin Island off the tip of Cape Wom is an uninhabited island where hawksbills nest in numbers. They are also reported to nest on the islands near Vanimo in the West Sepik Province (Pritchard 1979).

In Manus, hawksbills nest on the mainland and small islands especially Onnita Island, Sabben, Purdy, and Johnson Islands from June to August.

Hawksbills also nest in the Hermit and Ninigo Islands from July to August. In Long Island, Madang Province, hawksbills are the third most common species after greens and leatherbacks and nest occasionally on the beaches from May to July. They are also reported to nest on the mainland of the Madang Province.

The hawksbill is the second most common turtle in the Trobriand Islands after the green and nests on parts of Kiriwina Island and outlying islands in March and April. Tortoiseshell earrings and limesticks are a common sight in the Trobriands. Hawksbills are reported to be as common as greens in the Woodlark Islands.

Hawksbills nest on several islands in the Central Province, Idia and Hoidana, Fisherman's Islands in low numbers, from December to January. Nesting of

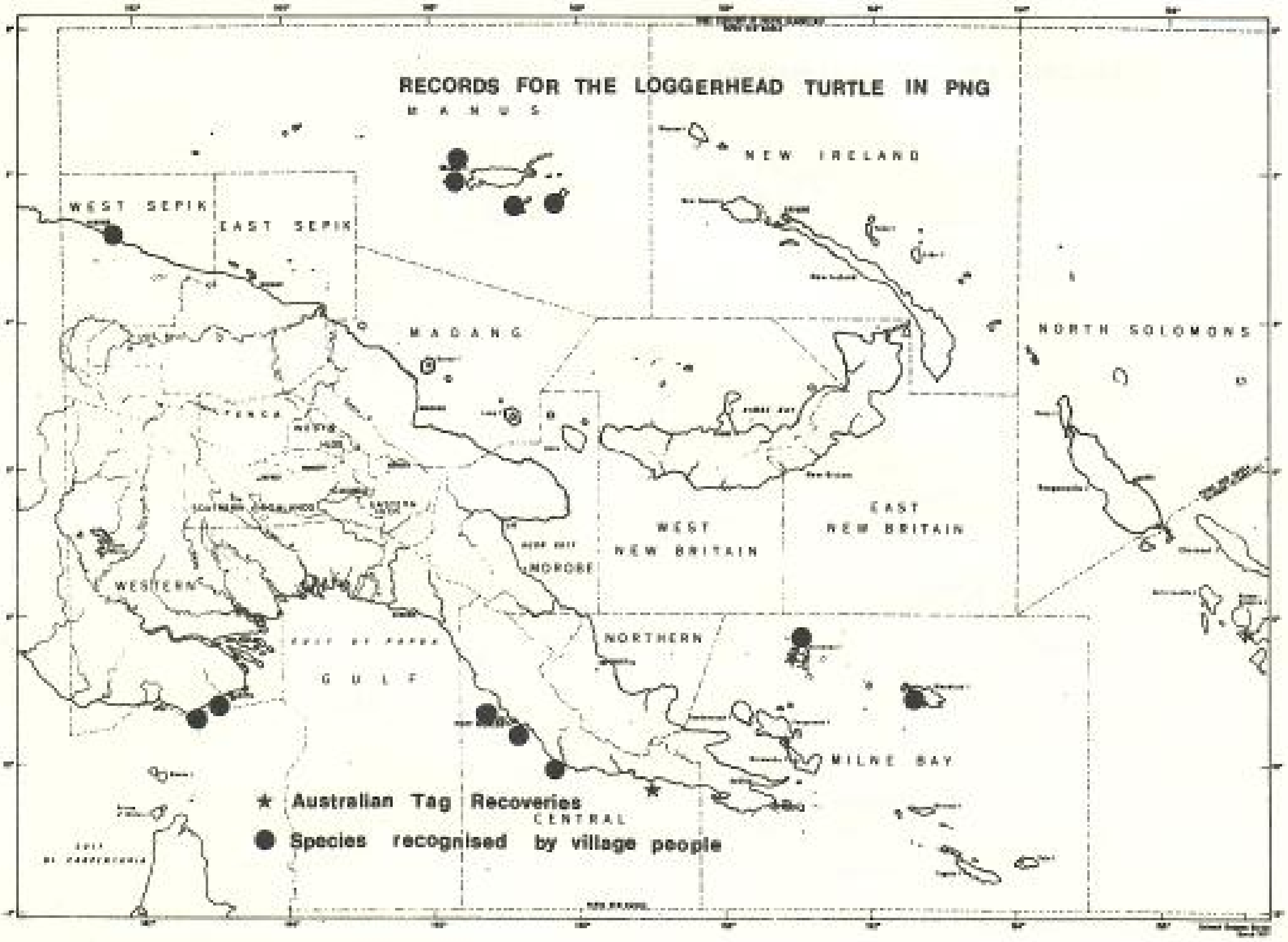

Figure 4. Records of the loggerhead turtle in Papua New Guinea.

hawksbills is also reported from the coastline near Daru, in the Western Province and at Garu Village in New Britain and on the southwest coast of New Ireland. Pritchard (1979) also saw a specimen that had been captured while nesting on the Gazelle Peninsula during the nesting season from September to January.

The Leatherback Turtle (Dermochelys coriacea)

The leatherback is easily identified from color photographs. Village people have no difficulty recalling this turtle.

Regular nesting is reported to occur widely along the north coast of New Guinea and on some of the larger islands but always in low densities (Figure 3). Reported regular nesting sites include Tulu village and Timonai village on Manus Island, Garu village, Kimbe Bay and Ganoi village in New Britain, along the southeast coast of New Ireland, on Long Island and parts of the mainland of the Madang Province, on Normanby Island in the Milne Bay Province and along the coast from Boiken to Turubu in the East Sepik Province and around Aitape in the West Sepik Province.

Many occasional nestings have also been reported, for example, on Kiriwina and Simsim Islands in the Trobriands, in the Woodlark Islands, on Lou Islands and Tingos village in the Manus Province, at Pilapila Beach near Rabaul. Apart from nesting, many sightings of leatherbacks floating at sea have been recorded.

This turtle and its eggs are usually eaten by village people. In Tulu village in the Manus Province the people eat this turtle whenever it comes up to nest. There are several disadvantages in eating this turtle, for instance, oily meat and a fishy smell that stays with consumers for many days. The shell is also boiled down to collect oil for wick lanterns.

The Loggerhead Turtle (Caretta caretta)

Village people tend to confuse the green turtle, the

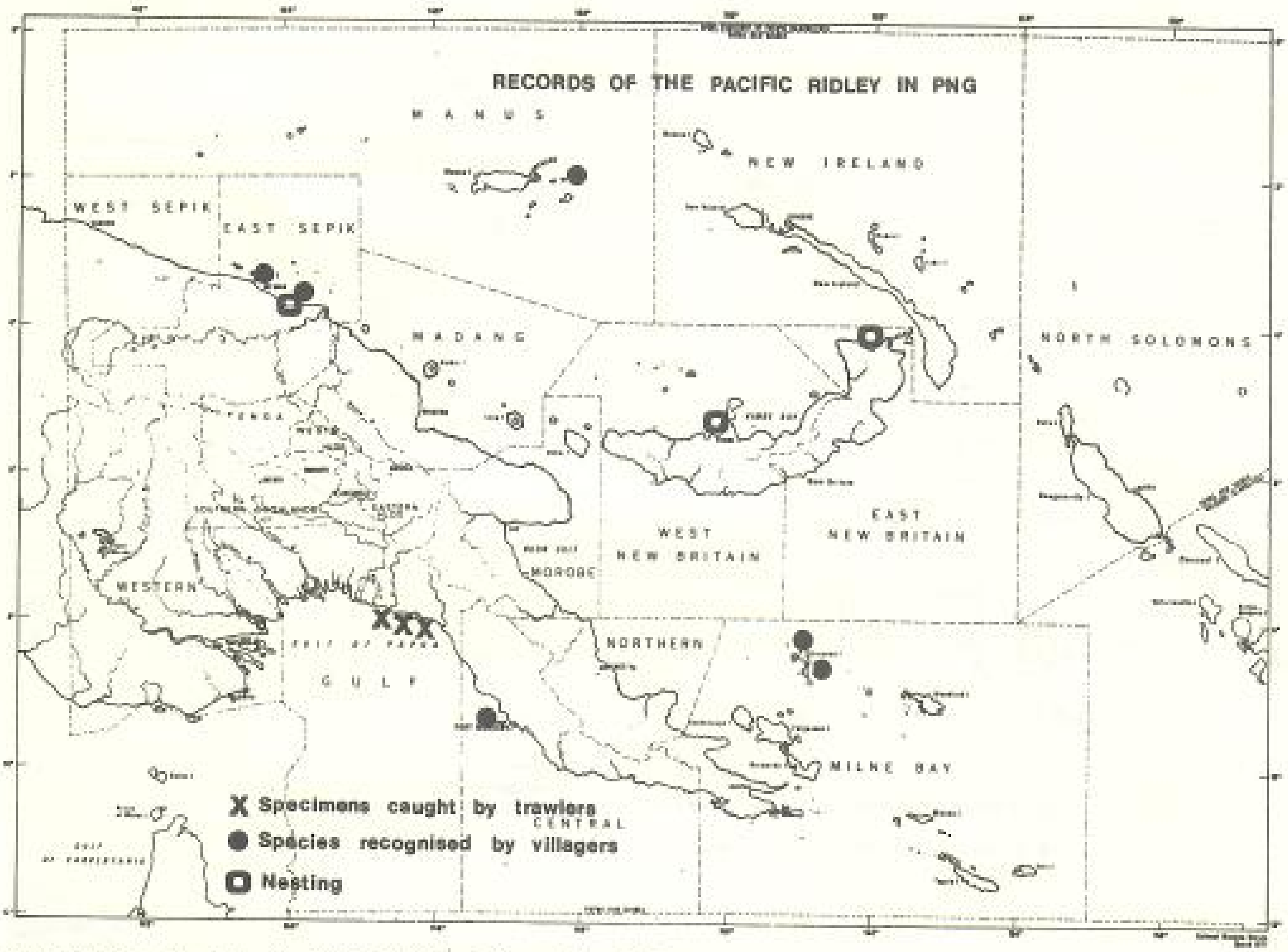

Figure 5. Records of the olive (Pacific) ridley in Papua New Guinea.

olive ridley, and the loggerhead. The only positive identification of this species in Papua New Guinea is from tag recoveries (Figure 4). There have been several tag recoveries of Australian-tagged loggerheads from the Trobriand Islands, where the village people report the mating and nesting of loggerheads on some of the outer islands. The loggerhead is also rather widely recognized and identified by a vernacular name along the coast of the Western Province; from Hula and Porebada villages and Fisherman's Island in the Central Province; in the Woodlarks in the Milne Bay Province; and from several locations in the Manus Province. They are always reported as uncommon at these locations with no known nesting.

The Olive Ridley (Lepidochelys olivacea)

Reported nesting sites for the olive or Pacific ridley in Papua New Guinea include: Turubu village in the East Sepik Province; Garu village in the West New Britain Province (Kisokau 1972); and in Ataliklikun Bay in the East New Britain Province (Figure 5 and Pritchard 1979).

The species is also recognized at several locations around Papua New Guinea and identified by the village people with a vernacular name. These locations include: Nuguria Island, Bougainville Province; Mamuan, Kabilomo, Garu, Marem, and Nakanai villages on the island of New Britain; Porebada village and Fisherman's Island in the Central Province; Ahus and Pak islands in the Manus Province (Rhodin, Spring and Pritchard, in press), and Kitava Island and Kaibola village in the Trobriand Islands.

The Flatback Turtle (Chelonia depressa)

The only records of this species in Papua New Guinea waters comes from the incidental catch of flatbacks by prawn trawlers operating in the Gulf of Papua (Figure 6). To date there have been only 11 such records.

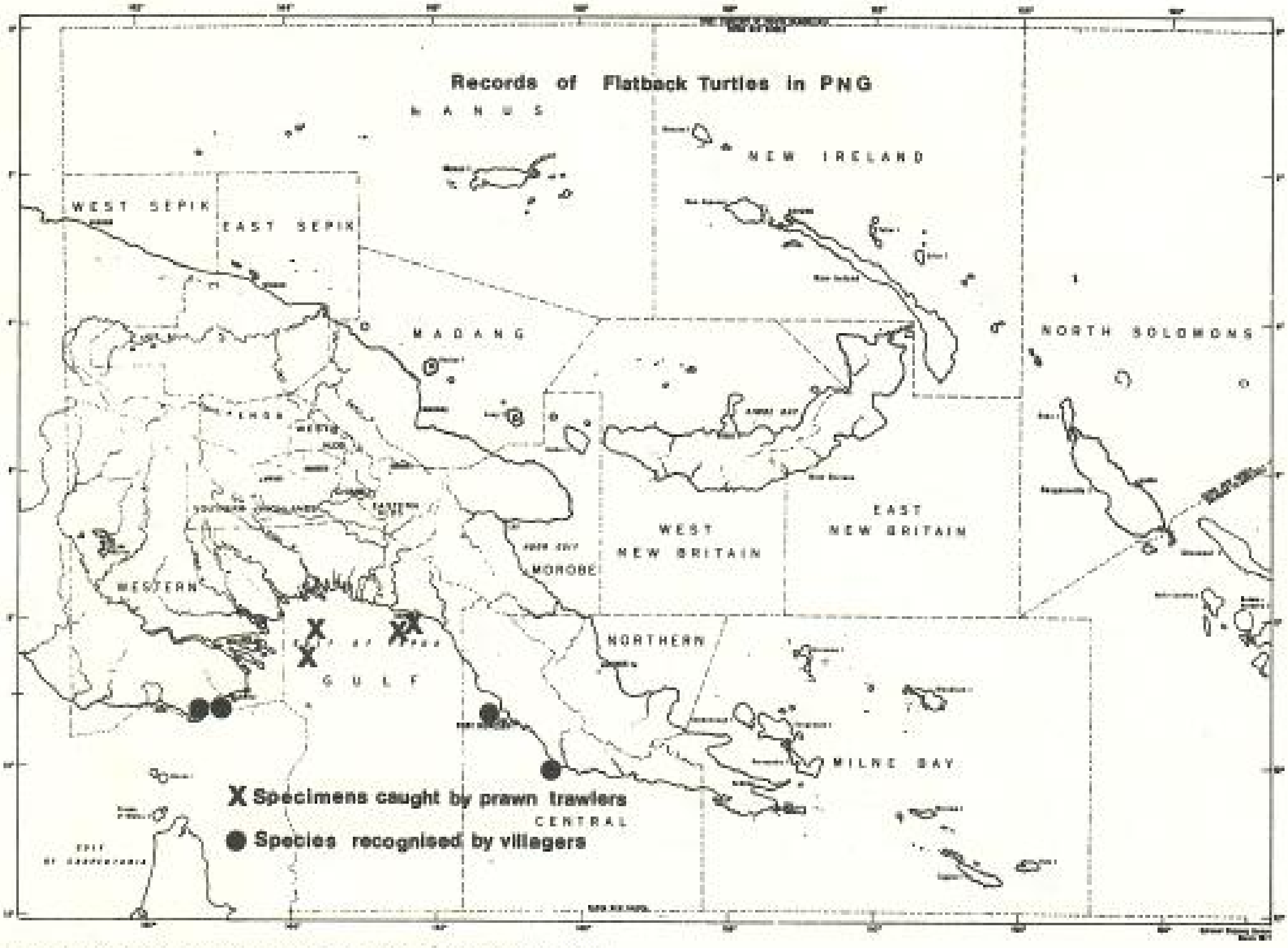

Figure 6. Records of the flatback turtle in Papua New Guinea.

There is no reported nesting of flatbacks along the coastline. This species is identified with a vernacular name from Fisherman's Island in the Central Province and from Tureture village in the Western Province (Rhodin, Spring, and Pritchard, in press).

Legal Status

Papua New Guinea signed the Convention on International Trade in Endangered Species of Fauna and Flora (CITES).

Under the *Fauna (Protection and Control) Act* of 1974, the export of all wildlife whether dead or alive, parts or products, requires an export permit issued by the Conservator of Fauna. Also under this Act, vertebrate wildlife may be exported only to approved institutions for legitimate scientific or zoological purposes (Parker 1978).

On a national level, the Wildlife Management Areas legislation allows landowners legally to protect their wildlife resources once the area and rules are gazetted in the PNG National Government Gazette.

Conclusions

The green turtle and the hawksbill are the most widespread and abundant turtles in PNG waters. The green turtle is the most heavily utilized for food. It is becoming obvious in areas where turtles are hunted for food that populations are declining. Many of the older people have observed the increased hunting of turtles and their subsequent decrease in numbers. There is a generation gap between the traditionally reared elders and the young people who have been exposed to a western way of life. Traditional respect and authority is eroding as a result of this generation gap, and traditional rules and regulations are being disregarded more and more by the younger people.

However, it is totally unrealistic to expect villagers to stop eating turtle meat. As an alternative, villagers should set aside beaches or islands as Wildlife Management Areas where the turtle populations could recover. Education through extension work will be important in stimulating village councils to consider the need for and to discuss ways to conserve marine turtles in their areas.

Acknowledgments

This paper could not have been prepared without the cooperation of the village people of Papua New Guinea who contributed information about their marine turtle resource. Nor could surveys have been conducted without the cooperation of the Provincial Wildlife staff. Also Fisheries biologists working in the Gulf have made available information on the incidental catches of ridleys and flatbacks in the Gulf of Papua. I would also like to thank Colin Limpus for making available tag-recovery data.

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Subsistence Hunting of Marine Turtles in Papua New Guinea

ABSTRACT

In Papua New Guinea marine turtles are heavily utilized by coastal and island villagers as a source of food, for traditional feasts and exchanges, and for sale in local markets.

In general there are many traditional rules and regulations concerning the hunting and use of turtles, but these are dependent on respect for traditional authority. In most areas this authority is eroding as a result of the younger generation's exposure to the western economies and way of life. Young people are taking advantage of modern equipment to catch turtles for everyday use and for sale in the markets. Village elders, beginning to notice the subsequent decline in turtle numbers, attribute it to the disregard of old traditions.

This paper summarizes the findings of surveys on the subsistence and cultural significance of marine turtles in Papua New Guinea (PNG). These surveys include a postal questionnaire, and village and market surveys.

Methods

In 1977 the postal questionnaire was prepared in the 3 main languages of Papua New Guinea: English, Motu, and Pidgin and was distributed to various schools, colleges, missions and government organizations around the PNG coast. The information received in these questionnaires was carefully assessed and used as background information for village surveys. Village surveys are a valuable source of data on traditions. Interviews are conducted informally, with village elders, councillors and turtle hunters participating. Information is collected on traditions such as hunting methods and their associated rituals, the use of turtles in the village, and legends. Village leaders are advised of a visit by a *tok save*, a message sent over the local radio so that villagers will be present when the interviewers arrive.

Daily market surveys are currently being conducted in Daru and Port Moresby.

Results

Around the coast and islands of Papua New Guinea people rely on the sea as a major source of protein. Fish, turtles, and shellfish provide the main wealth of the village. Often gardens are very poor, and so the people traditionally exchange their fish and turtles for garden produce such as sac-sac (sago), taro, and greens from the mainland or island villages.

The major source of protein is fish which is eaten daily. Second in importance are turtles. The most heavily utilized turtle is the green turtle (*Chelonia mydas*). However hawksbills (*Eretmochelys imbricata*) are also widely eaten, usually with little ill effect (Spring, this volume).

In most parts of PNG, turtles are highly valued for traditional use and for their cash value. However, in the Trobriand Islands, they have no special significance for the people who cultivate and prize yams far beyond their nutritional worth. Turtles are eaten when found but are not a sought-after food and certainly not used on important occasions such as feasts.

In all other coastal areas, however, turtles are or were traditionally eaten in feasts, for example brideprice repayments, funerals, the building of a new canoe, the opening of a new *haus boi*, the birth of a first child. Today, feasts are also held for nontraditional special occasions relating to business, political and religious activities such as Christmas, Independence Day celebrations, the opening of a new church or business group. When turtles are required for a feast, the chief or leader organizes the hunters and canoes to go out and get turtles, up to 60 for a big feast. Turtles are either kept on their backs in the shade in the village or in *banis* in the sea. While they are in *banis* they are fed seagrasses, chopped clams and fish to ensure that they do not get too skinny in the meantime. When all preparations have been made for the feast, the turtles are killed. If guests from other villages are invited, they bring exchange presents such as sac-sac (sago), and other items of wealth (for example, *tambu*, dogs teeth), according to the number of turtles which are provided by the host village. Turtles are usually given a quick roast and then cut up and boiled in a pot with a few greens. All of the turtle is eaten including parts of the shell, bones, blood, and internal organs. When a hawksbill with a particularly beautiful shell is caught and eaten, the shell is saved for making into combs or preserved as a decoration for the house or sold to tourists. In the past, the hawksbill shell was used to make a number of everyday items such as spoons and knives, but these are now supplied by trade stores. Hawksbill shell was also used to make some items of traditional *bilas* such as belts, bracelets, earrings, limesticks and brideprice items but these are rarely seen today.

In areas close to town centers, turtles are being hunted with little restraint, for daily consumption and for sale in the town markets. A large green turtle will fetch between US $90 and US $115 in the Port Moresby market, for example. Shells are also sold to tourists at between US $15 and US $30 for a good size shell.

However, there are other areas where turtles are no longer hunted at all; these are the Seventh Day Adventist villages, where the people do not eat meat. Of the areas I have surveyed, there are only a few locations where turtles are still abundant; two of these are Seventh Day Adventist areas, Massau Island in the New Ireland Province and the Hermit Islands in the Manus Province.

Turtles also contribute to the oral history of the village. There are many legends and stories to explain the origin of turtles, why they entered the sea, how they got their shells, and so on. Some clans believe they are descended from turtles, and stories describe this relationship. Some magic men claim to possess powers over turtles. There are 4 such men, to my knowledge, in the widely separated provinces of East Sepik, Western, Manus, and Milne Bay. Each of these men is highly respected within his village and only uses his magic for very important occasions. For example, at Ponam Island in the Manus Province, the traditional net is only used in association with magic. It was last used in 1975 when there were several important occasions occurring together—Independence, the ordination of a local priest, and the opening of a church.

Methods of Hunting

In Papua New Guinea turtle hunting methods have been traditionally passed down from generation to generation, with a few modifications along the way. Hunting techniques and their associated rituals differ from area to area, but they can be roughly grouped as follows.

Netting

The traditional net is rarely used today, but it was rather widely used in the *taim bilong tambuna*, the olden days. The net is made from bush fibers. The art of making the *kapet*, the traditional net, belongs to certain families and is passed down from generation to generation. Most nets have disintegrated today. However, in the Manus Province several are left and are used for very special occasions. The one on Ponam is considered a sacred object and is stored in its own house and looked after by an elder who possesses magic powers and who is highly respected in the community.

When turtles are needed, the people concerned see the 2 leaders of the turtle net and discuss their requirements. The leaders then confer and set a date for the hunt. Twenty-four men are needed to cast the net, 12 on each side (each leader is responsible for his own side). The leaders pass the message among the 12 men that a hunt is on and to prepare according to the rules. On the day of the hunt the canoes gather together and leave at dawn. The net, weighted with stones, is carried across 2 large canoes. There are 10 canoes altogether, 4 small ones on each side. The canoes halt at a passage and wait until a turtle is seen. Then the net is cast and some hunters jump into the sea with it. When the turtle is caught in the net the men call to the large canoers who converge. The small canoes duck in and pick up the turtles. Up to 7 or 8 large turtles can be caught in 1 channel. The whole process is carried out according to strict ritual, and so the turtle hunt becomes quite an occasion in the village.

Harpooning

This, the most widely practiced technique, is traditional in some areas and introduced in others.

FIXED-SPEAR TIP

This consists of a wood or bamboo harpoon with a fixed iron tip. This is used in the East Sepik Province, Madang Province and the Trobriand Islands. Two or three men in a small canoe hunt turtles, usually at night, using a lantern. When the turtle is speared, 1 or 2 men jump in the water and pull the turtle on to the canoe. Only a few turtles are caught on these hunting expeditions as there is limited space on the canoes.

DETACHABLE SPEAR TIP

In the Manus Province this widely practiced method was taught to the villagers by Japanese fishermen prior to the second world war. It consists of a wooden harpoon with a detachable spear tip made from a 3-cornered file connected to a *perei*, a wooden float, by a nylon cord. When the turtle is speared either from the canoe or by a swimmer in the water, the harpoon detaches, and the turtle is allowed to swim until it is exhausted. Then it is picked up by the canoe. This technique is also used in the Western Province, where villagers have magnificent sailing outriggers. A spotter on the mast directs the harpoonist at the prow of the boat.

PLATFORM

This was the traditional way of spearing turtles and dugongs in the Western Province. It is no longer practiced, but was 40 or 50 years ago. Turtle hunters would build a platform made of bush materials over the reef and wait for turtles and dugongs to swim past. When one did, it was promptly speared. The turtle was allowed to run and was pulled in when tired.

By Hand

In the St. Matthias Group in the New Ireland Province, turtles were traditionally caught by hand. Today the people are Seventh Day Adventists and do not eat turtle meat. The village elders believed that drinking turtle blood would increase their swimming and diving powers so turtles had to be caught without spilling a drop of blood. Canoes would chase a turtle until it tired. A hunter would then leap into the water, wedge a wooden pole in the soft skin of the neck under the shell, and flip the turtle onto its back. The turtle was then lifted onto the canoe alive and unhurt.

In Bipi Island, turtles were also traditionally caught by hand for feasts. The village chief would call all the hunters and tell them to prepare their canoes to go and catch turtles. Each hunter would prepare his canoe and take along his supplies (some food, tobacco, and betel nut). On reaching the turtle islands the hunters would prepare all the food in one pot and offer it to the spirits of the reefs and beaches. Next morning all the canoes would go to sea in a line and look for turtles. When a turtle was spotted a competition would ensue to see who could catch the first turtle. Each canoe would average 4 or 5 turtles, depending on the skill of the hunters. Turtles are also traditionally caught by hand in the Western Islands, the Trobriands, and Woodlark Islands. In the Woodlarks turtles are hunted on a dark night with calm water full of phosphorescence. Canoes follow the turtle's phosphorescent trail, then hunters leap on the animal.

Nesting Females

Taking nesting females is a rather widespread practice today. In the Manus Province it is a tradition with associated rules. In other areas it is nontraditional with little or no regulation. In Manus, there is a practice of calculating when nesting females will return to lay a second clutch of eggs. When an individual needs a turtle for a household occasion, he asks the village elder if he can catch a nesting female using this method. If fresh tracks are seen on the beach, the nest is dug up and the number of eggs inside counted. According to a formula which varies from one location to another, a number of small sticks or *yakets* are planted in the ground, each stick representing 1 day. When 2 or 3 sticks are left, the hunter returns to the site of the original nest and awaits the female turtle. This technique, though still current, is practiced less often, as nesting females are more scarce than in the past.

The Tulu village in the Manus Province maintains a strong traditional tie between 2 clans and the leathery (leatherback) turtle. The people believe that the leatherback turtle belongs to these 2 clans and that the turtle will not return to nest if this ownership is not recognized. Only members of the 2 clans can use divining methods to predict the return of the nesting female. Every female coming ashore to lay its eggs is eaten, if found. When the turtle is killed, it is cut up and divided according to tradition. The front end and the head go to one clan and the back to the other. The pieces in between are divided among the rest of the village. All the turtle is eaten and oil is collected from the shell and used for wick lanterns. In 1978 1 leatherback was eaten out of 5 that were nesting. Three of these nests were dug up (Pritchard 1979). In 1979 2 nesting females came ashore. Both were eaten and their eggs dug up. When I visited Tulu recently, the people were worried about the decreasing numbers of nesting females. There are usually between 12 and 14 nesting females in a good year.

Other Methods

Turtles are also incidentally caught in fishing nets and by hook. A few are also shot by speargun, but in general this practice is frowned upon by the village elders. At Kitava village in the Trobriand Islands, mating pairs are caught with ropes during the breeding season.

Turtle-Hunting Ritual

Ritual still surrounds turtles where they are caught for feasts, and strict rules are associated with their capture and consumption. In areas where traditional authority and respect is breaking down, especially around city centers beset by a need for money, traditional restraints on taking turtles (and other wildlife) are becoming less effective.

Missionary activity has also resulted in a breakdown of traditional rituals, but not always to the detriment of turtle populations. In the Western Province, turtles, once hunted only for feasts, are now eaten as a daily food. On the other hand, where the Seventh Day Adventist Church is influential, the people no longer eat turtle meat, and the turtle populations are increasing. In the more remote provinces, traditional ways are still respected and practiced.

Traditional Ownership of Reefs and Beaches

In most places the right to fish certain reefs and beaches is controlled by individuals or by clans. This enables some measure of control over exploitation of turtles in these areas. However, this system relies heavily on traditional authority and respect within the village. Also, in the old days, traditional laws were defended effectively by force.

Today this is no longer possible. The Wildlife Management Area system of the Wildlife Division enables traditional owners to legally take any offenders to court, thereby enforcing traditional rules, and placing the onus for enforcement on the villagers themselves.

Social Restrictions

These restrictions while not primarily of a conservative nature often have a side benefit of conservation.

Hunting rituals are usually designed to discipline the hunting party into a well-organized and efficient hunt. To prepare for the hunt, hunters usually cannot sleep with their wives during the preparatory period. They must organize their personal effects and dress neatly and not indulge in any gossip or bad thoughts or pry into other peoples belongings. Silence is usually observed during the hunt, only the leader giving orders. If a man's wife is pregnant, he cannot participate in the hunt, or go near the hunting party.

Village restrictions are usually based on the superstition that unless these rules are observed the hunt will be poor or the hunters may have an accident. There are many restrictions on the hunters' wives. For example, they cannot sweep or work until the men return; they must sit down in their houses and not walk about. Children cannot play or make a noise until the hunt is over.

People or clans who believe themselves related to turtles cannot eat turtle meat (East Sepik, Trobriand Islands). All villagers are also prohibited from eating turtle meat during the yam planting season in the East Sepik. In the Trobriands, if a person has eaten turtle meat, he or she cannot go near the yam gardens for 3 days, or else the garden magic will be affected. Magic men who have powers over turtles do not eat turtle meat for fear of losing their magic powers (Manus, East Sepik, Western and Milne Bay Provinces).

Conclusions

Marine turtles play a significant role in the lives of coastal village people as an important source of food. The rules and rituals associated with turtle hunting and the legends explaining their origin also contribute to the cultural heritage of the people.

The greatest threat to turtle populations today is the breakdown of traditional restraints on catching turtles, the incentive to catch more turtles than was previously required, for sale in markets, and the use of modern fishing gear. An old man from Bipi Island said: "Before, in the old days, there were plenty of turtles; we used to hunt them only when our elders said so. Today the young people are following new ways, shooting turtles with spears from canoes with outboards and spearfishing with diving masks. In my opinion, if we still follow the old traditions, turtles will still be plentiful, but the new generation are killing them indiscriminately and turtles are getting scarce."

Acknowledgments

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The Status of Australian Sea Turtle Populations

ABSTRACT

Six species of sea turtles occur in Australia. *Chelonia depressa* is endemic to the Australian continental shelf and is widespread and abundant in Queensland and Northern Territory, while *Chelonia mydas* and *Caretta caretta* are widespread and abundant in Queensland and Western Australia. *Eretmochelys imbricata* nests commonly in Torres Strait and the northern Great Barrier Reef of Queensland. *Lepidochelys olivacea* is poorly known with only low density nesting recorded from isolated areas of Northern Territory and Queensland. *Dermochelys coriacea* migrates along the central east Australian coast in appreciable numbers, but very few nestings occur. The sea turtle resources of Western Australia and Northern Territory have yet to be completely surveyed.

Except for one rookery, no major change in nesting population levels in the past two centuries has been identified. However, marked species-specific and synchronous fluctuations have been recorded for the east Great Barrier Reef *Chelonia mydas* nesting populations. All Australian sea turtles are protected through most of the important feeding grounds and rookeries. No major conservation problems for the species are currently identified except for a possible overharvest of green turtles in Torres Strait and the adjacent areas of southern Papua New Guinea.

Introduction

Large populations of 6 species of sea turtles inhabit Australian waters and nest in the northern states (Queensland, Northern Territory, and Western Australia). In Queensland there has been extensive regular monitoring and general research of sea turtles for many years. As a result Queensland's sea turtle resources are well documented, and reliable statements can be made concerning their status during the past decade. Surveys to define the extent of the sea turtle resources of the Northern Territory and Western Australia have yet to

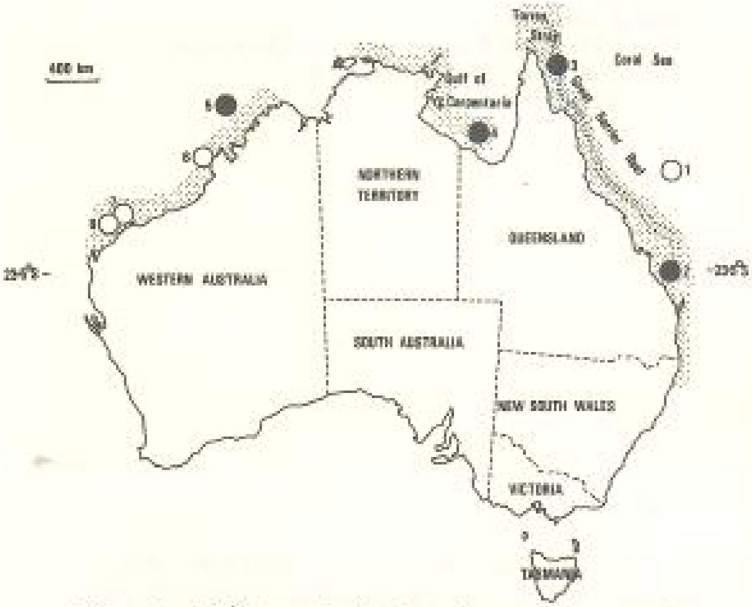

Figure 1. *Chelonia mydas* in Australia. ● = a known major rookery area for the species; ○ = a known rookery area which when surveyed may be of major importance for the species in Australia; ⁐⁐ = known feeding grounds of immature and adult turtles. 1) Diamond Islets, Coral Sea; 2) Capricorn-Bunker Group Islands, e.g., North West Island, Wreck Island, Hoskyn Island; 3) Raine Island-Pandora Cay; 4) Wellesley Group, e.g., Bountiful Island, Pisonia Island; 5) Browse Island; 6) Lacepede Islands; 7) Dampier Archipelago; 8) Monte Bellow Islands and Barrow Island.

be made, and only a partial knowledge of sea turtle distribution and abundance exists for these states. The resulting bias towards Queensland in the following summary reflects this patchiness of knowledge.

Distribution

The flatback turtle, *Chelonia depressa*, which is endemic to the Australian continental shelf, is widespread and abundant in northern Australia. The few records for the species from outside Australia have all come from trawling captures in the Gulf of Papua, southern Papua New Guinea. The remaining species of sea turtles occurring in Australia are the 5 species with a pantropical distribution: *Chelonia mydas, Caretta caretta, Eretmochelys imbricata, Lepidochelys olivacea* and *Dermochelys coriacea*.

In southern Australian waters, sea turtles are not abundant. *Caretta caretta* and *Dermochelys coriacea* are the most frequently sighted species. However very occasional sightings have also been made of *Chelonia mydas, Eretmochelys imbricata* and *Lepidochelys olivacea*.

The Green Turtle (Chelonia mydas)

QUEENSLAND

The green turtle is a widespread and abundant species in the state of Queensland (Figure 1).

Rookeries. Three major rookery areas, each consisting of several small adjacent beaches or islands are known in Queensland: 1) Raine Island-Pandora Cay of the northern Great Barrier Reef; 2) Capricorn-Bunker Group Islands of the southern Great Barrier Reef (including North West Island, Wreck Island, and Hoskyn Island); and 3) Wellesley Group of Islands in the southern Gulf of Carpentaria (including Bountiful and Pisonia Islands).

The annual nesting population of each of these major green turtle rookery areas is usually thousands of females. Several other small Great Barrier Reef rookeries (Bramble Cay, No. 7/No. 8 Sandbanks, Bushy Island and Bell Cay) each support annual nesting populations of hundreds of green turtles. Lower density nesting occurs widely throughout the state.

There have been marked fluctuations in the annual nesting numbers of green turtles throughout the Great Barrier Reef Province in recent years. The cause of these fluctuations is unknown, and they have occurred only for green turtles. The populations of green turtles in the feeding grounds which support turtles from these rookeries have shown no equivalent fluctuations. The changes in the annual nesting population at Heron Island (Capricorn Group, southern Great Barrier Reef) is shown in Figure 2. The populations of all the other Great Barrier Reef rookeries have shown approximately synchronous fluctuations. Thus at Raine Island, the densest of these rookeries, 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. The following year, when all the rookeries were at their lowest nesting density, only about 100 turtles nested at Raine Island nightly. Several thousand nesting turtles can be expected ashore nightly in an average nesting season at Raine Island.

Feeding grounds. Tag recoveries have shown that green turtles nesting in the southern Great Barrier Reef use different feeding grounds than the green turtles nesting in the northern Great Barrier Reef. Turtles tagged while nesting in the southern Great Barrier Reef have been recaptured around the perimeter of the Coral Sea, including southern Papua New Guinea and New Caledonia, while those from the northern Great Barrier Reef have been recaptured throughout Torres Strait, southern Papua New Guinea, southern Cape York Peninsula, Northern Territory, and Aru Island in Indonesia. The distribution of feeding grounds supporting the Wellesley Group nesting turtles is unknown.

Throughout Queensland there are large populations of green turtles ranging in carapace length from about 40 cm to adult male and female in most shallow bays and reefs. In particular the waters of the Great Barrier Reef and Torres Strait are rich in resident green turtles. There is currently no knowledge of the dispersal patterns from Queensland rookeries of the presumably oceanic posthatchling stages.

OTHER STATES

No major green turtle rookery is known for the Northern Territory. In Western Australia numerous green turtle nesting areas are known. The relative importance of all these areas has still to be gauged, but Browse Island, Monte Bello Islands, Lacepede Islands, Dampier Archipelago and Barrow Island appear to be major rookeries. Large populations of green turtles occur in feeding grounds along the coastal areas of the northern part of Western Australia and throughout the Northern Territory.

AUSTRALIAN TERRITORIES

Green turtles nest on most of the islands of the western Coral Sea. The most important of these rookeries appears to be the Diamond Islets. In the Indian Ocean, the species nests in very low density on Christmas Island, and the small turtle rookeries on each of North Keeling Island and one of the Ashmore Reef Islands are assumed to be green turtle rookeries.

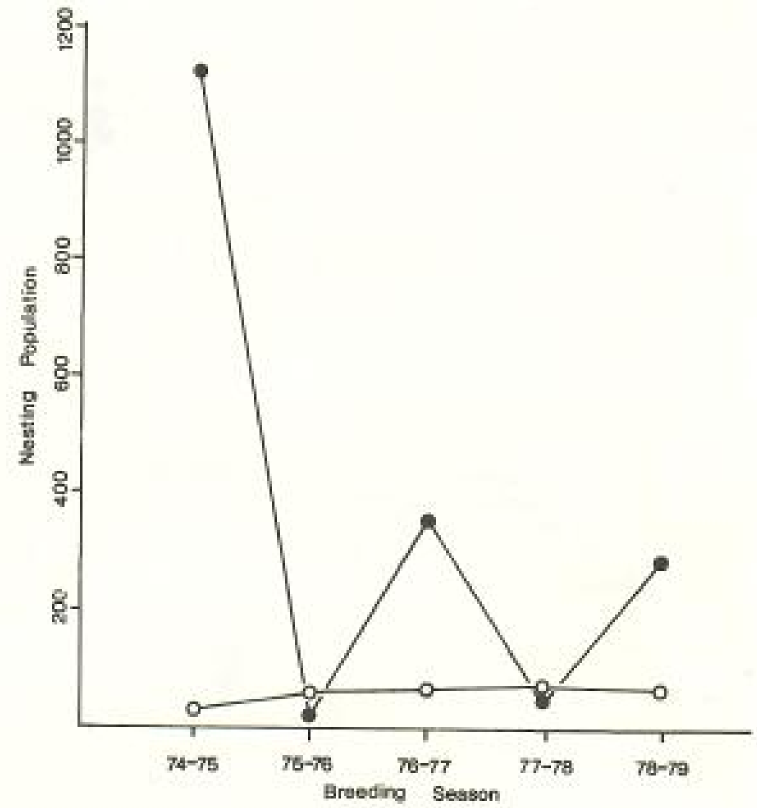

Figure 2. Annual fluctuations in the total nesting populations of sea turtles at Heron Island (Capricorn Group, Southern Great Barrier Reef). ● = *Chelonia mydas*, ○ = *Caretta caretta*.

*The Flatback Turtle (*Chelonia depressa*)*

QUEENSLAND

This state supports several important rookeries for the flatback turtle and a major feeding ground (Figure 3).

Rookeries. Queensland's most important rookery for the flatback is Crab Island which supports many thousands of nesting turtles annually (approximately year-round nesting is a feature of this rookery). Another major rookery area is centred on Wild Duck and Avoid Islands. Low-density nesting for the species occurs throughout the coastal areas of the Gulf of Carpentaria, Western Torres Strait, and central to southern Queensland.

Feeding grounds. The major feeding grounds for the flatback turtle are the Gulf of Carpentaria and the shallow coastal waters sheltered by the Great Barrier Reef. Dispersal patterns for post-hatchlings are unknown.

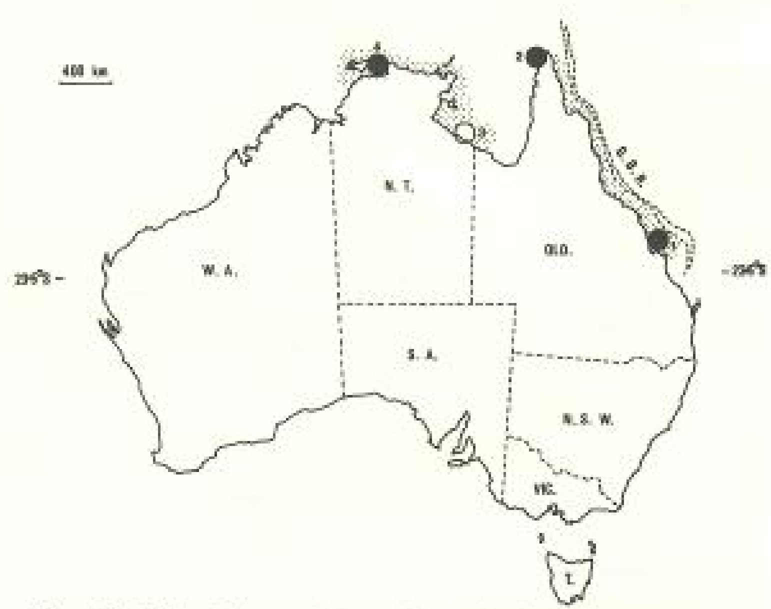

Figure 3. *Chelonia depressa* in Australia (symbols as in Figure 1). 1) Wild Duck Island-Avoid Island and adjacent areas; 2) Crab Island; 3) Sir Edward Pellew Islands; 4) Greenfield Island.

OTHER STATES

In the northern Territory, Greenhill Island is a major rookery while low-density nesting is known throughout the state. Only isolated nesting records are known from Western Australia.

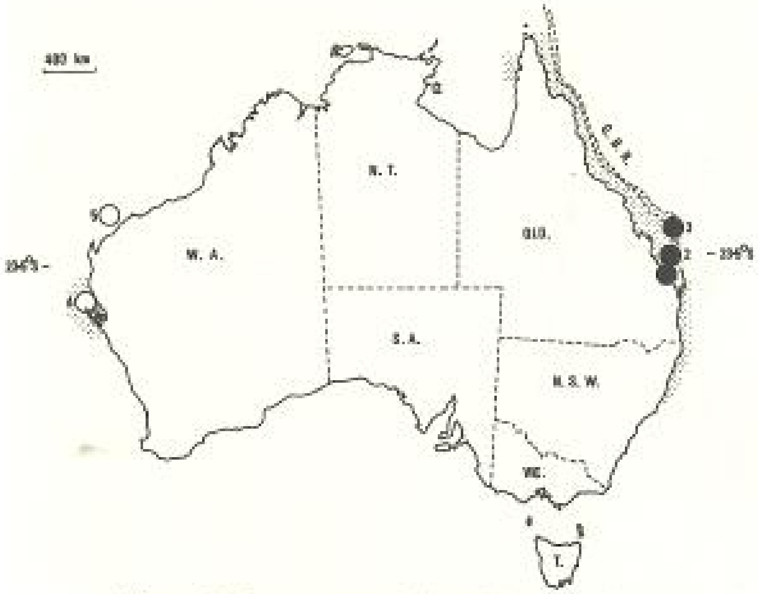

Figure 4. *Caretta caretta* in Australia (symbols as in Figure 1). 1) Bundaberg to Round Hill Head coast, e.g., Mon Repos, Wreck Rock beaches; 2) Crab Island; 3)Swain Reefs Islands; 4) Shark Bay area, e.g., Dorre Island, Bernier Island; 5) Barrow Island.

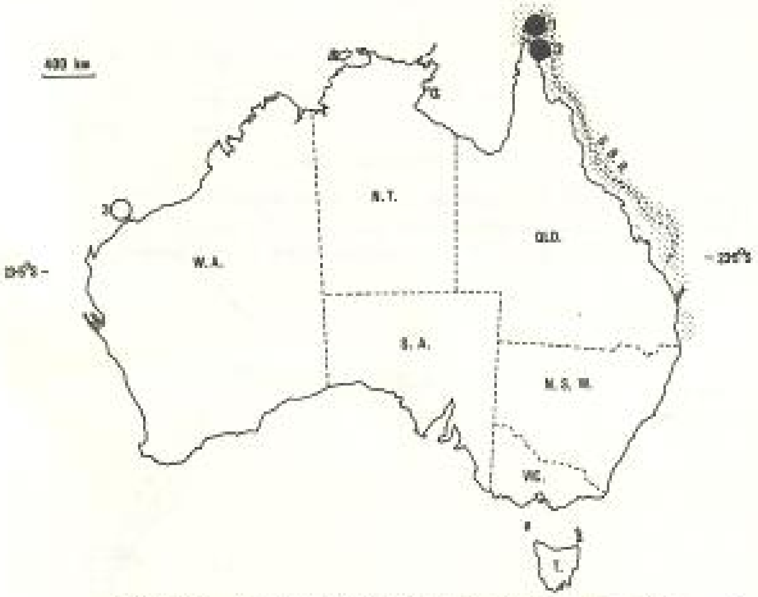

Figure 5. *Eretmochely imbricata* in Australia (symbols as in Figure 1). 1) Long Island and the islands of Torres Strait; 2) Milman Island and the inner shelf islands of the northern Great Barrier; 3) Dampier Archipelago.

The Loggerhead Turtle (Caretta caretta)

QUEENSLAND

In Queensland, the loggerhead is a widespread and abundant turtle (Figure 4).

Rookeries. The state has 3 major rookery areas, each consisting of several adjacent beaches or islands occurring in the subtropical to tropical areas in south to central Queensland: 1) Capricorn-Bunker Group Islands (including Wreck Island and Tryon Island); 2) Bundaberg to Round Hill Head coastline (including Mon Repos and Wreck Rock beaches); and 3) Swain Reefs of the southern Great Barrier Reef.

It is estimated that over 3,000 loggerheads nest annually in Queensland with approximately 1,000 of these nesting annually on Wreck Island alone. In addition low-density nesting occurs widely throughout the state south from Lizard Island (14°41′S).

Feeding Grounds. Tag recoveries indicate that loggerhead turtles nesting at the Capricorn-Bunker Groups and Bundaberg rookeries come from feeding grounds that extend widely along the entire Queensland east coast, eastern Gulf of Carpentaria, and Papua New Guinea including the Trobriand Islands. In particular, large populations of loggerhead turtles inhabit the Great Barrier Reef and the large shallow bays and estuaries.

OTHER STATES

Substantial numbers of loggerheads nest in the Shark Bay area (including Dorre Island) of Western Australia northward to at least Barrow Island. In eastern Australia, sporadic nesting occurs as far south as Newcastle (33°S) in New South Wales.

The Hawksbill Turtle (Eretmochelys imbricata)

QUEENSLAND

The hawksbill turtle is widespread but not abundant (Figure 5).

Nesting. Long Island of central Torres Strait is the only major rookery, and several hundred turtles are thought to nest there annually. Numerous small rookeries occur in 2 areas: 1) the islands of central to eastern Torres Strait; and 2) the inner shelf islands of the northern Great Barrier Reef.

Sporadic nesting extends throughout the Gulf of Carpentaria.

Feeding grounds. Although the species utilizes feeding grounds in the northern Great Barrier Reef and the reefs of Torres Strait, there are no tag recovery data to indicate the relationship between these feeding grounds and the rookeries.

OTHER STATES

Low-density nesting has been reported in several areas of the Northern Territory. There may be an important rookery area for the species in the Dampier Archipelago in Western Australia.

*The Olive Ridley Turtle (*Lepidochelys olivacea)

The olive ridley is a poorly known turtle in Australia (Figure 6).

Rookeries. No major rookeries have been recorded although low-density nesting is expected to occur widely across northern Australia from Coburg Peninsula in the Northern Territory to Crab Island in Queensland.

Feeding grounds. Large feeding ground populations occur in the Gulf of Carpentaria and along the Arnhemland coast. In eastern Australia the species is known from immature turtles collected at Cairns (North Queensland) and Geelong (Victoria). There have been no records of the species from Western Australia.

*The Leatherback Turtle (*Dermochelys coriacea)

The leatherback turtle is not a common turtle for most of Australian waters (Figure 7).

Rookeries. Nesting in eastern Australia is restricted to approximately 160 km of coast northward from Bundaberg where 1, or possibly 2, turtles nest annually. A recent report (Lindner, personal communication) of an isolated nesting in northern Arnhemland is the only record of breeding by this species outside Queensland.

Feeding grounds. Numerous adult and near-adult leatherback turtles pass through coastal waters from south Queensland to central New South Wales each summer. The rookeries from which these turtles originate are assumed to be those of New Britain and the Solomon Islands to the north of the Coral Sea. The species is also regularly sighted in the shallow waters of Shark Bay, Western Australia. For the remainder of Australian waters the species occurs only sporadically.

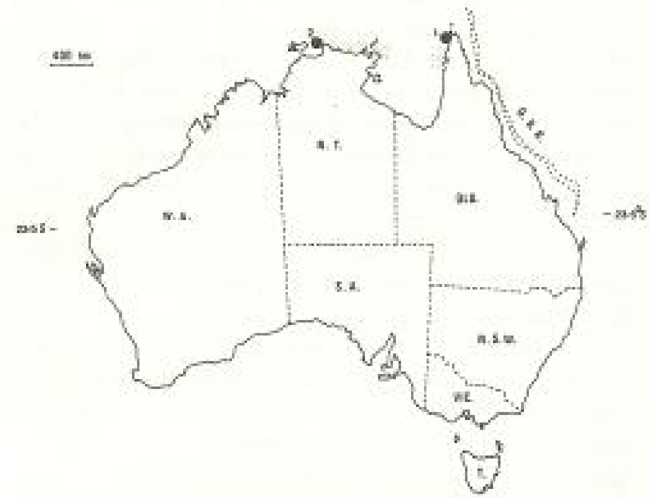

Figure 6. *Lepidochelys olivacea* in Australia. ● = known low density nesting; ⁝⁝⁝⁝ = known feeding grounds. 1) Crab Island; 2) Coburg Peninsula.

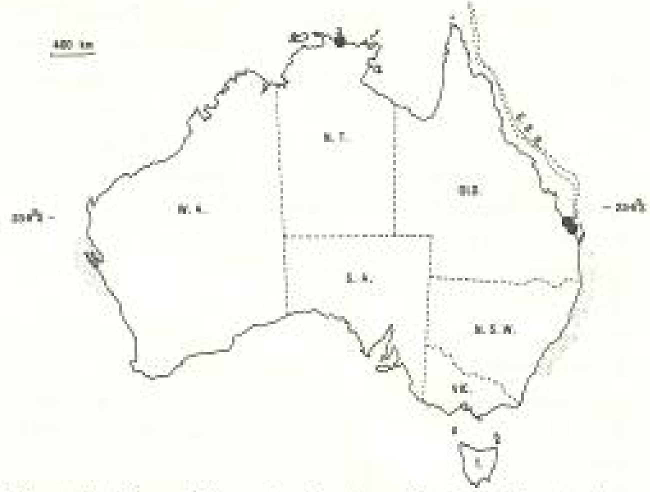

Figure 7. *Dermochelys coriacea* in Australia (symbols as in Figure 6). 1) Mon Repos, Bundaberg; 2) Wreck Rock; 3) Maningrida.

Conservation

Legislation

All sea turtles are totally protected in 4 of the Australian states—Victoria, New South Wales, Queensland and Western Australia with the exception that indigenous people in Queensland and Western Australia may take turtles for their own use. There is no commercial harvest of turtles within these states. In the Northern Territory only green turtles receive limited protection that restricts the method of capture and the locations from where turtles may be taken for commercial use.

Within Australian territorial waters, all sea turtles are totally protected as are those turtles nesting in areas administered by Australia such as Christmas Island, Cocos-Keeling Islands, most islands of the western Coral Sea.

Negotiations are in progress between the Australian Government and the Papua New Guinea and Indonesian Governments concerning the fishing rights (which will include turtles) for fishermen from these countries to fish within traditional grounds in Australian waters in Torres Strait, and several Indian Ocean island areas, respectively.

Australia is signatory to the Convention for International Trade in Endangered Species (CITES) which has resulted in the abolition of trade in sea turtle products into Australia in recent years.

Habitat Protection

In Queensland none of the major sea turtle rookeries are included in land administered for habitat protection by the state's National Parks and Wildlife Service. However several of the less important rookeries (Lady Musgrave, Fairfax, Hoskyn, Heron, and Bushy Islands—green turtle and loggerhead nesting) are National Parks. Low-density sea turtle nesting occurs on many of the other island and coastal national parks throughout the state.

In Western Australia the many coastal and island nature reserves provide habitat protection for sea turtle rookeries which include a number of those currently thought to be the more important for this state. These areas include: Cape Range National Park (green turtles) and nature reserves at Bernier and Dorre Islands (green turtles and loggerheads), Barrow Island (green turtles and loggerheads), and Lacepede Islands (green turtles).

Utilization and Exploitation

The annual catch of turtles by indigenous peoples for their own use throughout northern Australia has been poorly documented. Brief surveys of the harvest in Torres Strait area (including the adjacent Papua New Guinea coast) indicate that an annual harvest rate of the order of 10,000 green turtles occurs in the area, the majority of these adults. Over 40 percent of this harvest appears to be large females, which are being selectively caught. Approximately half of this catch is taken by Papua New Guineans and then mostly from within Australian waters for sale through their local coastal markets. There are insufficient records available to determine if this harvest rate is increasing or otherwise. The author believes that this harvest needs to be monitored.

In addition turtles are regularly being taken in coastal Northern Territory and several Indian Ocean islands and reefs including Keeling Island and the Ashmore Reefs. In these latter areas the catch is principally by Indonesian fishermen.

There is no indication of turtles being illegally harvested at any significant level elsewhere in Australia.

The experimental turtle farms, established by the Australian government sponsored company, Applied Ecology Pty. Ltd., on several Torres Strait islands, are in the process of being closed. Captive rearing of green turtles has been found uneconomical by cottage farm methods in this area, and plans call for all the farms to cease operation by early 1980.

Incidental Catch

Appreciable numbers of turtles are caught in prawn trawls and large mesh set nets in many areas including Gulf of Carpentaria, Shark Bay, and Moreton Bay. In no area is the mortality rate of these incidentally caught turtles considered to be significant since so few of the turtles are killed. This potential problem needs monitoring as changes are made in existing fishing methods.

Predation

Predation by terrestrial fauna on most Australian turtle rookeries is minor. However there are some rookeries where localized high levels of predation of eggs and hatchlings occur, principally by introduced predators such as foxes, dingoes, and pigs. Varanids are significant predators on a few rookeries. In areas adjacent to communities of indigenous peoples, some rookeries are subjected to an almost total harvest of the eggs. This applies particularly to some of the small hawksbill rookeries of eastern Torres Strait. Each rookery with an unnaturally high egg predation rate will probably need to be considered separately when planning management measures.

Population Trends

With only scant historical data available on most Australian turtle rookeries, it is difficult to compare present day population levels with those recorded by the early navigators and visitors to these rookeries (1770–1930 in eastern Australia). However, in eastern Australia there are no rookeries (with the possible exception of Bramble Cay) which have changed significantly in magnitude of rookery size or species composition when present day data are compared with those from the earliest records for the area. There is some indication that in the past few decades the green turtle nesting density at Bramble Cay in the Northern Great Barrier Reef has decreased markedly to its current low level. Whether this is due to the intensive regular harvest to which these nesting turtles have been subjected in the past or whether it is due to the natural gradual movement and reduction in size of the island that is occurring remains to be seen. In the other states there are no turtle rookeries with historical records suggesting that a major decline in populations has occurred.

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