

THE SEA TURTLES
OF
SOUTH EAST AFRICA

by
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This work is dedicated to my mother,
Mrs. C.M. Hughes
and to the memory of my late father,
Mr. Mitchell Hughes

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INTRODUCTION

Investigations into sea turtle biology began less than two decades ago and have been motivated mainly by the awareness that sea turtle populations are currently undergoing a serious decline in areas such as the Caribbean and parts of the Indian Ocean. This decline is due to overexploitation of stocks over the past three centuries and local environmental degradation of nesting areas. Pollution in its varied forms is also contributing to declines (IUCN, 1969).

Pleas for restraint in exploitation programmes have been made since 1620 (Carr, 1967) and predictions of extinction have also been voiced (Hornell, 1927) but despite some early research attempts (Schmidt, 1916; Moorhouse, 1933) no durable investigation was instigated until 1953 when Professor T. Harrisson started a long-term project in Sarawak. Unfortunately, religious objections curtailed his efforts although an associated programme produced the first comprehensive study on the green turtles of Malaya and Sarawak (Hendrickson, 1958).

Professor A. Carr of Florida commenced studies on the green turtle of the Caribbean in 1955 and this programme continues today, mainly in Costa Rica, and has provided a clearer understanding of the biology of the green turtle Chelonia mydas Linnaeus 1758.

In the sixties research programmes have started in eastern Australia, (based on Heron Island), Surinam and, under the auspices of the FAO (United Nations), in South Yemen and the Seychelles.

The present study on the South East African region can be regarded as a consequence of Carr's researches. In 1963 the Department of Bantu Administration and Development and the Natal Parks Board, South Africa became aware of the need to protect the nesting populations of loggerhead turtles Caretta caretta Linnaeus 1758 and leatherback turtles Dermochelys coriacea Linnaeus 1758 which were found to nest on the Tongaland coast of Natal, and whose presence was first reported by Bass and McAllister (1964). Since then research has been maintained on this coast

under the auspices of the Natal Parks Board. In 1969, the Oceanographic Research Institute, Durban became more deeply involved by providing laboratory, aquarium and administrative facilities as well as financial support, which, coupled with generous financial grants from the Southern Africa Nature Foundation (S.A. Appeal of the World Wildlife Fund) and the Gulbenkian Foundation, Lisbon, has enabled the execution of an extended survey of the South East African region. It was felt that as the sea turtles are migrants and travel extensively no successful conservation programme could be seen in its true perspective until the regional situation was at least partially understood.

An initial drawback was the dearth of relevant published works which necessitated lengthy tours to ascertain the distribution and nesting areas of the various species. Indeed, it was first necessary to establish the existence of one species; the olive ridley turtle Lepidochelys olivacea Eschscholtz 1829. Its presence was confirmed only in 1970 (Hughes, 1972a).

Old records from the study region showed that turtles were once "abundant" in certain areas (Bontekoe, 1619 in Loughnon, 1970; Peters, 1882; Smith, 1849) but no quantitative data were provided. More recent reports (Siebenrock, 1906; Vaillant and Grandidier, 1910; Decary, 1950; Rose, 1950) provided some more species identification but restricted themselves to generalities.

This thesis is, therefore, an attempt to summarize the existing knowledge of sea turtles in the South East African region and to present the results of a ten year programme on the loggerhead and leatherback turtles in Tongaland, Natal.

As a result of the expanded programme the distribution of the species within the study area has been ascertained. By comparing various morphometric features of the individual turtle populations in conjunction with intensive tagging, it has proved possible to suggest links between various populations and their environments. Thus the thesis has an ecological basis but tagging results have also provided information on the biology of the turtles, particularly the loggerhead and less so for the leatherback.

Further it should be stated that although considerable

morphometric data have been collected and presented this thesis is not a taxonomic work. Comments have been made on the taxonomic status of some so-called sub-species whose validity has been regarded as dubious for some time (Carr, pers. comm.). It is suggested that these sub-species are unjustified even on the grounds of convenience.

Finally, when comparing this work with that of such pioneers as Dr. P.E.P. Deraniyagala and Professor Archie Carr one is painfully aware of many short-comings and thus no claim of completeness is made. The thesis has been compiled and presented in the hope that it may contribute to a better understanding of the life histories of some species. This may, in turn, lead to a more rational exploitation of a valuable resource, and a better awareness on the parts of those governments under whose jurisdiction many sea turtle populations are to be found.

THE PHYSICAL ENVIRONMENT

As with all living organisms the behaviour and distribution of sea turtles is controlled, or greatly influenced, by the physical environment. All the species dealt with in this study have a circum-tropical distribution. Three species; the green, hawksbill and olive ridley turtles are restricted almost entirely to the tropics; the loggerhead is more tolerant of temperate waters, but only the leatherback is known to be capable of maintaining its body temperature above that of the ambient sea. It is thus the turtle most tolerant of cold temperatures and has been found in very high latitudes (Frair, Ackman and Mrosovsky, 1972).

The most striking environmental factor influencing the lives of sea turtles would, therefore, appear to be sea temperature. It will be shown later that this factor does affect distribution, both nesting and general, nesting activity, growth rates and normal activities of the turtles. Warm water is, in its turn, moved by the ocean currents enabling the penetration into temperate seas of migrating or nesting turtles. Tied as they are to the land for nesting purposes, beach profile and beach accessibility are important to the turtles. Waves and tides impinging on these nesting shores and the feeding areas can have a marked influence on the accessibility of beaches and food.

In order to have a full understanding of the environment this section is presented summarizing briefly the most important physical features of the study region.

The Landmasses

The south east African region embraces two major landmasses, approximately half of the east coast of Africa and the sub-continental island of Madagascar which split from Africa during the early-Cretaceous breakup of Gondwanaland (King, 1962: 60).

The coastlines contained within the study region have two remarkable features; a lack of relief immediately adjacent to the coast (dunes, however, can reach 200m, such as are found around Inharrime, Mozambique (Wellington, 1955)) and an uninterrupted profile. The absence of deep bays and gulfs is striking as well as the paucity of offshore islands (Stamp, 1953).

Exceptional areas are the northern section of Mozambique from Mozambique Island to the Tanzanian border and the north west coasts of Madagascar where there are numerous bays and sheltered inlets with which large mangrove stands are usually associated.

Continental islands are uncommon and most are found in Mozambique viz. the Querimba Islands (north of Porto Amelia), the Primeiras and Segundoes (17°S, 40°E) (Figure 1) the Paradise Islands (22°S, 35°E) and Inhaca (27°30'S, 32°30'E). All of these are within 20km of the mainland and their climates and structure are identical to the adjoining coast.

Madagascar has a few continental islands such as the Barren Islands (18°S, 44°30'E) but most are small and their descriptions lie beyond the scope of the present study.

Oceanic islands, although regarded as being of negligible significance to geographers, are of great importance to sea turtles. The isolation of these islands and their inaccessibility have resulted in a high degree of protection for many sea turtle populations.

Oceanic Islands relevant to the present study are Europa Island (22°21'S, 40°21'E; Figure 1), Tromelin Island (15°51'S, 54°25'E; Figure 1) and the St. Brandon Archipelago or the Cargados Carajos Shoals (between 16° and 17°S, 60°E; Figure 1). All are classic oceanic islands, far from land, rise from great ocean depths, particularly Tromelin, and are the peaks of undersea volcanoes or mountain ranges. All are noteworthy for their total lack of relief and small sizes (<5km in diameter).

The Mascarene oceanic islands of Mauritius and Reunion are referred to as stepping-off localities only. Once hosts to substantial populations of sea turtles (e.g. Loughnon, 1970; Toussaint, 1966), they are now deserted. Rodriguez Island

populations suffered a similar fate and the island was not visited during the current study.

The Ocean Currents

Dominating the south western Indian Ocean and influencing almost all aspects of the life history of the sea turtles are the ocean currents. Apart from the odd stray animal there is no evidence to suggest that each major oceanic circulation does not contain within it, its own discrete populations of sea turtles. This point is, perhaps, best illustrated by reference to the distribution of Kemp's ridley sea turtle Lepidochelys kempii Garman 1880 which is confined solely to the Gulf of Mexico and the north Atlantic Ocean, no specimens having been recorded from the southern hemisphere (Carr, 1957).

The study region is bounded in the north by the powerful south Equatorial Current which, during the summer months, is found between 9°S and 22°S. Flowing westwards it splits twice; the first split sends a flow of warm water southwards along the east coast of Madagascar, whilst the main flow carries on to the mainland of Africa striking Cabo Delgado at right angles. The second split sends water northwards along the Tanzanian coast and southwards down the Mozambique Channel as the Mozambique Current (Fairbridge et alii, 1966; Defant, 1961).

The east Madagascar Current flows around Cape St. Marie and, reinforced by re-cycled water from the Agulhas Gyral, (and occasionally joined by the Mozambique Current) forms the fast flowing Agulhas Current (Darbyshire, M., 1966; Duncan, 1970). During the southern hemisphere winter the Mozambique Current weakens substantially and has been shown to reverse (Menaché, 1961) and form a vortex circulation (Harris, 1970). This is a result of changes in the monsoon regime in the northern Indian Ocean and the northward movement of the south Equatorial Current.

From approximately 24°S the Agulhas Current flows southwards at the edge of the continental shelf. Along the Zululand coast it lies within a few miles of the shore, sweeps away from Durban as a result of a broader shelf, returns near East London

and finally leaves the coast near Port Elizabeth following the edge of the Agulhas Bank southwards. Thereafter there is intense mixing and the turning back of most of the current. This has resulted in eddy formations some of which are quasi-permanent and have received considerable attention recently (Bang, 1970a).

During the autumn the velocity of the current increases appreciably reaching up to 60cm/sec. (Darbyshire, J., 1964; Darbyshire, M., 1966). At this time vigorous mixing takes place over the Agulhas Bank with mixed water penetrating past Cape Point and up the west coast as far as 32°S (Shannon, 1966; Bang, 1970b). This penetration of Agulhas water is, however, restricted to the autumn months and during the remainder of the year there is no constant flow between the Indian and Atlantic Oceans. (Duncan, op. cit.).

The most southerly penetration (41°S, 17°E) of the current takes place during the autumn after which it turns eastwards flowing parallel with the West Wind Drift. Between 44°E and 60°E there are sections with a distinct northerly flow which suggests that the water circulating around the south western Indian Ocean forms an independent gyral (Duncan, op. cit.; Harris, 1970).

In sum there are probably three major gyral present in the study area; the large permanent south Indian Ocean gyral, the Agulhas gyral and the semi-permanent gyral in the Mozambique Channel. Figure 2 summarizes the circulatory pattern in the southern hemisphere autumn.

Temperatures

Sea temperature relations of the water are of maximum importance to marine zoogeography because they vary not only in location but also with the seasons (Allee & Schmidt, 1951). The study region is contained completely within the sub-tropical oceanic regime (Gross, 1967) and, as a result of the general circulation, is much warmer than the eastern half of the Indian Ocean at the same latitudes. The annual variation of temperature

is less than 5° except off the southern tip where warm and cold currents meet and predominate in turn. These regional temperature differences are important as barriers (Allee and Schmidt, op. cit.), and evidence will be presented later in this work to show that annual temperature variations can effect the migratory and nesting behaviour of sea turtles.

Figure 3 shows the sea surface temperatures of the region during the months of February and August. Figure 4 shows the surface temperatures around the southern tip of Africa during March and illustrates the mixing of Atlantic and Indian Ocean waters and the periodic presence of cold inshore waters that precludes the permanent residence of many tropical species of organisms in the area.

Air temperature is only fleetingly considered in this study despite the discussions by Hendrickson (1958), McAllister, Bass and van Schoor (1965), and Moorhouse (1933) who linked it with the turtle nesting season. It is suggested that sea temperatures are far more important to an animal that spends almost all of its life or, in the case of the male, all of its life in the sea. Furthermore it has been clearly demonstrated that the temperatures of the oceans greatly influence the climates of the coasts upon which they impinge. The periodic emergences of sea turtle females onto beaches in order to lay eggs would, therefore, be little influenced by local air temperatures which are normally only slightly cooler than the adjoining sea (Petterssen, 1958).

Waves, tides and salinities

As sea turtles spend most of their lives submerged the influence of waves and tides is almost negligible. During the nesting season, however, their influence can be substantial and has marked effects on the behaviour of the nesting female.

Eastern Madagascar and Africa south of Inhambane are moderate energy coasts and are exposed to swell waves throughout the year. Storm conditions, particularly at high tide periods,

can result in the erosion of thousands of tons of sand from nesting beaches during a single tide.

By contrast the west coast of Madagascar is sheltered both from swell waves and the short choppy wind waves generated in the Mozambique Channel by the south east trades. The latter waves are predominant in central Mozambique. Except during periods of cyclone disturbances the west coast is calm and has permitted the development of extensive domestic fishing skills amongst the coastal people who have long been famous for their lengthy voyages in open, outrigger canoes (See e.g. Bulpin, 1956). The hunting of sea turtles forms an important part of the fishing industry.

The oceanic islands are exposed to swell waves of considerable force which erodes sand from the eastern and south-eastern shores. Nesting beaches are restricted to the leeward (western) shores of all oceanic islands.

With the exception of the east coast of Madagascar and the oceanic islands east of 50°E, all of which have mixed tides (range 0,25 - 1,5m; semi-diurnal preponderant) all the coasts in the study area have semi-diurnal tides (range 0 - 25m) (Pattullo, 1966). Most tidal ranges are modest (1,3m - 2,0m) but in the constricted Mozambique Channel ranges become more extreme reaching 6,3m at Beira (Tinley, 1971a).

Salinities within the study region vary from 35°/oo to 35,5°/oo; an exception being found in north western Madagascar which, during January and February, has salinities lower than 34,5°/oo (Wyrski, 1971). Local patches of low salinity are found along the north Mozambique coast during the late summer. It is suggested that salinities are of little importance to sea turtles in general for they are osmotically highly adaptable (Manton, Karr & Ehrenveld, 1972). There are indications, however, that areas of reduced salinity are favoured by the olive ridley turtle Lepidochelys olivacea (Eschscholtz) 1829, (see Section 2(4), and Hughes, 1972a).

THE SEA TURTLES OCCURRING IN SOUTH EAST AFRICA

Sub-order : Cryptodira Cope 1870
 Family : Cheloniidae Cope 1882

Key

1. Upper jaw conspicuously bicuspid
 at symphysis; carapace covered
 with smooth skin (or small scales
 in juveniles) overlying a mosaic
 of small bones and showing 7
 prominent longitudinal ridges;
 limbs clawless Dermochelys coriacea (Linnaeus)

 Upper jaw not bicuspid; upper
 shell covered with large horny
 shields overlying large bony
 plates, and ridges 0-3; limbs
 with 1 or 2 claws 2
2. Upper shell with 4 pairs of
 costal shields of which the
 foremost pair is never the
 smallest and is separated
 from the nuchal shield 3

 Upper shell with 5 or more
 pairs of costal shields of
 which the foremost pair is
 the smallest and normally in
 contact with the nuchal shield 4
3. Snout not compressed; 2
 prefrontal shields on head;
 shields of upper shell not
 overlapping (except in very
 young turtles); usually a
 single claw on each limb Chelonia mydas (Linnaeus)

 Snout compressed; 4 prefrontal
 shields on head; shields of
 upper shell strongly overlapping
 (except in very young or very
 old turtles); usually 2 claws
 on each limb Eretmochelys imbricata (Linnaeus)

4. Upper shell normally with only 5 pairs of costal shields; bridge on either side of lower shell with 3 enlarged inframarginal shields without pores; colour of adults and young predominantly reddish brown Caretta caretta (Linnaeus)
- Upper shell normally with 6-9 (rarely 4-5) pairs of costal shields; bridge on either side of lower shell with 4 enlarged inframarginal shields, each with or without a pore; colour of adults predominantly olive, of young olivaceous black .. . Lepidochelys olivacea (Eschscholtz)

THE GREEN TURTLE

Genus Chelonia Brongniart 1800

Species: Chelonia mydas (Linnaeus)

- 1758 Testudo mydas Linnaeus. Syst. Nat., ed.10,1,p.197.
Ascension Island.
- 1849 Chelonia virgata (Dumeril). Smith.
Zoology of South Africa.
Reptiles. London. App. p.1-28.
- 1882 Chelonia mydas Linnaeus. Peters.
Reise nach Mossambique.
Zoologie, 3 Amphibien.
Berlin p.18.
- 1910 Vaillant and Grandidier, 26.
- 1937 Hewitt, 15.
- 1939 Deraniyagala, 218.
- 1950 Rose, 456.
- 1953 Deraniyagala, 20.
- 1957 Loveridge and Williams, 474.
- 1965 McAllister, Bass and van Schoor, 13.
- 1966 Legendre, 217.
- 1967 Hughes, Bass and Mentis, 7.
- 1967a Hughes and Mentis, 289.
- 1968 FAO, 31.
- 1969 Day, 238.
- 1971 Frazier, 375.

- 1971 Hirth, 1.1.
- 1889 Chelone mydas Boulenger, 10.
- 1906 Siebenrock, 36.
- 1950 Decary, 94.
- 1952 Fourmanoir, 170.
- 1952 Chelonia mydas agassizi Bocourt. Carr, 357.
- 1967 Pritchard, 201.
- 1967 Chelonia mydas japonica Thunberg. Honneger, 8.
- 1971 Chelonia mydas mydas Linnaeus. Hirth and Carr, 4.

Common names

Green turtle (English); groenseeskilpad (Afrikaans); tortue franche, tortue de mer, tortue verte (French); tortie de mer (Creole); tartaruga (Portuguese); icaha, pateri, casa (Makua); asa (Chimani); hasa (Shangane); sinembo (Shangane for juveniles); ifudu (Zulu); fano, fanojoaty (Vezo, Mahefaly, Antandroy, N. Sakalava); tsakoy (Sakalava); fanohara (Sakalava for juveniles); fanovua (Antonosy).

Peters' (1882: 19) common name itataruca from Mozambique Island is no longer in use and was undoubtedly a modification by the Africans of the Portuguese name for turtles (see above). Similarly his other name nruvi (ibid) was in error and should refer to the loggerhead turtle.

Description (Modified after Loveridge and Williams, 1957 p.476-477)

Snout short, beak not hooked, without cusps; edges of jaws smooth; cutting edges of horny sheath serrated; prefrontals elongate, a single pair; frontal azygous, small; frontoparietal large; parietals 2; supraocular rather large; postoculars almost always 4 although variable in hatchlings (see Table 1 and 2); supratemporals 2; forelimb with moderately enlarged scales along anterior edge, behind them several rows of scales, posterior edge with a series of enlarged scales; each fore- and hindlimb with 1 claw (2 in hatchlings); tail length dependant on sex, mature males having longer tail.

Carapace ovate, subtectiform (juveniles) or smooth (adults), nuchal region truncate, margin serrate posteriorly becoming less so with increasing size (Plates 1 and 2); dorsal shields juxtaposed (one instance recorded of fused dorsal shields forming one continuous plate); nuchal normally one (Tables 1 and 2) broader than long, not in contact with first costals, not in contact with second marginals; vertebrals normally 5, first much the broadest in adults (second broadest in juveniles (Plates 1 and 2)) all broader than long, II - IV longer than broad in adults but as broad as, or broader than, long in juveniles; costals normally 4, 4th the smallest; marginals normally 11 pairs; supracaudal always divided.

Plastron anteriorly sub-truncate, no obvious lateral keels; plastral shields juxtaposed; intergular moderate, rarely absent; brachials 2 or 3 with some smaller scales extending anteriorly; infra-marginals normally 4, without pores; interanal normally absent.

Colour

Carapace of hatchlings black or dark brown with bronze highlights on vertebrals, border white; plastron white; top of head and neck black, shields on side of head black, sharply outlined in white; superior eyelid pale grey; limbs black above with white border; lower half upper jaw, lower jaw and throat all white; undersurfaces of limbs dark brown to grey except at the border which is white (Plate 3).

Juvenile carapace colouring highly variable (see also Deraniyagala, 1939: 228-230). Up to 20cm in carapace length, passes through a dark grey phase; all underparts remain white with exception of flippers; thereafter colours show variability such as:-

- (i) Basic pale red-brown, streaked with dark brown and yellow, all radiating from medio-posterior of shields. Most common colour pattern up to 50cm carapace length. (Plate 4).
- (ii) Basic dark brown heavily blotched and streaked with pale brown, yellow, gold and red brown, rarer than (i).

- (iii) Basic rich red-brown, medio-posterior of shields with pale brown concentration surrounded by rich red brown with radiating streaks of dark brown gold and yellow. (Plate 5), rare.

At this stage all underparts either pure white or pale yellow; head brown or red brown with shields sharply outlined in white. Skin on upper surfaces brown to grey brown and on undersurfaces white to pale yellow.

Adult coloration has been given attention by numerous authors (Deraniyagala, 1939: 228-230; Carr, 1967: 216; Hirth and Carr, 1970: 5; Hirth, 1971: 1.1 - 1.4) and on the basis of carapace coloration some populations have been awarded sub-specific status (Hirth, op. cit.: 1.1).

The undersurfaces of adults are in general dirty white to yellow (plastron) with greenish olive under the limbs; upper surfaces in general similar to that of the carapace which is highly variable. Hirth and Carr (op. cit.: 5) mention a marked colour difference between the sexes in Yemen turtles and Frazier (1971: 390-392) found significant colour differences in the Aldabra population and concluded that; "females are richly pigmented with brown and, in most cases, brown forms a 'bullseye' effect by being conspicuously inside the area of concentrated dark pigment". Further that; "males are more spotted".

Results obtained during the present study suggest that Frazier's conclusions as regards the females exhibiting more brown pigment than males is correct. Table 3 contains a sample of adult green turtle carapace colorations from various localities in the study region and it can be seen that of the males none has brown pigment but of the females no less than 31% had black pigment only on an olive green base (see Frazier, op. cit.; figure 24, plate 26). Table 4 deals with a substantial sample of female green turtles from Europa (n=343) and Tromelin (n=31) and shows that 65% of the Europa females had no concentrations of pigment and 87% of the Tromelin females lacked pigment concentrations. Further, on Tromelin the colour differences between male and female in one instance at least, was negligible (Plate 6).

It is concluded, therefore, that although Frazier's suggestions may hold for Aldabra, (he predicted the correct sex by colour parameters in 85% of cases observed), they hold only as generalizations in the South East African region. His conclusions as to the value to which colour differentiation could be put are also doubtful for few juveniles were seen which could be attributed a sex on the grounds of the carapace coloration (No. (iii) in juvenile colours described above, this section, might be regarded as a female). No single case of discrete coloration in which the sex was not readily identifiable by the tail length, was observed. In the complete absence of proof to the contrary it is suggested that the full development of adult coloration probably occurs at the same time as the development of the conventional sexual characteristics viz. long tails and claws in the case of the male. Selected morphological characters and relationships at various stages of development might yet prove of more value in determining sex before maturity than the colour patterns.

It is concluded that as far as adult coloration in green turtles is concerned the adults in the study region show remarkable polymorphism which, it is thought, neither assists nor hinders the green turtle in spreading widely throughout the region. Frazier's suggestion that perhaps the different sexes live in different habitats against different backgrounds is considered unlikely as along the Natal coast of South Africa the ratio of males to females caught or washed ashore is 1:2. As it is a non-nesting area it is assumed that the turtles have been living there and further the habitat is homogenous along the coast.

Finally reference is made to the excellent colour plates in Frazier's paper; these photographs illustrate the polymorphism of the Aldabran population but could have been taken on Europa Island.

Size and mass

Methods

All hatchling measurements were taken with vernier slide calipers and hatchlings were weighted on an Ohaus triple-beam

balance. Adult measurements were taken "over-the-curve" using flexible steel tape, and straight line using light aluminium calipers. Methods of adult measurements are shown in Figure 22. Plastron length and width measurements were taken using calipers and these methods are not illustrated. See also foot notes** and *** in Table 7. Adults were weighed using a Salters spring balance.

Results

In the study region newly hatched green turtles have carapace lengths of between 45.2 and 51.9mm, and weigh between 18.4 and 29.4g. Table 5 summarizes hatchling data collected on Europa and Tromelin Islands and show a mean carapace length of 48.5mm. These hatchlings fall well within the ranges observed in other localities (Table 6), although the samples from which these latter comparative measurements have been drawn are small.

Hatchling mass is not a valid parameter because of variability resulting from the time of weighing (all hatchlings in this study were weighed the morning following emergence) and the duration of the emergence period. The latter depends on the depth of sand above the nest, as wind action or laying females, can alter the beach surface in relation to the nest.

Nesting green turtle females obtain curved carapace lengths of between 98.0 and 129.0cm (straight lengths 95.5 and 120.5cm) and masses varying between 124.85 and 208.8kg. Table 7 summarizes these and other size parameters for 2 localities but it should be pointed out again that mass data depends on the number of clutches of eggs that the female has yet to lay. A female's mass at the beginning of her laying season will be substantially different from her mass at the end (see Hughes, et. al., 1967: 19, and size and mass, loggerheads, below).

As insufficient data were collected during this present study to present a mass-length relationship the reader is referred to the graph in Hirth and Carr (1970: 14) showing the relationship in South Yemeni green turtles.

For Europa Island Siebenrock (1906: 40) gave a carapace length

figure of between 1 metre and 1m 20 which agrees with the present study results (see Figure 5). Loveridge and Williams (1957: 477) quote him as giving a weight of 450kg for an adult green from Europa but this reference could not be found in the original work and must be assumed to be in error. Furthermore, it is doubtful whether any green turtles nesting on Europa exceed a mass of 227kg.

It is of interest to note, however, that the Seychellois fishing in the St. Brandon Islands reported an extremely large sea turtle that they called the "Fakwa". From their description it was not a leatherback, which they know by another name, but appeared to be an enormous green turtle. The "Fakwa" is apparently extremely rare (Hughes, in press).

Frazier (op. cit.: 387) states that there is a paucity of data on adult green turtle males with which he could compare his substantial and enviable sample data. Having endeavoured in vain to collect male data during the present study only a few data are included in Table 8 and necessity demands a subjective comment on male sizes.

Frazier dealt with the long exploited Aldabran population and showed clearly that captured males there are smaller than captured females (p.387). On St. Brandon, where the population has also been persecuted over a long period, one male was seen captured, and two others observed in copula, all appeared markedly smaller than the females with which they were associated, and would thus agree with Frazier's data. He suggests that harpoon hunting, used in both localities, favours the capture of males and over the years has led to an unbalanced capture sex-ratio and thus a reduction in male size, their being captured before they can attain large size. He quotes figures which show that over the six years prior to his study male captures far outnumbered female. Although in general his argument is agreed with it is pointed out that capture records for 1970 and 1971 on St. Brandon show a preponderance of females, (293 males, 385 females).

On Tromelin and Europa Islands, where the turtle populations are not exploited, numerous males were observed to be the same size as females, neither noticeably larger nor smaller, and there seems to be little doubt that under natural conditions males do attain similar dimensions to that of the female (see Table 8, and Frazier, op. cit.: Fig. 6: 385).

In the majority of copulations observed during the present study males were definitely smaller than the females (Plate 6) and it is suggested that the younger male is more active than the large males and can mount more successfully. Further the lighter, smaller male may be favoured by the female who has to carry the male throughout copulation. If this is the case then harpoon hunting would certainly be selective for smaller males and it need not necessarily suggest that hunting pressure is causing a reduction in male dimensions.

Sexual dimorphism and sex ratios.

Insufficient data were collected during the present study on which to base a lengthy discussion on sexual dimorphism. Mature green turtle males in this region exhibit longer tails, and more strongly curved claws on the fore-flippers, than females as is found in all green turtle populations (see Carr, 1952: 348-349).

Sexual differences in coloration were discussed in section Colour above and found of doubtful value for the study region.

For details on morphometric differences the reader is referred to the work of Frazier (op. cit.: 383-390). In summary; he found that females have more domed carapaces than males and the plastron of the female is both absolutely and relatively larger than that of the male. Other sex differences in his Aldabran material were found in curved carapace length and width, straight length and width and head width but it is uncertain as to whether these differences would persist if animals of similar sizes were compared (see previous section on hunting selection of small males).

Sex ratios in green turtle populations have proved a stumbling block to biological studies of the species. Hirth (1971:4:1) quotes catch records from several sources and ends by stating that it is common to see more males than females off some of the major nesting beaches.

Frazier (op. cit.: 367) states, as mentioned previously, that male catches outnumber those of females on Aldabra Island. Hirth (F.A.O. 1967: 36) shows figures from the Customs Department, Mahé, which support this and further suggests (p.35) that the male:female ratio may be as high as 5:1 or higher. This tends to confuse matters because if the annual catches are predominantly male, and have been since 1964 at least (Hirth, op. cit.: 36), one would expect a relative reduction in the number of males caught, and, if anything, a sex ratio favouring the female.

The figures in Hirth's (ibid.) table are possibly misleading because they are of landings at Mahé from various islands although, apparently, mainly from Aldabra. As the harpoon is the favoured means of hunting turtle, the male is selectively hunted because it presents the easiest target, and thus one has an accumulation of male catches from the islands which would, it seems, distort the picture. For this reason the Seychelles data are not included in Table 9 which summarizes published data on green turtle catches (sources quoted) and data collected during this study.

Observations on Europa Island, protected since 1923, suggest that females outnumber males in the ratio of 3 or 4:1 near the shoreline and in the lagoon. It was suggested that the ratios may be somewhat different in the deeper water offshore but in a film "Turtle Island" (directed and produced by J. Stevens) there were numerous underwater sequences off Europa showing many more females than males and further that females were resting on the ocean floor moving only when disturbed. This latter trait would; (a) reduce the possibility of harpooning a female if she spends most of her time on the ocean floor, and (b) present a distorted picture as males crowd round a receptive female on the surface (c.f. Hirth in F.A.O. ibid.)

Bearing these points in mind and assuming that the catch and stranding records included in Table 9 are accurate, there seems little doubt that in natural populations female green turtles outnumber males. The difference in catches recorded in the table is highly significant ($p < .001$)

As to the actual sex ratio this would appear difficult to assess but it is suggested that it is at least two females for every male.

Distribution and populations

Figure 6 illustrates the distribution of the green turtle in the study region. Areas of optimum numbers are the west coast of Madagascar and the littoral waters of central and northern Mozambique. These areas of abundance correlate well with the presence of sheltered coasts harbouring extensive pastures of undersea vegetation such as Cymodocea ciliata and Zostera sp. As algae are readily eaten (see Section 3) the range of the green turtle is not restricted by diet and is the most ubiquitous sea turtle in the region.

Table 10 and Figure 7 indicate their abundance in relation to other species in the various countries in the study region. Data were derived from net catches, village middens and strandings although hatchling strandings are excluded. Cromie (1966, in Hirth, 1971:4:1) suggests that green turtles represent about 20% of all turtles found throughout the warm seas of the world. From Table 10 it would appear that this is an underestimation for the present study region. A more detailed assessment of populations off the south western coast of Madagascar shows that it is undoubtedly an underestimation in that area (Figure 8).

Despite the limitations of the data in Table 10 a comparison of nesting areas between the green turtle and the loggerhead turtle (the second most common species) suggests that the figures are a valid indicator of the species composition.

There are nine island nesting grounds of green turtles as against two mainland nesting beaches of loggerheads. Further, the green turtles nest widely on the mainland of Madagascar.

If one compares the nesting populations of Europa Island and the Tongaland area, the most heavily utilized areas for the green and loggerhead respectively, one finds:-

Tongaland.

The formula for calculating seasonal nesting populations of loggerheads is fully described in Hughes (1970:11-13). In summary:- Number Active Nesting Females = Highest Number of Clutches laid per night over X days. X days equals the re-nesting interval for the season or part thereof as there is normally a shortening of the re-nesting interval as the season progresses (see Section 5). Maximum recorded seasonal population 502 (see Section 2(3)).

Europa.

The density of tracks on the beaches of Europa precluded the use of the Tongaland method so a series of estimates were made of nightly emergences on the various beaches (Table 11). The Station Beach was worked in detail every night (Table 12 and Figure 9) and where completed track and head counts were periodically made on other beaches, generally after the peak nesting period had passed.

Tag recoveries on the station beach indicated that at least 44.27% of each nightly emergence laid successfully (see Table 13). Similarly from tag recoveries the re-nesting interval on Europa during November 1970 was 14 days (Table 14 and Figure 10).

The formula used for estimating the Europa population was as follows:- Number Active Nesting Females = Estimated Nightly emergence X Nesting Success (%) X re-nesting interval (in days).

$$\begin{aligned} \text{i.e.} &= 710 \times \frac{44}{100} \times 14 \\ &= 4374 \text{ females} \end{aligned}$$

It is assumed that every female laying within an average re-nesting interval is a separate individual. It should be pointed out that on the Station Beach tagging activity constituted a disturbance factor which was not present on the remainder of the island so the nesting success may have been higher elsewhere.

Comparing these two populations it can be seen that the monthly nesting numbers of green turtles on Europa is over 8 times the seasonal numbers of loggerheads in Tongaland and suggests that Table 10 is generally accurate viz. the green turtle is by far the most common species in the study region.

An estimate of the total number of green turtles in the study region is not possible but obviously well into the tens of thousands. The annual capture of green turtles, of all sizes, in south western Madagascar alone is around 7000 (Hughes, 1971: 117). Table 15 shows the estimated annual numbers of nesting green turtles on some of the nesting areas.

Beach preference and nesting areas

Figure 6 shows all of the significant nesting areas of the green turtle in the study region and it would appear that islands are preferred as nesting grounds. However, green turtles nest widely on mainland beaches not only in the study region but in other localities as well (Carr and Caldwell, 1956:1; Carr and Giovannoli, 1957:1; Hendrickson and Balasingam, 1966:69) and it is likely that they nested more densely on the mainland in pre-historical times and that human persecution has reduced their numbers drastically.

Green turtle nesting areas in the study region is restricted to north of the tropic of Capricorn, and has been observed during August (Primeiras, Mozambique), October, November and December (Europa, Tromelin and St. Brandon). Nesting occurs throughout the year on the latter three islands but has a midsummer peak.

Hendrickson and Balasingam (op. cit.: 73) suggest that it is possible that the "feel" of the sand may influence the female's selection of a nesting beach. In other words the texture of the sand may be detectable by the female turtle on stranding. Observations during the current survey render this possibility highly unlikely. On Europa alone sand textures varied from very fine sand close to the dunes to coral pebble beaches and all were utilized by turtles. Further, lower tides exposed bare rock over which females would travel to attain sand patches higher up. Stone and beach debris provided no obstacle to the turtles who appear markedly insensitive to any tactile stimuli (see also Carr, 1967:13). It can be argued that this particular sand sensitivity is present only on stranding and not during the later mounting of the beach but even this seems unlikely as the

texture of the sand at the water's edge is often coarse, and intermixed with shell fragments and bears no resemblance to the beach higher up where the female will lay her eggs.

During the present survey sand samples were collected from transects across the Station Beach at Europa, the north and south facing beaches of Tromelin and the south and west facing beaches of Casuarina Island. Figure 11 shows the beach profile on the Station Beach Europa Island and samples are labelled (a) from the upper beach platform; (b) from the central platform or 20 metres away from (a) and; (c) from the lower beach platform over which the sea washes during exceptionally high tides.

500 to 1000 gram samples were collected from the surface at each site and brought back to Durban in sealed jars. Smaller samples of 200 grams each were weighed out and oven dried at 50°C for at least 12 hours. Each sample was weighed and sieved for 20 minutes through a combination of the following sizes of Tyler Standard Screens:-

<u>Mesh size number</u>	<u>Mesh size (mm)</u>
14	1.168
20	0.833
28	0.589
35	0.417
48	0.295
65	0.208
100	0.147

The mass of the sand retained by each sieve was weighed and expressed as a percentage of the whole. Figure 12 shows the results graphically. Differences between upper level samples (a) and lower level samples (c) of every transect were tested for using χ^2 . A series of tests for differences between beaches at the upper level were also made and the results are summarized in Table 16.

Only one beach (Tromelin north, Figure 12) showed some degree of homogeneity, all other beaches had significantly smaller sand

particle sizes in the upper levels as compared to the lower levels. Further, there were significant and obvious differences between samples from the upper levels of the two beaches on Tromelin and the two beaches on Casuarina. All the beaches were significantly different from one another at the upper levels i.e. the section most heavily utilized by nesting females.

Successful nests are thus laid in coarse coral sand (Tromelin) and relatively fine coral/silica mixture sand (Casuarina). Further, on occasions, individual female turtles emerged in turn on both the north and south beaches of Tromelin Island. It is thus concluded that sand particle size is of negligible importance as regards beach selection by green turtle females.

Biometrics and the comparison of sub-populations

Table 17 summarizes the relationships between selected parameters in samples of green turtle populations from the study region.

Hatchlings

Figure 13 shows the relationship between the straight carapace length and carapace width in a sample of 50 hatchlings from Europa Island. The wide confidence limits indicate the variability of the sample and it is not surprising that there are no significant differences between the Europa and Tromelin hatchlings except in mass (Table 5) which, as has been suggested above, is an unreliable parameter. Figure 14 shows the relationship between carapace length and width for hatchlings from both localities.

Adult females

In adult female green turtles relationships between parameters are similarly variable. Table 7 compares selected parameters from nesting females from Europa and Tromelin and shows that there are significant differences in carapace length, plastron width, head length and head width. Figure 15 shows the relationship between the curved carapace length and curved carapace width for turtles from Europa and Tromelin.

From this data it would seem that Tromelin females tend to be shorter in carapace length but relatively wider. With increasing size, however, there appears to be no difference between the populations. Figure 16 shows the relationships between straight carapace length and curved carapace length in the two island populations and includes, for comparative purposes, data from Aldabra (Frazier, op. cit. 390). The Tromelin and Aldabra populations are similar but the Europa females are distinctly more domed lengthwise than the Aldabran populations. (Ratio: $\frac{\text{Curved C.L.}}{\text{Straight C.L.}} = 1.08 \text{ (Europa); } 1.06 \text{ (Aldabra)}$)

Figure 17 shows the relationship between straight carapace width and curved carapace width and there are no apparent differences around the mean levels between the three populations.

Figures 18 to 21 show the relationships between the straight carapace length and plastron length, plastron width, head width and head length respectively. Only in plastron width does the Tromelin population appear more variable than the Europa population. All other relationships could be regarded as variations within a single population.

No importance is attached to the differences noted in the head measurements because a comparison of female skulls from Europa, Tromelin, St. Brandon and South Africa showed that for six measurements (see Figure 22 for methods; Table 18) there were no significant differences between any of them ($p > .05$). Furthermore there was no correlation between any of the parameters measured suggesting that skull growth is highly variable (Table 18).

Considering that there are no differences between the hatchlings it seems strange that adult females are significantly smaller in the Tromelin population. This difference might be merely a sampling artefact because very few turtles were nesting on Tromelin during October 1971. Not having had any tag returns from turtles tagged on Tromelin the feeding ground of this population is as yet unknown but it may be that feeding opportunities are not as favourable for the Tromelin population. It is likely

that Tromelin turtles feed off the east coast of Madagascar which is a moderate energy coastline lacking in sheltered shallow bays in which are found growing the spermatophytes regarded as the most favoured food organism of the green turtle.

The apparent difference in food opportunities may be expressed also in the egg production. Table 19 compares the diameter and mass of individual eggs and also the clutch sizes and clutch mass of eggs from Europa and Tromelin Islands. Europa has a significantly higher clutch size although the individual egg measurements for the two populations are almost identical. The mass of the clutches are also, as expected, significantly different ($p < .001$, Table 19(b)).

There is no relationship between the curved carapace length of green turtles and the number of eggs laid (Figure 23) but it was thought that a relationship might be found between the size of the female and the space volume occupied by the eggs. Table 20 shows records of ten clutches from Tromelin Island and also that there is a significant relationship at the 10% level only; i.e. there is a tendency for larger females to lay larger clutches by volume and by mass. It is, however, unlikely that this tendency would explain the highly significant clutch size difference between the two populations.

It seems probable that the presence of a substantial population of large green turtles laying large clutches of eggs on Europa Island is an indication of the optimal feeding conditions along the sheltered western littoral of Madagascar.

It also seems possible that the somewhat more domed carapace of the Europa females as compared with those females from both Tromelin and Aldabra is a result of the greater egg production.

This is not certain for Aldabra, however, as Frazier's (op. cit.: 380) sample of 4 clutches (mean = 89 eggs/clutch) is rather too small on which to base conclusions, but would seem a plausible hypothesis to explain the difference between the Europa and Tromelin populations.

Discussion

It has been shown that the green turtle in the study area shows some variation but, in general, all parameters in each population overlap and none differ markedly from green turtle populations elsewhere. The colouring of green turtle carapaces is so variable that it is difficult to ascribe a reason for it and all must be of equal value or there should have been some selective pressure brought to bear on disadvantageous colouring.

With any attempt at distinguishing discrete populations of turtles in the study region on the basis of colour being negated, and the variability in adult morphometrics being such as to negate the possibility of their use in separating the populations, it is concluded that all the green turtles in the south western Indian Ocean are of the same strain but are divided into separate nesting populations which may or may not mix on feeding grounds. No tag data having been received as yet which would suggest one point of view or the other.

It is likely, however, that there is mixing because when the curved carapace lengths of adult green turtles (sex unknown) from Madagascar and Mozambique were compared, no significant difference was apparent ($n=72$; $p>.4$). As the South African coast does not host a nesting population it is assumed that green turtles found on the east coast are drawn from Mozambique and/or Madagascar.

It is also suggested that those differences that have been demonstrated are probably an indicator of the availability of food reserves and/or environmental conditions for there appears no other valid reason why one population should be different in size to another nor why their egg producing potential should be markedly different.

THE HAWKSBILL TURTLE

Genus Eretmochelys Fitzinger 1843Species: Eretmochelys imbricata (Linnaeus) 1766

- 1766 Testudo imbricata Linnaeus. Syst. Nat., ed.12,1,p.350.
 1882 Chelonia imbricata Temminck and Schlegel. Peters, 17.
 1910 Vaillant and Grandidier, 26.
 1889 Chelone imbricata Greef. Boulenger 183.
 1906 Siebenrock, 40.
 1930 Petit, 100.
 1950 Decary, 94.
 1937 Eretmochelys imbricata Hewitt, 16.
 1939 Deraniyagala, 187.
 1950 Rose, 327
 1953 Deraniyagala, 17.
 1956 Jones, 376.
 1957 Loveridge and Williams, 485.
 1966 Legendre, 217.
 1967 Hughes, Bass and Mentis, 50.
 1967 Carr, 227.
 1968 FAO, 3,33.
 1969 Day, 237
 1971a Hughes, 55.
 1971 Frazier, 398.
 1973 Hughes, 41.
 1952 Eretmochelys imbricata squamata Agassiz. Carr, 373.
 1966 Minton, 62.
 1967 Eretmochelys imbricata bissa (Rüppell). Pritchard, 203.

Common names

Hawksbill turtle (English); valkbekseeskilpad (Afrikaans); tartaruga (Portuguese); tortue ecaille, caret (French); fanoahara (Northern Sakalava, Vezo); fanojaty (South Sakalava); fanotanga (Antonosy); inhama (Chimani); inhapa, ngapa, xicore, mamba (Makua); sissassambanga (Shangane); taha (Xuabo).

Description

Snout elongate, compressed; beak drawn out but not hooked, without cusps; edges of jaws smooth; prefrontals not elongate, in 2 pairs; frontal azygous, small, rarely fused with frontoparietal (Loveridge and Williams, op. cit.: 487), fused in 1 specimen out of 5 in Durban Aquarium; frontoparietal large, entirely or semi-divided anteriorly; parietals 2, transverse in juveniles, decidedly elongate in adults; small interparietal present in one specimen out of 5 in Durban Aquarium; supraocular large; postocular 3 (Table 21), occasionally 4 (Loveridge and Williams, ibid.); supratemporals 2 or 3; forelimb with moderately enlarged scales along anterior edge, behind them several rows of scales, posterior edge with a series of enlarged scales; both fore- and hind limbs with 2 claws; tail short in females, longer in males.

Carapace ovate, subtectiform in adults, with 3 interrupted keels in young but only a trace of the lateral ones persisting in adults; nuchal region truncate, margin serrate in juveniles, strongly serrate in adults; dorsal shields juxtaposed in hatchling (Loveridge and Williams, ibid.), strongly imbricate from less than 1 year old through to adult becoming juxtaposed in aged individuals; nuchal broader than long, not in contact with first costals, not in contact with second marginals; vertebrals 5, occasionally 6, exposed portion of each broader than long at all ages, the first no broader than the others in young, broader than the others in adults; costals 4, 4th smallest; marginals most commonly 11 pairs, occasionally 12 pairs or mixed 11/12; supracaudals 2.

Plastron anteriorly rounded, 2 prominent lateral keels; plastral shields more or less imbricate from less than 1 year of age, juxtaposed in aged individuals; intergular either present or absent; inframarginals normally 4 pairs without pores, occasionally 3; interanal either present or absent.

Table 21 summarizes the lepidosis of hawksbill turtles handled during the current survey.

Apparently the tortoiseshell scales of the female are far more robust than those of the male.

Colour

No hatchlings were collected during this study so colour descriptions start from specimens ranging in age between one and two years.

Juvenile coloration is highly variable being either, more commonly, dark brown with the carapace flecked, streaked and blotched with gold and pale brown, or with the predominant colour being golden yellow with flecks and streaks of various shades of brown (Plate 7). The plastron is normally pale red-brown with pale patches. Head and limbs dark-brown with all scales clearly outlined in white or creamy yellow (Plate 8).

Sub-adult and adult carapace colouring mainly darker in tone some almost black with yellow blotches (Plate 9); colour of plastron almost uniform red-brown; head and limbs very dark brown verging on black with scales outlined in pale brown or very dark yellow.

Size and mass

Data in this section is based mainly on unsexed material collected in middens and/or stranded animals from the Natal coast. As most of the latter are juvenile or sub-adult (Table 22) no comment can be made on size differences based on sex. No hatchlings were handled during the present survey but Siebenrock (1906: 40) gives the carapace length of two hatchlings from Majunga as 38.0 and 43.0mm.

Adult hawksbills in the study region can attain a curved carapace length of 86.0cm (straight carapace length 78.6cm) and a curved carapace width of 75.10cm (straight carapace width 62.8cm). The measurements exceed those described by Loveridge and Williams (op. cit.: 488).

One adult female hawksbill in the Durban Aquarium has attained a curved carapace length of 93.5cm (straight carapace length 78.6cm), curved carapace width of 89.5cm (straight carapace width 62.8cm), a plastron length of 71.9cm, width of 59.5cm, and a head width of 12.8cm.

All measurements fall within the range for the Caribbean hawksbill population described by Carr, Hirth and Ogren (1966:5), and are little different to specimen 5 described by Frazier (op. cit.: 398), nor are they markedly different from the South Yemeni hawksbills (range carapace length 63.5 - 72.5cm) described by Hirth and Carr (op. cit.: 21).

Figure 24 shows the relationship between straight carapace length and mass based on stranded specimens and captive animals in the Durban Aquarium. Despite the obvious shortcomings of using some captive material in the preparation of the graph it is felt justified on the grounds that no other graph is available. The mass of the large female in the Durban Aquarium is 139.1 kg (306 lbs) but she is displaying signs of obesity.

Sexual dimorphism and sex ratios.

No data were collected during the present survey dealing with either sexual dimorphism or sex ratio.

Distribution and populations

Figure 25 shows the distribution of the hawksbill turtle in the study region. Areas of highest numbers are western and northern Madagascar, where they are, incidentally, most heavily exploited (Hughes, 1973; Figure 4: 42), and Mozambique north of Beira. South Africa must be regarded as a marginal area for the hawksbill because of 11 recorded strandings all have been either sub-adult or juvenile (Table 22).

Their contribution to the total sea turtle population is shown in Figure 7 and in Figure 8 it can be seen that in Mozambique it is the second most common species and probably is in the western region of Madagascar also. The problems with the latter area is the fact that so many hawksbills, particularly juveniles, are transported for sale and thus beyond record.

It is not possible to assess the populations accurately as no breeding grounds were worked during the current survey. Data gathered during two visits to Madagascar suggest that approximately 2500 hawksbills are killed annually in the territory. Table 23

summarizes these data and the figures were derived from direct specific information and, in the case of most adults, from annual weights of tortoiseshell handled or exported (2.5 kg ■ 1 adult) (see also Hughes, 1973: 43). It can thus be seen that the contribution of the hawksbill to the total species composition in Madagascar is probably higher than recorded in Figure 8.

Beach preferences and nesting areas

As only two hawksbill nests were observed during the current survey few comments can be made on either beach preferences or nesting areas.

Hawksbills nest on the Primeiras, the St. Brandon Islands (Mr. L. Couacaud, Manager, Mauritius Fishing Development Co., pers. comm.), Tromelin and the mainland of Madagascar particularly on the north-east coast. Thus, most of their beaches are shared with the green turtle and it is assumed that their beach preferences are similar. Figure 25 shows the known and reputed nesting areas and it is believed that the beaches of north-eastern Madagascar are the most heavily utilized by nesting hawksbills. It was thought, until recently, that hawksbills were almost entirely disparate nesters and did not exhibit mass or even modest nesting agglomerations such as has been demonstrated for all other species. Recent surveys by Dr. H.R. Bustard (pers. comm.) indicate that this may not be the case as he had found such agglomerations off the north Queensland coast. Such a situation, comprising modest agglomerations, may pertain in north-eastern Madagascar.

Biometrics

With the paucity of available material biometric relationships are presented hesitatingly. Figure 26 shows the relationship between curved carapace length/curved carapace width and between the straight carapace length/straight carapace width using Bartlett's regression. More refined regression analyses were considered unjustified because the data were unsexed and from widely scattered localities.

Figure 27 shows the relationship between straight carapace length and the plastron length and would suggest that there is a consistent relationship throughout the life time of the hawksbill turtle. Figure 28 showing the relationship between head width and straight carapace length and shows slightly more variation. Evidence for allometric growth is best illustrated in the ratio between these two parameters. At carapace length 20.0cm the ratio is 0.18 and at 60.8cm the ratio is 0.14. This ratio in a Caribbean hatchling (data from Carr, Hirth and Ogren, op. cit.: 5) is 0.34, and 0.33 in a South Yemeni hatchling (Hirth and Carr, op. cit.: 20).

Measurements from 7 hawksbill skulls are presented in Table 24.

Discussion

There are no obvious differences between the hawksbill material collected during the present study and the material described by Hirth and Carr (op. cit.: 6) or Frazier (op. cit.: 398-399) from South Yemen and Aldabra respectively.

Carr (1952: 373) states that hawksbills are not known from the Cape of Good Hope and that it is very doubtful that they meet the south Atlantic stocks in this region. Strandings recorded during the present study show that they do occur around the Cape (and from the Atlantic shore; Blaauwberg Strand, South African Museum No.43300; Woodstock Beach S.A.M. No.43299) so mixing probably does occur when or if individuals passing round the Cape are transported up to warmer latitudes. It is considered highly unlikely that the Angolan stocks move down the west coast of Africa to the Cape because this would entail a deliberate movement, through waters as low as 14°C, over a distance of at least 1600 km. These strandings provide a demonstrable link, or the possibility of one, between the western Indian Ocean stocks and the Atlantic stocks and might be taken as further evidence against the taxonomic separation of the two oceanic populations.

As it is the separation stands on such nebulous grounds as carapace "more heart-shaped", and upper surfaces of head and flippers "less black" and these criteria seem unjustified as was implied by Carr (1952) and ignored by Loveridge and Williams (op. cit.).

THE LOGGERHEAD TURTLE
Genus Caretta Rafinesque 1814

Species: Caretta caretta (Linnaeus) 1758

- 1758 Testudo caretta Linnaeus. Syst. Nat., ed.10,1,p.197.
- 1889 Thalassochelys caretta Boulenger, 184.
- 1910 Vaillant and Grandidier, 26.
- 1930 Petit, 100.
- 1950 Decary, 94.
- 1966 Legendre, 217.
- 1933 Caretta gigas Deraniyagala, 66.
- 1936 Deraniyagala, 249.
- 1939 Caretta caretta gigas Deraniyagala, 164.
- 1943 Deraniyagala, 84.
- 1944 Deraniyagala, 95.
- 1945 Deraniyagala, 16.
- 1952 Carr, 393.
- 1953 Deraniyagala, 13.
- 1967 Carr, 223.
- 1967 Pritchard, 196.
- 1937 Caretta caretta Hewitt, 15.
- 1950 Rose, 455.
- 1963 Bass and McAllister, 1.
- 1965 McAllister, Bass and van Schoor, 13.
- 1967 Hughes, Bass and Mentis, 7.
- 1969 Day, 238.
- 1971a Hughes, 53.
- 1971 Frazier, 401.
- 1972b Hughes, 15.
- 1972 Hughes and Brent, 40.

Common names

Loggerhead turtle (English); karetseeskilpad (Afrikaans); gros tête, tortue couanne (French); tartaruga (Portuguese); ilongosi (Zulu, Thonga); eluvi, rufi (Makua, Swahili); ngambo (Shangane); sinyola (Sisonga); amphombo (Vezo, Sakalava, Mahefaly, Antandroy); fanomena, fanovema (Antonosy); tsiasara, tsiarara (North Sakalava).

Description

Snout relatively short, occasionally compressed; beak distinctly hooked, unicuspid; edge of jaws smooth; prefrontals not elongate, in 2 pairs; frontal azygous, small, longer than broad; fronto-parietal as broad as long, semidivided both posteriorly and anteriorly and occasionally laterally; parietals broken up; supraocular large; postoculars normally 3 per side but somewhat variable; supratemporals in 3 pairs; forelimb with moderately enlarged scales along anterior edge, behind these numerous small scales, posterior edge with a series of distinctly enlarged scales; both fore- and hind limbs with two claws the outermost of which becomes recessed and gradually reduced in size through time until maturity when it is barely visible; tail short in juveniles and remaining so in females, adult males have a longer tail (see Sexual Dimorphism, this section).

Carapace ovate during most of lifetime, post-hatchling to sub-adult specimens occasionally as broad or broader than long; tectiform, hatchlings have three interrupted keels the two outermost of which become weaker with age; central keel develops sharp spines on vertebrals until the carapace length reaches 30cm where with the broadening process mentioned above the keels flatten out; keels still visible as interrupted bumps at straight carapace length 65cm; 4 plastral keels low and interrupted disappearing by the time the straight carapace length reaches 50cm; nuchal region truncate, margin markedly serrage in sub-adults, less so in mature animals; dorsal shields juxtaposed; nuchal normally 1 occasionally 2, broader than long, in contact with first costals where costals are 5 or more each side, not in contact in rare instances when costals are 4 per side; vertebrals normally 5; costals 5 per side, first smallest; marginals normally 12 pairs, supracaudals always 2.

Plastron anteriorly rounded, scutes juxtaposed; intergulars and interanal either present or absent, more normally absent; inframarginals normally 3 pairs without pores.

Table 25 summarizes the lepidosis of a sample of loggerhead hatchlings from Tongaland, Natal and Table 26 summarizes the lepidosis

of adult and sub-adult loggerheads from various localities in the study region. It can be seen that with the exception of the supracaudals all shields show variation. From the total sample combined; adults, sub-adults and hatchlings, the definitive scalation is as follows:-

Nuchal 1	:	91.3%	(n = 175)
Vertebrals 5	:	95.4%	(n = 175)
Supra caudals 2	:	100.0%	(n = 175)
Costals 5L 5R	:	85.1%	(n = 175)
Marginals 12L 12R	:	67.1%	(n = 173)
Infra-marginals 3L 3R	:	87.1%	(n = 70)
Post-oculars 3L 3R	:	78.2%	(n = 119)

Table 27 summarizes osteological data collected from 31 loggerhead carapaces from the Natal coast and 4 examples of the neural patterns are illustrated in Figure 29.

In the bony carapaces nuchal always one; neurals highly variable but most commonly 10 only occasionally interrupted by pleurals; suprapyrgals normally 2, occasionally 1 or 2; pygal 1; pleurals in 8 pairs and peripherals 12 pairs; ribs enter peripherals 4,5,6,7,8,9,11 and 12.

Colour

Newly hatched loggerhead turtles in Tongaland are plain grey-brown when dry, pale red-brown when wet; red-ochre and yellow-ochre coloured specimens have been observed in clutches emerging through sand discoloured by forest humus of similar colour; underparts and skin dark brown to black except in the centres of the plastral shields which are lighter in tone; beak and eyelids black or very dark brown; beak lightens within months to red-brown and the centres of scales on flippers also lighten rapidly. By the time the turtle reaches a carapace length of 100mm the overall upper coloration is predominantly red-brown with some streaking in either light or dark brown.

Albino hatchlings have been observed only rarely (Hughes, Bass and Mentis, 1967: 35).

With the increasing size there is a lightening of the underparts through a blotched creamy-white to a rich golden yellow which suffuses the throat, sides of neck and head and underparts of flippers (Plate 10) but seldom reaches the upper surfaces of the neck and flippers which are always darker in colour. The carapace colour intensifies and becomes either plain red-brown, red-brown with darker streaks or dark brown with streaks. At adulthood, in the Tongaland population, streaked carapace coloration is more common than the plain red brown (Table 28).

Adult plastra and skin-underparts are variable from dirty-white through yellow-white, pink-yellow to plain yellow. Yellow often persists on the throat, sides of head and neck; when this occurs the centre of the head scales are a darker red-brown. Occasional females with almost melanistic coloring having intense black on upper surfaces, are encountered in Tongaland.

Size and mass

The Tongaland loggerhead hatchling has a carapace length of between 38.7 and 48.8mm. The mean carapace length of 1004 hatchlings taken from 121 clutches over 8 seasons is 44.7mm. As with green turtles, material was weighed and measured the morning following emergence and only emerged hatchlings were investigated because Hughes and Mentis (1967: 65) showed that there were significant differences between successfully emerged hatchlings and those remaining behind in the nest.

Table 29 compares the length and range of length of the Tongaland hatchlings with data from other localities (sources quoted) although only one group of data, that from South Carolina, is really comparable. The Japanese sample, although fairly substantial, is extracted from a continuous column of measurements which is divided into clutches but to which is not attributed the time interval between hatching and measurement.

On average it would appear that the Tongaland loggerhead is fractionally smaller than all other populations with the possible

exception of the Colombian record which appears to be from a single specimen and thus hardly comparable. However, there has been an apparent seasonal variation in mean carapace length over 8 seasons in Tongaland and it is therefore highly probable that similar seasonal variations occur in other localities. Taking this into consideration the widely separated populations so far investigated appear to be remarkably stable as far as hatchling size is concerned. The range of mean sizes is only 1.1mm.

Adult female loggerheads in the Tongaland population can reach a curved carapace length of 107.0cm (straight carapace length 98.54cm) and a mass of 140kg but both of these measurements are extreme. Table 30 summarizes the measurements and mass of loggerhead material collected in various localities in the study region. Table 31 compares the mature female straight carapace length with those from other localities (sources quoted). Figure 30 shows the size distribution of curved carapace length in Tongaland females for 7 seasons in Tongaland, Natal. It is perhaps worth noting that there was no difference between the mean curved carapace length and best estimate standard deviations of the 1965/66 population ($n = 134$) and the 1972/73 population ($n = 259$) ($p > .7$).

There is no doubt that the Tongaland female does not attain the dimensions of the Atlantic population on the eastern America seaboard so the suggested difference observed in the hatchling measurements is probably real.

The modal curved carapace length for the 7 seasons illustrated in Figure 30 shows variation from 92-97cm although the past 3 seasons have shown a decrease from 96-95-93cm. It is clear that further work will be required to see whether the modal length will stabilize or continue to shift. It is suggested that it will continue to change within the illustrated range for one cannot discern any size classes in the mature nesting population in Tongaland. Females appear to mature at differing sizes and thus size cannot be correlated with age.

Table 30 includes data from male loggerhead turtles taken along the Natal coast and these measurements would suggest that

the males only rarely attain the same dimensions as the mature females in Tongaland. This is, however, a doubtful observation because no males have been measured in Tongaland and when one compares the female material collected off the Natal coast with that of mature nesting females there are significant differences in every parameter ($p < .001$) except that of plastron width which difference is not significant ($p > .2$). This would suggest that the Natal coast female material is immature and it is thus likely that the male material is similarly immature. Figure 31 shows the size distribution (straight carapace length) of all material gathered in Natal (males, females and juveniles), unsexed material from Madagascar and a sample of mature females from Tongaland.

There is nothing in the material collected to suggest that male loggerhead turtles obtain dimensions any greater than that of the female and it seems likely that they can attain equal dimensions. There are however, some sexual differences (see below, this section).

Figure 32 shows the relationship between straight carapace length and mass based on material collected along the Natal coast, both sexes included. Few data from captive material are included in the graph for loggerheads in the larger sizes tend to become obese in captivity. Uchida (1967, Figure 6: 503) gives a graph showing the relationship between body length and mass derived from data collected from 2 loggerhead specimens reared in captivity. Masses of wild material collected on the Natal coast do not fit the line but tend to be lighter at each level. This is to be expected as captive animals tend to lead more sedentary lives and thus as mentioned above, attain a greater mass which would have undoubtedly influenced Uchida's results.

Uchida did not include fully adult specimens in his graph and the mass of mature nesting females from Tongaland were not included in Figure 32. In Tongaland, variations in the relationship between mass and different measurements are so great that it is not possible to arrive at a satisfactory formula for deriving the body mass of any individual female turtle from straight carapace length or any other parameter. One turtle on three separate occasions,

was weighed at 114.6, 115.5 and 126.4kg and another female weighed 107.3 and 116.8kg on different occasions (Hughes et. al. 1967: 19). As clutch masses are around 6kg and one turtle can lay up to 5 times, a nesting female's mass can vary by 30kg, or 25%, in a 120kg animal and is thus a most unsatisfactory parameter.

It is perhaps appropriate to mention the unfortunate lack of temperature data when presenting growth data or mass data. Sea turtles, being poikilotherms, respond to temperature differences and it is very likely that the data presented in some publications are based on material grown either in artificially heated water or in aquaria with equable temperatures throughout the year but not necessarily those to be found in the natural habitat of the turtle under study. Caldwell (1962a: 6) stated that water was pumped from the nearby shore and thus was sufficiently close to the "natural" ambient temperature to make growth rate, and thus mass, indicative of that in a wild state. This may apply in the Florida region but is not applicable to the Natal coast. Firstly, turtle hatchlings are swept past Durban and thus spend little time in the vicinity, and further, travel south to colder latitudes which would undoubtedly affect their growth rates and mass (see section 3). From published data (cf. Brongersma, 1972: 147) loggerheads from Florida probably pass out of Florida waters and are subjected to cooler temperatures than those that pertain around the coast of Florida, this would cast doubt on Caldwell's conclusions.

To conclude this section Figures 33 and 34 are presented. Figure 33 shows the mean monthly coastal temperatures in Tongaland, Durban, Port Elizabeth and Cape Agulhas and the range of temperatures between 1969 and 1972 inclusive.

Figure 34 shows the sea temperature taken 150 nautical miles away from the coast at the same four points and over the same period. All data were extracted from the 10 day sea surface temperature charts issued by the South African Maritime Weather Office, Cape Town.

Included in Figure 34 is the annual range of temperature roughly in the centre of the Agulhas Gyral (33°S; 35°E) for 1963. These data were extracted from Wyrski (1971).

It can be seen that the length/mass relationship expressed in Figure 32 is derived from material that has grown up in waters whose temperatures vary from between 14.0°C (Cape Agulhas) and 27.7°C (Tongaland) and it is probably as near a natural relationship as it is possible to obtain.

Sexual dimorphism and sex ratios

Two loggerhead turtles, a male and a female, have been reared in the Durban Aquarium from hatchlings through to 9 years and 4 months of age. No external sexual differences were apparent until the animals reached a straight carapace length of between 60.0 and 67.0cm (6-7 years of age) when the tail and claws of the male started to lengthen perceptibly. Figure 35 shows the differences in tail and claw growth of the two sexes. Finer distinctions, if any, have been obscured by the female's tendency towards obesity.

Sufficient wild material has been gathered to show that there are other differences between the sexes apart from the tail length (ratio male : female; 3 : 1) and claw length (3:1). A comparison of 9 parameters summarized in Table 30, between Natal coast males and females show no significant differences except in plastron length ($p < .05$). Male loggerheads have shorter plastrons than females (Figure 44) presumably to accommodate the strong muscular tail, as was suggested for the green turtle by Frazier (op. cit.: 388).

Females are also more domed than males. The ratios of straight carapace length/curved carapace lengths are:-

Natal males	:	1	:	1.06
Natal females	:	1	:	1.07 (immature)
Tongaland females	:	1	:	1.08 (mature)

Further, the ratios of straight carapace widths to curved carapace widths are:-

Natal males	:	1	:	1.23
Natal females	:	1	:	1.22
Tongaland females	:	1	:	1.27

The males appear to be relatively wider (Figure 36) than females but there is no significance when whole figures are compared.

When compared to the Natal females, males show a tendency towards having wider heads ($p < .2$). It is regrettable that there was insufficient adult male material with which to compare Tongaland females. Table 32 summarizes skull data from a sample of loggerhead material and there was no significant difference between the sexes in any of the parameters measured.

As so few male loggerheads have been seen in the Tongaland area it is difficult to assess the sex ratio in a wild population. Stranded loggerheads along the Natal coast, however, consisted of 13 males and 22 females giving a ratio of 1 : 1.7. This would suggest that the sexes ratio is similar to that suggested for the green turtle i.e. 1 : 2.

Distribution and populations

Figure 37 shows the distribution of the loggerhead turtle in the study region. Although common along the African and Madagascar coasts it appears rare near oceanic islands. Only one sub-adult specimen has been studied at Aldabra (Frazier, op. cit.:401), loggerheads are known in the St. Brandon Islands but seldom encountered. Occasionally loggerheads appear off Reunion Island but never, apparently, as adults nor as permanent residents.

Legendre (1966: 217) stated that loggerheads were observed in the channels of the lagoon on Europa Island. During a six-week visit to Europa during the present survey no loggerheads were observed and it was suggested by Mr. Andre Mauge, a member of the Legendre expedition, that this may have been a misidentification, there being confusion between juvenile greens and loggerheads.

From Figure 8 it can be clearly seen to be the most common species off the east coast of South Africa constituting 59.0% of the total population. They are also very common off the south coast of Madagascar.

With only two nesting areas, only one of which has been studied in detail, an estimation of the total population is difficult.

In the 56km protected area in Tongaland, Natal some 1791 loggerhead females have been tagged over the past ten years. Recovery rates have reached the 47% level (see Section 4, below) so it is possible that approximately 4000 females utilize this nesting beach, but this will depend on the nesting lifetime of the individual female. If it spreads over a ten year period such an assumption will be justified. If it is much less or much more then some revision will have to be made when more definite information is forthcoming. Only two females have been observed to nest in four separate nesting seasons so far but the loss of plastic tags used in earlier seasons has confused results.

Hearsay reports in South East Madagascar claimed up to twenty females per night nesting along the coast between Fort Dauphin and Saint Luce. Assuming that the loggerhead behaviour in Madagascar is similar to that of Tongaland, this would suggest that the nesting population is in the region of 280-300 females per season which makes it only slightly smaller than the Tongaland population. Taking into consideration the much wider nesting distribution of the loggerhead on the mainland of Africa i.e. from 20°S to 28°S, it is likely that there are no more than 10,000 nesting females in the study regions. This figure is made up of approximately 4,000 in Tongaland, 3,000 in Madagascar and 3,000 in the remainder of the African mainland. If the adult sex ratio (see sub-section above) is in the region of 2 females to every male then the total sexually active population of loggerhead turtles in the study region would be in the region of 15,000. The Tongaland population appears similar in size to that described for Colombia by Kaufmann (1971: 76) although his total figure of 400-600 females per season is an extrapolation and not from direct observation. Although no specific figures have been published on the North America populations it would appear to be far in excess of the Tongaland population. No details are available on the Australian or the Japanese populations.

Beach preference and nesting areas

In the study region loggerheads nest only on silica sand

beaches, generally with offshore reefs, rocky outcrops and forest covered dunes backing the beaches. The physical background to the beaches frequented by nesting loggerheads does, however, appear variable as Bustard (1968) states that loggerheads will nest in areas where grasses comprise the only ground cover. Baldwin and Lofton (op. cit. 327) reached a conclusion similar to the present author's in that the Atlantic loggerheads showed a preference for a beach backed by high dunes or vegetation which presents a dark and broken horizon to a turtle in the water. In the case of the study region in Tongaland there is only one locality between 35 and 38km (23-25 miles) south of the Bhanga Nek camp (Boteler Point) which is "open", i.e. with no immediately close sand dunes or vegetation.

Figure 38 shows a composite picture of the littoral zone of the Tongaland nesting beaches and Figure 39 the profile of a portion of beach heavily utilized by loggerheads. McAllister, et. al. (1965: 18) suggested that of the two types of beaches found in Tongaland viz. the retrograded type (Figure 39) and the flatter prograded type (inset Figure 39), the loggerhead showed a preference for the retrograded type. As the beaches in Tongaland are notoriously unstable and can change from one type to another, or indeed, disappear completely leaving bare rock during a single tide, it would appear more accurate to state that the retrograded beach is the most common in Tongaland and thus more heavily used than the prograded beach, but both are used. In Figure 38 the 6.8km (4 $\frac{1}{4}$ mile) north stretch is prograded but it can be seen that there is little difference in the nesting activity between this stretch and adjacent retrograded beaches. Loggerheads in Tongaland nest at all accessible levels of the beach above the high water mark and this distance can vary from the lowest levels, occasionally being washed over by exceptionally high spring tides, to the tops of 30 metre dunes necessitating a crawl of nearly 300 metres.

As was shown for green turtle nesting beaches, sand particle size on Tongaland beaches is also variable and it appears of negligible importance in the choosing of a nest site. Figure 40

shows the sand particle composition of sand samples taken above the high water level at 12 different sites within the protected area.

There is a tendency for loggerheads to nest on beaches fronted by, or adjacent to, outcrops of rocks and/or sub-tidal close inshore reefs (see Figure 38). A similar situation appears to pertain at Mon Repos, Australia (Bustard 1968). As this necessitates negotiating rocky channels or the rocks themselves this seems peculiar when a completely obstacle free access may be available within a few hundred metres or less. It is suggested that this may be associated with the final orientation mechanism which will be discussed later in Section 4. The suggestion by Hughes, *et. al.* (1967: 13) that this is possibly because the loggerheads feed on the reefs is discounted in view of the fact that the "loggerheads" seen feeding on the reefs during the day have subsequently proved to be green turtles.

The loggerhead turtle is the only true temperate waters nester. Nesting distribution within the survey area is on the mainland of Africa between Pomene (23°S) and St. Lucia Estuary mouth (28°S). Occasional incidents of nesting still occur around Durban (30°S) and there is one recorded nesting having taken place at Dassen Island (K. Edwards, *pers. comm.*)(34°S; 19°E) and at Mossel Bay (34°S; 22°E) (Hewitt, 1937: 15) although the latter nesting was not positively identified as a loggerhead.

Although the present nesting distribution on the main land of Africa ends abruptly at about 27°S there is a distinct possibility that nesting once occurred further south. The first law to protect sea turtles and their eggs was passed just after the turn of the present century. It is highly unlikely that this law was passed to protect the Tongaland nesting beaches whose existence became generally known only in 1963 (Bass and McAllister, *op. cit.*: 287). Further Hewitt (*op. cit.*: 15) mentions a report that sea turtles were once heavily exploited along the south coast of Natal at least as far south as 32°S but the report did not state whether these were all taken in the sea or on beaches. Brongersma (1972: 146) points out that the loggerhead turtle breeds further north

than any other species in the Atlantic Ocean reaching 35°N on the North American coast and 35°N on the African coast (Pasteur and Bons, 1960: 27). It also nests in Turkey and Italy (Bruno, 1969 in Brongersma, ibid.).

In Japan the loggerhead nests as far as 35°N (Nishimura, 1967: 29). In the southern hemisphere the Australian population nests as far south as Bundaberg at 25°S (Bustard, 1968) which is very similar to the South East African population. The common denominator for every loggerhead turtle nesting area appears to be the 25°C summer isotherm which forms the poleward limit of every loggerhead nesting area with the possible exception of north west Africa. Table 33 summarizes these data and it will be seen that of 9 nesting beaches 7 are limited in the polar extreme by the 25°C summer isotherm, 1 is limited by the 26°C isotherm (Madagascar) and only in North West Africa does nesting appear to take place in seas having temperatures less than 25°C. Data is so limited from this region, however, being restricted to a mere statement that the species nests in the region, that further debate must be deferred until the exact or even approximate status of a possible nesting population is established. The record published may refer to a single stray nesting.

On the equatorial boundary of the nesting range the summer temperature does not exceed 28°C for 5 areas, 27°C for 4 areas and in the Mediterranean does not exceed 25°C.

In conclusion the loggerhead appears to favour silica sand beaches although they are known to nest rarely on coral beaches such as are found on Heron Island, Australia (Bustard and Greenham, 1968: 269). Sand particle size appears to be of minor importance as most silica beaches are made up of fine to medium grain sand (Figure 40) and the nesting range is directed not by latitude, for they are found from 10°N to 43°N of the Equator, and 10°S to 28°S of the Equator, but by temperature. The range of temperatures favoured by nesting loggerheads is between 25°C and 28°C although successful nestings have been recorded south of their limits in the study area. There is no nesting north of the 27°C summer isotherm in the study region neither in Madagascar nor in Mozambique.

Biometrics

Table 34 summarizes the relationships between selected parameters of loggerhead material collected during the present study.

Hatchlings

Figure 41 shows the relationship between carapace length and carapace width in a sample of 50 loggerhead hatchlings from Tongaland. Figure 42 shows the relationship between the carapace length and mass. Both relationships correlate well in comparison to the variability exhibited by green turtle hatchlings (see relevant section, above.).

As the head width also correlates well with the carapace length (Table 34) it is likely that this stability of characters is a reflection of the limited size of the Tongaland population.

The good correlation between carapace length and mass of hatchlings is due probably to the stability of the beach in the higher levels, where most nests are laid. Sand movement by wind or other vectors is limited along most of the beaches in Tongaland. Further, even if sand movement does result in a greater thickness of sand above the nest the generally lower temperatures in Tongaland, as compared to Europa Island, would probably cut down on water loss despite the additional exertion required of hatchlings during emergence.

Extreme cases of sand movement leading to a sand cover exceeding thicknesses of one metre or more have been observed and hatchling mortalities have proved high on the rare occasions that incidents of this nature have been recorded. It should be pointed out that in very extreme cases hatchlings would, or might, not reach the surface in which case there is little possibility of their failure to emerge being recorded. These instances are, however, regarded as being of negligible importance in considering the overall ecology of the beach. In 90 cases of wild nests being marked there was only one recorded showing a sand build-up of some 50cm above the original beach level.

In conclusion, Tongaland loggerhead hatchlings exhibit stability in morphological relationships so that mass and

width vary positively with the carapace length.

Juveniles

Uchida (1967: 497) in his work on rearing 2 loggerhead turtles in Japan showed that in the early stages there were inflection points in the relationships between carapace length and width, and he provided striking evidence of morphological changes in juvenile turtles, particularly on the head.

In the study region wild material of carapace length between 10cm and 60cm is completely lacking. This paucity is experienced not only in South Africa but in Mozambique and Madagascar as well.

In the 60cm to 70cm straight carapace length range there is more variability in the relationships than in the hatchling stages or the adult stages and it is around this size that sexual changes become apparent. As can be seen from Table 34 there does not appear to be any significant correlation between straight carapace length and straight carapace width, nor with plastron length and width. There is a tendency for the head sizes to increase positively with the carapace length but this is expected. The juvenile stage thus appears to be a stage of morphological fluctuation prior to the development of adult characteristics.

Sub-adults and mature females

From a straight carapace length of 70.0cm loggerhead turtles start to exhibit relationships which in some cases can be related to sex.

Figure 43 shows the relationships between curved carapace length and straight carapace length in sub-adult males, sub-adult females and mature females. There is no difference between the sub-adult males and females in the smaller size classes but males tend to be less domed than females in the larger size classes. Further, mature females are more domed than sub-adult females so there is a possible change with maturity in order to accommodate the developing eggs. Males tend to become relatively flatter in profile.

The divergence of relationships can be seen also in Figure 36 showing the relationship between straight carapace length and straight carapace width.

It shows that males are relatively wider than females both when compared to the sub-adult and mature females. There are obviously some relative changes in the carapace width as the female attains maturity, possibly the doming effect mentioned above results in a relative or even real narrowing in the carapace width. Carr (1952: 386) suggested that the carapace appears narrower in the male; Figure 36 would suggest the exact opposite although it must be reiterated that there is a dearth of fully adult male material which might shed a different light on the apparent relationships.

Perhaps the most striking relationship is that shown in Figure 44 which, as mentioned previously in the sexual dimorphism section above, shows that males have a significantly shorter plastron. This relationship appears to become more marked with increasing size and there is little difference in the relationship in mature and immature females.

The relationship between straight carapace length and head width is shown in Figure 45 and once again there is a relative change in mature females. In the growing female there is a positive relationship; the head grows in proportion to the carapace. Once maturity has been reached the head becomes relatively smaller in relation to the straight carapace length.

The relationship between head width and carapace length in mature females is variable. Figure 46 shows this relationship in a sample of 50 females from Tongaland. The variability is clearly shown by the width of the 95% confidence limits. There is a tendency for larger females to have larger heads but the correlation is not good (Table 34).

Figure 45 showed that males apparently have larger heads in relation to the carapace length than females. Figure 47 shows the relationship between the skull length and width in 9 males and 7 females from Natal and the regressions would suggest that males have relatively wider skulls than females.

There is also the possibility that fully adult males may occasionally exhibit an exaggerated skull growth apparently out of normal proportion to the carapace length. In Madagascar two skulls were collected on separate altars below each of which was a loggerhead carapace. The fishermen owning the altars were closely questioned and both were emphatic that each head and carapace were from the same specimen and that both had been males. It is perhaps worth mentioning here that the Vezo fishermen on the south west coast of Madagascar are highly skilled fishermen and extremely knowledgeable with regard to sea turtles and hence unlikely to make a mistake as regards sex identification.

As there is an element of doubt concerning these two specimens the measurements taken thereof have not been included in any of the graphs or tables in this section. However, it is felt that they should be mentioned because of the extrapolations found in some published works which suggest, on the basis of skull width that loggerheads have attained masses of over 500kg (cf. Carr, 1952: 385; Pritchard, 1967: 197).

The straight line carapace length of one Malagasy specimen was 87.8cm and the dried head width was 20.4 (skull width: 19.7cm); the second had a carapace length of 88.7cm and a dried head width of 21.1 (skull width : 20.6cm). If the head of the second specimen had been found without the carapace and fitted to the line presented in Figure 45 a carapace length of almost 100cm would have been recorded, an error of some 11.3cm, and a mass (see Figure 32) of 120kg.

Such enlarged heads are not restricted to the males. Figure 46 shows one female with a curved carapace length of 100.0cm (straight 92.1) with a head width of 22.4cm, well outside of the confidence limits. It is also the largest head width recorded in Tongaland.

The above is included merely to add support to Carr's (ibid) suggestion that such extrapolations of mass from partial material, particularly the skull, is not justified.

Discussion

Carr (1952: 393) in his discussion on the range of the Indo-

Pacific loggerhead Caretta caretta gigas Deraniyagala 1933 suggested that geographic intergradation with the Atlantic C.c. caretta may occur along the coast of South Africa where the loggerheads of the Atlantic and Indian Ocean meet. Further, that variation within the two stocks also brings about an overlapping of the distinguishing characters although a majority of specimens are recognizable as belonging to one race or the other.

From data presented in this section above it would appear that the loggerhead from the study region is little different from the Atlantic stock either in lepidosis or in osteological data. Deraniyagala (1953: 13) separated the Atlantic and Indo-Pacific stocks on the basis of marginal shields, neural bones and temperament. Disregarding temperament immediately as being of subjective value only, and thus unjustified as a taxonomic character, it can be seen that the South East African loggerhead is in no way different to the Atlantic stocks as regards the shield patterns. Both have 5 pairs of costals and, most commonly 12 pairs of marginals. Further, it would appear that Deraniyagala (op. cit.: 16 and Figure 18: 17) confused the issue by counting supracaudal scales as marginals. In his figure both loggerheads illustrated have 5 pairs of costals and 12 pairs of marginals which would place them in the same category as loggerheads from the present study region.

Brongersma (1961: 12) reached a similar conclusion and provides further evidence that the separation of caretta and gigas cannot be justified on the grounds of marginal scalation.

With this conclusion it is of interest to compare the South East African stocks with the Pacific stocks. Dr. Nishimura of the Seto Marine Biological Laboratory, kindly supplied 16 loggerhead hatchlings from the Japanese breeding grounds and, although it would appear that these were hatchlings collected out of nests and not emerged, there were no differences in scalation to justify separation:- 75% had 5 pairs of costals, 44% had 12 pairs of marginals, and 37.5% had 11 pairs of marginals, the remainder of the sample had mixed patterns. Further, in his paper on loggerheads in Japan (Nishimura, 1967: 22, Table 1)

he gives the scalation of 78 loggerheads and in the marginal counts he includes the supracaudals. Deducting the supracaudals from his figures one finds that only 3% have 12 pairs of shields such as in the Atlantic and South East African stocks; 68% have 11 pairs of marginals and 19% have 10 pairs, the remainder are mixed. Incidentally, the apparent difference between Nishimura's numbers of marginals (p.25) and those above results from the discounting of specimens with mixed and supernumerary marginals.

If Nishimura's data are representative of the Japanese stock there appears to be grounds for separating the north Pacific stock from that of the Indo-Atlantic, but a more substantial sample of data from a higher number of clutches is desirable before such a step could be taken. Nishimura's sample consists of hatchlings from 7 clutches one of which had only two units.

Other scale counts are either consistent in every population so far studied e.g. infra-marginals (3 pairs), post-oculars (normally 3 pairs) or so variable as to be of no value; such as the head scales (Brongersma 1961: Figure 3: 17), Nishimura op. cit., Figure 3: 26).

Thus the only remaining characters on which separation might be justified is the number of neural bones and the number of cases of interruption by costals. Brongersma (1961: 16) states that very few Atlantic specimens have been studied with regard to neural patterns and appears extremely doubtful of the value of these neural counts.

Deraniyagala (1933: 69, footnote 1) gives his source of information as regards the uninterrupted nature of the neural bones in Atlantic loggerheads as Dr. C. de Sola but there are neither figures, tables nor raw data to support this statement. This alone would cast doubt on Deraniyagala's separation of the two stocks.

From Table 27 and Figure 29 it would appear that the somewhat more substantial sample from the study region raises even more doubts regarding the value of this character.

South East African material shows a range of neural bones from 9 to 13 which should, according to Deraniyagala (1953: 13),

refer these loggerheads to the 'gigas' stocks. However, Brongersma (1961: 16) gives two neural counts from Atlantic loggerheads stranded in the Netherlands and presumably of North American origin (Brongersma, ibid.). The neural counts vary from 9 to 11, placing them within 'gigas' range but in their uninterrupted pattern they fall in 'caretta' range.

Further, Brongersma (1961: 20, figure 5c) shows one set of neural bones from Noordwijk which is interrupted by costal bones. In this example one can count either 12 neural bones with number 2 divided, or 13, either count should refer this specimen to 'gigas' stock.

Material from the study region shows quite clearly that this character is variable and if a substantial series of carapaces were to be investigated in the North Atlantic it would probably be found to be equally as variable. Brongersma's three specimens certainly display variability and it seems highly unlikely that these animals were from Indo-Pacific stock.

In conclusion it would appear that this character is highly variable, the uninterrupted nature of the pattern is extremely limited; (6.5% in the study region) and the exact extent of this character in the Atlantic stocks has still to be demonstrated. Thus it would appear that until more substantial samples are investigated this character must be regarded as invalid and the trinomial 'gigas' discarded.

It might be argued, of course, that the presence of some interrupted neurals in the material from South East Africa is indicative of 'mixed' stock, but there remains the open question as to where Deraniyagala's material originated. Loggerheads do not nest in Ceylon (Deraniyagala, 1939: 182), West Pakistan (Minton, 1966: 61) or Malaysia (Balasingam, 1969: 67). Deraniyagala's (ibid.) suggestion that they nest on the Maldives is not acceptable on the data he presents. However, Smith (1931: 65) quotes Maxwell (1911) as stating that up to $1\frac{1}{2}$ million loggerhead eggs were taken annually from the Irrawaddy division of Burma so it appears likely that the Sinhalese specimens came from Burma. Ceylon is

well within the migratory range of the loggerhead turtle (see Section 4 below). It is unfortunate that no other details of the Burmese population are available which might show demonstrable differences between it and the South East African stocks, and in turn with those of the Atlantic. There is, therefore, no evidence to suggest overlapping of stocks from the northern and southern Indian Ocean and unless there was substantial immigration the occasional stray animal would soon be absorbed and its characters lost in those of the local population.

The term 'gigas' is also misleading because although Deraniyagala stated (1933: 62) that the loggerhead "appears to grow to gigantic proportions in the tropics more than elsewhere" his data does not justify this claim and few of the loggerheads dealt with in this present study match the generally larger loggerheads found in the western Atlantic.

This leads to the question as to why the western Atlantic loggerheads should be larger than the South East African stocks. Brongersma (1972: 149) accepts the minimum length of loggerhead females at nesting maturity to be around 75.0cm based on data from Tongaland (Hughes et. al. 1967: Fig. 6), although even for Tongaland this is an extreme case. The smallest loggerhead found nesting in the United States had a straight carapace length of 79.0cm (Caldwell, et. al. 1959: 305) so there is very little difference between the minimal maturation size of these two populations of loggerheads.

As with the green turtle females in Costa Rica (Carr and Goodman, 1970: 783) loggerhead females in Tongaland show almost negligible growth after reaching nesting maturity, i.e. after having started their nesting lifetimes (see Section 4 below). Carr (1971: 32) after 15 years of accumulating data has suggested that Costa Rican green turtle females grow approximately 2.54mm per year. However it is not known whether a female nests immediately she attains sexual maturity or whether there is a variable delay between attaining sexual maturity and actually starting to lay eggs.

If size could be related to age then the differences in size between the Atlantic loggerheads and those from Tongaland might

be as a result of the Atlantic population being made up of older animals. It is difficult to subscribe to this view because it appears that the loggerhead (see Section 4 below) and the green turtle in Costa Rica (Carr and Goodman, ibid.) reaches maturity at widely differing sizes.

The difference in hatchling size is almost negligible (Table 29), the growth rate after reaching maturity is severely limited, therefore the differences must arise during the juvenile and sub-adult stages.

Two possible explanations are suggested:-

- (i) It may take a longer time for the Atlantic loggerheads to complete their migratory drifting and return to the natal beaches, (of course it has not been proven that they do return to the natal beaches, but there is no evidence as yet to suggest the contrary), if this is the case then their pre-nesting growth would continue over a longer time and produce a larger female.
- (ii) Feeding opportunities may be better in the North Atlantic and environmental conditions may be more favourable in the Atlantic than in the Agulhas gyral and this would enhance pre-nesting growth.

These two factors may be combined and thus encourage growth to larger sizes. Examining these suggestions more closely it seems that many Atlantic loggerheads are found at sea well away from the natal beaches. Brongersma (1972: 150) has provided an impressive series of data suggesting that many Western Atlantic turtles are carried to Europe, the Azores and Madiera. Around Madiera they occur in substantial numbers and a thousand or more are captured and slaughtered each year (Brongersma, 1968a: 131). Brongersma gives the carapace lengths of 5 specimens varying from 34.5cm to 58.9cm which would make them between 3 and 4 years old even with rapid growth rate.

If, as Brongersma (1972: 157) suggests that it takes at least one and two years to reach Europe, and one assumes that this is in the Gulf stream, moving between 1 and 4 knots, then it might be

assumed that they would take at least another three years to return to the Americas. The distances involved are as follows:-

American nesting grounds to Europa: 6000km in 1-2 years
 Europe via Azores to America :10400km in 3-5 years (?)
 Total distance :16400km in 4-7 years (?)

However, Carr (1957: 57) in his illustration of drift-bottle recoveries in the north Atlantic, shows that a drifting object can take about a year to reach the Florida region from the eastern side of the Atlantic so the time taken for turtles to make this trip may be less than suggested above. However, sea turtles at 3 or 4 years of age are probably not drifting under the full control of the currents and are more than capable of directing their movements. It is thus suggested that on reaching an area of abundant food the turtles may remain there, by choice, for varying periods.

Thus although the Atlantic stocks may pass through waters with temperatures as low as 15°C they could spend some time, up to two or three years, in the Sargasso Sea where pleustonic fauna and other food organisms abound in temperatures between 24° and 28°C.

By contrast the Tongaland loggerheads, if they travel around the Agulhas gyral, have only some 8000km to travel which would bring them back to the vicinity of the mainland of Africa at a younger age. Extreme temperatures in the centre of the Agulhas gyral vary between 27°C and 18°C so Tongaland loggerheads would be subjected to lower temperatures over longer periods and thus, theoretically, should have a lower rate of growth than the Atlantic stocks. Further, the Agulhas gyral is probably not as richly endowed with food organisms as is the Sargasso Sea. A final point is the fact that the majority of the loggerheads found off the relatively cool east and south coasts of South Africa are immature and their growth rates to maturity in such an environment should be relatively slow. No data are available on the Atlantic stocks to compare with results from the study area.

It should be pointed out that evidence for these hypotheses are mainly negative but there are some positive data. Tongaland loggerheads are swept southwards by the Agulhas Current (see Section 3, below) and no juvenile loggerheads have been collected off South Africa, Mozambique or Madagascar. In the Atlantic, juvenile turtles have been found in Europe, the Azores and Madiera but not on the mainland of America; if they are not near the mainland of origin then they must be in the open sea as evidence suggests that they are. Carr (1952: 387) quotes Gatesby (1730-1749) as writing:- "They range the Ocean over, an instance of which (amongst many that I have known) happened the 20th April, 1725, in the latitude of 30 Degrees North, when our boat was hoisted out, and a Loggerhead Turtle struck as it was sleeping on the surface of the water; this by our reckoning appeared to be midway between the Azores and the Bahama Islands, either of which Places being the nearest Land that it could come from" Carr (*ibid.*) cites Murphy (1914: 4) who reported that he saw numerous loggerheads 640 to 800km off Uruguay between latitude 32°54'S and 37°S, where the mean sea surface temperatures range between 15°C in August to 20°C in February. Murphy claimed that some of these loggerheads were fully a metre in length which would make them adult animals.

Accepting the possibility of the open ocean wanderings there is no doubt that the size of the north Atlantic necessitates longer periods in the open ocean in more ideal conditions for the loggerhead than are found in the south western Indian Ocean. This is probably the reason for the larger sizes exhibited by the north American loggerhead.

The occasional small female encountered in the American rookeries can be explained, either as being a female whose small size is genetically controlled or one which has spent a very short period in the Sargasso Sea area or one which may have missed the area, remaining in the general circulation and brought directly back to the mainland.

Once the Tongaland female has nested, her growth rate is drastically reduced, and even in optimum conditions such as may be found in the Mozambique channel and off the East Coast of Africa where most mature females are to be found (see Section 4, below), she can never attain the same dimensions as that of her American counterparts.

THE OLIVE RIDLEY TURTLE
Genus Lepidochelys Fitzinger 1843

Species: Lepidochelys olivacea (Eschscholtz) 1829

- 1943 Lepidochelys olivacea olivacea (Eschscholtz).
Deraniyagala, 81.
- 1953 Deraniyagala, 14.
- 1957 Loveridge and Williams, 495.
- 1939 Lepidochelys olivacea (Eschscholtz). Deraniyagala, 123.
- 1952 Carr, 403.
- 1966 Minton, 61.
- 1967 Carr, 227.
- 1967 Pritchard, 204.
- 1971 Frazier, 403.
- 1971a Hughes, 56.
- 1972a Hughes, 128.

Common names.

The olive ridley sea turtle (English); olyfkleurige ridley seeskilpad (Afrikaans); tartaruga (Portuguese); xicore (Chimani); oulo, ouzo, asa (Makua) tsipioko, tsioke (Sakalava); tsiarara (Antandroy); tsiashara (northern Sakalava); mondroy (Tankarana).

Description

Snout relatively short, not compressed; beak scarcely or slightly hooked, not bicuspid in specimens from the study region; edge of jaws smooth; prefrontals in two pairs, anterior pair greatly enlarged in one hatchling from Warner Beach, Natal; frontal azygous, longer than broad in 3 young specimens; sometimes broader than long in hatchlings (Loveridge and Williams, op. cit.: 496); frontoparietal large, broader than long, semi-divided, fused to parietals in one specimen; parietals transverse in young specimens, elongate in adult specimen from Mozambique (Hughes, 1972a: Figure 3: 130)(Plate 11) postoculars 3/3, occasionally 4 (Loveridge and Williams, ibid.); supratemporals semi-divided, large; 2 claws on each limb clearly distinguishable at carapace length 28.5cm; tail short in hatchlings and juveniles, longer in adult males.

Carapace ovate, can be as broad as, or broader than, long

in adult specimens; hatchlings have 3 interrupted strong keels, the vertebral keel being the most pronounced and this persists until at least a carapace length of 28.6cm, lateral keels have disappeared by then; nuchal region truncate; margins slightly serrate in juvenile specimen in Durban Aquarium (Plate 12); dorsal shields slightly imbricate in hatchlings from Warner Beach, Natal but are soon juxtaposed and remain so; nuchal normally 1, but occasionally 2, broader than long, in contact with first costal; vertebrates 6-8; costals 6-8 per side; often not paired; marginals almost invariably in 12 pairs, occasionally 12/13 or 13/12; supracaudals always 2.

Plastron anteriorly rounded; 2 distinct keels persisting until carapace length of at least 28.5cm; occasionally present in adults but very weak; plastral shields juxtaposed; intergular either present or absent even within a single hatching; infra-marginals 4 per side, occasionally 3 per side, all with pores in six specimens examined; interanal either present or absent.

Table 35 summarizes the lepidosis of olive ridley material gathered during the present survey and it falls within the range of olive ridley material from other localities (cf. Carr, 1952: 404; Deraniyagala, 1939: 129; Schulz, 1968: Plates 1-3; etc.).

Colour

In 5 hatchlings from Warner Beach, Natal, the general coloration was olivaceous black; plastral keels, lower jaw and cutting edges of upper jaw with white patches; throat grey; trailing edges of fore-flippers with white flecks.

By the time the carapace length has reached 10cm the general colouring lightens; plastron, lower jaw, most of upper jaw, throat, sides of neck, underparts of flippers, and under surface of tail all white; edge of carapace white; upper skin surfaces pale grey; scales on head pale grey outlined in white; carapace dark grey with centres of shields paler grey (Plate 12).

Mature animals have plain olive grey carapaces; top of head grey brown with shields outlined in yellow white; upper surface of skin and flippers dark grey; plastron creamy yellow; skin

underparts dirty white; sides of head creamy yellow with centres of shields grey; lower jaw yellow-brown; upper jaw yellowish along lower edge, grey-brown near nostrils; leading edge of flippers light yellow-brown (Plate 13).

Size and mass

Only 5 ridley hatchlings from one clutch were examined in the study region. Carapace length varied between 42.9 and 44.6mm; carapace width 34.1 to 37.7mm; head width 15.6 to 16.3mm; mass 16.8 to 22.3g

No juvenile material has been found in the study area and only one noticeably sub-adult specimen. Taken off Durban it measured 49.2cm by 47.4cm (straight line carapace measurements).

No nesting females were encountered and the data below were collected mainly from village middens and ship's catches in Madagascar and Mozambique. In most cases the material is unsexed and although assumed to be adult this is not certain as most specimens were observed in South West Madagascar where the ridley is not known to nest.

Largest ridley carapace measured was 73.0cm over the curve (straight: 68.2cm); curved carapace widths reach 73.5cm (straight: 63.2); the maximum head width recorded was 3.5cm; and the maximum mass 40kg (a male measuring 66.4 x 63.2cm, straight).

Table 36 summarizes the measurements of all the ridley material gathered during the present survey. The range of sizes is illustrated in Figure 48 and compared to other localities the general size is very small, ranging from 49.0 to 70cm straight carapace length. Pritchard (1969a: 113) gives the range of mature nesting females in Surinam as 62.0 - 73.7cm, and that of the Pacific Honduras population as 58.5 to 75.0cm, (Pritchard, ibid.). The largest ridley recorded does appear to come from the Indian Ocean, however, as Deraniyagala (1939: 162) claimed a female of 79.0cm carapace length. The only substantial sample of clearly sub-adult material appears to have been recorded from near Japan (Nishimura, Shirai, Tatsuki and Sugihara, 1972: 420), and the range of this sample was 21.0 to 62.0cm.

Details in Table 36 show that the material from southern Madagascar is smaller than that from northern Mozambique. Although the sample from the latter area is regrettably small, a comparison between the two showed a significant difference ($p < .05$) between the carapace lengths.

A further noteworthy point is that in mature females from Surinam, in every case the carapace is longer than wide (Pritchard, 1969a: 112-113) whereas the sample from Madagascar 8 out of 21 show a carapace width as broad or broader than the carapace length. One of the northern Mozambique specimens shows this feature.

It is possible that this feature is indicative of immature animals as has been seen in some loggerheads (see sub-section 3 above).

There is, however, no suggestion of this in the data presented by Nishimura *et. al.* (*op. cit.*) nor in those data presented by Cadenat (1949: 19; 1957: 1373) and Deraniyagala (1939: 162). As all the samples presented, including that of the present study, are small, further comment must be deferred until larger samples are available.

Sexual dimorphism and sex ratios

No data were gathered during the present survey which would indicate either unusual sexual dimorphism or sex ratios.

Only two whole specimens were encountered; one a sub-adult, and the other a male having a tail 24.5cm in length. All measurements of this turtle are included in Table 36.

Distribution and populations

Figure 49 shows the distribution of the olive ridley turtle in the study area. Areas of relative abundance are northern Mozambique and West and North West Madagascar. In southern Mozambique and South Africa they are regarded as rare. They have not been recorded from any oceanic islands in the area. Frazier (1971: 403) disputes Deraniyagala's (1939: 163) claims that olive ridley occurs in the Seychelles and adds that it does not occur in Aldabra.

Figure 7 shows their estimated contribution to the total sea turtle population of the study region, but no other comment can be made on the real size of the populations. There is little doubt that, in comparison with the other recorded populations such as are found in the Pacific Central Americas (see Pritchard 1969b: Table 11: 17; Richard and Hughes, 1972: 301), the South East African populations are insignificant. The possible reasons for the limited size will be discussed later in this section.

Beach preference and nesting areas

No evidence was collected during the present study to indicate that there were any mass emergences of ridley turtles. Reputed nesting areas are indicated in Figure 49 and the south latitude extreme appears to be 15°S which coincides with the 28°C mean summer isotherm.

The nesting record of an olive ridley from Warner Beach, South Africa (30°S) is regarded as a stray female and is noteworthy only because of the high latitude, the equal of which has not been hitherto recorded.

As the nesting distribution of the olive ridley turtle coincides with that of the green and hawksbill turtles it appears that their beach preferences are similar but they appear to be more restricted in their distribution than either of the above (see Discussion, below).

Biometrics

With the limited material collected during the present survey there are few relationships that can be presented here. Figure 50 shows the relationship between straight carapace length and straight carapace width. The formula for converting curved carapace length into straight carapace length is:

$$y = .886x + 3.29 \quad (r = +.98; p < .001)$$

Table 37 contains details of 11 olive ridley skulls (unsexed) from the study area with their relationships. Although there is some variation evident, skull length and width are positively related. Unlike the green turtle the olive ridley shows a

positive correlation between the orbit height and the skull length. There is a similar correlation although not so pronounced between the jaw spread and skull length but the jaw width and nostril width appear variable bearing no relationship to the skull length.

Discussion

From the limited data presented in this section the olive ridley population in the study region is no different to other populations except in the incidences of broad carapaces and the apparent modest size.

It was thought that if a comparison was made between physical environmental parameters typical of the regions known to harbour olive ridley populations and those of the study region, the modest size of the local populations might be explained.

Table 38 summarizes parameters such as the salinity of coastal waters, range of sea surface temperatures, rainfall, presence of mangroves along coast, presence and relative abundance of neritic fauna and the organic content of the coastal waters in each area known to contain olive ridley turtles.

The most striking feature of the table is the low salinity in areas having an abundance of olive ridleys. The reason for the low salinities being shown by the rainfall figures for adjacent landmasses. The exceptional areas in the table as regards salinities are Tanzania, Northern Mozambique, West Africa (Senegal) and Northern Australia.

In the Tanzania-Northern Mozambique area there are numerous large rivers discharging into the sea and this should provide local pockets of low salinity, at least during the summer months. More favourable conditions are found off North West Madagascar where higher rainfall results in salinities of 34⁰/oo over an extensive area during the summer months. This is the only locality in the study region in which such salinities are found (Wyrski, 1972).

Although the samples collected during the present survey were small there is no doubt that the olive ridley is far more numerous

in North and West Madagascar than in northern Mozambique. This was evident both in the numbers of specimens observed; 10 (including damaged material) in Mozambique as against about 70 (including damaged material) in Madagascar, and in the opinion of local fishermen from the two regions. Many Mozambique fishermen denied knowledge of the ridley whereas on the West coast of Madagascar all knew the turtle well.

Only limited quantitative data have been presented on the olive ridley populations of West Africa (Cadenat, 1949: 17; Villiers, 1957, 1962: 50) and Northern Australia (Cogger and Lindner, 1969: 153; Bustard, 1972: 201) but in both areas salinities are higher than those apparently favoured by the olive ridley, and this might explain the small size of these populations.

Availability of food must also control the distribution of the olive ridley and would appear to be a plausible reason for the presence of these turtles in the Mozambique Channel. The waters of northern Mozambique from Beira northwards are extremely rich in prawns, shrimps and crabs as are the waters of North western Madagascar. The male olive ridley noted in Table 36 above was taken in a prawn trawl in 6 fathoms (12 metres) and one specimen from Nossi Be was taken in an experimental prawn trawl at 110 metres (Dr. A. Crosnier, Director, O.R.S.T.O.M., Nossi Be, pers. comm.) which would seem a remarkable depth for any sea turtle except that Nishimura, et. al. (op. cit.: 424) have also reported ridley captures in bottom trawls at depths of 80, 99 and 94m.

The abundance of neritic fauna which would attract the olive ridley, is also linked to the presence of mangrove stands from where originates the detritus-rich bottom muds and sands on which the prawns feed (see section 3; feeding in adults).

It seems likely that during the pluvial periods of the Pleistocene when conditions were much warmer than at present (e.g. a mean annual world temperature of 22°C as against 14.4°C today (Cowan, 1960)), and precipitation higher, areas of suitable environment for the olive ridley would have been more extensive. However, with the cooling of world climates, and the resultant

shrinkage of suitable habitat, the olive ridley populations are likely to have dwindled and the smaller known populations such as that of Tanzania - Mozambique, and to a lesser extent of North West Madagascar, are possibly relict populations surviving only in what might be regarded as marginal areas when considering the physical environmental requirements of the species.

THE LEATHERBACK TURTLE

Family Dermochelyidae Wieland 1902

Genus Dermochelys Blainville 1812Species: Dermochelys coriacea (Linnaeus) 1766

- 1930 Sphargis coriacea Petit, 100
- 1950 Decary, 94.
- 1952 Dermochelys coriacea schlegalii (Garman). Carr, 452.
- 1967 Pritchard, 206.
- 1889 Dermochelys coriacea Boulenger, 10.
- 1910 Vaillant and Grandidier, 26.
- 1937 Hewitt, 16.
- 1939 Deraniyagala, 38.
- 1950 Rose, 456.
- 1953 Deraniyagala, 10.
- 1963 Bass and McAllister, 287.
- 1965 McAllister, Bass and van Schoor, 13.
- 1966 Minton, 1966.
- 1967 Hughes, Bass and Mentis, 7.
- 1968 FAO, 3.
- 1969 Day, 237.
- 1971a Hughes, 57.
- 1971b Pritchard, 7.

Common names

Leatherback turtle, leathery turtle, luth (English); leerug seeskilpad (Afrikaans); tartaruga (Portuguese); tortue luth (French); ivundu (Thonga); inhaca (Makua); tortie caiman (Creole); valozoro (Vezo, Makefaly); ronto (Sakalava).

Description

Snout somewhat elongate in hatchlings, exaggerated by the presence of an eggtooth; beak deeply notched in middle, bicuspid; edge of jaw denticulate; prefrontals broken up into 6 shields; frontoparietal large; all other shields broken up; all skin surfaces, including flippers, covered with fine scales somewhat larger on the leading edges of flippers; limbs clawless; tail

projects 5mm beyond tip of carapace and has a sharp dorsal ridge.

Carapace narrower than long; heart-shaped deeply indented anteriorly, posteriorly prolonged into a caudal point; 7 clearly defined ridges made up raised polygonal plates; neural ridge consists of 26 to 30 plates; right costal ridge of 27-36 plates; nuchal indentation, between 1st right and 1st left costal ridges, between 9 and 17 plates; chin scales bordering lower jaw between 11 and 19. Table 39 and Figure 51 shows the frequency of scale counts in a sample of leatherback hatchlings from Tongaland. Plate 14 shows a typical hatchling from Tongaland.

Plastron similar, being made up of numerous polygonal plates raised in 5 ridges the median consisting of a double row from one third of its length from the front; interior of plastron slightly pointed, posterior sharply pointed.

Adults lack defined scales, skin on carapace stretched over the ridges which are sharply defined (Plate 15); carapace always longer than broad; caudal point pronounced although occasionally broken.

Colour

Leatherback hatchlings when dry, have a pale grey carapace, black when wet, with longitudinal ridges white, some pale grey; ridges forming extreme edges of carapace always white; upper surfaces of head mainly black, some headshields with white or grey; upper jaw almost entirely white, black anteriorly and along cutting edge; lower jaw white; upper surface of neck black with 5 rows of lighter shields (grey to white); throat and chin white; upper surfaces of flippers black, bordered in white, white flecks on shoulders; undersurfaces of flippers black towards extremities, paler grey nearer body; plastron basically black or dark-grey, 5 ridges broadly white, some white scales anteriorly on either side of median ridge; upper edge of tail ridge white (Plate 14).

Only one juvenile leatherback having been seen, and that was very dead, the following colour description is presented with some trepidation; upper surfaces black flecked with pale blue or

grey spots; plastron almost entirely white with continuous black smudges forming crudely defined lines; undersurfaces of flippers mixed black and white in almost equal proportions, more white than black near body. This description is similar to that of Deraniyagala (1939: 94).

Adults always basically black in the study region; carapace intense shiny black spotted and flecked, either heavily or sparsely, with pale grey or blue; head basically black, spotted, flecked or blotched in pale grey or blue; with red to pink blaze on top of head (gives the impression of being scar tissue); upper surfaces of skin appears lighter in tone than carapace but this is possibly an illusion created by the matt surface of the skin, which is similarly spotted and flecked with pale grey or blue, undersurfaces, including plastron a variegated mixture of pink white and black, appears highly variable; tail black, (Plate 15).

Size and mass

In Tongaland leatherback hatchlings have carapace lengths ranging between 54.8 and 63.4mm, carapace widths between 36.3 and 43.5mm, head widths between 16.9 and 18.5mm and a mass of between 27.5 and 41.0g (Table 40).

Table 41 compares the carapace length of Tongaland leatherback hatchlings with those from other areas (sources quoted). With the exception of the Surinam population all other areas appear to have larger hatchlings, but the samples are small. Further comment on the relative size of the Tongaland leatherback hatchling must be deferred until more substantial samples are available for comparison.

Only one juvenile leatherback has been recorded in the study region. Details were supplied by Mr. R. Rau, South African Museum, Cape Town, and are included in Table 40. Brongersma (1972: 108 and Table 6) discusses the size and mass of a large series of strandings in European coasts and the smallest leatherback recorded there was in the region of 91.5cm total length; roughly the same size as the juvenile taken off Cape Town. Thus the specimen is of value in that leatherbacks in this size

category are only rarely encountered. The only known growth data on leatherbacks was reported by Deraniyagala (1939: 94, Table V). At 624 days (1 year 8.6 months) the carapace of a captive specimen measured 43.5cm so the Cape Town specimen should be at least 3 years old.

Adult female leatherbacks in Tongaland range between 133.5 and 177.5cm in curved carapace length. Figure 52 shows the size distribution (curved carapace length) in 7 seasons in Tongaland and that of the combined sample. The only comparative groups of data are those of Pritchard (1971b: 10) from French Guiana, and Bacon (1969: 27, Table 4) from Trinidad. There are no obvious differences between the two samples nor between them and the Tongaland data. Some consideration was given to excluding a markedly small female, recorded during the 1971/72 season in Tongaland (Figure 52), on the grounds that the recording may have been a misprint but Bacon (*ibid.*) has recorded an even smaller female from Trinidad so the data have been accepted.

Insufficient data were collected on which to base a mass-length relationship but some remarks on mass from material from the study region are considered to be of value.

Table 40 summarizes the details collected from stranded specimens and the female from Laaiplek remains as one of the heaviest leatherbacks on record at 646 kg. This female had recently completed a nesting season for her ovaries were heavily scarred, contained a few ova mainly blackish in colour, suggesting that they were being resorbed, and some small yokeless shelled eggs were found in the oviduct.

The female from Mtunzini was killed on the beach before she could lay her eggs and examination showed that she contained 902 ripe ova, remarkably homogenous in size, being approximately 35.0mm in diameter. In the oviduct were 113 shelled eggs, ranging from 52.3mm to 55.5mm in diameter, in addition there were 31 yolkless eggs of varying sizes. Thus she contained a total of 1015 eggs and ova which weighed approximately 28.9 kg. The stomach was empty.

The female from Durban was caught in the anti-shark nets and was weighed piecemeal at the Durban Aquarium. The mass of the separate parts were as follows:

	<u>Mass (kg)</u>	<u>% of total</u>
Fore-flippers from carpals:	8.64	5.6
Hind-flippers from tarsals:	3.64	2.4
Head :	5.91	3.8
Neck :	9.55	6.2
Forequarters :	30.00	19.3
Hindquarters :	16.36	10.5
Plastron :	14.55	9.4
Carapace :	23.18	14.9
Heart :	2.73	1.8
Liver :	6.59	4.3
Lungs and fat :	16.36	10.5
Stomach and intestines :	13.64	8.8
Miscellaneous :	4.09	2.6
	<u>155.25</u>	<u>100.1</u>

As with nearly all other specimens examined the stomach and intestine contained nothing but a pink fluid.

The Ramsgate specimen had its duodenal tract completely filled by a sheet of heavy plastic measuring 3 metres by 4 metres when spread out. The sheet was so tightly packed that considerable force was required to open it initially, and it must have had a serious effect on the passage of food from the stomach. Whether a complete blockage had been affected was difficult to ascertain because there was pink fluid in the lower gut.

Pritchard (1971b: 11-12) reviews most of the recorded mass data from stranded leatherbacks and it is sufficient to state that none are markedly different from those recorded in the study region.

Sexual dimorphism and sex ratios

No data on either of the above were collected during the present study. Pritchard (1971b: 13) comments that there are no obvious differences in adult size between the sexes. Deraniyagala

(1939: 98) states that males display a concave nasal profile, domed skull, comparatively depressed body and elongate tail.

Distribution and populations

Figure 53 shows the distribution and apparant relative abundance of the leatherback in the study region. As this is a more pelagic species than the others it is difficult to ascertain their exact distribution but they would appear to be more common in the temperate waters.

It must be pointed out that their apparant scarcity in the sub-tropics may be a result of their avoiding the coral reef areas (sea beach preferences, below) where most fishermen are active. In south west Madagascar the fishermen know the leatherback well but in the north of the territory fishermen disclaimed all knowledge of it.

Two specimens have been stranded on Mauritius (Vaughn, 1940; Desjardin, 1837) and they are regarded as extremely rare in the area.

Leatherbacks are commonly caught off the Cape of Good Hope by trawlers and are occasionally brought back to port. Details of some leatherbacks caught in Cape waters are included in Table 40.

No estimation of the size of the population is possible. In the Tongaland protected area 169 different females have been tagged over the past ten seasons but insufficient data have been forthcoming to allow any extrapolation of these figures to try and assess the total size of the nesting population. Due to their wider nesting distribution the tagging effort on leatherbacks is not as intensive as for the loggerheads. Table 42 shows the estimated annual nesting populations of leatherbacks during the past ten seasons in Tongaland. The method of estimating leatherback populations is the same as that used for loggerheads (see subsection 1, above; and Hughes, 1970: 11-13).

There is little doubt that in comparison with the leatherback populations in French Guiana (estimated population 15 000) and Trengganu, Malaya (4 000) (Pritchard, 1971b: 34), the Tongaland population is modest in size.

However, Pritchard (*ibid.*) based the method of estimating the above figures on rather sparse data from Tongaland viz., that some leatherbacks nest after intervals of 2 to 3 years. As there have been shifts in absences and, further, that recovery rates in Tongaland have proved to be unpredictable and erratic it is felt that it is completely unjustified to use these limited data for general overall estimates. The percentage recovery rates are included in Table 42 and reasons for the great variability will be included in Section 4, below.

Beach preference and nesting areas

Figure 53 shows the distribution of leatherback nesting sites in the study region. Other than the silica sand beaches of Tongaland and southern Mozambique no traces of other nesting beaches have been found. The latitudinal distribution of the nesting region is the same as that described for the loggerhead; from 23°S to 28°S. An occasional nesting has been recorded south of 28°S; in March, 1970 a leatherback nested on the beach at Beachwood, Durban (30°S).

It is pertinent to note that the recent discovery of a leatherback colony in Angola is of interest because the apparent southern limit of nesting, in the Quicama National Park, coincides with the 25°C summer isotherm in the South East Atlantic. I am indebted to Messrs Brian Huntley and David Wearne, Angolan Veterinary Department, for the information on distribution (see also Anon., 1971: 24-25).

The reasons as to why leatherbacks in the study area should utilize only the Tongaland and adjacent beaches are difficult to assess. As they share the beaches with the loggerhead one might assume that their requirements are similar. However, one finds leatherbacks nesting where loggerheads are regarded as rare visitors; for example; Trengganu, Malaya; Ceylon; Costa Rica and Trinidad.

Pritchard (1971b: 17) describes the various beaches used by leatherbacks and the one feature common to all appears to be a steeply shelving slope which would suggest that there is a

relatively unobstructed approach to the beach. Any major obstructions would break the incoming waves causing them to lose energy and thus their ability to build steep slopes on the beaches; a more gently slope of beach would result. Gentle slopes are more a feature of the Tongaland beaches than steep slopes which are highly localized. The most extensive stretch of steep sloping beach is the 5.6km long, deep water approach section immediately south of Black Rock (see Figure 54).

McAllister, et. al. (1965: 18) stated that while loggerheads favoured sand with a fine texture, leatherbacks preferred beaches with coarse sand. Hughes, et. al. (1967: 13) pointed out that these observed correlations were probably incidental. As was shown in Figure 40 (in loggerheads, above) sand particle size, in the upper levels of the beach where the turtles lay, is fairly homogenous with no striking differences as were observed between sand samples in green turtle areas. Occasional and obvious differences are found only in the wash zone and littoral slope.

As with the other species it is thought that sand particle size is not important in the selection of a nest site by leatherbacks but rather is it related to the physical nature of the seabed immediately offshore.

Figure 54 is a schematic presentation of the nature of the offshore seabed in Tongaland (see also Figure 38) coupled with the leatherback nesting distribution during the 1971/72 season, the best leatherback year ever recorded in Tongaland. A quantitative assessment is as follows:-

	<u>n</u>	<u>%</u>	
Obstruction free (Deep water approaches	: 55	14.8)	81.1%
(Shallow water	: 246	66.3)	
Scattered rocks	: 31	8.4	
Continuous rocks	: 24	6.5	
Accessible only at high tide	: <u>15</u>	<u>4.0</u>	
Total successful nesting emergences:	<u>371</u>	<u>100.0</u>	

Although a deep water approach section is shown in Figure 54, and mentioned above, its full extent is only 5.6km (3.5 miles) and despite the fact that it has the clearest approaches over the longest continuous distance, the nesting density is not

markedly higher than those beaches with shallow unobstructed approaches. It is felt, therefore, that deep water approaches are not necessarily preferred to those with shallow water, the preference being shown only in that both are obstruction free. 81.1% of leatherback nestings took place on these beach types.

It is thus concluded that for Tongaland leatherbacks, beach selection is based on a minimum temperature limit of 25°C, as with the loggerhead, and the availability of beaches having approaches that can be safely negotiated by such a large animal whose collision with rocks could result in serious body damage.

Hendrickson and Balasingam (1966) undertook a detailed study of sand particle sizes in green and leatherback turtle nesting sites in eastern Malaya and concluded, on finding that leatherback beaches had coarser sand, that the 'feel' of the beach was important in the final selection of a beach by a nesting turtle (p.73). Having questioned this conclusion several times in the present thesis, and disagreed with it, it should be pointed out that these authors also suggested (p.76) that inter-specific competition might bring about some spatial separation between the two nesting populations.

In Tongaland, the small numbers of leatherbacks nesting greatly reduces the incidence of inter-specific destruction of eggs and although there are clear indications of separation between the loggerhead and leatherback nesting sites (compare Figures 38 and 54) there is a great deal of overlap. If the numbers of turtles in the past had been greater, then the situation may have been somewhat different with a very clear separation of the nesting groups. Should the leatherback population increase a separation may yet develop.

It seems unlikely that the relatively small loggerhead would intimidate a leatherback and that, in digging its nest to a depth of 46cm, it would destroy leatherback eggs laid at a depth of 75cm. Digging leatherbacks, however, would certainly intimidate loggerheads and destroy loggerhead nests.

It is suggested, then, that the numbers of leatherbacks utilizing a beach would determine the spatial distribution of all

smaller species, including the green turtle, if the nesting seasons coincide. Therefore, it seems reasonable to assume that the use of the Trengganu beaches by a heavy density of leatherbacks precludes the use of that beach by the green turtle or any other species. The statement by Hendrickson and Balasingam (op. cit.:3) that green turtles nest both north and south of the beaches used by leatherbacks can be taken as evidence that the green turtle probably would nest there but for the presence of the leatherback.

Biometrics

Despite the presence of a nesting assemblage in Tongaland the amount of data that could be tested for relationships is regrettably small.

In hatchling leatherbacks the relationship between carapace length and width is weak and insignificant ($p < .9$, Figure 55), as is the relationship between carapace length and head width ($p < .9$, Figure 56). The carapace length-mass relationship is somewhat more positive (Hughes, 1971b: 21, Figure 8).

In adult females laying in Tongaland the carapace length-width relationship still displays variations but somewhat less so than in hatchlings (Figure 57) whilst the carapace length and head width are more positively related ($r = + .63$, $p < .05$).

Pritchard (1969a: 123) and Brongersma (1972: 107) have commented on the confusion arising from one set of data being presented as 'over-the-curve' measurements and others as straight line. Both methods are applied in Tongaland and the formulae for converting curved to straight-line measurements are as follows:-

$$\text{Carapace length} \quad y = 0.8x + 23.01 \quad (p < .001)$$

$$\text{Carapace width} \quad y = 0.682x + 7.49 \quad (p < .02)$$

Insufficient skull data were collected for analysis but details of 3 skulls are included in Table 43.

Discussion

Pritchard (1971b: 7) agrees with a suggestion by Smith and Taylor (1950, in Pritchard, ibid.) that the taxonomic separation of the leatherback into Atlantic and Indo-Pacific stocks was based solely on geographical convenience and had no basis in fact.

In considering the data presented in this sub-section, there is general agreement with the statements of these authors; in almost every respect the Tongaland leatherbacks appear the same as those described from other areas. As leatherbacks are quite commonly taken in the waters around the Cape from both the Atlantic and the Indian Ocean, and that it has been adequately demonstrated that leatherbacks are found in latitudes far more extreme than the Cape (cf. Brongersma, 1972: 103); (leatherbacks can do this as a result of being able to maintain their internal body temperatures well above that of the surrounding sea (Frair, Ackman and Mrosovsky, 1972: 791), there is no demonstrable temperature barrier around the Cape and there is probably free interchange between the two ocean stocks.

There are, however, few complete descriptions of animals from each colony and some characters may yet appear showing a weak differentiation between populations. Carr and Ogren (op. cit.: 27) made the first serious attempt to present some quantitative scale counts on hatchlings. Compared with their scale counts, the Tongaland leatherback hatchlings have fewer scales on the right costal ridge but the range of counts is wide, the sample sizes small (Carr and Ogren's counts were based on samples from 2 clutches) and this one feature cannot be accepted as grounds for separation. More extensive samples from more areas are required.

Clearly the modest size of the Tongaland leatherback population requires comment. Most leatherback colonies are well within the tropics and nesting is seasonal in all areas except those such as Ceylon, which has consistently high sea temperatures (27° - 28°C), and where nesting emergences have been noted in nearly every month of the year (Deraniyagala, 1939: 63-64). Nesting areas in temperate waters such as Tongaland, and perhaps Florida, have modest populations and the nesting distribution does not exceed the poleward extreme of the 25°C summer sea isotherm.

In egg production and fertility the Tongaland leatherback differs from other populations in that clutch sizes are larger and fertility apparently higher (see Section 5, below and Pritchard, op. cit.: 23, 24-25). The numbers of clutches laid by each female seems consistent throughout their range (see Section 5, below).

In Tongaland the killing of leatherback females on the beach has always been rare and the ama-Thonga Africans are even today frightened of the turtle, although the same cannot be said for Mozambique where killing is widespread. Similarly, in Tongaland with the numerous, and easy to locate, loggerhead nests the hunting pressure on leatherback eggs was probably negligible. Therefore the modest population cannot be attributed to poor fertility, small clutch size or hunting pressure; neither on the nesting turtle nor its eggs. Sub-adult leatherbacks have been caught in the cold waters off the Cape and Europe (Brongersma, ibid.) and adults are known to travel long distances (see Section 4, below). Thus in the sub-adult and adult phases the leatherback has ample food over vast areas of ocean. The markedly similar size of females in widely separate nesting populations would suggest that all populations have similar feeding opportunities in the pre-nesting phase where growth is most pronounced. Thus, if no obvious reasons are available in the adult and sub-adult stages, nor in the egg production and fertility, to explain the differences in population size, a possible reason may be found when considering the movements of the hatchlings.

Many workers have tried to rear leatherback hatchlings and there has been a spectacular lack of success. Deraniyagala (op. cit.: 95) succeeded, in the mid-thirties, in keeping one alive for 662 days but no further success was achieved until very recently when Hendrickson (pers. comm.) reported that in Hawaii, leatherbacks have now been reared to a mass exceeding 10kg. Hendrickson recommended that the temperature of the water in tanks should not vary from 26.7°C (80°F). As such a steady-state situation seldom exists in nature one can assume that the critical temperature should be around that figure. He further stated that if the turtles were kept in cooler water the gut packs with undigested food and the animal dies. This would suggest that the leatherback hatchling is incapable of raising its body temperature (as adults do) in order to maintain efficient body metabolism. Thus it is suggested that the ambient sea temperature plays an important part in the survival of hatchling leatherbacks.

The following points are pertinent:

The Agulhas Current attains its highest velocity during the late summer months when hatchlings are entering the sea (see Section 1, above). The direction of current flow is important because it could carry hatchlings to areas of optimum, marginal or hostile conditions.

Some leatherback hatchlings from Tongaland (and Mozambique?) are carried southwards by the Agulhas Current (see Section 3, below) and it can be assumed that the distribution of hatchlings from other nesting grounds is also influenced by ocean currents.

Thus, reviewing briefly the current directions off leatherback nesting beaches around the times of hatchling emergence one finds:-

- (a) Trengganu - August current flow is northwards into the Gulf of Thailand where there is a gyral which persists for several months. The sea temperature ranges between 28° and 31°C (Ichiye, 1966: 340; LaFond, 1966a: 833).
- (b) French Guiana - August current is northwards flowing towards the Caribbean; sea temperatures between 26° and 28°C (Plutchak, 1966: 310).
- (c) Ceylon - Currents flow away from the island in either monsoon season and irrespective of direction hatchlings would be carried into water of temperature between 27° - 28°C (LaFond, 1966b: 111).
- (d) Florida (?) - August current northwards as the Gulf Streams; cold inshore water north of nesting areas with temperature differences of 10°C. North Atlantic gyral water varies from 20°C in the north to 28°C in the south (Defant, 1961: Plates 3a and 3b).
- (e) (i) Mozambique - March to April current southwards, some water turned back into gyral in Mozambique Channel where temperatures vary between 27°C and 28°C.
- (ii) Tongaland - March to April current southwards towards waters as low as 20°C, localized upwelling along south coast brings temperatures down to 14°C (see Section 1, above). Agulhas gyral central waters vary between 19° and 27°C.

From the above it can be clearly seen that in areas of concentrated leatherback nesting activity the ocean currents carry hatchlings into waters between 26°C and 31°C which is the range within which Hendrickson's temperature recommendation is contained.

Tongaland leatherback hatchlings, in contrast, are carried into waters which have temperatures well below the figure stipulated by Hendrickson, and it is likely that their survival chances are reduced. Undoubtedly some would be fortunate and be recirculated into the Mozambique Channel gyral perhaps by moving northwards in the inshore counter-current, whilst others may survive in the warmer northern half of the Agulhas gyral, but it is likely that numerous leatherbacks perish in the cold waters around the southern tip of Africa.

This hypothesis although based on rather flimsy evidence provides a plausible reason for the modest size of the leatherback nesting population in Tongaland.

It could be suggested also, that the larger clutch sizes and greater fertility is a response to the pressure on the population brought about by the high mortality of hatchlings in cold waters. Females laying larger clutches of eggs would be selected for, as hatchlings emerging from small clutches would have fewer chances of survival. It also raises some questions, viz. how long does it take for a leatherback hatchling to reach the stage where it can exercise some control over its internal temperatures and is this extra heat generated by movement?

Friar, et. al. (op. cit.: 793) considers that heat is generated by muscular activity and the behaviour of captive leatherback hatchlings might corroborate this; it is a characteristic of hatchlings kept in tanks to swim almost incessantly against the walls often causing considerable abrasive damage to the head and fore-flippers. Once a hatchling stops swimming during the day and hangs its flippers, its demise is imminent. If the heat is generated by muscular activity it is possible that the larger the animal the more efficient the mechanism and this would make the leatherback most vulnerable to cold water in its youngest stage of life.

Thus there would be tremendous selective value in leatherbacks nesting on beaches where offshore currents carry hatchlings to parts of the sea where temperature stress would be minimal.

It is concluded that the Tongaland nesting beaches have modest populations because of the Agulhas current carrying hatchlings to waters that are not ideal for, or even hostile to, their survival.

It may be added that first reports from Angola suggest that the leatherback nesting population is large, up to several hundred animals per season, and if this proves to be true, their presence may provide additional evidence to support the suggestions made above, because the offshore current flow is northwards and would carry hatchlings into equatorial waters having surface temperatures of between 26° and 28°C.

MAJOR STAGES IN THE LIFE CYCLE OF THE LOGGERHEAD TURTLE WITH COMMENTS ON OTHER SPECIES

Introduction

Research into the life cycles of sea turtles necessitates considerable speculation because from the time newly emerged hatchlings enter the sea from the nesting beaches, very limited quantities of material are available and it is from this limited material that major stages of growth and behaviour must be deduced.

Firstly the mortality rate of hatchlings in the first few weeks, or months, is apparently enormous and their almost complete disappearance for varying periods makes study difficult, forcing the use of negative evidence.

An added problem lies in the ageing of the material that does become available. Attempts to find growth rings in bone, nail, cartilage and shields have all proved futile and, further, it will be seen that growth rate is highly variable so size is an unsatisfactory guide except in very general terms. It must be added that growth rates in mature females are almost untracable after the first nesting season which makes ageing by size even less justified.

In this section, therefore, some meagre facts are presented, spiced with speculation and an awareness of many shortcomings. It is felt, however, that there are sufficient facts on which to base these speculations and although a great deal remains to be learnt and more detailed evidence is required for confirmation, the life cycle of the loggerhead is presented with some conviction. The fragmental information on other species is included for record purposes.

Methods

In this sub-section only the methods are to be discussed, the results are all incorporated in later sub-sections.

Hatchlings

Tagging

As in all localities, hatchling tagging has proved an almost insurmountable problem. Carr (1967: 108-110) describes

the difficulties encountered in trying to tag green turtle hatchlings. Several methods have been tried in Tongaland.

During the 1967/68 season 623 loggerhead hatchlings were tagged with a small plastic tag normally used for trout. This tag was attached to the edge of the carapace immediately adjacent to the inframarginal bridge and held in place by pieces of nylon monofilament fishing line. There were no recoveries (Hughes, 1970: 8-9).

The 1969/70 season saw a new attempt using small lengths (2 to 3mm) of stainless steel wire which were implanted under a selected vertebral scale by means of a hypodermic syringe. Although in turtles of 50cm carapace length and less the tags stood out clearly under X-ray, the limitations of the method were obvious and it would be useful only in the early stages. 3141 loggerhead and 22 leatherbacks were tagged and released. There were no recoveries (Hughes, 1971b: 7).

Dr. H.R. Bustard (pers. comm.) reported that mutilation: tagging, or notching of the carapace, had proved successful in experiments in Australia, and that after $4\frac{1}{2}$ years the excision was still clearly visible and appeared to be permanent. During the 1971/72 season a programme of notching was initiated and continued during 1972/73. An ordinary leather punching tool was used, its advantage being that it has six punch sizes, all but one of which are sufficiently small to use on loggerhead hatchlings. The site chosen for notching during the 1971/72 season was the first marginal scale immediately left of the left supracaudal scale; in the 1972/73 season the scale notched was the first marginal immediately right of the right supracaudal (Plate 16). After notching, the wound was immediately coated with Gentian Violet (1%) and left to dry.

Some hatchlings came from the experimental hatchery but most were gathered at night on the beaches. 5 000 were dealt with in 1971/72 and 5250 in 1972/73. All were notched, a sample weighed and measured the morning following capture, and released the next evening. Mass and size samples were between 100 and 400 hatchlings per season.

The method proved to be quick, neat and although there was an initial reaction to the notching, the hatchling's behaviour returned to normal within a few minutes and no further signs of discomfort were observed. Notched hatchlings kept in captivity were harrassed by other hatchlings biting the notched area but it is felt that this is unlikely to occur in the sea (Hughes and Brent, 1972: 42).

Recoveries of notched hatchlings will be discussed later.

Growth studies

In March, 1972, 200 loggerhead hatchlings were brought to Durban from Tongaland and installed in a plastic swimming pool measuring 3 x 3 x 0.5m. A strong flow of water, pumped directly from the sea, passed through the tank maintaining a slight circular current. For two months there were no casualties then in May problems developed, including fouling of the tank, which led to a heavy fungal infection and this resulted in very heavy mortalities. If caught early, the affected areas; mainly the eyes and divisions between carapace scales, responded to treatments with Gentian Violet (1%). Weekly dips in Gentian Violet would be practiced during any future mass growth experiments.

A further reason for mortalities was attributed to a drop in temperature in May and that the tank received no sun after the end of April. In June this situation was realised and the tank moved to the roof of the aquarium where it was exposed to the sun. It was too late, however, and mortalities continued. Thus in the long term the experiment was a failure but growth results from the early stages are useful as an indication of what might be expected from wild hatchlings at similar temperatures and some are included below.

Temperature tolerances

During April, 1972 an experiment was devised to test the response of loggerhead hatchlings to sharp changes in water temperatures.

4 perspex tanks measuring 55 x 40 x 40cm, each containing 66 l of water, were suspended to the water line in a large temperature

controlled behaviour tank (6 x 2 x 1.7m) in a basement experimental room at the Oceanographic Research Institute. Water temperature in the behaviour tank was set at 12°C but by situating the perspex tanks at different points in the tank it was possible to obtain temperature differences that held steady for three days prior to the start, and showed few variations throughout the duration of the experiment. Four temperature regimes were established; 18°C, 17°C, 15°C and 14°C and these were checked three times daily.

30 hatchlings were randomly selected from the yard tank, sponge-dried and weighed to the nearest 0.1g on an Ohaus triple-beam balance.

Ten hatchlings, chosen as controls, were marked with Indian ink so as to be individually identifiable and returned to the yard tanks which had a temperature of approximately 24°C throughout the experiment.

The remaining 20 were divided into 4 groups of 5, and, using a different colour paint on each group, were marked individually. Each group was then placed directly into a perspex tank representing temperature changes of 6°, 7°, 9° and 10°C.

The experiment ran for two weeks during which time the hatchlings were fed three times daily at 0900, 1200 and 1500 hours. Pieces of sardine or hake were weighed to the nearest 0.01g and suspended at the surface of the water. A fifth piece was placed in a separate tank to ascertain water absorption, if any. Food mass intake of hatchlings was adjusted in accordance with the mass deviations of the control food sample.

Hatchlings were weighed after 7 and 14 days. The results of the experiment are discussed later.

Stranded and net-caught material

During the course of each hatchling marking season appeals were made, through the news media of Natal and the Cape, for the return of stranded hatchlings to Durban. The public response was gratifying.

Sub-adult and adult material came mainly from the Natal coast,

having been caught in the Anti-Shark nets set by meshers under contract to the Natal Anti-Shark Measures Board. The meshers were requested to submit a monthly report on turtle catches but this proved tedious as a result of a low incidence of turtle catches so they agreed to submit a report only when a turtle was caught. The response from individual meshers varied from enthusiastic to indifferent.

Dead specimens were brought to the Institute where their statistics were recorded and the stomach contents examined. As the majority of specimens had been dead for some time few reproductive data were collected. The carapace, skull and gut contents were retained and the remainder discarded.

The first year (the "lost" year)

Hatching and orientation to the sea

These aspects of turtle behaviour have been thoroughly investigated by many workers; Carr and Ogren (1959: 14-15) described the emergence of leatherbacks in Costa Rica and Carr and Hirth (1962: 68-70) described the mechanism of social facilitation in green turtles. Hughes (1969: 9) described the emergence of loggerheads in Tongaland and the means of ascent through the sand appears identical in all these species.

Bustard (1967: 317) described the incidence of emergence arrest at the beach surface, if hatchlings approached it during the heat of the day. He also mentioned hatchlings lying dormant, with a few showing their heads above the sand, in a small depression caused by sand filtering down amongst the hatchlings. During the present field study this was found to be a common sight on Europa Island.

Mrosovsky (1968: 1338) investigated this behaviour and found that the critical temperature in Surinam beaches was 28.5°C above which hatchlings were inhibited from movement. This temperature limit is similar on Europa Island where no hatchlings were observed to emerge until the beach temperature dropped to 29°C which normally occurred between 1600 and 1730 hours. Daylight emergence occurred daily on Europa Island which would suggest that it is not light

which is the inhibiting mechanism.

This temperature inhibition applies also in loggerheads and leatherbacks in Tongaland where daylight emergences are a rarity; only 3 instances having been recorded in 10 seasons. Two emergences (1 loggerhead and 1 leatherback) were observed on overcast days and another loggerhead about noon on a hot clear day. In the latter case all hatchlings died within 15 metres of the nest. During hatchling tagging in Tongaland it has been noticed that throughout the night of capture the level of activity in the retaining boxes has been high. With the coming of daylight the hatchlings became quiet, not moving again until evening.

There are indications that the critical inhibitory temperature is lower in Tongaland. Figure 58 shows the mean daily sea and beach temperatures during the 1966/67 season, together with the 1800 hours beach surface temperature from the 8th January when hatchling emergences were first recorded. It can be seen that beach surface temperatures rarely reach 29°C.

	<u>nights</u>	<u>%</u>
Beach surface temperature at 1800 hours : 29°C	4	12.9
28°C	5	16.1
27°C	10	32.3
26°C	4	12.9
25°C	5	16.1
24°C	2	6.5
23°C	<u>1</u>	<u>3.2</u>
	<u>31</u>	<u>100.0</u>

Hatchlings in Tongaland, either leatherbacks or loggerheads, emerge from 1900 hours and have been observed to emerge throughout the night. As the above temperatures were recorded at 1800 hours one could expect a further drop of 0.5°C by 1900 hours. Thus it would seem that the inhibiting temperature is in the region of 26.5°C to 27.0°C. It is perhaps of interest to note that the offshore sea surface range is remarkably similar (cf. Figure 33).

Sea finding orientation has been exhaustively investigated (Ehrenveld, 1966; Limpus, 1971; Mrosovsky and Carr, 1967; Mrosovsky

and Shettleworth, 1968 and Mrosovsky, 1970). No investigations have been undertaken in Tongaland as hatchling behaviour does not differ from that described for other areas. Mrosovsky (1970: 650) summarizes by stating that any kind of visual stimulus has some effect on the seafinding orientation of hatchlings and that the orientation depends on a relatively uncomplicated type of tropotactic reaction.

Initial activity

It is common knowledge that once hatchlings have emerged there is frenzied activity and if placed in water there is continuous swimming. In the initial stages this behaviour has high survival value for it removes the hatchlings from the predator infested littoral zone. Dr. D. Hughes (pers. comm.) suggested that a green turtle hatchling may cover up to 7 km during the first night and this is likely to be somewhat more than the smaller, less vigorous loggerhead. Local currents assist the Tongaland loggerhead in its removal. Harris (1964: 237) has shown that mass movement of water in the surf zone is northward and there are cells terminated by powerful rip currents sweeping up to a kilometre offshore. These cells are between 500 and 700 metres in length so hatchlings, although swimming, would have little distance to drift before being carried out beyond the surf zone. The larger, more powerful leatherback probably needs no assistance from the rip currents.

Captive loggerhead and leatherback hatchlings refuse food for at least two days after emerging on the beach so it is assumed that this is the minimum length of time spent swimming out to sea. As the Agulhas Current flows within 10 kilometres of the Tongaland coast all hatchlings should be well within its flow before commencing feeding.

Green turtle hatchlings from Europa and Tromelin Islands are carried rapidly away from the shore by strong currents. As frigate birds are efficient predators of green turtle hatchlings and can remain a threat within 100km of the islands, a longer and faster swim by green turtle hatchlings would have high survival value.

The role of ocean currents in dispersion: The Agulhas Current

It has long been assumed that the ocean currents play an important role in the movements of sea turtles at all stages of their lifetime. Deraniyagala, (1938: 540) and Parker (1939a: 121; 1939b: 156) linked the stranding in Europe of loggerhead and Kemp's ridley turtles with the Gulf Stream and North Atlantic Drift.

Other workers have accepted the role as fact and based dispersal hypotheses thereon (Brongersma, 1968b: 118; Carr, 1957: 54; Deraniyagala, 1943: 89; Pritchard, 1967: 30).

Proof that ocean currents act as distributing agents has not been forthcoming until recently. It would now appear that in the case of Tongaland loggerhead and leatherback hatchlings the Agulhas Current plays a significant role in their distribution. During 1967, Mr. Peter Dreyer of Cape Town reported that hatchlings were occasionally washed ashore at Cape Agulhas, 1650km south of the Tongaland nesting beaches. A serious effort was made to gather more information and stranded hatchlings, with encouraging results which led to a preliminary report summarizing the data collected (Hughes, 1970: 16-21). It appeared that at Cape Agulhas in particular, strandings were occasionally substantial, up to several hundred hatchlings coming ashore at a time. Further, there appeared to be a modal increase in size with increasing distance from Tongaland. It was assumed that the hatchlings came from Tongaland but it was not proven. Sufficient recoveries of loggerhead hatchlings, marked in Tongaland during the 1971/72 and 1972/73 seasons, have now been recorded to remove all doubts as regards the origin of some of the stranded hatchlings.

Data from six marked hatchlings recovered away from Tongaland are presented in Table 44. Figure 59 shows the size distribution (carapace length) of all recorded strandings of loggerheads and leatherbacks during the period February - June over the past 6 years. Localities are shown on Figure 60 which shows also the release and recovery points of drift cards released during the present survey; the lines connecting the points are not meant to indicate the lines of drift.

Figure 61 shows the size distribution of loggerhead hatchlings stranded during 1973. Table 45 presents data collected from unseasonal and unusual strandings of hatchling and early juvenile sea turtles in South Africa.

Discussion of the data presented will be deferred until the end of this section.

The tolerance of loggerhead hatchlings to temperature changes

Figure 62 illustrates the results of the experiment on temperature tolerance carried out on loggerhead hatchlings during April 1972. Each line in the graph illustrates the mean response of each group to the different temperature regimes expressed in terms of mass loss and mass gain. The first 14 days represent the period in which the groups were in the experimental tanks, the remaining 14 days the response to the warmer conditions in the control tanks at 24°C.

Differences in mass between each group were apparent within the initial 7 days of the experiment. Compared to the control group mass increase was reduced in those hatchlings at 17°C and 18°C; the 15°C turtles remained almost static and the 14°C turtles lost mass steadily. During the 2nd week the lower temperature groups had continued to lose mass, the mass gains of the 17°C and 18°C groups were reduced, whilst control hatchlings continued to gain mass steadily. The experiment was terminated at 14 days because it was obvious that continuation would result in mortalities; two hatchlings from the 14°C group died within 3 days of being returned to the control tank.

The immediate response to the 24°C water was surprising and it is noteworthy that within a week the rate of mass gain was almost identical for all five groups.

It was thought that the quantity of food ingested per day by each group would be indicative of their activity. The results are illustrated in Figure 63. The 18°C and 17°C groups reflected an almost rhythmic feeding pattern; taking food in increasing quantities for 2 or 3 days then reducing intake sharply, followed by a gradual increase again. The lowest temperature groups were

far less active and fed more erratically but with a weak pattern still apparent in the early stages. The pattern broke down in the latter half of the experiment.

Discussion

In summary the experiment showed that loggerhead hatchlings can:-

- (i) Survive sharp drops in sea temperature.
- (ii) Continue to feed and grow in temperatures as low as 17°C.
- (iii) Survive for at least 14 days in waters having temperatures of 14°C.
- (iv) Recover immediately if returned to warmer waters and gain mass at the same rate as they had previously been doing in warmer water.

Thus hatchlings entering cold water will experience growth arrest which will result in their being markedly smaller than their siblings that have not been subjected to cold temperatures.

The tolerance of loggerhead hatchlings to adverse temperature conditions has high survival value in the study region. Hatchlings are carried south along the east and south coasts of South Africa in the Agulhas Current (see sub-section above). Large eddies and counter-currents are features of the circulatory system and wind variations often result in localised upwelling, particularly along the south coast, with sea temperatures dropping suddenly to 14°C. Should wind, eddy currents or upwelling result in hatchlings being situated in cold water they have up to 14 days in which to be blown or drifted into warmer water. The effects of local upwelling would not persist for as long as 14 days (F.P. Anderson, pers. comm.) thus posing no long term threat to the loggerhead hatchling unless in its period of relative inactivity it is blown ashore by onshore winds.

Further comments will be made in the general discussion below.

Growth rates

Figure 64 shows the mean and range of growth rate, expressed in terms of carapace length, in a sample of 200 loggerhead hatchlings over a period of 10 weeks. The weekly mean sea temperature of the

tank for the same period is also shown.

Mean growth rate was steady throughout most of the period of study but declined with the temperature during the final fortnight. Variations in growth rate was marked after one week and became increasingly so. At 12 weeks when mortalities showed a sharp increase, the carapace length variation in 168 hatchlings was from 55mm to 85mm (Insert; Figure 64).

Despite the limitations of captive growth studies in general and this study in particular it is felt that the data presented in Figure 64 is useful for comparison with wild growth rates because temperatures were similar to, if not slightly higher than, the sea temperature which wild hatchlings would be subject to (see Figures 33 and 34).

Further, from the stranding records of hatchlings during 1973 (Figure 61) where considerable size variation is apparent, there seems little reason to believe that loggerhead hatchlings in the wild state are not subject to growth variation such as has been shown for the captive group in Figure 64.

Further evidence to support these suggestions is derived from the recovery of notched hatchlings. The carapace lengths of notched hatchlings recovered during 1972 and 1973, and identified by the letters A, B, C, D, E and F (Table 44), have been entered on Figure 64 at their minimum possible age i.e in 4 out of 6 cases the time between their possible release (the termination of the notching programme) and the date of their recovery (Table 44).

Specimen B has been awarded a minimum age of 8 days on the grounds that; it had to travel a distance of 400km; the speed of the Agulhas Current reaches 60cm/sec. in the autumn (see Section 1; Ocean Currents) and thus would take at least 7 days to cover the distance at 50-60km/day; and it is assumed that a half day was required to enter the current and a half day to drift ashore.

For similar reasons Specimen C, with a distance of 1100km to travel, has been awarded a minimum age of 21 days.

Specimen D is recorded at the minimum possible age. With Specimen B, these two hatchlings show a growth rate apparently more rapid than the experimental animals. It is suggested that

this is unlikely because the remaining specimens are well below the size of captive hatchlings of similar ages.

Predation

Loggerheads and leatherbacks

In Tongaland hatchlings are preyed upon mainly by the ghost crabs Ocypode ceratophthalmus and O. kuhlii. Table 46 gives an indication of the percentage loss to ghost crabs from emerging loggerhead clutches. There are numerous factors affecting the predation rate; size of clutch; the fewer hatchlings the higher the percentage kill, state of tides e.g. low spring tides result in the hatchlings being exposed for longer periods, etc.. Although the crabs constitute the biggest single threat, their victims are often stragglers, or those with poor orientation facility and it is thus advantageous to have these hatchlings removed from the population gene pool.

Other predators in Tongaland are feral dogs, which can cause chaos within a single hatching but are more a danger to eggs than hatchlings; rusty spotted genets (Genetta rubiginosa) water mongoose (Atilax paludinosus) and occasionally during the day the yellowbill kite (Milvus aegyptius) has been seen to take hatchlings.

Ants (Dorylus spp.) can also destroy hatchlings en route to the surface. It would appear that the ants attack the hatchlings which then dissipate their energy trying to dislodge the ants rather than continuing to climb towards the surface. These ant attacks are restricted to nests laid hard against the dune forest margins and are of negligible importance.

Green turtle hatchlings.

On the islands of Europa and Tromelin the two major terrestrial predators are hermit crabs (2 species; Caenobita rugosus and C. cavipes) and the frigate bird Fregata minor. Ghost crabs on the islands are small and scarce posing a negligible threat to hatchlings.

No detailed figures are available on hermit crab predation. Unlike the ghost crab which takes a hatchling down its burrow, the hermit crab consumes the hatchling on the surface of the beach, leaving a cleaned carapace. A morning count over 50 metres of beach on Europa Island revealed 124 cleaned carapaces. The hermit crabs (Plate 17) pursue a hatchling with agility lifting their shells high above the sand. On catching the hatchling the shell is dropped onto the beach as a dead weight which the hatchling cannot pull. Immediately a hatchling has been stopped hermit crabs descend upon the victim from metres around and form a pile over the hatchling. Hatchlings following in the track of the victim have a much higher chance of survival.

The frigate bird decimates all daylight emergences both on the beach and in the sea. A typical example of their effect on a daylight emergence:-

1630 hours - hatchlings start to emerge onto beach.

1631 hours - frigates attack in increasing numbers.

1642 hours - 133 hatchlings have emerged.

1645 hours - all hatchlings have been eaten.

Distance of nest from sea - 45 metres.

Estimated numbers of frigates - 40.

Two frigate birds were collected and both had 6 hatchlings in their crops: 2 hatchlings were still alive and released only to be taken immediately by other frigate birds.

Other predators on the islands are the pied crow (Corvus albus; Europa Island), rock crabs (Grapsus spp.) and moray eels (Echidnae). The black rat (Rattus rattus) previously introduced to all the islands visited, have been seen on the beaches and would probably take hatchlings as would the numerous small sharks, particularly the reef blackfin shark (Carcharhinus melanopterus), in the lagoon on Europa.

Paulian (1950) claimed that on Europa the pink-footed booby (Sula sula) preyed on hatchlings. No suggestion of this was seen during two visits to Europa.

Near Europa Island green turtle hatchlings were found in the stomachs of the red devilfish or red snapper (Lutianus argentimaculatus) and the yellowfin tunny (Germo albacora) (Mr. D. Willans, pers. comm.)

A juvenile green turtle (straight carapace length 25.7cm) was removed from the stomach of an oceanic white-tip shark (Carcharhinus longimanus), caught some 107km off Durban.

Feeding

Table 47 summarizes the stomach contents of 37 loggerhead hatchlings collected on the beaches of Cape Agulhas. Unfortunately much of the material examined was fragmentary and the only food organism clearly identifiable was Physalia. The nature of the other identifiable matter; feathers, plastic beads, bark, etc. suggests that loggerhead hatchlings will eat anything that is floating and small enough to swallow. Captive hatchlings feed voraciously on Physalia, Porpita, Velella and Janthina janthina. The grit found in the stomach and intestines of some of the hatchlings examined might be fragments of Janthina shell.

No identifiable material has been found in stranded leather-back hatchlings.

The juvenile green turtle taken from the stomach of a shark 107km off Durban had its stomach filled with Janthina janthina.

Parasites, epizoots and injuries

Hatchling leatherbacks and loggerheads, on stranding at Cape Agulhas, have been found to harbour internal parasites (roundworms, sp?) and numerous external epizootic organisms such as goose-neck barnacles (Lepas spp. and Conchoderma virgatum), acorn barnacles (Balanus sp.) (Plates 18 and 19), and the bryozoan (Membranipora membranacea).

The occasional loggerhead hatchling has been found with fine strands of green algae on the plastron but it is not common to all.

Injuries are uncommon and restricted to the hind flippers from which crescent shaped pieces are missing (Plate 20). Such wounds, if persisting to adulthood, could be misidentified as shark bites.

General discussion

From the data presented above it is concluded that loggerhead and leatherback hatchlings spend at least three months under the direct influence of the Agulhas circulation; feed on pelagic organisms and, as they collect numerous surface epizotic organisms, it appears that they are relatively inactive.

The wide variation in the sizes of hatchlings stranded on the South African coast requires comment (Figure 59). At 60cm/sec. the Agulhas Current could carry a drifting hatchling from Tongaland to Cape Agulhas in 32 days. The notched hatchlings found at Cape Agulhas (Table 44) took 48 days which would suggest that the turtles do not remain in the main stream of the current but are probably delayed by eddy circulations or possibly winds. If this is assumed, then the wide range of hatchling sizes can be explained. If caught in an eddy of high water temperature and optimal growth conditions, a larger hatchling will result. In the same period of time, siblings caught in an inshore eddy coming into contact with upwelled water will be smaller. (cf. Figure 62).

Stranded hatchlings are a direct result of inshore eddies coming into contact with water of low temperature associated with the south east wind. At Cape Agulhas, Mr. P. van As (pers. comm.) reported two loggerhead hatchlings walking out of the sea shortly after the termination of a south easterly gale which resulted in a strong northerly current with water of 15°C.

Strandings during 1973 show a clear association with the south east wind. Between the 4th and 27th April there were substantial strandings of hatchlings along the shores of Cape Agulhas. Hundreds came ashore over the weekend of the 6th, 7th and 8th at Waenhuiskrantz (Dr. R. van der Westhuizen, pers. comm.).

At the Heunignes Research Station weather records showed that the south-easter started on the 3rd April (Dr. N. Fairall, pers. comm.) and blew almost continuously until the 26th April. The last hatchlings reported were on the 27th April.

The numbing effect of cold water is illustrated by the behaviour of a loggerhead observed during the present study on Cape Agulhas during April, 1970 when the water temperature dropped from 21°C to 17°C. The hatchling had been washed ashore at high tide and

left in the debris line as the tide fell. It is thought that with exposure to the sun the hatchling had recovered sufficiently to walk back towards the sea. After maintaining a direct line for 20 metres it suddenly lost orientation and circled and wandered for about a metre and then stopped. It was found at 1630 hours alive but weak and it died within an hour.

The possibility that stranded hatchlings have been subjected to varying periods in cold water, and thus growth arrest, must be taken into consideration when viewing the sizes of recovered notched hatchlings. From Figure 64 it would appear that the wild growth rate is markedly slower than the captive specimens. It is almost certain that the notching does not affect the hatchling adversely as, with specimens E and F (Table 44) was a third unmarked hatchling measuring 52.2mm, suggesting that the three were in a group (resulting from water mass movement, not conscious adhesion). The size distributions in Figure 59 would seem to indicate group arrivals in different size classes but in the 1973 recoveries (Figure 61), only the Cape Agulhas strandings during April suggest a size group.

Table 45 shows some extreme cases; firstly, some hatchlings collect at Port Elizabeth in late March measuring over a 100mm carapace length. No hatchlings have ever been seen to emerge in Tongaland during December so if the stranded specimens did originate there they are less than 12 weeks old. They might, however, have come from Mozambique, the stranding of a 60.0mm loggerhead in northern Tongaland during early March (Table 45) suggests that this might be possible as loggerheads are known to nest as far north as 23°S.

The stranding of a 112mm loggerhead $4\frac{1}{2}$ months after those mentioned above show the wide range of sizes emanating from a single season. The largest and only juvenile specimen found in South Africa was the 219.0mm specimen from George (Table 45). Assumed to be approximately one year old this turtle showed a faster rate of growth than ever recorded in the Durban Aquarium.

With the exception of this single specimen no juvenile loggerheads have been recorded from the entire South African coast and no more hatchlings after early June (again with the exception

of the 112mm specimen in August). This would suggest that the currents bear the hatchlings away from the coasts either into the Agulhas gyral via the Agulhas return current or around the Cape of Good Hope into the South Atlantic. It is suggested that hatchlings travel in both directions but with the majority recycling in the gyral. Unless hatchlings passing around the Cape are blown close inshore on the west coast there are no temperatures low enough to form a barrier preventing their entrance into the South Atlantic. Whether or not these hatchlings make their way back to the Indian Ocean is a matter of great interest.

It is assumed that the leatherback turtle is subject to the same influences as the loggerhead but is possibly less hardy (see Section 2, above).

Accepting the role of ocean currents it would appear that green turtles from Europa Island are kept within the Mozambique Channel gyral with the occasional stray being carried southwards by the Agulhas current (Table 45 and the specimen from the stomach of an oceanic white-tip shark).

Tromelin green turtle hatchlings should be carried to the coast of Madagascar and possibly recirculated in the gyral between the Mascarene ridge and Madagascar.

With both nesting areas the gyral is small and would ensure that turtles are brought within reach of suitable feeding grounds within a few months.

Green turtles can change to the adult vegetarian diet at about 6 months of age.

Loggerheads on the other hand are swept into larger gyral (Figure 60) which would necessitate long periods at sea e.g. the Tongaland loggerheads enter the Agulhas gyral or even the South Indian Ocean gyral. Loggerheads from South East Madagascar are probably carried into the south Indian Ocean gyral and some may find their way into the Agulhas gyral; in either direction a long sea voyage is obligatory (Figure 60). Evidence presented in the following subsections will show that this is a plausible hypothesis.

Little comment is possible on the hatchling distribution of hawksbills and ridleys although the stranding of a young hawksbill (Table 45) would suggest that they follow a similar pattern to that of the green turtles. No ridley hatchlings have been stranded.

In summary, the ocean currents play an important, if not the dominating, role in the initial year of life in sea turtles. After the first year the influence of the currents declines according to the requirements of the species.

Growth rate to maturity and beyond

Having discussed growth rates in the hatchling stages it is pertinent, and convenient at this point, to establish an approximate time scale for the stages which will be dealt with later in this section. These stages are expressed in terms of straight carapace length as follows:

Juvenile stage	: 15.0 - 60.0cm
Sub-adult stage	: 51.0 - 80.0cm
Adult stage	: 81.0cm upwards

In the preceding sub-section it was noted that loggerhead growth rates in the first year are variable both in captive specimens and those recovered from the tagging programme. Further, early hatchlings and late hatchlings will be subject to different sea temperature regimes and will also show variation in growth rates. These combined factors should eventually lead to a stage where no age class would be discernable in terms of size or time. In support of this suggestion Table 48 is presented showing, in 2cm classes, the size range of loggerheads stranded or caught along the Natal coast during the past 5 years. There is no indication of any size class being associated with a particular time of the year. Thus any growth curve related to time, based on carapace length or mass, must be regarded as an approximation only.

This being accepted, Figure 65 is presented showing an approximate growth curve relating time and straight carapace length. The data were collected from captive loggerheads in the Durban Aquarium. The oldest two loggerheads have been reared from hatchlings to $9\frac{1}{2}$ years of age, always at ambient sea temperatures (see Figure 33) and all specimens are fed twice daily on either pilchard or hake. In presenting this curve it must be stated that the tanks through which the turtles have passed are variable in size, are often unsuitable and can have considerable effect on the growth rates of the turtles.

For example, one specimen, now 5 years old, was kept in a basement tank containing 7200 litres of water and reached a mass of 10.5kg and remained at the same mass for eight months.

Transferred to the main fish tank containing 800,000 litres of water, its mass increased by 3.6kg in 23 days, and doubled in another 73 days to 20.9kg. In the same time the carapace length increased from 41.0 to 49.0cm.

As a result of these variables and the obvious shortcomings of using captive material as a source of data, errors of up to two years in the suggestions as to the duration of the various stages in the life cycles discussed later must be tolerated until an accurate ageing method becomes available. The possible future recovery of some turtles, notched as hatchlings in Tongaland, might also provide a guideline as regards age at maturity.

Included on Figure 65 are growth data from other sources. Data from foreign sources are summarized in Brongersma (1972: Table 11) whilst data from East London and Port Elizabeth were provided by Messrs. A. Parkins and T. Dalton respectively. Uchida (1967: 500) and Parker (1926; 1929, in Brongersma, *ibid*) recorded growth rates consistently more rapid than those observed in Durban and it would be of value to know whether the hatchlings were kept in heated aquaria during the first winter after hatching.

Temperatures, as has been shown, is critical during the first year after which the main factor governing growth rate is probably availability of food. This is exemplified by comparing the growth rates recorded in Durban, where no heating facilities are available, and those recorded in Port Elizabeth where hatchlings are kept at 21.1°C throughout the first winter. At the end of the first year Port Elizabeth turtles are larger than those in Durban (Figure 65) and are then transferred to unheated external ponds in which they thrive. Thus the age at maturity might be dependant on what environmental conditions the hatchling finds itself during its first winter; if in the southern part of a gyral growth rate will be reduced and vice versa if it is the northern part where temperatures are more amenable.

If the data collected from recovered wild hatchlings, notched in Tongaland, are valid then it would appear that all of the growth rates reported, with the exception of the East London data, are too rapid in the early stages. As far as the Durban data are concerned,

unsuitable tanks may have reduced the growth in the juvenile stages.

Commenting on the reported ages of loggerheads at maturity it seems likely that Uchida's (op. cit.: 497) suggestion of 6-7 years is slightly previous and Hughes' (1972b: 21) suggestion of 10-12 years is certainly too long. During the past two years the oldest loggerheads in the Durban Aquarium have shown a sharp decline in growth rate possibly prompted by the limitations of the tank.

It is therefore suggested that under optimal conditions loggerheads can reach sexual maturity in 6 years (Uchida, ibid.) but in the more hostile conditions likely to be encountered by the Tongaland loggerhead the age of maturity is probably nearer eight. From this suggestion it can be assumed that the juvenile stage can terminate between four and five years and the sub-adult stage would last two or three years, with the size of the turtle at sexual maturity being variable.

Although there is obviously a minimum size at which loggerheads are capable of nesting there are few data to support the suggestion that a nesting turtle of 85cm curved carapace length is a neophyte nester or that a large female of 98.0cm curved carapace length is an old turtle. The Tongaland programme has been underway for 10 years and during the 1972/73 season 47% of the females handled had nested at least once, twice and occasionally three times before. If there was substantial growth after a female had nested for the first time it would be expected that those that were known to be older, i.e. those that bore tags implanted in previous seasons, should be significantly larger than the untagged group which must contain a certain proportion of neophyte nesters.

Figure 66 shows the size frequency, in 1cm classes, of tagged and untagged loggerheads encountered during the 1972/73 season. The mean curved carapace lengths of tagged and untagged turtles were 94.34cm (S.D. 3.92; n=119) and 93.6cm (S.D. 4.39; n=138) respectively. The apparent difference in length was not statistically significant ($P > .1$) although larger samples in future might show that a difference does exist.

It had been thought that carapace length measurements would show differences as the turtles aged. Unfortunately since the inception of the Tongaland programme standard field measurements have been taken over-the-curve using flexible steel tapes (Hughes, et. al., 1967: 10) and the substantial loss of plastic tags (see Section 4) has masked the inaccuracies of the method until the 1972/73 season.

Figure 67 shows measurement differences in loggerheads after intervals of one, two, three and five years, and in leatherbacks after intervals of two, three and six years. Allowances of up to 1cm had been made for measurement error but differences exceeding 5cm are obviously intolerable, and cast doubt on all the more acceptable measurements. Thus as far as mass data are concerned over-the-curve measurements are acceptable but at the individual level they must be regarded as useless.

It can be concluded, however, that in considering the lack of significance between the sizes of tagged (older) and untagged loggerheads (including younger animals) growth rate might be present but less than 0.5cm/year as most of the tagged turtles (91.0%) had been absent for at least two years. From the highly unsatisfactory data in Figure 67 only one dubious conclusion can be reached viz. if growth is continuous it is small, because after 5 years one loggerhead showed a 4cm decrease in length and even with an error of 5cm it is still remarkably similar to its original measurement.

There are no indications of remarkable growth rates in the leatherback data either.

No data are available on growth rates for green turtles in the study region but in Tortuguero, Costa Rica, Carr and Goodman (1970: 783), on analysing 15 years of measurement data taken with calipers, suggest that green turtles mature at various sizes, there being no tendency for a large green turtle to be an old animal.

Carr (1971: 32) maintains, however, that growth does occur in mature green turtle females and suggests that is in the order of 2.54mm per year which, as he claimed, is difficult to detect on an animal reaching a carapace length of 1200mm.

Carr's data on the green turtle does, however, lend some support to the apprehensive suggestion made above that a similar, barely traceable, rate of growth may be exhibited by the Tongaland loggerhead after it has reached nesting maturity.

The longevity of the loggerhead turtle is therefore impossible to judge from size. Flower (1937: 14) gives the longevity record of an Atlantic loggerhead as 33 years based on a captive specimen in the Lisbon Aquarium. In the study region the longest lived loggerhead was one which lived for 26 years in the East London Aquarium.

If one accepts eight years as a minimum age for sexual maturity then the oldest known female loggerhead nesting in Tongaland is a female (No.C207) which was first tagged in 1964 and was recorded in 1972/73, a total spread of 9 years. Added to the suggested minimal age at sexual maturity she is at least 17 years old and measures approximately 101.0cm over the curve of the carapace.

Although great ages are popularly attributed to sea turtles there is no scientific justification to this belief and only tagging programmes of long duration will provide an answer to the question of longevity.

Juvenile stage

Loggerheads, leatherbacks and olive ridleys

From Figure 8 it can be seen that there is a total absence of juvenile loggerheads and juvenile olive ridleys along the coast of the study region and only one juvenile leatherback has been caught off Cape Town (Table 40).

Surveys of material in fishing villages where the hunting pressure on littoral sea turtle populations is intense, has shown that up to 60cm carapace length, these species are not present. Fishing is undertaken by net and harpoon and there is no selection, neither by size nor species. It would appear, therefore, that the juvenile stage of these three species is spent in the open ocean as was suggested in the previous section.

Added justification for this conclusion may be adduced from reports from skin divers in Reunion Island who claim that juvenile loggerheads are periodically found on the eastern littoral of the island but seldom remain for long periods. Individual size appears to be in the range 40-50cm carapace length and are sufficiently frequent to have a local name La tortue blonde. Adults are very rare around Reunion and are known as Gros tête (see Section 2, above).

Current configurations (Figure 2) would suggest that these juveniles originate in South East Madagascar but they could be from the African nesting grounds as their size would indicate that they are between 3 and 4 years of age (Figure 65) or roughly a year younger than the size at which loggerheads return to the littoral.

In the total absence of evidence to the contrary, and, considering the data presented above, it would appear that loggerheads in the study region spend at least 4 or 5 years well away from the littoral zone and thus the situation is similar to that suggested by Brongersma (1972: 144) for loggerhead movements in the North Atlantic and by Uchida (1973: 15) for the North Pacific.

It is assumed that the drifting juvenile loggerheads feed on pelagic organisms such as Janthina janthina, J. prolongata and Physalia. Pouchet and de Geurde (1886, in Brongersma, op. cit.: 158) found pteropods, goose-necked barnacles, fragments of medusae,

pieces of bark, etc. in the stomachs of juvenile loggerheads caught in deep water near the Azores, suggesting that, like the hatchlings, juveniles will feed on anything that is floating (see also section on feeding in sub-adults, below).

In the light of the above, juvenile leatherbacks are probably in the open ocean as well but it is doubtful whether they drift as does the loggerhead. The olive ridley juveniles should be found in the Mozambique Channel gyral but there are few data on these small populations.

Greens and Hawksbills

Juveniles of both species are found along the littoral throughout the study region, even as far south as Cape Agulhas. Brongersma (1972: 228) suggests that green turtle juveniles move over long distances and the presence of green turtle and hawksbill juveniles at the Cape would support his views. The nearest green turtle nesting ground is Europa Island, 2800km away, and it is possible that they come from even further afield. On Europa Island the lagoon has numerous juvenile greens from 20.0cm carapace length upwards. From Hirth's (1971: 3: 17) review on growth data of the green, these Europa specimens would be at least one year old.

A similar age may be ascribed to the 2 smallest hawksbills measured during the present survey. One taken at Nossi Bé, Madagascar and in the O.R.S.T.O.M. collection, measured 19.8cm straight carapace length. The other from Durban measured 18.0cm.

It would appear, therefore, that the pelagic stage in greens and hawksbills lasts for little more than a year and they return to the littoral, changing to the diets typical of the species viz. sponges (hawksbills) and algae and sea-grasses (greens) (Table 51).

Little is known of the behaviour of hawksbill juveniles but some green turtle juveniles would appear to remain for extended periods in suitable feeding areas.

On the 16th December, 1969 a juvenile green turtle (carapace length 36.7cm) was tagged (A 201) and released at Inhassoro, Mozambique. 33 days later it was recaptured at the same locality.

During January, 1967, 2 juvenile green turtles were caught in rock pools 4.8km north of the Bhanga Nek camp in Tongaland. They were tagged with conspicuous yellow plastic tags (4970, 4841) and released. 10 months later a tagged juvenile was seen at the same place. Unfortunately it avoided 3 members of staff trying to catch it so the number was not ascertained but there was no doubt as to the presence of the tag.

This apparent tenacity to a general locality was reported by Schmidt (1916: 16) who tagged and released juvenile greens in the West Indies.

Some idea of the frequency of juvenile hawksbills in Madagascar can be derived from Table 23 which shows the annual harvest of the various size classes.

Sub-adult to adult stage

Return to the littoral

As shown in Figure 31 the smallest loggerhead recorded in the study region is 60.5cm straight carapace length. This suggests an age of between 4 and 5 years (Figure 65).

As only one sub-adult olive ridley has been taken in Natal no suggestions are made concerning their age, and the same applies to the leatherback of which only one sub-adult has been taken.

Sub-adult hawksbills and greens have been dealt with above.

Feeding changes

Loggerheads

Table 49 summarizes the stomach contents of 26 loggerhead turtles from the Natal coast. These data have been grouped into 3 size categories:- 60-70, 71-80 and 80cm plus straight carapace length.

55.6% of the smallest size group are still feeding on floating material as was recorded for the hatchlings. The remainder contained littoral and benthic organisms.

60.0% of the 70-80cm group had the remains of benthic organisms in their stomachs but the remainder had floating material, the one specimen having the carapace shields of a hatchling loggerhead; the only incidence of cannibalism recorded in this area.

The larger size groups contained only benthic organisms comprising mainly molluscs. Table 50 gives a species list of identifiable molluscs. The most frequently eaten species are Bufonaria crumenoides and Ficus subintermedius and these are illustrated in Plate 21.

Hermit crabs appear frequently in stomach contents but whether they are deliberately eaten or are mistaken for Mollusca is difficult to assess. The more active hermit would make it easy prey for the loggerhead as its movement might render it more noticeable.

There is no doubt that molluscs are favoured because bivalves are commonly ingested. One turtle (Table 50) had 6kg of crushed black mussel Perna perna shells in the stomach and gut. The shell in the rectum showed no damage from digestive juices.

The crushing power in loggerhead jaws is illustrated by the rarity of whole shells in stomach contents.

During the past ten nesting seasons in Tongaland only 3 dead female loggerheads have been washed ashore. Two had empty stomachs but the third contained fragments of crab, spiny rock lobster, spiny sea urchin and in the oesophagus was jammed a porcupine fish Diodon sp. which is assumed to have caused the death of the turtle.

The only other report of a turtle eating fish was described by Mileham (1965: 20) who saw 'a huge turtle' swimming in a shoal of pilchards Sardinops ocellata near Durban. The turtle was in the centre of the shoal with a circle of fish around it. Mileham reported that it took mouthfuls of fish at leisure.

Other species

One sub-adult olive ridley was examined and the stomach contained the crab Philyra globulosa which, according to Barnard (1950: 384), prefers muddy ground. Some small fragments of pagurids were also present suggesting that at 49.2cm straight carapace length the olive ridley is already a bottom feeder.

Hawksbills have been found to eat only sponges.

Table 51 summarizes the stomach contents of 12 green turtles from the Natal coast, juvenile, sub-adult and adult. The main algae eaten by the green turtle in this region are two Gelidium spp., Codium duthieae and Caulerpa filiformis.

In Mozambique one green turtle stomach examined contained Cymodocea ciliata, Halodule univervis and Zostera sp., all of which are listed by Hirth (1971: 3: 16).

With one exception all leatherbacks examined have had empty stomachs and intestines. The exception had the plastic sheet (Section 1).

Parasites and epizoots

Loggerheads

In considering the presence of epizootic organisms on loggerheads of different sizes it is suggested that further evidence is provided to show a marked change in behaviour by the host animal.

Table 52 shows, in grouped size classes as in Table 49, the epizoots on the carapace of loggerheads from the Natal coast. It can be seen that in the smallest turtles the goose-neck barnacle Lepas sp. is still present on two animals (Plate 22). The typical acorn barnacle Chelonibia sp. of adult loggerheads is found on only 18% of the turtles whilst 64% have no adherents.

As the size of the turtle increases so does the frequency of Chelonibia; 18% to 21.4% to 47.4%. In a sample of 30 loggerhead females from Tongaland 73% carried Chelonibia.

Thus it would appear that in the 60-70cm size class there is a change in life patterns resulting in conditions unsuitable for Lepas but favourable for Chelonibia.

In mature females the carapace occasionally has burrowing barnacles Stephanolepas sp.(?), small skin barnacles Platylepas sp., red and green algae and the leech Ozobranchus maggoi. Although uncommon, up to 49 leeches have been found around the cloaca of a single turtle (Hughes, et. al. 1967: 27).

Other species

Neither parasites nor epizoots have been found on the hawksbill and olive ridley material examined.

Nesting female leatherbacks normally carry small acorn barnacles Platylepas sp. on the skin. At sea leatherbacks have been photographed accompanied by sucker fish Echeneis naucrates and pilot fish Naucrates ductor (Condon, (1971): 117).

Juvenile green turtles in Mozambique have been found with heavy infestations of Chelonibia (see Hughes, 1971a: Figure 10) but these epizoots are rare in adult females. Of 343 nesting females on Europa Island 92.7% had no adherents; 7.1% had either

Chelonibia (only 1 each on three cases) or the burrowing barnacle Stephanolepas sp., three were so heavily infested with this parasite that half of the carapace was one continuous tumour (see Hendrickson, 1958: 524).

94% of laying females on Tromelin Island had no adherents, the remainder only Chelonibia.

Europa Island harbours an unusual parasite; the mosquito Eretmapodites plioleucas (Viette, 1966: 202). It is no exaggeration to state that there are millions of mosquitoes and they descend on nesting females, piling up to 2cm thick on the eyelids, and over the joints between the carapace shields.

Onset of sexual maturity and general movements

Loggerheads

In previous sections it has been shown that in the 60-70cm carapace length class the first signs of sexual maturity become apparent (Section 1; Figure 31). At the same time there is a change in feeding emphasis from floating to benthic food organisms. These changes are accompanied by changes in the epizotic organisms adhering to the carapace.

From Figure 8 it can be seen that at least 64.0% of the loggerheads recorded from the Natal coast are clearly immature, if the 80cm carapace length class is taken as the mature size and indications are that this is an underestimation.

Figure 68 shows the catches of loggerhead, and other turtles, in the anti-shark network since 1965. A histogram showing unidentified turtles caught between 1965 and 1968, when shark-meshers had no means of identifying species, is included. In all 85 loggerheads have been caught since 1968 as compared to 49 greens, and it can be assumed that a large proportion of the unidentified turtles, 176 in all, also consisted of loggerheads. Of this substantial catch only one has borne a tag from the Tongaland programme (Table 53, No.A49). It was taken at Warner Beach, south of Durban, during late January 1970 having just completed a nesting season.

Figure 68 shows also that the turtle catches correlate well with the sea temperature (cf. Figure 33) and these data suggest that either turtles are moving along the coast following the advances and retreat of warm water, or that they are moving away from the coast during the cold winter months. For example, at Durban the coolest temperature is recorded in August (20.5°C) whilst offshore temperatures are 21.1°C. In September the situation is reversed with cooler temperatures offshore (20.3°C) and Durban temperatures rising (20.8°C); Figures 33 and 34).

That there is movement, however, is clear and the data, applying as it does to all species except the leatherback, would favour the coastal movements.

Accepting that movement is characteristic of loggerheads the question arises why more adults are not caught in the nets. There is no doubt that some specimens are not brought to the Institute because of their size but as many animals were inspected as they were brought ashore this cannot be taken as a serious reason for the paucity of adults. Of all the females caught only one has been fully mature (i.e. nested, No.A49) and the largest female measured had a carapace length of 87.0cm which is just above the mean size recorded in Tongaland (86.4cm, Table 30).

The most obvious answer, and valid up to a point, is the fact that 97.0% of extra-nesting area recoveries of females tagged in Tongaland have come from Mozambique, Tanzania and Zanzibar (see Section 4). There would appear to be almost complete segregation between adults and young stock.

However, the fact that one female has been found south of Tongaland suggests that the answer is more complex and may involve territories.

Table 54 summarizes the known recapture data on extra-nesting area tag recoveries of loggerheads. (Many other recovery records lack dates or tag numbers (see Section 4)). With one possible exception all these turtles have been captured at dates suggesting movement associated with the nesting season.

Those turtles taken immediately after the completion of a nesting season have travelled long distances at substantial speed. It must be pointed out that speeds recorded in Table 53 must be regarded as minimal for the time interval is calculated from the last sighting in Tongaland although the turtle may have nested again and been missed by the staff.

The Zanzibar and Tanzanian recoveries showed that a loggerhead turtle, after a season of laying, can maintain a speed of 40km/day for 66 days or less. The purpose of this swift and lengthy migration would suggest that the turtle has a goal, possibly a feeding range or territory.

There are suggestions that sea turtles, with the exception of the olive ridley and leatherback, do have feeding territories. Carr (1952: 387-388) describes a large loggerhead which was seen

over a period of many years in a creek in Georgia. Some 9.6km up the Kromme River, Cape Province, there is, apparently, a large sea turtle (loggerhead?) well known to local residents.

Carr (1955: 206-236) described several convincing stories showing the ability of green turtles to return to a home territory and the same coral head near which they had been previously caught. The speed of the return was comparable to the speeds exhibited by migrating loggerheads.

Sleeping rocks are respected in the main tank of the Durban Aquarium, where the large hawksbill female has a particular spot in which no other turtle sleeps.

To summarize the above; tagged loggerhead females are taken mainly north of Tongaland in months associated only with the nesting season; they move with deliberation suggesting a goal to which the turtle returns after the nesting season.

Thus the apparent lack of mature females from the Natal coast might be explained simply as segregation or, that in regaining their territories, they swim directly down the coast, thus avoiding the shark nets which are normally within 200 metres of the shore and often situated in bays. Once in the home territory their movements are very limited thus reducing the chances of getting caught.

If turtle territories do exist the lack of tagged turtle catches during months not associated with the nesting season might also be explained.

To this must also be added the possibility that the larger loggerheads may prefer deeper water which would remove them from nets restricted to the littoral zone. However, in Madagascar, the balance between immature and mature size loggerheads taken on the littoral is very even (Figure 31) suggesting that in more tropical waters adults show no preference for deeper water.

Establishment of a territory - the mechanism of dispersion

If the concept of a territory or home feeding range is accepted it is possible to provide another reason for the higher

catch of immature turtles in the shark nets. The sub-adult stage is a period of change and movement and the turtles have not yet established a territory and are possibly driven away from suitable areas by resident adults.

From these movements the widespread nature of the loggerhead population might also be explained. Turtles tagged in Tongaland have been caught 2880km north and 430km south of the tagging sites, a total spread of 3310km. The speed of travel suggests that this is not merely random wandering, nor does the re-nesting recovery rates in Tongaland (see Section 4) which have shown a consistent increase every year.

Therefore it is suggested that most, if not all, adult female loggerheads have home ranges or feeding territories as do most carnivores. Immature animals are therefore forced, on their return to the littoral and contact with the adults, to move constantly as they mature, until they find a suitable vacant niche. Movements can be southwards, although this is possibly not favoured by adults because of the cold winter temperatures, or north which might necessitate a long voyage before an unoccupied niche is found. Large populations would mean longer voyages and a wider dispersal of the species.

Predators and injuries

The main predator of sea turtles from the juvenile stage through adulthood is the shark, two species of which, in the study region, have been found to contain portions of larger sea turtles in their stomachs. These are the tiger shark Galeocerdo cuvieri and the Zambezi shark Carcharhinus leucas (Bass, 1972: Table 37)

A sub-adult hawksbill was found in the stomach of a brindle bass or garrupa Promicrops lanceolatus shot by skin-divers in Mozambique (Condon, (1971): 253).

It is perhaps noteworthy that of 44 mainly sub-adult loggerheads examined along the Natal coast only 1 (2.2%) had any obvious natural injury.

In Tongaland, mature nesting females show a higher incidence of injuries. During the 1965/1966 season, of 204 adults 21% had notable injuries; 67.5% were on the flipper, 20.9% on the carapace, and the remainder deformations (lumps etc.) for which no ready explanation is available.

This marked difference in injuries particularly on the flippers would suggest that adults survive more shark attacks than younger turtles.

As females tend to nest near rocky areas in Tongaland, they are exposed to carapace damage arising from collisions with rocks. Some carapace injuries appear to have been caused by sharks because the large crescent-shaped gaps could hardly be caused by anything else.

As was mentioned in hatchling predation (Plate 20) some flipper injuries if they persist to adulthood, might be mistaken for shark bites but in the light of sub-adult data presented above it would be a rare occurrence.

Few data are available on other species. One juvenile green brought into the Durban Aquarium had the last marginal of the left side of the carapace neatly excised. All other juveniles had no injuries.

On Europa Island only 35 green turtle females (9.1%) out of 383 had external injuries, 48.6% of which were flipper injuries and the remainder on the carapace. Hendrickson (1958: 522) estimated that 4% of the green turtles nesting on the Talang Islands off Sarawak had injuries attributable to sharks.

It might be concluded that the higher incidence of injuries on loggerheads as compared to greens is merely a result of there being so many more green turtles. However, the differences in feeding areas might have some effect as the loggerhead feeds on deeper reefs than the green, which, because of its vegetarian diet, is normally found in shallow water. Loggerheads rising for air from a 10 or 20 metre deep reef must be exposed to attack for longer periods than, for example, a green turtle rising from 2 or 3 metres.

General discussion

It has been shown that the loggerhead turtle is a hardy species surviving in temperatures not favoured by the olive ridley, green and hawksbill. Almost all of its early life is spent in the temperate latitudes seldom penetrating sub-tropical waters. This would add credence to the suggestion made by Nishimura (1967: 32) that the loggerhead could be regarded as an antitropical species.

With regard to the study region this statement requires qualification because many adult females are found in sub-tropical waters reaching as far north as 6°S (Section 4). It would appear that many adults come into temperate waters during the nesting season only.

Thus, in the first year of life, it has been shown that warm water is important to maintain a rapid rate of growth and it seems that after maturity females prefer warmer water. It would appear that there might be a link between the two stages.

Hatchlings carry no fat but sub-adults are almost always extremely well insulated, layers of fat around the inner surface of the carapace reaching thicknesses of 2cm. This fat would ameliorate the effects of cold temperatures and enable the sub-adults to survive the cooler winter temperatures of the South African east coast. There are suggestions that they can live in the cold waters of the west coast as a healthy sub-adult loggerhead was taken off Saldanha Bay during October, 1962 (Dr. P. Best, pers. comm.).

During a nesting season a female can lose a quarter of her body-weight (see Section 2) and much of her fat reserves would be used up in egg production. She would be, therefore, ill prepared to face the low winter temperatures of the temperate waters and would probably retreat to warmer waters as has been suggested by tag recoveries (Section 4) and the lack of captures in the anti-shark network.

The presence of a feeding territory to which the effete female could return and recover in relative peace would be an advantage, particularly if the younger loggerheads were geographically

separated from the adult stock and thus not competing for food. This situation protects the female in her vulnerable stage when she requires adequate food supplies.

With the green turtle such spatial separation of sub-adult and adult stocks is not necessary because of the unlimited quantities of vegetable matter at their disposal.

As far as the other species in the study region is concerned insufficient data have been collected on which to base conclusions other than the fact that there is no inter-specific competition for food except in the hatchling and juvenile stages when they are in the open ocean.

MIGRATION, RE-MIGRATION, ORIENTATION AND RECRUITMENT
IN SEA TURTLE POPULATIONS WITH PARTICULAR REFERENCE
TO THE LOGGERHEAD TURTLE IN TONGALAND

Introduction

Intensive and continuous tagging programmes on sea turtle populations have been undertaken in Sarawak, Costa Rica, Australia and Tongaland. As the first three regions have mainly green turtles much of the general sea turtle biology available in literature is based on the behaviour of the green turtle.

Harrison (1956: 513) was the first to show that the green turtle did not nest every season and he confirmed the findings of Moorhouse (1933: 3) that green turtles nested several times within a season. The size of the Talang Islands on which he worked ensured that virtually every emerging turtle was checked and it was not until the third season after the year of initial tagging that 14 turtles returned to nest out of 1514 turtles originally tagged.

From Costa Rica, Carr and Giovannoli (1957: 18) showed that long-range migrations were a proven feature in the life-cycle of green turtles but, as Harrison found in Sarawak, the recovery rates in turtles returning to Costa Rica was strikingly small (Carr and Ogren, 1960: 14) and after 15 years is still small, there having been only 447 recoveries from some 7000 turtles tagged (Carr and Carr 1970a: 336). Apparently recovery rates in the Australian programme on Heron Island are similarly small and it has been suggested that the re-nesting behaviour of the green turtle is inefficient (Bustard, pers. comm.).

In the study region the tagging programmes currently underway on the green turtles of Europa Island, the Glorious Islands and Tromelin Island have not been going long enough to add much to the knowledge of green turtle biology other than the fact that long range migrations are normal in this region.

The Tongaland programme, however, was the first to concentrate on the loggerhead turtle with a lesser emphasis on the leatherback of which there are very few in this area. From the data presented below it will be seen that the loggerhead would appear a more efficient nester than either the green or the leatherback; that it has a fairly well developed orientation ability and is the equal of the green turtle in its migratory ability.

Materials and methods

Patrols

The Tongaland research area originally covered some 32km and was fully described by McAllister, Bass and van Schoor (1965). Since 1969 and aided by the arrival of a beach buggy in 1970 tagging has been extended to cover 56km and, beach state permitting, this area is patrolled at least once per day by vehicle.

Intensive foot patrols are now carried out 8km north and south of Bhanga Nek camp with the assistance of 2 university students and 2 trained African staff members ensuring double nightly coverage of the most heavily utilized stretch of beach (see Figure 38).

During the 1971/72 season although record tagging figures were obtained for both the loggerhead and leatherback there were clear indications that the patrol methods were inefficient i.e. the contact success between the staff and emerging loggerhead turtles was unsatisfactory. It was shown by Hughes and Brent (1972: 41) that at the single contact level the results were satisfactory i.e. up to 84.79% of the emerging turtles were handled at least once during the course of the season. At the multiple contact level, however, results were unsatisfactory, the most successful year being 1968/69 in which 47.38% of all emergences were encountered, but the season was the one in which the fewest turtles were recorded. It appeared clear that the more turtles present the less one handled in a relative sense (see Figure 69).

Thus during the 1972/73 season the double patrol on foot was instigated along with more intensive buggy patrols and the results were gratifying: for the entire protected area the single contact success was 87.29% and the multiple contact success 48.31%. In the intensive patrol area the multiple contact success was 57.26%. It would appear, therefore, that although there is room for further improvements the patrol methods in Tongaland are now relatively efficient, although it is noted that 1972/73 was not a particularly successful year for loggerheads.

Leatherback handling has been consistently more erratic because of their smaller numbers and the fact that they are less concentrated than the loggerhead (Figure 54). Single contact handling is normally in the region of 60.0%, and multiple contact 20%.

Tagging

During the first two seasons in Tongaland small plastic tags bearing only a number were applied to nesting turtles. (McAllister, et. al. 1965: 14).

In the 1965/66 season a larger plastic "Rototag" was used bearing a number and a return address (Hughes, et. al. 1967: 8) and the following 3 seasons saw the use of a round yellow plastic tag normally used by the Oceanographic Research Institute, Durban for tagging sharks (Hughes and Mentis, 1967 : 57).

All plastic tags proved useless in the long run as virtually every tag has been lost. Few have persisted as long as two seasons and consequently a very substantial body of data has been lost. Fortunately, because most of the plastic tags necessitated punching a hole in the flipper, it has been possible to recognise a returning turtle because of a callous, or even two, in the site where tags are normally implanted viz. between the two innermost scales on the distal edge of the foreflipper.

With leatherbacks, identification of animals having lost tags is not as easy and they are now tagged twice; once in the distal edge of the foreflipper and again on the inner margin of the hindflipper, an insurance that has paid off on at least one occasion.

Since the latter half of the 1969/70 season only monel metal clinch tags supplied by the National Band and Tag Company have been used with excellent results.

Only monel metal tags have been used on green turtles during the past three years and the tags are implanted in the same site as used on loggerheads.

Results

Migration, from extra-nesting area recoveries

Loggerheads

Table 53 gives details of recovered loggerhead females away from the nesting beaches. In addition to these recoveries, there have been other tagged turtles taken but no details recorded; the tag being thrown away or the turtle released alive. These details came to light during the questioning of fishermen in Mozambique. All recoveries are shown on Figure 70.

It is of interest to note that only two loggerhead turtles have been recovered away from the tagging beaches in Mon Repos, Australia. Both turtles had travelled north over extensive distances, 2160km and 1760km, one at a speed of 31km per day and immediately after a nesting season (Bustard and Limpus, 1970: 358; 1971: 230), thus showing migratory behaviour similar to that exhibited by Tongaland loggerheads.

As mentioned in the previous section only 1 of 34 recoveries of Tongaland females has been taken south of the nesting ground and the possible reasons for this have been discussed.

There seems little reason to believe that the migration exhibited by loggerheads is merely random wandering for in both Australia and South East Africa, turtles have covered long distances at relatively high speeds.

Other species

Table 54 summarizes details of the only extranesting area recovery of a tagged leatherback female from Tongaland. One recovery is insufficient data on which to base conclusions.

Details of four recoveries of green turtles tagged on Europa Island are also summarized in Table 54 and the possible routes are illustrated in Figure 70. One turtle (A246) showed some determination by swimming 1200km in 48 days; a mean daily speed of 25.0 km/day.

From these tag recoveries it would appear that most, if not all, of Europa's breeding stock is drawn from the waters of Madagascar.

The recruitment source of green turtles nesting on Tromelin is as yet unknown but it is expected that they feed on the east coast of Madagascar. The general situation of Tromelin in relation to Madagascar is a miniature parallel to the Ascension Island - Brazil relationship as described by Carr (1965: 79).

Remigration from season to season tag recoveries

Loggerheads

To date, 1791 individual loggerhead females have been tagged in the Tongaland protected area (Figure 69). At the end of the 1971/72 season 1652 females had been tagged and over a nine-year period (1964/65 - 1972/73) 514 remigrating animals have been logged back in the protected area. Unfortunately only 183 of these returns have borne whole tags, the remainder having either broken tags or callouses.

Table 55 summarizes all remigration returns in terms of intervals between their initial tagging or previous encounter and they are also expressed as a percentage of all turtles handled during the particular season.

Figure 69 illustrates the increasing percentage of remigrations recorded in Tongaland over the past 10 seasons. In conjunction with this is shown the increasing numbers of turtles handled each year (Line A), and the increasing numbers of turtles utilizing the Tongaland protected area (Lines B and C). Line C shows the trend since the 1967/68 season when a more accurate method of estimating total nesting population was put into practice.

In both handling success and in the estimated total nesting populations, fluctuations are clearly recorded and similar fluctuations have been observed in green turtle populations in the study area.

Table 56 summarizes details of 10 loggerhead females that have returned in 3 or 4 separate seasons.

Although tag losses have been substantial and some remigrants have undoubtedly been missed in subsequent years it is thought that these missed turtles are relatively few in number. Therefore the most striking feature of the data is not the number of turtles that have returned but rather the number that have not. Some 1138 turtles have been tagged, released and have not been seen again.

Either they are nesting on some other beaches and, apart from the odd female who moves along the Tongaland coast, there is

no indication that this is occurring on a sufficiently large scale to explain the absence of such a large number of females, or these turtles are not nesting anywhere. Until data becomes available suggesting alternate nesting grounds it must be accepted that these non-returning turtles are not nesting.

At this point it is perhaps pertinent to examine the concept of reproductive periodicity or the remigration cycle as has been postulated for the green turtle and other species.

Harrisson (1956: 515) on recording the returns of 14 green turtles (out of 1514 tagged) on the Talang Islands stated that green turtles do not breed more than once in three years. On the basis of Harrisson's data, Hendrickson (1958: 503) introduced the term cycle suggesting that "the Sarawak Chelonia mydas probably follow a triennial cycle of breeding". Carr and Ogren (1960: 14) postulated for Tortuguera greens a"strong three year cycle" on the recovery of 16 turtles out of 495 tagged three years previously, and a weaker two year cycle with 7 returns out of 114 originally tagged.

Carr and Carr (1970a: 335) summarized the remigration data of the then 15 year old tagging programme in Tortuguero, Costa Rica and noted that 447 returns had been recorded, 48 of which were multiple returns, so the actual number of individual turtles was 399. As the total number of green turtles tagged during this period was in the region of 7000, it is difficult to understand how these authors could postulate reproductive cycles for a population on the basis of a 5.7% remigration rate, particularly in view of the fact that in the same paper (p.336) it is stated that site-fixity is strong in Tortuguera green turtles. Carr and Carr (1972: 426) show that the green turtle has a remarkable guidance ability and can return to the same stretch of beach in subsequent years. Thus, if the population as a whole has this ability to orientate accurately it would seem highly unlikely that 95% of the turtles would be missed year after year.

Results are perhaps more striking from the Sarawak Islands where every turtle was individually logged and there was no possibility of tagged turtles nesting unseen. A similar situation

exists on Heron Island, Australia where every turtle is logged and low recovery rates are normal (Bustard, pers. comm.).

It will be shown below that site-fixity in the Tongaland loggerhead is well developed and thus in spite of the fragmentary data in Table 55 an attempt must be made to explain the low recovery rates of remigrating turtles.

The Oxford Concise Dictionary (5th Edition, 1972) defines the term 'cycle' as "a recurrent period of events". As only 514 (31.1%) out of 1652 loggerhead females have returned to Tongaland after their year of initial tagging the term cyclic can be applied to the behaviour of the entire population only with some hesitation.

In Table 56 six out of ten individual remigrant loggerheads have shown a shift in their remigration intervals which negates the possibility of turtles showing regular remigration patterns. Thus if individual turtles exhibit irregular remigrations it is improbable that the population as a whole would have regular patterns and the data in Table 55 would suggest that irregularity is characteristic of reproduction by Tongaland loggerheads. For example, the 1972/73 season was preceded by three seasons in which monel tags were used yet only 56 monel-tagged turtles returned; 6 having nested in the previous season, 41 two seasons previously and 9 three seasons before. Besides these, 67 calloused turtles were logged back suggesting intervals of four or more seasons.

Thus there is a certain proportion of the Tongaland loggerheads exhibiting irregular cyclic nesting behaviour and the following explanations might be considered:

- (i) That these irregular intervals are possibly related to the environmental conditions in which the turtle finds itself after a nesting season. The poorer the conditions the longer the interval before the turtle returns to nest again.
- (ii) More simply, it might also be that there is considerable genetic variation in the reproductive capability of each individual. Some females are capable of annual reproduction e.g. No's 42, 47, A129, and A946 (Table 56), all of which have nested for three consecutive seasons, whilst considerably more require at least one season's absence to prepare for another laying season, the remainder requiring two or more seasons to re-attain reproductive preparedness.

- (iii) A loggerhead female may become more irregular in her remigration absences as she ages. It should be remembered that the killing of females was stopped only in 1963 and the mortalities up to that date must have had some effect on the apparent behaviour of the turtles. Nest-robbing was intense prior to 1963 and this too must have had an effect on recruitment rates, reducing the numbers of young turtles in the population.

Unfortunately, as far as age being related to irregular nesting behaviour, there is as yet no data for or against this suggestion, and this is expected as nesting behaviour would be confusing until a more natural balance between old and young turtles was re-established. That this balance is re-establishing itself might be evidenced by the change in the upward slope of percentage recoveries shown in Figure 69 during the 1969/70 season. Unfortunately, it is thought more likely that calloused animals were missed in the preceding seasons. More convincing evidence may be found in the marked increase, during the 1972/73 season, of two year nesters from 5.6% to 15.7%.

Thus it can be seen that the reproductive behaviour of the Tongaland loggerheads is both confusing and unusual. It is confusing in that irregularity appears to characterise the behaviour and unusual in that so many females appear to nest only once in their life-time. Virtually every living creature has some form of cyclical reproduction, often regular but which is susceptible to environmental influences resulting in an apparent irregularity and referred to as fortuitous breeding. To interpret the limited returns of multiple nesters as suggesting that only some loggerheads have nesting cycles whilst the majority have the ability to nest once only appears to be plain bad science but the facts insist that the possibility be stated:- Loggerheads are site-tenacious in that they remain in the protected area for most of the nesting season, patrol methods are relatively efficient, and as far as is known they do not nest on any other beaches. (In support of this point it should be remembered that the Tortuguera green turtles show an even lower remigration rate). However, only many more years of research will confirm or deny this possibility which, it must be confessed, seems to be applying a rather drastic cut with Occam's Razor.

Leatherbacks

Table 57 summarizes all the remigration returns of leatherback turtles to Tongaland over the past nine seasons. Table 58 gives details of 15 multiple remigrations and it can be seen that shifts in migration intervals occur and there is no cyclic phenomenon because recoveries have been recorded in consecutive seasons, and after absences of one and two seasons.

The leatherback population in Tongaland is really too small on which to base conclusions but there does not appear to be any marked difference between their remigration behaviour and that exhibited by the loggerhead. The discussions concerning loggerhead can be taken to apply equally to the leatherback.

Other species

As yet no remigration returns have been reported from either Europa or Tromelin Island. No tagging programmes have been instigated on olive ridleys or hawksbills.

Orientation, from within season recoveries

Loggerheads

It has been shown above that the loggerhead population in the study region is spread over some 3200km of the East African coast. The fact that during the 1972/73 season in Tongaland 47% of the nesting females had nested at least once before, indicates that loggerheads possess a well developed navigation ability enabling them to orientate with considerable accuracy to a relatively small stretch of beach.

However, before considering the accuracy of remigrating females it is pertinent to examine first the adherence of nesting females to a particular stretch of beach throughout a nesting season.

Hughes et. al. (1967: 22) and Hughes and Mentis (1967: 60) suggested that there was no significant tendency for turtles to emerge at the same site on consecutive emergences throughout a nesting season. These authors suggested that as there were no obvious pressures that would necessitate a turtle, with at least 160km of nesting beaches at their disposal, having a highly developed orientation mechanism, such lack of precision was to be expected. It was thought that no highly developed directional ability such as is exhibited by some of the green turtles nesting on Ascension Island (Carr, 1965) is required for a littoral population such as the Tongaland loggerheads.

The conclusions of Hughes et. al. (op. cit.) were not entirely in error because there is no significant tendency for turtles to return to the exact site on each emergence but there are indications that the stretch of beach used by the nesting turtles is very small in comparison with the overall distribution and thus their directional ability is highly developed but not perfect.

During the 1971/72 and 1972/73 seasons records of loggerhead movements were arranged in 4 phases:-

Phase 1 The spatial interval between emergences in early November and late November.

- Phase 2 The spatial interval between emergences in late November and early December.
- Phase 3 The spatial interval between emergences in early December and late December.
- Phase 4 The spatial interval between emergences in late December and January. (including all January - January recoveries)

If an animal was recorded in early November and recovered only in early January the spatial interval between the first emergence and last emergence was entered on the early January record.

Figure 71 illustrates the spatial intervals of all recorded loggerhead turtle emergences in Tongaland at 4 separate phases of the 1971/72 and 1972/73 seasons in 800m ($\frac{1}{2}$ mile) classes. It should be noted that this does not infer that any individual turtle is included in the same column through each phase. An individual may emerge within 400 metres of its previous emergence in Phase 1 and move 3200m in Phase 2 and remain in that position through Phases 3 and 4. From the figure it is clearly seen that there is a fair degree of accuracy but a somewhat higher degree of movement. Hughes *et. al.* (*ibid.*) stated that there did not appear to be any tendency for successive nests of individual turtles to be sited consistently either northward or southward of the preceding nests. This conclusion must now be reassessed because more data than those extracted in random fashion previously, are now available.

Examination of Figure 71 reveals a degree of skewness in Phase 4 where there are more northward movements than southward movements. This is clear from Figure 72(A) which shows all the data from Figure 71 expressed as percentages. It can be seen that the numbers of animals emerging within an 800 metre zone from emergence to emergence is between 20% and 30% throughout the season; a northward moving component is present which increases at the end of the season, similarly a southward moving component is also present which declines steadily from Phase 2.

In an attempt to assess just how important and extensive these movements are it was decided to extend the width of the

zone of stability from 800 metres to 1600 (Figure 72(B)); 3200 (72(C)); 6400 (72(d)) and 9600 metres (72(E)); this last figure representing less than a fifth of the total protected area in Tongaland.

From the series of graphs it can be seen that most, (i.e. up to 90%) of the movements of loggerheads are contained within 9600 metres of coast and those turtles moving either northwards or southwards i.e. more than 4800 metres away from their previous emergence, are relatively rare and the northward movements are only just more numerous than the southward movements.

From the data presented above three conclusions can be reached:-

- (i) Although it might be possible to accept the mode of each graph and say that each turtle has a target area of 800 metres width for which it aims with some 20-30% success, the considerable movement exhibited by each female renders this unlikely. It seems more acceptable to suggest that each turtle navigates to a particular stretch of coastline up to 9600m in total width within which it nests consistently.
- (ii) There is a tendency for there to be more southward moving animals in the early part of the season which might be interpreted as turtles arriving from the north.
- (iii) There is also a tendency for there to be more northward moving animals at the end of the season which might be interpreted as the return of turtles starting northwards again.

However, all movements might be explained as responses to current drift and/or weather and surf conditions. For example towards the end of the season the Agulhas Current increases in velocity and the inshore, northward flowing counter-current presumably also increases in velocity. This might result in tendency for females to shift northwards between their penultimate and ultimate clutches. On the other hand the investigations may be the cause of these movements because of the interference factor. This factor certainly applies in certain cases; for example, one female was disturbed and renested the same night 12km from the original emergence site. This point can never be resolved

because a degree of interference is necessary in order to tag or check the number of an existing tag. During the past 3 seasons interference has been kept to a minimum and few turtles are turned over for tagging purposes. Only when the turtle's imminent return to the water necessitates it being temporarily halted is the turtle turned.

Between season orientation

Having established that the Tongaland loggerhead does not adhere to a specific site but rather to a relatively narrow zone during the course of a nesting season, it is now possible to assess the remigration orientation of turtles that have been away from the beaches for a year or more.

Table 59 summarizes all the emergence data of 56 loggerhead females that remigrated to the Tongaland beaches during the 1972/73 season. The spatial differences between their original tagging site and that of their first encounter in the 1972/73 season is expressed in Figure 73 at 400 metre intervals. A table containing the remigration data from the 1971/72 season is to be found in Hughes and Brent (1972: 56) and these data have also been illustrated in Figure 73.

From Table 59 no single turtle has adhered strictly to the same site and some show wide deviations. Thus, if the turtles are orienting to a zone rather than a spot and, if some lateral movement is characteristic, it is likely that a recovery at the exact site of a previous emergence would be by chance. Out of 85 remigrants only 5(5.9%) were recovered at the same site. Of the four included in Table 59; No's A124, A923, A939, and A963 only the last turtle, A963, showed no deviations but it was only encountered once in each season. In the other 3 cases their zone of adherence was remarkably small:-

A124	:	maximum deviation 800m
A923	:	maximum deviation 1200m
A939	:	maximum deviation 1200m

From these three it is possible to suggest that some turtles can orient with great accuracy but most turtles have a less perfect mechanism.

The modal deviations in Figure 73 were 400 metres (1972/73) and 800 metres (1971/72) and the mean distance moved, was 4536 metres (1972/73) and 3352 metres (1971/72). The similarity at different zonal levels links the within season behaviour with that of the between season. No less than 93.1% of the remigrants logged back during 1971/72 were within 9600 metres of their initial encounter site and 91.1% during 1972/73.

Thus, these remigration returns would add support to the conclusion of the preceding section that loggerhead turtles can orient with considerable accuracy to a definite stretch of beach when one considers the 3200km-plus distribution of the population. This zone varies with the individual turtle from being as narrow as 400 metres but seldom wider than 9600 metres.

It is confidently expected that with the replacement of lost plastic tags by monel tags and the increasing returns from year to year that further confirmation of these conclusions will be forthcoming in future seasons in Tongaland.

The leatherback

Table 60 summarizes every leatherback within-season recovery since the Tongaland programme started in 1963. These data are illustrated in Figure 74 as deviations from the site of original encounter. As 7.1% of the turtles have re-emerged at the same site, and there have been some remigrations to the Tongaland beaches (Table 58) there is obviously some directional ability in the Tongaland leatherback population.

However, as shown in Figure 74 deviations of up to 40km have been recorded which would suggest that this orientation mechanism is either imperfect or unnecessary. It is felt that in considering the small numbers of leatherbacks utilizing the area and the widely scattered suitable beaches available to, and favoured by, leatherbacks (see Section 2) further comment on the orientation ability of leatherbacks is simply not justified on the data presented.

Pritchard (1971b: 21) made mention that in South America, leatherbacks tagged in Surinam moved up to 100km eastwards between nestings in as short a time as 17 days. It is obvious that this is a negligible distance for a leatherback to swim and taking Pritchard's data into consideration it would appear that the local leatherback population may be southward moving through the Tongaland protected zone. If it is a moving population this might explain the low within-season recoveries recorded in Tongaland. It might be assumed that the leatherbacks are moving southwards with the warm water in the spring and it is perhaps noteworthy that in the 1971/72 season the season was very cold in the early stages (see Section 5) which might have temporarily halted the southward movement and resulted in the record tagging figure of 39 turtles. These are, however, merely speculations and confirmatory studies must be carried out on more substantial populations of leatherbacks.

Green Turtles

No migrations of green turtle females to Europa or Tromelin Islands have so far been recorded but from a five week stay on Europa sufficient data were collected from within-season recoveries to lend support to the suggestions of Carr and Carr (1972: 426) that the green turtle has a highly developed direction finding ability.

On Europa Island the tagging effort was restricted to a 500 metre beach immediately in front of the weather station. The beach was divided into 50 metre sections and a note made of the emergence site of each turtle. Of 382 turtles tagged on the beach, 111 (29%) were not seen again. 575 re-emergences were made on the study and adjacent beaches by the remaining 272 turtles.

It should be noted that only some 44.27% of these emergences were known to be successful nesting emergences (cf. Table 13) having an interval of approximately 14 days between them. The remainder had intervals varying between 1 and 13 days. Few

turtles emerged at exactly the same site more than twice but in terms of deviations from their previous emergence the turtles would appear highly selective in their nesting sites. Figure 75 illustrates the deviation data from the 575 emergences.

It is unfortunate that more regular patrols could not be carried out on the remaining beaches on Europa (see Section 2) because this would have given a better idea of the spread of turtles from the study beach.

Indications are that the turtles tended to return to their original beach; firstly in the high recovery rate (71%) and also in the relatively few tagged turtles observed away from the study beach. For example the night patrol of the 18th November 1970:-

The Patrol started at 2100 hours and work on the study beach was completed first:-

Results: 55 turtles : 30 (55%) untagged; 25 (45%) tagged.

Then a check patrol was carried out between the study beach and the lagoon covering beaches Lagoon II, Reef and Lagoon III and minor beach IV (refer Table 11)

Results: 418 turtles : 406 (97.1%) untagged; 12 (2.9%) tagged.

Grand Total for evening: 473

As there were turtles coming and going throughout the period of the patrol these figures must be regarded as minimal and there were the remaining beaches which were not checked that night. At this stage of work 382 turtles had been tagged.

As some tagged turtles were recovered away from the study beach it is obvious that there is some movement between emergences, but the high recovery rates, from what must be regarded as a small tagging sample, can be interpreted as a general adherence to a nesting beach and show that in their emergence behaviour, green turtles in the study region do not differ from Caribbean green turtles.

Other species

No orientation data have been collected on either the hawksbill or the olive ridley.

Recruitment, from general tag returns

Loggerheads

In Figure 69 it was shown that during the 1972/73 season the percentage remigrants to the Tongaland protected beaches had reached 47%. Within a few seasons this steady climb should level off and it should prove possible to assess with a high degree of accuracy the recruitment rates in the Tongaland loggerhead population.

In an attempt to assess the reasons for the present recruitment, which is also shown in Figure 69 as increasing trends in new animals, handling success and estimated total population, each seasonal sample of measured females was divided into 5 size classes and their numbers expressed as a percentage of the total sample.

These data from 7 seasons are summarized in Table 61 and the size class percentages are illustrated in Figure 76 with trend lines fitted using Bartlett's regression formula.

The smallest and largest females tend to contribute a steady proportion of each annual population but their combined contribution is small and not of particular importance.

In the early stages of the programme the 86-90cm curved carapace length class contributed over 20% of the total but has shown a steady decline over the following six seasons whilst the modal size class has shown a corresponding increase. The 96-100cm class has also shown an increase.

A possible explanation lies in the killing that went on prior to 1963. If turtles were killed on a reasonable scale and it has proved difficult to ascertain the exact extent of the persecution, there should have been a reduction in the number of larger (older?) turtles which would not have been made up by new recruits by 1965. Thus younger turtles i.e. new recruits, would have contributed more substantially to the population as a whole.

With the progressing seasons there has been an increasing remigration of older animals and presumably in the larger size

groups these are reinforcing the new recruits and giving the modal size class the tendency to increase.

The 1968/69 season is unusual because of the fact that so few animals arrived in Tongaland, it was the poorest season in ten and showed a preponderance of larger females. It is possible that some years previously there had been an almost total failure of eggs or an unduly high mortality of hatchlings and the number of new recruits was thus reduced resulting in the emphasis being placed on larger turtles.

The fluctuations in annual nesting populations as shown in Figure 69 might be traced back to "good" seasons or "bad" seasons but this will become apparent only after future seasons of accurate monitoring (see also Section 5).

It has been suggested in a previous section that loggerhead turtles mature at various sizes and it is suggested that from the figures in Table 61 for the 1972/73 season there is no particular emphasis on the smaller size classes which would suggest that these are the principal source of recruits. It seems likely that the modal size class in which loggerhead females reach maturity is in the 91-96cm curved carapace length class and thus new recruits to a population of loggerheads will be found in all size classes.

If remigrants to Tongaland continue to increase at the rate recorded in the past three seasons then within the near future, it should prove possible to allocate the percentage new recruits within each size class and the true variation in size of turtles at their first season of nesting will be ascertained.

Finally it is suggested that the annual recruitment rate will be found to be relatively high, between 20% and 30%. The reason for this suggestion is linked to the previous section in that many tagged turtles have not been recovered in Tongaland. Despite the large numbers of non-returning animals the overall population trends continue to move upwards and it is thus reasonable to assume that there must be many new recruits. This should be expected because of the total protection afforded the nesting

colony since 1963. It will be of interest to see whether there is a sharp increase in total numbers within the next few years.

The success of the conservation programme will be judged on the recruitment of neophyte nesters and so far the results are promising.

Leatherbacks

As mentioned in a previous section there is a possibility that the leatherback population is drifting and not static; i.e. they do not adhere to a particular nesting zone unless it be a very wide zone. This reduces the chances of encounter and makes any assessment of recruitment extremely difficult.

Table 62 summarizes the size class composition of the seasonal measurement samples of leatherback females in Tongaland. The seasonal numbers are small and it is not possible to determine whether there has been any change in the size class composition since 1965.

Other species

No data have been collected on recruitment rates in other species.

Discussion

From the data presented above it is clear that the loggerhead turtle has a well developed direction finding ability which enables them to return periodically with great accuracy to the Tongaland beaches.

The guidance mechanism employed by these turtles would appear to be complex and it is pertinent to examine the most feasible theory on turtle orientation in the light of the data collected on the loggerhead.

Chemoreception

Koch, Carr and Ehrenfeld (1969: 167) postulated the possibility of green turtles finding Ascension Island by following an olfactory gradient of increasing strength between the feeding ground and the nesting ground. Carr (in press: 3) added to this and suggested that use may be made of sub-surface equatorial counter currents.

Considering that nearly all of the Tongaland loggerheads have been taken north and hence up-current, of the nesting grounds, it seems unlikely that chemoreception can be seriously considered as a long range guide because the possibility that counter currents and eddies could carry an olfactory cue for 3600km is difficult to imagine.

Chemoreception might, however, play an important role in the final choice of a nesting site. Richard and Hughes (1972: 306) showed that green turtle nesting along the east coast of Costa Rica was clearly correlated with the outflow points of large rivers, being situated immediately down-current of each river mouth, the Tortuguero River being, apparently, particularly attractive to green turtles.

In Tongaland nesting is clearly associated with the Kosi Bay Estuary which has an outflow point immediately up-current of the main nesting areas. Figure 77 shows the nesting activity concentration points over eight seasons in Tongaland (see also Figure 38 for an individual season).

To suggest that this association is a direct result of outflow from the estuary mouth is, however, not necessarily justified.

Firstly, outflow is limited to low tides, as during high tides sea water enters into the lake system thus the net outflow of possible olfactory cues is limited.

Secondly, the longshore drift is normally northward although it does change if a northerly wind blows steadily for more than two days. Thus, what little outflow there is would be carried northward and not southward where the turtles nest.

A third reason for the nesting orientation not being linked to outflow through the estuary mouth is the distinct break in nesting distribution along the favoured 24km of coast. It would be expected that if orientation was directly linked to outflow there would be an even distribution of nests over the area of most powerful olfactory cue. Variations in current directions should be evened out over eight seasons but each season has emphasized the site selection.

Finally, it is perhaps noteworthy that during 1965 the estuary mouth was closed for five months (Breen and Hill, 1969:285) so there was no outflow at all and this did not markedly affect the homing accuracy of the nesting turtles (Hughes, et. al., 1967: 14).

It was noted in Section 2 that loggerheads in Tongaland showed site selection in that they always emerged near intertidal reefs and where there were no rocks nesting was either minimal or non-existent. It was suggested that inter-specific competition for nesting sites between the leatherback and loggerhead might have led to spatial separation and the preference by loggerheads for rocky areas. This may have some effect but the site selection exhibited by loggerheads does not justify this as the sole reason. The cumulative data in Figure 77 shows firstly the preference for rocky areas and then the greater concentration in the northern section of the protected area, and herein may lie the link between site selection and olfactory cues.

If there is a link between the Kosi Bay Lake system and the orientation of nesting sea turtles, and the link is not directly associated with outflow through the estuary mouth, then it must be an underground link.

Tinley (1971b: Appendix 6) discusses at length the presence of impermeable hardpan layers which act as highly efficient aquifers in the Tongaland region, and cites, as a good example of such an aquifer, dune rock along the coastal zone. Evidence of freshwater seepage may be adduced from the dune rock itself which is formed through the cementing of sand under the influence of fresh water and a strong calcareous component. Therefore there is a possibility that there is drainage from the Kosi Bay Lake system via hardpan horizons to the shore line. If the hardpan continues out onto the beach, a relatively stronger flow would be present at that point as compared to a section of beach where the hardpan layer either dips or has been eroded away resulting in the water flow diffusing through a thick layer of sand and being further diffused by wave action as it enters the sea.

One could assume that the water draining over hardpan layers might itself provide the olfactory cue towards which turtles home if it had distinct properties.

For example, in Figure 77 there are two modal points in the peak nesting areas in the north of the protected area. Immediately south of each point there is a dramatic drop in nesting activity, whereas north of the modal points there is a very much less drastic fall in activity. In other words the nesting distribution is skewed to the north.

It has been mentioned above that coastal longshore drift is predominantly northward and this would carry the olfactory cue in a northerly direction away from the point of entry into the sea. The skewed distribution shown in Figure 77, and Figure 38, would lend support to this suggestion. Figure 78 illustrates the relationship between the Kosi lakes and the main turtle nesting areas and shows the possible sources of the cue medium.

It is possible, however, that the association between the lakes and the nesting beaches may be less direct and may involve the turtles providing their own olfactory cue. Loggerhead nests have a distinct smell which would appear to be a strong disadvantage in areas with large numbers of terrestrial predators. In Tongaland

feral dogs find turtle nests from which all surface traces have long been obliterated by wind action. On the Hutchinson Island rookery in Florida, raccoons cause extensive damage by digging up loggerhead nests (see Gallagher, Hollinger, Ingle and Futch, 1972: 6; Rounta, 1967: 291). It would seem that the selective disadvantage of having a powerful odour attached to the eggs must be outweighed by a selective advantage or the colony would have been wiped out. It would appear feasible that the advantage derived from having large numbers of turtles nesting in one area, would be by producing more eggs than could be dealt with by the predators and thus reduce, to a tolerable level, the harmful effects of predation.

These predators can find the nest when it is freshly laid which would suggest that the smell is associated with the mucus exuded by the female in the process of laying but this might be later reinforced by the breakdown of unhatched eggs which as is well known by workers dealing with turtles, has an extremely pungent odour.

Therefore if the turtles leave an olfactory cue in the sand it is logical to assume that the more turtles utilizing an area the stronger the olfactory cue and in turn the more attractive will be the area to nesting turtles.

As it is unlikely that the cue will be carried by winds it must be carried by dissolving in interstitial water and draining down towards the sea by gravity. If one considers the rainfall regime in Tongaland, one finds that in September or October there is always a period of rain preceding the beginning of the turtle nesting season (see Tinley, 1958: Fig. 2). This could be sufficient to initiate the percolation of olfactory cues down to the water table, or more simply, there is possibly a continuous leaching downwards to the water table.

The link with the lakes might be as a result of their maintaining a high water table which would flow, albeit slowly, even in times of drought which may have a marked effect on seepage points further south.

Further the drainage lines on the hardpan layer (dune rock) may cause the olfactory cues to be channeled to a particular outlet where it would enter the sea in relatively high concentration, being distributed by the longshore drift as was mentioned above.

Thus longshore drift, local winds and variations in wave patterns would shift or dilute the cue medium over limited areas before mixture with the sea rendered it untraceable. Further if the cue was gradually seeping over the rock layer it would tend to concentrate in rock pools and the lower beach during low tide periods and be at its strongest at the turn of the tide.

If the cue was either direct seepage from the Kosi lakes or the turtle-originating cue carried in this seepage, two separate outlets situated some 10km apart would explain the apparent zone target postulated above, rather than a specific point target, for the Tongaland loggerhead.

Similarities in the properties of the two cue sources either as a result of their being from the same original source (the Lakes), or from their being simply a 'loggerhead' cue, would explain the periodic shifts by nesting turtles from the northern concentration to the southern and vice versa. Variations in sensitivity on the part of individual turtles would easily explain the ability of some turtles to orientate with remarkable accuracy whilst others are less precise.

Boteler Point is a good example, situated between two high nesting density areas, to show that the presence of rocks alone is not the attraction. It probably lacks a seepage point or a nesting density sufficiently high to create a cue.

The presence of nesting turtles in the southern part of the protected area is a little enigmatic. Either there are smaller seepage areas with a unique character making them attractive to turtles and into which is channelled turtle-cue, or these seepage outlets are not perennial because of the lack of a major water course inland and in times of drough they stop, lose their guidance role, and hence their nesting turtles, and have to be built up again. There is no other obvious reason why

these southerly beaches are not more heavily utilized by the nesting turtles. If cues were weak or even non-existent in some seasons new recruits would probably nest in the strong cue areas further north and further reinforce these zones.

Thus the presence of a water table containing either identifiable water or acting as a carrier appears to be of value to loggerhead rookeries. In Madagascar the most important stretch of loggerhead nesting beach is separated from a long string of brackish and fresh water lakes by a set of high dunes.

In the United States there are three documented loggerhead rookeries on the east coast separated by large areas of apparently suitable beach (Caldwell, Carr and Ogren, 1959: 296). Baldwin and Lofton (1959: 320) show that the Cape Romain nesting beaches are backed by hectares of salt marsh which would maintain a high water table.

In Georgia, Jekyll Island and Little Cumberland are closely associated with mainland marsh areas whilst Hutchinson Island in Florida is backed completely by the Indian River Lagoon (see Caldwell, Carr and Ogren, 1959: 298; Routa, 1967: 288; and Gallagher, Hollinger, Ingle and Futch, 1972: 3).

Gallagher, et. al. (op. cit.: 7) note a series of interesting intervals recorded from tagged loggerheads and the Hutchinson Island turtles seem somewhat less accurate than Tongaland turtles and this would be expected with such a wide area (22 miles, 35.12km) having an identical lagoon backing.

It will be of interest to see if future work in these areas shows a nest distribution that can be correlated with particular sites and longshore current direction.

From this hypothesis several other behavioural traits of the loggerhead are brought to mind.

Firstly the sand-smelling behaviour observed not only in Tongaland loggerheads but in other species as well (see for example Carr, 1967: 21). With the Tongaland loggerhead sand-smelling occurs immediately after stranding when the beak is thrust into the wet sand. Some females walk up the beach thrusting the beak in front of them like a ploughshare.

This behaviour, previously thought of as tactile testing of sand consistency, might now be described as it was originally named i.e. 'sand-smelling'. If the cue is seeping to the shore line in drainage lines and then being carried northwards along the immediate shoreline the sand from the high tide mark down should be impregnated with the cue medium. The turtle stranding after low tide has a broad guide path which it can follow up the beach.

The strength of the cue distributed over the beach between high and low tide mark might also inform the female when she is above the high tide mark. There is possibly a sharp drop in the cue strength when the female passes the high tide mark which would trigger a new set of responses resulting in the turtle being susceptible to external stimuli. The presence of a bank, log or vegetation is then sufficient to trigger nest building behaviour.

It has been noted in Tongaland that the presence of a large log or bank below the high water mark does not generally stimulate nesting behaviour. On the contrary females take vigorous avoidance actions and if unsuccessful in bypassing or climbing the obstacle will return to the sea without nesting. Higher up the beach a relatively minor bank or patch of vegetation will immediately prompt nesting.

If no obstacle is encountered some turtles in Tongaland have been observed to walk for hundreds of metres before laying.

Baldwin and Lofton (op. cit.: 322) were the first to note that loggerheads execute exploratory crawls. These 'half-moon' tracks, often observed in Tongaland, might be explained as the tracks left by an emerging turtle which not having found the correct cue, has immediately returned to the water.

Finally, the presence of a distinct smell in the egg chamber must be the first sense imprint experienced by the hatchling loggerhead. It hatches within an enclosed chamber permeated with the smell and ascends for three or four days in company with its identically tainted siblings and only thereafter is it exposed to foreign stimuli through vision and surface odours. It is suggested that visual stimuli are dominated, during the night emergence, by the seaward orientation drive based on a single light source.

In conclusion it is suggested that chemoreception of a water-borne guidance cue, either as a property of the water itself, or in traces left by heavy nesting of the species in previous seasons, is of importance in the within season and remigration finding of a specific nesting site. A chemoreceptive agent and its distribution along the coast agrees with the data collected and explains various, as yet poorly understood, aspects of nesting behaviour in the Tongaland loggerhead.

Nordeng (1971: 412) and Solomon (1973: 232) have provided convincing evidence that char and salmon utilize a chemical cue or pheromone, derived from their own relatives or group, as a guide to their home stream rather than the cue being provided by the stream water itself. In other words the pheromone is species specific or even group specific. A similar pheromone-guidance mechanism may be employed by sea turtles.

It is not suggested that chemoreception is acceptable as a long range navigation system because all migrations should require a reversible mechanism if the turtle is going to return to a favoured feeding ground or sleeping rock. Further a chemical trace carried by a surface current would be uni-directional and could not apply to turtles coming from both north and south of the nesting area.

Not having undertaken any specific work on long range navigation it is not intended to enter into a detailed review of navigational possibilities to explain how loggerheads get to Tongaland, but it is felt that Hirth (1971: 3: 23) is right in suggesting the answer may lie in non-visual theories. The most appealing theory, is that using lines of the earth's magnetic field, which can orientate particles in molten rock as has been shown in a recent spate of articles supporting the continental drift theory. Sea turtle eggs have a long incubation period and are in a fixed spot for up to 60 days which might be ample time for the position to be implanted. Just how this happens and by which means the turtle can later perceive their position is beyond the scope of this work.

In concluding one can only acknowledge that the Tongaland loggerhead, and Europa and Tromelin green turtles, are fine navigators but it seems likely that human understanding of their feats may never be realized.

THE REPRODUCTIVE BEHAVIOUR AND POTENTIAL OF SEA TURTLE
POPULATIONS IN SOUTH EAST AFRICA WITH ESPECIAL REFERENCE
TO THE TONGALAND LOGGERHEAD CARETTA CARETTA THE TONGALAND
LEATHERBACK DERMOCHELYS CORIACEA AND THE GREEN TURTLE
CHELONIA MYDAS

Introduction

The following section deals with the activity and behaviour associated with the nesting season excluding orientation and site selection which has been dealt with in a previous section.

In Tongaland, it is unfortunate that patrol methods are not as efficient as desired. The records are seldom sufficiently complete and recourse must be made to interpretive treatment of data that could be perfectly straight forward if every turtle was handled. Observations on green turtles on Europa and Tromelin Islands are even more scantily recorded and details are reported below for completeness and in the full knowledge that the data are drawn from minimal samples.

The problem of too short a working time must be faced once more with regards to the reproductive lifetime of the loggerhead turtle and the conclusions contained within some of the sub-sections must be accepted as tentative. Definite, conclusive results can only be forthcoming from long term tagging studies.

Methods

Many of the data contained below have resulted from direct observation or are derived from the recovery of tagged females.

Fertility and hatching success in turtle clutches are based on nests excavated after the departure of the hatchlings. On Europa and Tromelin Islands nests were inspected as found and the results are therefore fortuitious. In Tongaland natural nests were marked immediately after laying and excavated after the hatchlings had gone but were not interfered with in any way which could have affected the hatching success. The eggshells, hatchlings and eggs remaining in the nest were then counted.

The fertility of unhatched eggs was adjudged on the presence or absence of blood spots. If the embryo was microscopic then the egg would be regarded as infertile. Bustard (1972: 99) discusses the possibility of numerous microscopic embryos being killed during laying and indeed, this is thought to be possible. Development of the embryo must commence immediately after fertilization and before the shell is laid down. If a turtle is disturbed by bad weather or research workers and laying is delayed for some days the embryos would be well advanced when the eggs are eventually laid and be susceptible to damage from the fall into the nest. It is felt, however, that any errors contained in the fertile-infertile data is of limited importance when compared to the emergence success.

Although small pilot hatcheries, into which have been moved clutches of loggerhead and leatherback eggs, are operated annually in Tongaland, few of the data collected therefrom are included in this section. Details concerning the hatchery programme are to be found in the Lammergeyer reports (see for example Hughes, 1972b: 15-16). It is sufficient to say that barring natural disasters, the mean hatching success has been as high as 68.7%.

All egg measurements have been taken with Vernier calipers and the mass recorded on an Ohaus triple-beam balance.

Results

Factors influencing the nesting season

During 1971, three turtle nesting grounds in the south western Indian Ocean viz. Europa Island, Tromelin Island and St. Brandon, were found to have a lower nesting activity than expected during November. This phenomenon was also observed in Tongaland where all loggerhead activities were markedly lower during November than those recorded during the two previous seasons (Hughes and Brent, 1972: 44).

Table 63 summarizes loggerhead and leatherback nesting and tagging records, expressed as a monthly percentage of the season's totals, and sea surface temperatures for the months of November, December and January during the 1969/70, 1970/71, 1971/72 and 1972/73 seasons.

Figure 79 illustrates the sea surface temperatures for the four seasons and compares them with the loggerhead nest records. It can be seen that during the 1971/72 season the sea temperature was lower in October and November and appeared to result in the season having a slower start. As it was a record season, with January nest records abnormally high it is assumed that the lower temperatures off Tongaland did not result in loggerheads nesting in Mozambique where warmer temperatures must have prevailed. Thus the lower temperatures retarded the start of the season but did not restrict eventual nesting intensity. A χ^2 test between the four seasons showed no significant difference between three of them but between the 1970/71 and 1971/72 seasons, which are the most divergent, there was a significant difference at the 5% level. Therefore, sea temperatures are almost certainly linked with nesting activity, although other environmental factors may be involved.

As it is considered unlikely that the female loggerhead is sensible to temperature differences of 2°C it is probable that these differences are brought about by the resultant efficiency of the body functions of the animal i.e. by advancing or retarding egg development.

Table 64 summarizes the mean inter-nesting intervals of individual loggerhead turtles during the 1969/70, 1970/71, 1971/72 and 1972/73 seasons. Each season is divided into five phases and the mean inter-nesting interval is compared with the mean sea temperature during each phase. A statistical comparison between the two sets of data showed a highly significant negative correlation ($r = -0.861$; $p < 0.001$) which suggests that the influence of low temperature is expressed by the retardation of egg development. Hence the lower the sea temperatures in October and November the later the season.

McAllister, et. al. (1965: 30) expressed the nesting season in terms of air temperatures extracted from the records at St. Lucia Meteorological Station, and inferred that the season was influenced by air temperature. Although there is a great similarity between sea and air temperatures in oceanic regimes this is not necessarily so along the coastal areas of large landmasses, take for example the development of sea advection fogs. It is felt therefore that it is better to express the turtle nesting season in terms of sea temperature. It is also more logical when considering the activity of an animal that spends almost all of its lifetime immersed in the sea. As sea turtles are to a greater or lesser degree poikilothermic it would be expected that ambient sea temperatures would affect their activity.

Table 63 includes the leatherback data from the same four seasons and there is no significant difference between any of the nesting activities recorded. This would be expected in the light of the findings of Mrosovsky and Pritchard (1971: 630) and Frair, Ackman and Mrosovsky (1972: 792) all of whom have shown that the leatherback can maintain its body temperature up to 18°C above the ambient sea temperature and the findings of Greer, Lazell and Wright (1973: 181) showing that the leatherback has a countercurrent heat exchanger.

Sea temperatures also influence the nesting of green turtles in the St. Brandon Islands. Figure 80 shows the sea surface temperatures over 15 years in St. Brandon and compares them with the monthly exploitation figures recorded from the islands over the same period.

Although the peak nesting activity is almost invariably associated with the highest sea temperatures there is nothing to suggest that sea temperatures have any influence on the numbers of turtles nesting. The fluctuations in numbers are clearly wide and the seasons for these fluctuations remain a mystery.

It is concluded, therefore, that sea temperatures are linked with the nesting season and can advance or retard nesting activity.

Mode of arrival

Loggerheads

Caldwell, Berry, Carr and Ragotskie (1959: 309) suggested on the basis of limited tag returns, that there were indications of group adherence and nesting in Atlantic loggerheads and further that gravid animals arrived off the nesting beaches in small groups.

As in America, clumped tag returns have been recorded in Tongaland, because of a number of turtles tagged on any single evening, a certain proportion of them will be recovered some 14-16 days later. These results depend to a large degree on the handling success of the patrols. Whether these observations can be interpreted as cohesive group nesting, however, is open to doubt for several reasons:-

- (i) The 'group' may be extended over an area of 56km and can be hardly considered cohesive. Similarly, the loggerhead has a reasonably well developed site fixity and the chances are high that they will emerge in proximity to the site of their initial emergence, thus suggesting group behaviour.
- (ii) The Tongaland loggerheads exhibit a surprisingly consistent re-nesting interval which appears to be linked to the ambient sea temperature (see above), so any two or more females tagged on a specific evening, irrespective of their mode of arrival, are likely to be recovered within a day or two of one another at their next emergence. Therefore they can be regarded as a fortuitous group only.

- (iii) Even if a number of turtles did arrive as a group off Tongaland it is unlikely that all would have identical stages of egg development and thus the group would soon lose its identity as individuals responded to the nesting urge.
- (iv) Figure 81 represents the cumulative nesting records for the 1972/73 season based on the interesting periods recorded during the season (see Table 64). The number of days contained in each interval is shown on the figure. It is assumed that the number nests contained within any single period were laid by separate individuals. The periods become shorter as the season progresses as was shown in the previous subsection. For example:

Period 1: all nests laid from the 16th October to the 2nd November inclusive.

Period 2: all nests laid from the 17th October to the 3rd November inclusive, etc.

From the figure there appears to be a steady accumulation of females arriving to nest on the Tongaland beaches followed by a more abrupt but still smooth withdrawal.

Figure 81 has an unexpected peculiarity and that is the trough between the two peaks. The first peak is the expected trend viz. there should be an accumulation of new arrivals and then the numbers should remain more or less static until turtles begin to depart, having completed their nesting.

There are two possible reasons for the apparent drop in nesting activity; the first is that the turtles were nesting elsewhere but there are no data suggesting this, or, that during this period, which was characterised by severe south westerlies, a very substantial number of nests were not recorded. This can very easily occur because if a strong wind develops halfway through the evening all traces of nests are obliterated within minutes and it is possible to 'lose' up to forty nests in a night. This point does, however, illustrate the value of the method used to estimate nesting populations in Tongaland; there is little possibility of an overestimation and all estimates must be regarded as minimal.

From the above data it is concluded that:-

- (i) The recording of fortuitous groups of tagged turtles on the nesting beaches cannot be interpreted as being indicative of group arrivals off the nesting beaches.

- (ii) There are no indications of substantial group arrivals, neither by direct observation nor in the accumulative nesting records. Thus, if there are groups, they appear so small at present as to be indistinguishable from a steady stream of individual arrivals. However, group arrivals may take place but this will only be proven through direct observation and not through tag recoveries.

Other species

Clumped recoveries of tagged leatherbacks have also been recorded in Tongaland, two animals have been recovered twice in subsequent seasons, but it is felt that this need not be indicative of conscious group adhesion.

No data have been collected on the three other species in the study area but there are records of mass movements of sea turtles in other areas (see, for example Carr, 1955: 237 on).

Courtship behaviour

Loggerheads

Off the Tongaland beaches copulation and courtship is seldom seen as all mating seems to take place some one to two kilometres offshore in 15 to 20 metres of water. Mating couples seem to spend most of their time underwater.

No courtship behaviour has been seen off Tongaland but in the main tank in the Durban Aquarium mating took place on the 6th October 1970. It is of interest to note that both the male and female loggerheads involved had been in the main tank for 8 years or more and no copulatory behaviour had been previously recorded. Having had no contact with the open sea for 8 years this pair commenced courtship behaviour at the same time as turtles are starting to gather off the Tongaland beaches. Loggerhead nests have been recorded as early as the 20th August and occasionally in September but nesting normally starts at the end of October or early November depending on the water temperature.

In the main tank, copulation between the two loggerheads was preceded by several days of courtship activity with the male pursuing the female around the tank, normally slightly above her. No pattern was observed, but this may have been due to the confines of the tank, and the animals periodically touched their beaks together. Occasionally the male would break away from the female to pursue a young loggerhead male that had not yet begun to exhibit his secondary sexual characteristics. The older male bit pieces out of the rear end of the younger turtle's carapace.

Off Tongaland a pair of males were observed fighting for five minutes before being disturbed by the presence of a diver. Apparently the fight consisted of slow motion biting and thrusting at one another with no serious damage resulting from the encounter (Mr. M. Schleyer, pers. comm.).

Copulation in the Aquarium lasted up to an hour on the one occasion that it was observed in full. No eggs were observed to be subsequently laid by the female but they may have been laid at night and consumed by the other occupants of the tank.

Green turtles

Around Europa Island and Tromelin Island copulating and mating behaviour was observed daily. It would appear to be an arduous ordeal for the female because females were observed to come ashore on Tromelin Island to escape the attentions of males. On one occasion a female was observed to beach herself on numerous occasions to avoid two small males which tried to mount her the moment she left the shallows. Bustard (1972: 143) reported similar beaching behaviour on Bountiful Island, Australia.

Numerous authors have reported mating behaviour in green turtles because unlike the loggerhead, mating takes place close inshore (see for example Hendrickson 1958: 482; Carr and Giovannoli, 1957: 30; Frazier, 1971: 377). Only Bustard (op. cit.: 144) has described the actual courtship actions. Off Europa Island during this study a pair of green turtles were observed to exhibit a

repetitive series of movements which are assumed to be courtship behaviour because the patterns agree in parts with the description reported by Bustard.

On Europa Island the turtles were in some three metres of clear water below a high reef point from which obstruction-free observations could be made.

There were five basic movements and these are illustrated in Figure 82. Briefly these were:-

- (i) A circling pattern lasting for about a minute followed by:
- (ii) The turtles stopping and facing one another underwater and maintaining their positions with gentle movements of the flippers, then;
- (iii) closing in on one another with the flippers seeming to embrace as their bodies swing downwards to a vertical position, then;
- (iv) a close embrace plastron to plastron and nuzzling of the neck and shoulder region.
- (v) Finally the female sliding over the male's back. This latter movement was remarkable because males are normally the ones that mount but one had the decided impression that the female was doing the courting!

The entire pattern took some 3-4 minutes to complete after which there would be some random swimming around, as they both rose to breathe, and after a minute the circling started the pattern again. Three full cycles were observed in 20 minutes after which the male swam away.

It is not suggested that this is the normal behaviour of Europa's green turtles as this activity was seen only once, and it was unusual in that the female was so active.

Other species

No observations were made on courtship behaviour by other species in the study area.

Stranding and the choice of nest site

Loggerheads

Baldwin and Lofton (1959: 324) found no correlation between the tidal phase and the strandings of loggerhead females on the Cape Romain beaches of the eastern United States. However, Hughes *et. al.* (1967: 24) commented that in Tongaland there were indications of a response to the tidal state and this has been further investigated during the 1971/72 and 1972/73 seasons. Records were kept of turtles emerging prior to and after midnight over a full tidal cycle.

Hughes and Brent (1972: 51-53) discussed the results obtained during 1971/72 and concluded that there was a definite link between tidal state and nesting activity. It was shown that during neap tides there was more nesting activity prior to midnight when the high tide takes place during the first half of the night and vice versa during spring tides when activity was higher in the second half of the night.

Figure 83 shows the distribution of loggerhead nesting activity on the peak spring and full neap tide periods during December, 1972 and January, 1973. Unfortunately emergences after midnight on some nights could not be allocated a specific time and consequently have been lumped.

The data are more specific than the 1971/72 season and although the general trend is similar to that found during the previous season, reversals show that the association is not exclusive. Furthermore, a comparison between loggerhead emergences during a rising tide and a falling tide showed no significant differences ($p > 0.10$) neither on the peaks of tidal phases nor throughout the month of December.

It is thus concluded that loggerhead females strand at any time of the night but show a preference for higher tidal periods probably in response to the numerous outcrops of rock that precludes nesting at the lowest tides. Furthermore Figure 83 shows clearly that there is no tendency for loggerheads to emerge immediately after dark, which is normally around 1900 hours.

The occasional loggerhead female has been observed to emerge during the daylight hours but this is rare.

Bustard (1972: 68) has described the stranding behaviour of the loggerheads in eastern Australia and in no way does his description differ from the behaviour of Tongaland loggerheads.

The possible factors governing the choice of nest site in Tongaland loggerheads have been discussed in Section 4.

Leatherbacks

Figure 84 shows the recorded encounters with emerging leatherback females during two full seasons in Tongaland. As they emerge on beaches having no obstructions there is no reason for leatherbacks to respond to tidal state. In Tongaland one might expect to encounter a leatherback any time after 2100 hours irrespective of tides.

Pritchard (1971b: 18) has described the stranding behaviour of the leatherback turtle in French Guiana and there is no notable difference in the behaviour of the Tongaland leatherbacks even in stranding time as Guianan leatherbacks emerge in the middle hours of the night.

The choice of nest site seems to be dictated by the nature of the offshore sea bed (Figure 54).

Green turtles

On Europa and Tromelin Islands there is a response to the tidal state by nesting green turtles. At dead low tides the turtles cannot get over the extensive wave platform and the animals must wait until there is sufficient water over the reef. Thereafter turtles come in as long as it is possible, whether the tide is rising or falling.

Carr and Giovannoli (1957: 28-29) have described in detail the stranding of green turtle females and there appear to be no behavioural differences between Tortugueran turtles and those in the study region.

Other species

No data are available on other species in the study region.

Digging of nest and general behaviour

Loggerheads and leatherbacks

McAllister, et. al. (1965: 22-27) described in detail the nest digging behaviour of the Tongaland turtles. Hughes et. al. (1967: 24 and 42) gave the duration of the various phases of the process. There is considerable variation but a loggerhead seldom spends less than 45 minutes on the beach and leatherbacks less than an hour.

Neither species is aggressive although there is an occasional reaction to tagging involving the opening of the beak. No investigator has ever been deliberately bitten in Tongaland.

Green turtles

Although it is thought that the time involved in nesting depends to a large extent on the consistency and dryness of the beach, particularly in the case of the green turtles of Europa where the nesting density is very high and the upper surfaces of the beach dry due to turning by nesting females, some examples of the duration of nesting activity from three localities are given in Table 65.

Green turtles seldom show any aggression towards investigators and during the present survey only one incident was recorded. On Europa Island one female (No. A365) exhibited what appeared to be threat behaviour by thrusting its head at the investigator and flapping its fore-flippers vigorously. These actions were repeated three times and there was no suggestion of the head being withdrawn or a return to the sea as is normal with green turtle females.

Other species

No details are available on other species from the study region.

Return to the sea

Loggerheads and leatherbacks

Loggerheads in Tongaland return directly to the sea and make no attempt to avoid reef exposed by a falling tide. McAllister et. al. (1965: 29) have described the return to the sea by leatherbacks in which they mentioned the occasional circles, some three metres in diameter, executed by females. No ready explanation is available for this behaviour as it is not a common feature.

Green turtles

On Tromelin Island and the Primeiras there is no great expanse of reef exposed at low tide so turtles can attain the sea with no problem.

On Europa, however, falling tides often expose the turtles to lengthy hauls of several hundred metres over exposed reef or sandbanks. Further, the turtles penetrate through small gaps in the raised coral reef and on returning to the sea cannot find the gap and crawl over the top of the reef, occasionally falling into holes from which they cannot extricate themselves. During a six week stay on Europa some 50 females perished in this way.

If faced with a long crawl over the reef females will enter shallow pools and remain there splashing themselves occasionally until the tide comes in.

In the lagoon at Europa, green turtle females, if caught on the exposed sandbank, were observed to dig body cavities in the sand, exactly as the nesting body cavity is dug, and once water had percolated into the hole splashed themselves in the same way as those observed in rock pools. This is a daily occurrence on Europa.

Other species

No data are available on other species in the study region.

Factors affecting the inter-nesting intervals

Loggerheads and leatherbacks

It has been shown in the sub-section on factors influencing the nesting season that there is a strong correlation between sea temperature and the internesting interval in Tongaland loggerheads.

Hughes and Brent (1972: 49) showed that during the 1971/72 season leatherbacks responded only slightly to the cooler temperatures by having internesting intervals of ten days whereas the more normal period is nine days. During the 1972/73 season the interval was 9.7 days (n=22, range: 8-12).

No basking behaviour by loggerheads has been observed off the Tongaland beaches but one leatherback was seen from the air floating on the surface about one kilometre offshore.

Green turtles

Insufficient time was spent on any of the green turtle nesting areas to record whether there was a response to sea temperatures by nesting females but it is assumed that temperatures are important because basking behaviour took place throughout all days with calm seas. This may, however, be a warming process after the turtle has spent an hour or so sleeping on the bottom. The reasons for this being that no individual turtle was observed to spend more than nine minutes floating at the surface. During this time breathing varied between three intakes to 18. At the surface about two thirds of the carapace was exposed and after a few moments the exposed portion would be dry. Movement was restricted to lifting the head and the occasional stroke by the hind-flippers. As, on Europa Island, there are between 200 and 400 turtles on the surface at all times of the day it is difficult to watch an individual because the slightest distraction results in confusion.

Number of nests and eggs per season

Loggerheads

Table 66 shows the number of nests recorded in the Tongaland protected area during the past four seasons and the estimated total nesting population of females during each season. Although not entirely justified a simple division suggests that the mean number of nests laid per season is four.

Table 66 shows also the observed number of nests laid by individual females and it can be seen that numerous females lay up to five times in one season which would, at roughly 15 day intervals between each nesting, span the two month nesting season.

If, however, every female lays five times, then either winds wipe out the traces of more nests than is expected or there is some movement on the extremities of the protected area resulting in nests being laid outside and thus not recorded.

It is likely that nests are missed for both reasons and it is suggested that the Tongaland loggerhead lays either four or five times during a season. Thus the total egg production of an individual female is estimated at between 450 and 570 eggs per season at a mean clutch size of 114 eggs. (Table 66).

In Tongaland the policy has been not to kill females under any circumstances so only one turtle has been examined in detail. Table 67 summarizes the number of ova in each ovary (ova smaller than 5.0mm estimated by mass) and there is nothing to suggest the total reproductive lifetime of the female. Apart from the mass of minute ova there were 169 developing ova of various sizes which did not suggest any particular size grouping. However, as the animal was killed near the end of the season it may be that these were merely remnants which would be reabsorbed in due course. Caldwell *et. al.* (1959: 316) found some evidence of grouping of ovarian eggs in Atlantic loggerheads killed early in the nesting season and similar quantities of minute ova.

Leatherbacks

Table 66 shows also that leatherback turtles in Tongaland lay up to 8 clutches per season giving the total egg production of normal yolked eggs as 800 or more. With the substantial movements of leatherbacks between layings it is likely that many nests are laid outside of the protected area and hence unrecorded.

One female killed outside of the protected area on the 29th December 1971 was found to contain 902 well developed ova measuring approximately 35.0mm in diameter with 113 shelled yolked eggs ready to lay. This made a total of 1015 eggs which, if spread over 8 nestings, would be 127 eggs per clutch which is well within the observed range of leatherback clutch sizes in Tongaland (Table 66). At nine layings this would mean the clutch size would be 113 the size of the one clutch that was ready for laying.

Green turtles

Insufficient time was spent on any green turtle nesting ground to ascertain the number of eggs or nests made by green turtle females in the study region. Details of egg sizes and numbers may be found in Table 19.

Other species

Only one clutch of hawksbill eggs were inspected on Ilha do Fogo, Mozambique. The clutch size was 124 and the mean egg size 40.18mm ($\sigma = 0.14$, $n = 20$).

The reproductive lifetime

Loggerheads

The Tongaland programme is still too young to have produced conclusive results on the reproductive lifetime of the loggerhead. In Section 4 it was shown that reproduction by individual animals

was irregular so time is not a suitable indicator and it is not yet possible to assess the duration of the reproductive lifetime.

Although two and three recorded nesting seasons per individual are common, only two females have been logged in four separate seasons out of nine (Table 56). It is reasonable to assume that if this was a frequent occurrence, more data would have been collected even with the loss of tags. However, as these tag losses have been heavy, it is tentatively suggested that the reproductive potential of a loggerhead female is spread over four nesting seasons spanning a highly variable length of time. As each female has a massive reserve of ova it would appear that preparation for a nesting season is heavily dependant on the environmental conditions surrounding the female during non-nesting periods.

Thus, accepting four seasons nesting at approximately 513 eggs per season, the total number of eggs laid during a reproductive lifetime is around 2000.

Leatherbacks

As the same time-drawbacks as was outlined above for loggerhead turtles apply to leatherback results and there are fewer data it is not intended to make any quantitative suggestions concerning the reproductive lifetime.

It can be said only that leatherbacks lay up to 1000 eggs per season for at least three nesting seasons giving a possible maximum number of eggs as 3000 per reproductive lifetime. Many more data are required before these figures can be confirmed or added to.

Other species

During the present survey insufficient data were collected on which to base discussions on the reproductive potential of other species.

Factors affecting the hatching success of eggs

Bustard and Greenham (1968: 275) showed that, in Australia, the chloride concentration in the sand is not a limiting factor in the hatching success of eggs except below high spring tide levels where the chloride concentrations can reach lethal levels. At 365 mg Cl-/Kg dried sand they reported 65% egg mortality in green turtle clutches.

Loggerheads in Tongaland rarely lay near the high water mark but leatherback nests are often situated close to, either above or below, the high water mark. Hughes (1970: 33) reported the results of a survey of leatherback nests in Tongaland, showing that 17(30%) out of 56 nests were laid in this marginal zone. Sand samples from eleven sites had a mean chlorinity value of 180 mg Cl-/Kg dried sand (range 66-499, S.D.111).

Thus, variation in chlorinity values is wide in this narrow zone and the highest values might endanger some of the clutches laid there. If mortalities do occur this might be another partial explanation for the moderate extent of the leatherback population in Tongaland.

Other factors observed in Tongaland are:-

- (i) Waterlogging through continual emergence in water either through being buried too deeply above a shallow rock layer (observed only in hatchery nests) or as a result of beach erosion and waves washing continuously over the nest.
- (ii) Predation through feral dogs (the most serious threat), ants (Dorylus spp.) (in those nests laid close to the natural bush), and monitor lizards (Varanus spp.).

Hill and Green (1971: 11-13) suggest that in Surinam some 11.8% of each clutch is destroyed by ghost crabs but they did not explain how they distinguished between eggs burst by the prodding stick used to find the nest originally and those eaten by crabs. They showed also that they had burst some five eggs per clutch. It is thought likely that the contents of the burst eggs would have attracted the crabs and thus give the impression that they were predators. In Tongaland neither species of ghost crab has

been observed, either directly or indirectly, to inflict damage on turtle eggs. On numerous occasions crab tunnels have been found leading into nests after the hatchlings have departed but there has been no evidence to suggest that the crabs had been there prior to hatching and attacked eggs or hatchlings.

On Europa Island considerable damage is inflicted by nesting females digging up previously laid eggs. (see Bustard and Tognetti, 1969: 939-941).

Reproductive success

Table 68 summarizes the fertility, hatching and emergence success of clutches laid by loggerhead and leatherbacks in Tongaland, and by green turtles on the islands of Europa and Tromelin.

As the loggerhead data included in Table 68 was based on marked nests not interfered with in any way until after the expected incubation period had elapsed, they are more realistic than those reported by Hughes et. al. (1967: 32) who dealt with emerged nests only.

The hatching success of leatherbacks in Tongaland is similar to that reported by Schulz (1968: 72) for leatherbacks in Surinam and by Pritchard (1971b: 24) for Mexico. The markedly lower emergence success suggests that the metre, or more, climb to the surface of the beach is a laborious undertaking for hatchling leatherbacks.

No obvious reason is available to explain the differences between the hatching and emergence successes of the green turtle samples as both are from oceanic islands with similar sand beaches. Perhaps larger samples taken at the same time of the year would show less difference because the Europa sample was collected in early December and the Tromelin sample in October after a cold winter season.

Survival rate to maturity

Loggerheads

Despite the premature stage of research in Tongaland some tentative suggestions concerning the survival rate to maturity are pertinent here.

Taking the past four seasons as being the most thoroughly recorded and averaging the data one has:-

- (1) Mean number clutches/season : 1660 (Table 68).
 Mean number eggs/clutch : 114 (Table 68).
 Therefore total number eggs/season : 189240.
 As mean hatching success is 78.6% the total number of hatchlings is 148743 and the mean emergence success 147229. However ghost crab predation is 3.7% (Table 46). Therefore the number of hatchlings entering the sea is 141782.
- (2) The percentage remigrants, both with tags and those that had lost tags, recorded during the 1972/73 season was 47% therefore the recruitment rate is at most 53%. It is likely, however, there are some remigrants that have never been tagged before so the recruitment rate could be any percentage between 53% and 0. It would seem unlikely to be less than 10%.
- (3) The mean number of females utilizing the Tongaland beaches during the past four seasons is 420 (Table 68).
- (4) The sex ratio between males and females is thought to be one male for every two females (see Section 2).
- (5) Therefore if the recruitment rate is considered at the 50%, 40%, 30%, 20%, and 10% levels we have the following possibilities:-
 - (i) The 50% recruitment rate.

No. of females	:	210
+ Males (1:2)	:	105
Total	:	315

Survival rate from 141782 hatchlings entering the sea: 0.22%

(ii) 40% recruitment rate.

No. of females	:	168
+ Males	:	84
Total	:	252
Survival rate	:	<u>0.178%</u>

(iii) 30% recruitment rate.

No. of females	:	126
+ Males	:	63
Total	:	189
Survival rate	:	<u>0.133%</u>

(iv) 20% recruitment rate.

No. of females	:	84
+ Males	:	42
Total	:	126
Survival rate	:	<u>0.089%</u>

(v) 10% recruitment rate.

No. of females	:	42
+ Males	:	21
Total	:	63
Survival rate	:	<u>0.044%</u>

Therefore, as far as the present data permits it would appear that the survival rate to maturity is between 0.2% and 0.044%. In whole figures this means that only one or two hatchlings per thousand reach maturity after entering the sea.

That these figures have some value may be derived from the suggested total production of an individual female. So far the Tongaland data suggests that an average female lays 4.5 times per season for four seasons. At 114 eggs per clutch her total egg production is 2052 eggs.

From these eggs 1537 hatchlings might be expected to reach the sea having lost 3.7% to ghost crabs. In order that the population remains stable at least one female must survive to maturity but as there is thought to be one male for every two females it is easier to consider the production of two females as follows:-

Total hatchling production	:	3074
Two female and one male survivor:	:	3
Percentage survival rate	:	<u>.098%</u>

At this survival rate the annual recruitment rate in Tongaland would be 139 turtles, consisting of 93 females and 46 males.

At 93 females the nesting recruitment rate would be 22.0% which is thought to be a plausible figure. Within the next five years it will be possible to ascertain the accuracy of these suggestions.

It is to be hoped that for a time the recruitment rate will be higher than this hypothetical calculation as the population recovers from the artificial mortality imposed prior to the protection efforts instigated in 1963.

Other species

Insufficient data are available on other species on which to base discussions on survival rates.

Discussion

In general the nesting behaviour of all three species dealt with in the study region is identical to reported accounts from other regions. There seems to be little doubt that the sea temperature has considerable influence on the nesting season and fluctuations in sea temperature can be linked with interesting intervals and incubation periods (Hughes and Brent, 1972: 47). Responses to tidal phases are negligible in leatherbacks, slight in loggerheads, and direct in green turtles from Europa Island. There is no relationship at all between moon phase and nesting activity within a season (see Figure 85) as was first reported by Baldwin and Lofton (1959: 324).

One unexplained aspect of turtle nesting activity is the fluctuation in numbers of females coming to the beaches each season. In Tongaland, loggerhead numbers have varied between 217 (1968/69) and 502 (1971/72) and leatherbacks from five (1966/67) to 55 (1971/72). These fluctuations have been observed in green turtle nesting areas as well, e.g. Tortuguero (Carr and Carr, 1970b: 283), Sarawak (Banks, 1937: 529), and the St. Brandon Islands (see Figure 80).

No obvious reason for these fluctuations is available. Banks (*ibid.*) suggested that one season of high rainfall resulted in the following season being poorly attended by turtles but he presented limited data and the actual link between rainfall on the nesting ground and a potential nester which may be a long distance (1600km) away is not clear. Of course, referring back to Section 4, it is possible that heavy rainfall leaches out or diffuses the olfactory turtle cue resulting in the following seasons's nesters being unable to find the nesting ground, depending on whether such a cue does exist and if it is used as a long range guide. This immediately raises the question as to where the turtle does lay her eggs if she cannot find the home nesting ground, or if she reabsorbs the eggs.

Further, it seems unlikely that temperature would have any influence on the numbers of turtles nesting considering the wide distribution of the loggerhead population in the study region.

At the individual turtle level there is no suggestion of differences in egg production or general behaviour, and the percentage contributions of remigrants and new animals continues to rise at a consistent rate every season, irrespective of overall numbers (see Figure 69).

Exploitation of the adult stocks away from Tongaland might be an explanation but there are no data to support this and it is considered unlikely.

Finally, there is the possibility that a poor nesting season is the result of a previous nesting season experiencing a natural disaster with excessively high egg and/or hatchling mortality, and a subsequent loss of recruits. This too seems unlikely in that it would be expected that in such a season the percentage remigrants would appear markedly higher which is not the case.

The present evidence suggests that whatever the cause of these fluctuations it affects both recruits and remigrants. It must be assumed therefore that it is an environmental factor, not variation within individual females, and must be far-reaching to cover the spread of the whole population. Temperature, rainfall and food could all be considered local phenomena as values vary from area to area and perhaps it is a combination of all three or might simply be the availability of food.

THE COMPARATIVE EXPLOITATION OF SEA TURTLE
POPULATIONS; EXTENSIVE DOMESTIC HUNTING OF
THE GREEN TURTLE CHELONIA MYDAS IN SOUTH WEST
MADAGASCAR VERSUS INTENSIVE COMMERCIAL HUNTING
OF THE GREEN TURTLE IN THE ST. BRANDON ISLANDS.

Introduction

Overexploitation has led to a widespread decline in sea turtle populations and the concern generated by this trend resulted in the creation and successful financing of the present extended survey and research programme. Consequently, one aspect of the research was to try and assess the current exploitation levels in South East Africa and ascertain which steps might prove necessary to rectify damaging, or potentially damaging, exploitation policies.

Throughout most of Madagascar, and the whole of Mozambique, sea turtle hunting is fortuitous and disorganised and valid assessments of exploitation levels cannot be made. Two areas, however, were exceptional:-

The Vezo tribesmen of South West Madagascar are skilled fishermen with a long tradition of seamanship. Sea turtles figure prominently in their diets and it proved possible to collect reasonably accurate exploitation data.

In the St. Brandon Islands a series of fishing companies, based on Mauritius, have been exploiting the green turtle populations for 160 years or more. The current lessees have kept exploitation figures since 1937 and the quality of their data collecting has been improving with time.

Thus it has proved possible to compare domestic and commercial hunting of the green turtle and the data are presented below.

Materials and methods

South Western Madagascar

The portion of Madagascar with which this section is concerned is 668km long and bounded by Morondava in the north

and Androka in the south (Figure 1). The region is characterised by a dry climate, low relief, and a sheltered coast dominated by wide fringing reefs and shallows richly endowed with undersea vegetation. Within the area fishermen operate from 48 villages, 19 of which were visited during October, 1970. The turtle catches were assessed by inspection of village middens and the altars displayed along the beaches. Traditionally the Vezo (pronounced Vez) tribesmen slaughter sea turtles within sight of the sea and display the heads, carapaces and plastra on raised platforms normally situated at the top of the first sand dune. In earlier times this was regarded a necessity for ill-luck dogged those who failed to acknowledge the tradition. In modern times these once semi-sacred altars (Rantsana) appear to have become mere trophy exhibits by whose size the skill of the fisherman is judged.

It should be stated immediately that no claim is made for absolute accuracy. The data included below are based on the material examined and close questioning of the fishermen themselves. A problem arises from the fact that all fishing is undertaken in piroques; a dug-out canoe with outriggers which is either paddled or sailed, with limited capacity, so many turtles have to be butchered at sea and the carapaces, heads and plastra discarded.

From each estimated total monthly catch provided by the village a quarter was subtracted, that is, it was assumed that for three months of the year no turtles are caught at all. By so trimming the figures allowance has been made for adverse weather periods and exaggerations on the part of fishermen interviewed.

St. Brandon

The St. Brandon Islands are situated some 392km north-north east of Mauritius and lie between 16° - 17° S, and 59° - 60° E (Figure 1). The entire shoal comprises a crescent shaped coral reef, 38km long by 5km wide, bulging eastwards into the South Equatorial Current. Altogether there are 63 islands and sandbanks

on the reef or nearby, 20 of which were visited during November 1971. No island exceeds 110 hectares in area or attains a height of over three metres A.S.L.

All exploitation data reported below were obtained through the kind offices of the Mauritius Fishing Development Company, Port Louis. General impressions on the present situation was derived through questioning the fishermen and nest-track counts on the islands visited.

Results

Domestic hunting in South West Madagascar

Methods employed

Quite apart from the direct slaughter of nesting green turtles that is practised throughout the region, hunting is undertaken either using nets made of nylon with a 20cm mesh, or harpoons. This does not imply that net fishermen do not use harpoons as well because up to three harpoons are standard equipment on all piroques.

Two types of harpoon are in common use:

The Samona, Samonda or Teza (Hughes, 1973: 116)

This harpoon has a robust blade 12cm in length with opposing 2cm barbs one of which is curved. The head is detachable from the 215cm wooden shaft. This is the most widely-used harpoon.

The Kisaisnitsa

This harpoon has a non-detachable head consisting of three separate, strong tines, each 12cm long, barbed, and set equidistant from one another around the head of the shaft. The shaft is wooden, some 2.5m long, at the end of which is attached a rope or strong cord. Used mainly for fish it is infrequently employed on turtles but several carapaces were examined that bore unmistakable marks of the Kisaisnitsa.

Despite the long tradition of sea turtle hunting in Madagascar it was remarkable how unsophisticated were the uses to which turtle products were put. As a harpoon thrust rarely proves fatal, many turtles are brought back to the village and dismembered at leisure. The procedure of dealing with the turtle was as follows:

The turtle is placed on its back on a bed of branches or leaves and the plastron is cut off and discarded - no attempt is made to utilize the valuable cartilaginous calipee apart from minor trimming of the edges. The flippers are then hacked off, dropped into a large pot or drum of boiling water situated nearby, and are soon followed by the rest of the meat. Finally the intestines and other parts are roughly cleaned and dropped

into the pot. Oil rising to the surface of the water is scooped off by the womenfolk.

The carapace of the green turtle is scraped clean of fat, the edges of the carapace trimmed thus removing most of the calapash and the remainder of the carapace is deposited on the fisherman's altar. The head is generally severed last and not used. This is in contrast to the African's usage in Mozambique where the head is boiled whole and then smashed to obtain the large jaw muscles. The fishermen showed complete disregard for the obvious suffering of the turtles which continued to raise their heads even after their flippers had been removed and they had been disembowelled. According to Decary (1950: 98) the turtle is not killed outright because it is semi-sacred and thus the fisherman does not have the right to "kill" it.

There were no special recipes for preparing the meat, everything was boiled and no practical secondary uses were found for any part of the carapace, plastron or head except for the decoration of the altars. The heads are impaled on stakes at the head of the altars, or on the fences surrounding the fishermen's huts.

Annual harvests

All sea turtles not required for domestic consumption are transported, either piecemeal or whole, to nearby markets and sold. Prices quoted for complete turtles varied somewhat from place to place but the approximate prices during 1970 and 1971 were as follows:

Juvenile turtles	:	1 500 Fmg.	(R3-25)
Sub-adult turtles	:	10 000 Fmg.	(R25-00)
Adult turtles	:	20 000 Fmg.	(R50-00)

The mean monthly turtle catch, of all species and sizes, was 23 per village investigated. As there were 48 villages the overall monthly catch was 1104 making an annual catch of 13,248 turtles. Table 69 summarizes the contribution made by the green turtle, all sizes, to the above figure, and it is clear that the green turtle is by far the most important sea turtle as it comprises 51.5% of the annual catch.

The estimated cash value to the Malgache fishermen is also included in Table 69 and, as only about 50% of the turtle is utilized, values are based on 50% of the gross mass. Naturally, it is unlikely that the fishermen actually gain financially from their turtle catches as few villages have a market town close by where turtles and their perishable products could be sold, and even in those villages close to markets such as Tulear, two out of three turtles are apparently consumed in the village. These monetary and meat figures provide an indication of the green turtle's value as a source of protein and, to a lesser extent, as a source of supplementary income to the coastal villagers with limited means of obtaining hard cash.

Present state of turtle populations

As regards the present state of the green turtle populations recourse must be made to the subjective comments of the fishermen themselves. In most cases the fishermen did not feel that there had been any marked decline in green turtle populations. This is in marked contrast to Mozambique where some fishermen complained of widespread declines.

This must be regarded as a promising sign that the hunting pressure is not having too adverse an effect on the total population. In searching for the reasons that allow an enormous crop of sea turtles to be taken annually without resulting in declines one must reach the following conclusions:

- (i) The nesting areas from which these turtles originate must be relatively safe from exploitation. It would appear that most nesting areas are situated on islands sufficiently far from the mainland to inhibit extensive sea voyages in open canoes. The incredibly high density of nesting green turtles on Europa Island (see Section 2) would indicate that this nesting population is in a healthy state and thus the hunting in Madagascar is doing little harm. This depends, of course, on whether most, or all, of Europa's turtles are drawn from Madagascar. Tag recoveries so far indicate that they are (see Section 4).

- (ii) The small size and scarcity of villages along the coast allows a nesting turtle on the mainland a greater chance of emerging, laying and returning to the sea undetected, and further that the nest will remain undisturbed.

Thus it may be concluded that green turtles can withstand extensive hunting when it is non-selective and aimed at the animals during the non-breeding phases of their lifetime. From Table 69 some 47% of the total catch is sub-adult and juvenile and this contribution is probably higher because juveniles are the most easily transportable and it is likely that many are sold and thus untraceable.

Commercial hunting in St. Brandon

Methods employed

The St. Brandon Islands region is immensely rich in fish-life and the catching thereof constitutes the main reason for the presence of men on the islands. The turtle fishery is a sideline compared to the fish catches which can total 2-3 metric tonnes per day for the entire island group. All fishing is undertaken from five metre open boats, also known as piroques but quite different to the Malgache outriggers, and these are sail driven with the exception of a few which have 6 H.P. outboard motors.

Each piroque carries a complement of two to five men drawn from four settlement islands; Raphaël or Establishment Island, Avoquer Island which is vacated during the summer months because of the cyclone danger, Coco Island, and Albatross Island. Altogether there are roughly 100 men and between 20 and 30 piroques operating within the island group. All fishing is by handline and every fisherman has a harpoon for fortuitous hunting of green turtles.

(i) The Johnkin Harpoon (Figure 86)

The Johnkin harpoon is possibly the most unique harpoon in the world because the head is only 4cm long and barbleless. The edges of the blade are lightly scored, each fisherman having his own design.

The head is detachable and attached to it is a strong cord known as a chicote.

The hunting procedure is simple particularly if the fishermen are after copulating sea turtles. A quiet approach is made from the direction opposite to which the turtles are facing and the harpoon is plunged into the carapace of the nearest animal, more often than not the male. Line is immediately played out, as the stricken turtle sounds, but kept taut with tension being gradually increased until the turtle's flight is halted. The turtle soon tires of pulling the piroque, is hauled to the surface and manhandled into the boat.

With the release of tension the harpoon head is easily removed by pushing it hard against the carapace and quickly jerking it out. The hole is immediately plugged by a wooden bung trimmed on the spot. If this hole is not plugged the turtle, on being placed into the turtle holding pen, will die when water enters the body cavity. Apparently the damage inflicted by this harpoon has no ill-effects and subsequent deaths are almost non-existent.

In the past, and to a large extent at present, the piroques were solely sail driven which cut down their manoeuvrability making advantageous approaches to turtles more difficult. Undoubtedly there were, and still are, many escapes by turtles. Today, however, there are more outboard motors being brought into common use and this will allow much simpler and quicker approaches to be made to copulating animals. It will also allow closer inshore hunting around some of the islands. Being solely under sail many fishermen were understandably reluctant to approach the islands too closely, particularly along the eastern shores where the waves are generally large.

(ii) Hunting with snorkel and speargun

A recent innovation on the islands and at present restricted to Raphaël Island and its environs. Only two fishermen are presently using spearguns.

(iii) Turning turtles on the nesting beaches

This is a traditional method of capturing females and undoubtedly the most damaging from the turtle population point of view. The paucity of turtles around the settlement islands is almost certainly a direct result of this capture method.

All captured turtles are kept in a concrete holding pen on Raphaël Island until such time as the supply vessel arrives to ship them to Mauritius. Slings are placed around the foreflippers of the turtle which is then swung bodily onto the boat using a power winch. Placed on their backs on the deck, they are regularly hosed down and mortalities over the 26 hour voyage to Mauritius are extremely rare.

Annual harvests

(1) Purchase, transport and sale

All turtles captured or killed by the fishermen must be sold to the Company in terms of their contracts. Payment for an adult turtle is at a fixed rate of Rupees 17.00 (R2-50) each. As this sum must sometimes be divided between five fishermen from a piroque the gain of an individual fisherman is low.

After transport to Mauritius the Company sells the turtles at the quayside for Rupees 160.00 (R23-00) each and they are then either sold privately through a cold storage firm or slaughtered in the marketplace and sold piecemeal at Rupees 3.00 (R0.40) per 500g. If only a quarter of a 200kg green turtle is sold at that price the animal is worth Rupees 300.00 (R43-00). When there are large landings, turtles are often stockpiled alive in the market where they may lie for days before being killed.

Females are preferred by the buyers because:-

- (i) They carry more meat than males
- (ii) They more often than not contain ova which are sold at Rupees 0.20 for a shelled egg and Rupees 0.04 for an unshelled yolk.
- (iii) They are normally larger and thus have a more cartilaginous calipee and calipash which is not sold in Mauritius but is exported at Rupees 27.00 (R3-88) per kg. As 2.5kg of this material is obtained from an adult green turtle the total value of the turtle as a whole would exceed Rupees 350.00 (R50-00) on the local market.

(2) Catch records

As stated above green turtles have been exploited in St. Brandon since at least the beginning of the 19th century.

Unfortunately there are few detailed records from early times but 21 were sent to Port Louis in 1879 (Dupont, 1880: 4) and 43 and 42 in 1886 and 1887 respectively (Boucherat, 1888: 1162). These catches are extremely modest and must have done little damage to the turtle populations. Stanley-Gardiner and Cooper (1907: 23) reported that in 1903 the turtle hunting was well organised. They made no mention of over-exploitation on St. Brandon although they referred to Agalega's turtle populations as declining.

Increased pressure on the turtle populations probably started with the commencement of fairly regular voyages between the islands and Mauritius. Around the turn of the century there was also an increase in the number of fishermen; from 36 men in 1881 to between 80 and 100 today depending on the time of the year.

Unfortunately there are no continuous catch records until 1937, ten years after the islands were taken over by the current lessee, the Mauritius Fishing Development Company, but since then records have been kept with increasing accuracy. From 1957 monthly catch records have been kept and in 1970 and 1971 sexes have also been noted.

Figure 87 summarizes the annual catch records since 1937 and a trend line has been fitted using Bartlett's regressive formula.

Table 70 summarizes the monthly landings of green turtles since 1957 and Figure 88 shows the sex ratios for 1970 and 1971.

The present state of turtle populations

From Figure 87 the trend line of exploitation shows a barely perceptible decrease over the past 35 years and this could be interpreted as a well balanced and stable recruitment-exploitation situation. However, the following points must be considered:

- (i) The use of outboards has recently improved the success of hunting turtles at sea.
- (ii) The use of skin-diving equipment, limited as it is at present, has enabled some fishermen to pursue turtles in places which were previously inaccessible.

- (iii) Thus, although the numbers of fishermen have remained relatively stable over the past thirty years, they are using more sophisticated methods to obtain roughly the same number of turtles.

This would suggest that there are less turtles than previously. Therefore it would appear that the green turtle population in St. Brandon is delicately balanced and any new pressures could have deleterious effects on the turtles and as a consequence on the fishery itself.

The sex ratio figures indicate that a substantial amount of hunting takes place in the open sea as 50.9% of the turtles killed during 1970 were males which are not known to come ashore in St. Brandon as they have been reported to do in other areas (see e.g. Hirth, 1971: 3: 25). The change in emphasis during the latter half of the 1970/71 season may have been a result of the departure of males or that male numbers had been drastically reduced. Whatever the reason the figures suggest that hunting is being executed in a non-selective and, from one point of view, satisfactory manner.

The emphasis on females towards the end of the 1970/71 season does provide grounds for concern because the greatest possible danger facing any programme exploiting a natural animal resource, be it turtles or fish, is the hunting of a female during her period of peak reproductive potential. In the case of the green turtles on St. Brandon the period of highest reproduction is November to February inclusive. From Table 70 and Figure 80 it can be seen that this is not always so but on average St. Brandon has a mid-summer nesting peak as is normal in green turtle nesting colonies.

On St. Brandon 50% of the annual catch is taken during mid-summer. During the 1970/71 season from November to February 370 turtles were caught, 52.2% of which were females many of which have been caught before they had completed their nesting season. In many cases the females might not have even started the season. As green turtles normally lay upwards of 600 eggs over three, four, or more emergences during a nesting season killing a female on her arrival means the loss of 600 potential turtles. As the

Company derives no profit from eggs recovered from slaughtered gravid females it is, in fact, losing its potential future harvests for no reason at all.

Furthermore in green turtle nesting assemblages copulating couples are normally escorted by one or two other males. This is well known in St. Brandon where the fishermen take advantage of the male's interest and harpoon them. It is not known how important it is to have numbers of males competing for fertilization of the female but it is logical to assume that avoidance of interference with copulating couples can only be advantageous to the fertilization process.

During November, 1970, 24 males were taken compared to nine females, in December 86 males and 79 females. These figures suggest that many turtles are interfered with during copulation and this must have a damaging effect on the resulting fertilization of eggs. The net result is probably a drop in emergence success of hatchlings thus posing a serious threat to the maintenance of recruitment.

The present state of the turtle population on St. Brandon does not appear healthy and the dramatic drop in numbers harvested during the 1971/72 season when only five turtles were taken, is probably indicative of a future, possibly final, decline in the population.

Despite the exploitation data in Figure 87 there were other indications of declines. During 1971 twenty islands were visited (Table 71) and on many islands there were old nesting pits covered with vegetation suggesting that the stretches of utilized beach is diminishing i.e. there are fewer turtles nesting than formerly.

The manager of Albatross Island said that turtles had once nested extensively on the island but there have been few in the past few years. Older fishermen remembered fleets of turtles during the breeding months as late as the middle-fifties but these fleets have now disappeared. The Company itself has suspected that the turtle populations are declining and in 1964 declared one island, North Island, as a turtle reserve and its sanctity is more or less observed in that fishermen rarely land on the island (it is not an easy landing even in relatively calm

weather). They can still, however, hunt the turtles around the island, a simple matter if the piroque is equipped with an out-board motor.

A far greater effort is required if the Company is to continue deriving some economic benefits from this turtle population. In the full report to the Company and Mauritius Government a series of recommendations were made which, if implemented, might result in a recovery of the population (Hughes, in press).

Discussion

From the data presented above it is obvious that the green turtle is exploited extensively in the study region. Despite the similarities in the hunting methods of the examples used there are fundamental differences in the time of hunting.

In south western Madagascar the Vezo fishermen have hunted non-nesting turtles at all stages of their life cycle for generations, and their annual harvests are substantial. Considering Europa Island, where many of Madagascar's turtles originate, the nesting population is in a healthy state, if quantity of nesting turtles can be taken as an indicator. In addition to the harvesting of green turtles away from Europa, prior to 1923 the slaughter of nesting females on Europa itself was so substantial that in 1950 bone debris was still to be seen lying on the beaches in heaps (Paulian, 1950). Thus despite the undoubtedly increasing harvests by Malgache fishermen, the Europa nesting population has recovered from the earlier slaughter and thus it is concluded that a well protected nesting ground can provide sufficient stock to withstand extensive hunting pressure. The total protection of Europa and other islands by the French authorities on Reunion has ensured a consistent food resource for the coastal villagers of Madagascar, as well as creating a more stable future for the green turtle.

On St. Brandon the general turtle situation is showing signs of deterioration from a lack of the simplest resource management. St. Brandon is a nesting ground and hunting is allowed throughout the year and the turtles are harassed on land and sea.

The importance of green turtles to the people of Mauritius is not maximal but neither is it inconsequential. The mean annual catch is only 302 adults but this provides 25,670kg of meat worth Rupees 154 020 (R20 535-00). As virtually all of the red meat consumed in Mauritius must be imported from Madagascar even this modest amount of locally produced meat saves valuable foreign exchange. Yet despite the local value and disregarding entirely the aesthetics of animal conservation, the authorities continue

to permit the squandering of such a valuable resource. When, as is clear from the recovery of the Europa population from a period of intense exploitation, even minimal conservation legislation enforcing a closed season, would probably lead to a resurrection of the turtle population and consequently a steady, although modest, harvest.

Thus these two exploitation examples show the enigmatic situation of Reunion, a relatively underdeveloped island with limited resources, expending time and money on protecting green turtles in order to benefit the coastal peoples of Madagascar. Whilst, not 200km away, the Mauritius Government makes no effort to safeguard an important ancillary source of protein for its own people.

In conclusion, and it has been stated before, the green turtle is a resilient animal which has survived centuries of exploitation. As a source of high quality food it is an important factor in the lives of less developed coastal peoples in the study region. Given peace during the nesting season the green turtle can continue to be an important food resource and can, with minimal management, increase its contribution to the well being of peoples of the south western Indian Ocean.

THE CONSERVATION SITUATION OF SEA TURTLE POPULATIONS IN THE SOUTH WESTERN INDIAN OCEAN

Introduction

It has been shown in this present work that the study region hosts five of the seven extant species of sea turtles. It is thought that a brief review of the conservation situation is both pertinent and necessary in view of the fact that the survey project was motivated in response to a drive by the International Union for the Conservation of Nature and Natural Resources (IUCN) to improve the survival prospects of sea turtles throughout the world.

Present status

As a result of the recent survey it is clear that no single species in the study region is in immediate danger of extinction. Unrestricted domestic hunting of nesting females in Mozambique (Hughes, 1971a: 53), northern Madagascar (Hughes, 1973: 115) and in the St. Brandon Islands (see Section 6) is giving cause for concern but provided protective measures are instigated in the near future there is no cause for alarm.

Legislation in the countries surveyed is as follows:

(i) South Africa

All sea turtles fully protected by law at all times of the year. Specific legislation in Natal in which the only nesting grounds are found states:-

Coastal Fishing Ordinance, No.19, of 1958,
Section 4.

Protection of Turtles

4. No person shall capture any turtle or take or destroy the eggs of any turtle.

The general situation in Natal is good. Nesting loggerheads and leatherbacks are given maximum protection by the Natal Parks Board and the killing of non-nesting turtles in the Natal Anti-Shark Measures Board's network is purely fortuitous and although regrettable is not considered to pose a threat to any single population.

Despite almost continuous pressure from concerned individuals and organisations the proposed Tongaland Marine Park is not yet a reality. From the nesting sea turtles point of view this is no great problem because of the excellent protection programme run by the Natal Parks Board. These beaches are now, however, in the control of the Kwa-Zulu Territorial Authority and thus the tenure of the Natal Parks Board is limited. The ultimate future of the area is still uncertain.

(ii) Mozambique

Sea turtles, their eggs and young, are fully protected by law throughout the territory of Mozambique under Article No.2627 of the 7th August, 1965.

Until recently there was almost universal disregard for the law with many Port Captains, under whose jurisdiction most fishing activities fall, professing ignorance of the law and permitting unrestricted hunting to continue in their areas.

Turtle protection was at a minimum until 1971 when the authorities, prompted mainly by Mr. Ken Tinley of the Department of Veterinary Services, Mozambique and Mr. Tony de Freitas, Research Director of the Fisheries Research Division of Mozambique, started to give priority to marine conservation. Since then there has been rigid enforcement of laws whenever possible and directives issued to all Port Captains and agents to punish offenders. The situation has, therefore, improved both in general surveillance and in the creation of the Paradise Islands Marine Park which includes some turtle nesting beaches.

Legislation is being considered at present providing three more marine parks, all of which will include nesting beaches; viz.

- (a) The Primeiras Islands
- (b) The coastline adjoining the Maputo Elephant Park
- (c) Some of the Querimba Islands north of Porto Amelia (see Figure 89).

Even with these new marine parks the future of the sea turtles in Mozambique is not assured because of the present political situation and the fact that enforcement of the laws over such a vast coastline is difficult.

(iii) Madagascar

Sea turtle legislation in Madagascar is adequate but, like Mozambique until recently, surveillance is minimal resulting in a threat facing mainland nesting species such as the hawksbill and loggerhead turtles. The laws concerning sea turtles are:

(a) Resolution of 23rd May 1923 (J.O. a/vi/23 p.439)

Instituted areas reserved for turtles:-

- Nosy Avambo or Ilôt Boise (Diego Province)
- Nosy Iranja (Nosy Bê Province)
- Chesterfield Island (Morondava Province)
- Nosy Trozona (Tulear Province)
- Nosy Ve (Tulear Province)
- Europa (Now under French Surveillance, see below)

The protected species are the green turtle (Chelonia mydas) and the hawksbill turtle (Chelonia imbricata).

(b) Resolution of the 24th October 1923 (J.O. 17/11/23 p.856).

It is forbidden to capture sea turtles; when they are laying; and when the width of the carapace, measured across the plastron, does not exceed 0.50m.

The above legislation is completely ignored by all fishermen and even, it appears, by state officials themselves. For example one taxidermist's firm in Diego Suarez is given an annual licence to take 400 juvenile hawksbills and throughout the country stuffed juvenile hawksbills are displayed for sale in almost every major market place and general store.

All other species are exploited mainly for domestic consumption but the juvenile hawksbill is an article of commerce and is undoubtedly the most threatened species in the territory. (see Hughes, 1973 for further details).

There are no mainland reserves in the area where hawksbills and loggerheads (and possibly olive ridleys) can nest unmolested. A slow but steady disappearance of these species must be anticipated unless some positive action is taken.

(iv) Reunion and its dependancies

There are no longer any sea turtles nesting on Reunion Island itself but the islands of Europa and Tromelin

host substantial and important nesting populations of green turtles. Juan do Nova and Les Iles Glorieuses do have nesting turtles but at present these populations are of negligible proportions.

During August 1971 all four islands were gazetted as protected areas with nature reserve status. Various French conservation experts are currently pressing to have the status raised to that of full National Parks. The situation is, therefore, satisfactory as all sea turtles are receiving full protection.

The Reunion Meteorological Administration under whose jurisdiction the islands fall are experimenting with the rearing of green turtles with a view to increasing the numbers of turtles available to the Malgache coastal peoples. These experiments are being executed with the direct cooperation of the Division of Fisheries, Reunion.

There are no grounds for concern in any area under Reunion administration and the conservation situation is excellent.

(v) Mauritius and its dependancies

As with Reunion there are no longer any nesting sea turtles present on Mauritius. The St. Brandon situation (Section 6) has already been described as unsatisfactory but not desperate.

The Mauritius Government is at present reviewing the sea turtle legislation in order to enforce recommendations suggested at the termination of the St. Brandon survey. Further a pilot green turtle rearing project has been instigated at the Mahebourg fish farm with a view to replacing the turtles currently captured in St. Brandon with captive stock. This should enable the St. Brandon stocks to recover.

Discussion

As mentioned, no single species is endangered in the study region but all could benefit from enforced legislation. There is no doubt that turtle populations respond readily to protection of the nesting grounds provided that the actual numbers of turtles has not reached too low a level.

Two good examples of response to protection are the Europa Island green turtles and the Tongaland loggerhead population (see Figure 69). Both populations have undergone varying degrees of persecution from which the Europa greens appear to have completely recovered, and the loggerheads are gradually increasing in numbers.

Our inexact knowledge of seasonal nesting frequencies precludes any consideration of exploitation on nesting grounds in the immediate future for any species but if, for example, the Tongaland loggerhead population continues to increase at the current satisfactory rate then some limited exploitation based on the research results obtained over the years should prove feasible.

In the study region surveyed where the hunting of sea turtles, and the consumption of turtle products, is traditional and regarded as a right and not a privilege, turtle conservation must be applied in recognition of the sea turtles, role as a natural resource. Preservation for aesthetic value alone in a protein-poor region is unjustifiable and can expect no support from government bodies incapable of providing substitute sources of protein. On the other hand these government agencies should not use this as an excuse for inaction for by so doing they are jeopardising the resource as a whole.

Adequate and convincing proof of the viability of sea turtle populations is available and the responsibility for the conservation and management of this resource lies in the hands of the individual governments.

The economic potential of marine reserves containing turtle beaches can hardly be measured. There are thousands of kilometres of coastline for free-ranging sea turtles which could be traditionally harvested by coastal fishermen. Marine reserves form the source of stocks.

Conditions in Madagascar, Mozambique and Mauritius are suitable for the development of turtle farming centres. Much experimental work remains before large scale projects can be undertaken but the recent successes of Mariculture Ltd., Grand Caymen in having captive females laying fertile eggs, bodes well for the future (Mr. M. Fisher, pers. comm.).

Finally, there is the tourist potential. Both marine reserves and turtle farms are attractions to the tourist public. If marine reserves are incorporated into varied habitat or ecosystem reserves the attraction of the area increases immensely and well-addressed educational programmes can only improve their value.

Except in cases of dire extremity all conservation efforts should contribute education and aesthetics, and generate some financial return. Sea turtle conservation need not be an exception and, indeed, few other animal groups can offer all three criteria in return for such a modest financial outlay.

Recommendations

(a) Reserves

As a result of the surveys executed in the region over the past five years it has proved possible to pinpoint several areas in which turtle nesting populations are found in sufficiently high numbers to benefit from formal protection. Table 72 summarizes the suggested reserves and provides comments on the protective status of the area at present (see also Hughes, 1971c).

(b) Closed seasons

In areas such as Madagascar where turtle hunting is legal there should be a closed season from November to February for all adult turtles.

Juveniles and sub-adults could be taken throughout the year as the sea turtle's life cycle is such that heavy predator pressure is anticipated before adulthood. The adult female appears to be the most valuable unit in the population and every effort should be made to protect her during the nesting season.

(c) Egg-gathering and hatcheries

With species that may require more than mere formal protection and/or where the spatial extent of the nesting ground far exceeds the practicalities of formal protection, the concept of egg gathering by the local inhabitants for sale to a central hatchery is sound. This type of scheme has been practised extensively in Malaya (Balasingam, 1967: 37) and Surinam (Pritchard, 1969a: 138) and has been successful.

The method has three advantages; it is cheap, it could save thousands of eggs which would otherwise be eaten, and it provides local tribesmen, particularly women and children, with the opportunity of earning some pocket money. The disadvantage of lowered hatching success as has been found in all hatchery programmes (see e.g. Hughes, 1969) must be ignored. Table 73 summarizes localities in the study region where this form of conservation management could be practised to advantage.

SUMMARY

This thesis is an attempt to bring together all of the current knowledge on the sea turtles of South East Africa. There are five species known to occur and their environmental requirements are discussed at length.

All five species are individually dealt with, their taxonomic and numerical status briefly reviewed, and their characteristics compared with other known populations elsewhere in the world.

The green turtle Chelonia mydas is found to be the most ubiquitous species and numerically superior to all others. Despite being variable in carapace coloration no quantitative differences were found between the local turtles and their Atlantic and Pacific counterparts. The population of the study region appear to be divided into discrete nesting populations, of which the Europa Island assemblage is the most extensive with the largest and most fecund nesting females. It is suggested that this reflects the ideal feeding conditions found off the west coast of Madagascar where tag recoveries have indicated that most of Europa's green turtle populations are domiciled during the non-nesting periods.

The hawksbill turtle Eretmochelys imbricata is found throughout the study region although rare in temperate waters. No quantitative differences can be found between the local stocks and those elsewhere. It is the most endangered species in the area.

The loggerhead turtle Caretta caretta is found to be the second most common species and, because of the presence of a nesting area in Tongaland, is dealt with in more detail than the other species. An attempt has been made to explain its life history. It was found that after hatching the loggerhead is distributed by the Agulhas Current, is tolerant of sharp changes of temperature and is transported into the South Indian Ocean and South Atlantic Oceans. It is suggested that after a period of up to five years it returns to the mainland as a sub-adult residing mainly along the coast of South Africa. After reaching maturation and nesting the fully adult loggerhead appears to go northward into the tropics.

Loggerheads are found to migrate over long distances and females can home with accuracy to a 10km selected stretch of beach. There is some evidence to suggest that the final orientation mechanism might be based on a pheromone secreted by laying females. Tag recoveries indicate that the period of absence from Tongaland is highly variable amongst loggerhead females. The survival rate of loggerhead hatchlings is found to be between one and two per thousand. It is found that loggerhead females can lay up to 2000 eggs in its reproductive lifetime which endures for at least nine years. It is suggested that the animal recruitment rate is between 20 and 25%. The longevity of the loggerhead in the wild state is at least 17 years.

The olive ridley turtle Lepidochelys olivacea is found to occur in Northern Mozambique and West and North-West Madagascar. Numbers are modest and there does not appear to be any difference between the local population and those populations found elsewhere in the world. It is suggested that the modest numbers in the study region are a result of the limited extent of suitable environment and that the local populations are probably relict.

The leatherback turtle Dermochelys coriacea is found to occur throughout the study region but rarer in the tropics. Only one nesting ground is found and it is of limited size. It is suggested that this small size is linked directly with the Agulhas Current which carries hatchlings into the cooler latitudes and possibly to waters in which hatchlings are not equipped to survive. It is further suggested that leatherbacks have a relatively poorly developed orientation mechanism and the availability of the nesting sites is dictated by the nature of the offshore sea bed.

It is found that sea turtles are extensively exploited in the study region but most exploitation is domestic and, with the exception of a few nesting areas, is aimed at the turtles away from the breeding grounds and is considered to do little damage to the populations as a whole. There is only one truly commercial turtle fishery in the area and it is considered that it has been mismanaged. If recently implemented conservation measures are consistently applied the population should recover.

Finally the conservation situation in the study region is discussed and recommendations made to ensure the continued survival of all species.

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Shields		Europa		Tromelin		Shields		Europa		Tromelin	
		L	R	% Freq. (n=200)	% Freq. (n=172)			L	R	% Freq. (n=200)	% Freq. (n=172)
Post-oculars	2	2		0,5	3,0	Marginals	9	11		0,0	0,6
	2	3		1,5	2,0		10	10		1,0	0,0
	3	2		0,5	2,0		11	10		3,0	1,7
	3	3		13,5	15,0		10	11		1,5	0,6
	3	4		8,0	2,0		11	11		84,0	93,0
	4	3		9,5	9,0		12	11		3,0	0,6
	4	4		47,5	52,0		11	12		4,0	2,0
	4	5		8,0	2,0		12	12		3,5	0,6
	5	4		5,0	1,0		11	13		0,0	0,6
	5	5		5,0	1,0					<u>100,0</u>	<u>99,7</u>
	3	5		0,5	0,0	Costals	4	4		85,5	98,3
	4	2		0,5	0,0		4	5		6,5	0,6
	2	4		0,0	2,0		5	3		0,5	0,0
				<u>100,0</u>	<u>100,0</u>		5	4		4,0	1,2
Nuchals	1			87,5	87,2		5	5		2,5	0,0
	2			12,5	12,8		6	5		0,5	0,0
				<u>100,0</u>	<u>100,0</u>		6	6		0,5	0,0
Vertebrals	4			0,5	0,0					<u>100,0</u>	<u>100,1</u>
	5			83,0	93,0	Infra-marginals	3	3		0,5	1,2
	6			13,0	5,0		3	4		1,5	1,2
	7			1,5	0,6		4	3		1,0	0,0
	8			1,5	0,6		4	4		88,5	89,5
	9			0,5	0,6		4	5		2,0	3,5
				<u>100,0</u>	<u>99,8</u>		5	4		3,0	1,2
							5	3		0,5	0,0
							5	5		3,0	3,5
										<u>100,0</u>	<u>100,1</u>

Table 1. Lepidosis of green turtle hatchlings from Europa and Tromelin Islands. (Nomenclature after Loveridge and Williams, 1957). Samples consist of randomly selected groups, each comprising 10 units or less, collected from emerged batches of hatchlings. Hatchlings found in excavated nests are not included.

Shields	Typical N.		Europa Isld.		Tromelin		St. Brandon		Mozamb.		S. Africa		Madag.		\bar{x}	n.
			% Freq.	n.	% Freq.	n.	% Freq.	n.	% Freq.	n.	% Freq.	n.	% Freq.	n.		
Post-oculars	4L	4R	70	30	59	29	100	2	100	9	100	15	100	4	88,17	89
Nuchals	1		100	30	100	29	100	2	100	29	100	21	100	56	100,00	167
Centrals	5		97	30	100	29	100	2	100	29	100	21	100	56	99,50	167
Supra-caudals	2		100	30	100	29	100	2	100	29	100	21	100	56	100,00	167
Costals	4L	4R	100	30	97	29	100	2	100	29	95	21	100	56	99,50	167
Marginals	11L	11R	100	30	89	28	100	2	100	29	95	21	98	50	97,00	160
Inter-gular	1		70	30	86	29	100	2	100	9	100	16	100	3	92,67	89
Inter-anal	absent		97	30	100	29	100	2	100	9	94	16	100	3	98,50	89

Table 2. Lepidosis of green turtles Chelonia mydas from various localities in S.E. Africa.

Locality	Sex	Concentration	C o l o u r s			Density*
			Base colour	Streaks	Spots	
Europa Isld.	♂	Black	Olive green	-	Black	Dense
Tromelin Isld.	♂	-	Olive green	-	Black	Dense
Durban	♂	-	Olive green	Black	Black	Dense
Europa Isld.	♀	Brown	Red-brown	Browns	Brown	Medium
Europa Isld.		-	Red-brown	-	Browns	Medium
Europa Isld.	"	-	Olive	-	Black	Sparse
Europa Isld.		-	Dark olive	-	Black	Medium
Europa Isld.	"	-	Dark brown	-	Bl.&Br.	Dense
Europa Isld.		Brown	Dark brown	Browns	-	Dense
Europa Isld.	"	-	Olive grey	-	Bl.&Br.	Medium
Europa Isld.		Brown	Grey-brown	Browns	-	Medium
Europa Isld.		-	Olive-green	-	Black	Sparse
Europa Isld.	"	-	Pale-brown	-	Black	Dense
Europa Isld.		Brown	Pale-brown	Browns	-	Medium
Europa Isld.		-	Pale-brown	Browns	Brown	Medium
Europa Isld.	"	Brown	Pale-brown	Browns	Brown	Medium
Europa Isld.		-	Brown	-	Brown	Dense
Europa Isld.		-	Olive-brown	-	Brown	Dense
Europa Isld.		Brown	Olive-brown	Occasional	Brown	Sparse
Europa Isld.	"	-	Olive-brown	Dark brown	-	Dense
Europa Isld.		Black	Olive-green	-	Black	Medium
Europa Isld.		Black	Olive-green	-	Black	Dense
Europa Isld.		Black	Olive-green	-	Black	Medium
Europa Isld.		Black	Olive-green	-	Black	Medium
Europa Isld.	"	-	Olive	-	Black	Sparse
Tromelin Isld.		Brown	Olive-green	Browns	-	Medium
Tromelin Isld.		-	Pale brown	-	Bl.&Br.	Dense
Primeira Isld.	"	Brown	Olive-brown	Browns	-	Medium
Primeira Isld.		Black	Olive-green	Black	Black	Sparse
Primeira Isld.		Brown	Olive-green	-	Brown	Sparse
Natal Coast		-	Dark brown	Brown	-	Medium
Natal Coast	"	-	Dark brown	Brown	-	Medium

Table 3. Details of adult green turtle carapace coloration from various localities in the study region. *Density of pigmentation is categorized as D=66%+, M=50%, Sparse less than 30%.

			With Conc.(%)	Without Conc.(%)
(a)	Europa	n=343	35,0	65,0
(b)	Tromelin	n=31	13,0	87,0

Table 4. Incidence of pigment concentrations on the carapaces of green turtle females on Europa and Tromelin Islands.

	T r o m e l i n			E u r o p a			Differences (df : 98)
	Mean	Range	$\hat{\sigma}$	Mean	Range	$\hat{\sigma}$	
Carapace length (mm)	48.62	45.2 - 51.9	1.62	48.49	45.8 - 51.4	1.37	p. >0.6 N.S.
Carapace width (mm)	40.18	36.9 - 44.4	2.00	39.86	36.3 - 42.5	1.95	p. >0.5 N.S.
Head width (mm)	16.13	15.4 - 16.9	0.67	15.92	15.0 - 16.8	0.36	p. >0.05 N.S.
Mass (g)	23.96	19.8 - 29.4	2.58	22.85	18.4 - 26.2	1.81	p. >0.01

Table 5. Comparative size and mass of two samples of 50 green turtle hatchlings each from Europa and Tromelin Islands. Samples were selected randomly from grand samples of 200 (Europa) and 172 (Tromelin) collected in groups of 10 or less from emerged clutches only, i.e. Europa sample is derived from 20 clutches.

Locality	C.L.	Range	N _t	N _c	Source
Europa Isld.	48.49	45.8 - 51.4	50	20	
Tromelin Isld.	48.62	45.2 - 51.9	50	17	
Aldabra & Astove	50.07	-	184	4	Frazier, 1971 : 381
Yemen	46.90	44.0 - 48.4	20	1	FAO, 1967 : 15
Ascension	51.70	49.1 - 55.0	100	?	Carr and Hirth, 1962 : 24
Costa Rica	49.70	46.0 - 56.0	100	?	Carr and Hirth, 1962 : 24
Heron Island	54.00	51.0 - 57.0	3	?	Moorhouse, 1933 : 16
Surinam	53.50	51.0 - 55.0	?	1	Pritchard, 1969 : 95
Ceylon	-	49.0 - 54.0	?	?	Deraniyagala, 1939 : 229
Galapagos Islands	<u>46.20</u>	<u>41.0 - 49.5</u>	29	?	Pritchard, 1971 : 8
	Mean: <u>49.91</u>	Overall Range <u>44.0 - 57.0</u>			

Table 6. Straight carapace length measurements (mm) for green turtle hatchlings from various localities.
(N_t = No. of turtles; N_c = No. of clutches).

	Europa				Tromelin				Diff.	Df.
	Mean	Range	\bar{x}	n	Mean	Range	\bar{x}	n		
Carapace length (curved)	113.69	98.0 - 129.0	4.69	50	110.84	99.0 - 127.0	6.60	44	p > .01	92
Carapace length (straight)	106.47	95.5 - 120.5	5.89	29	104.10	95.9 - 112.0	3.93	28	p > .02	55
Carapace width (curved)	104.45	92.0 - 115.5	6.38	30	103.04	94.5 - 115.0	6.43	45	p > .3 N.S.	73
Carapace width (straight)	81.61	69.7 - 90.7	4.61	29	80.61	75.1 - 86.8	3.47	29	p > .3 N.S.	56
Plastron length	87.94	79.9 - 97.6	5.05	30	85.92	80.0 - 92.0	4.03	29	p > .05	57
Plastron width	74.42	68.1 - 80.7	3.60	30	72.52	66.6 - 78.5	3.22	29	p > .02	57
Head width	14.84	13.2 - 16.4	0.71	30	14.33	13.2 - 15.8	0.70	29	p > .01	57
Head length	20.57	17.4 - 24.6	1.50	30	19.81	17.4 - 22.3	1.13	29	p > .02	57
Mass (kg.)	166.92	124.85 - 208.8	23.36	30	159.84	127.1 - 183.9	19.95	29	p > .2 N.S.	57

Table 7. A comparison of various parameters from nesting green turtle females on Europa and Tromelin Islands. The Europa sample was randomly drawn from 383 measurements; plastron width measurement taken between inner margins of carapace and includes infra-marginals; head length measured along the curve between the posterior central junction of the parietals and the anterior central junction of the prefrontals with the nares.

Locality	Curved Carapace Length	Straight Carapace Length	Curved Carapace Width	Straight Carapace Width	Plastron Length	Plastron Width	Head Length	Head Width	Mass
Durban	113.0	107.3	102.0	79.6	90.0	71.2	22.3	15.7	-
Tromelin	100.0	-	88.0	-	-	-	-	-	-
St. Brandon	106.5	100.0	96.5	77.6	-	-	18.4	14.2	147kg.

Table 8. Some measurements and weights of green turtle males from the study region.

Locality	Males (%)	n	Females (%)	n	Ratio	Source of data
South Yemen	44	1925	56	2451	1 : 1.3	Hirth and Carr, 1970:18
Nicaragua	29	27	71	66	1 : 2.5	Carr and Giovannoli, 1957:16
Nicaragua	28	105	72	277	1 : 2.6	Carr and Giovannoli, 1957:16
Baja California, Mexico	32	33	68	71	1 : 2.2	Caldwell, 1962:10
Baja California, Mexico	24	48	76	152	1 : 3.2	Caldwell, 1962:10
Baja California, Mexico	11	27	89	210	1 : 8.1	Caldwell, 1962:10
Baja California, Mexico	8	37	92	428	1 : 11.5	Caldwell, 1962:10
South Africa	37	14	63	24	1 : 1.7	
St. Brandon, Mauritius (1970)	51	221	49	213	1 : 1	
St. Brandon, Mauritius (1971)	33	72	67	145	1 : 2.0	

Table 9. Sex ratios from commercial catches of green turtles.

Locality	Green turtle		Hawksbill		Ridley		Loggerhead		Leatherback	
	n	%	n	%	n	%	n	%	n	%
South Africa (mainly Natal)	52	30.8	21	12.4	4	2.4	80	47.3	12	7.1
Mozambique	29	54.7	11	20.8	5	9.4	5	9.4	3	5.7
Madagascar (west region)	204	53.8***	49	12.9**	52*	13.7	74	19.5	-	-
Species composition overall	47.4		13.5		10.2		26.5		2.5	

Table 10. The species composition of littoral sea turtle populations in the study region.

- * 43 of these were found in one village so percentage contribution should be less.
- ** Certainly an underestimation as many hawksbill shells are sold whole and thus not traceable. (See also Hughes, 1973).
- *** Quite likely an underestimation as a result of whole juveniles being taken directly to market and sold.

	Beach	Approx. length	No. of females per night	Counts
1	Lagoon 1	1 km	60	96, 56
2	Lagoon 2	1 km	50	40, 68
3	Reef and Lagoon 3	2.5 km	350	406, 310, 320
4	Beach (minor)	25m	10	12, 8, 9
5	Station	500m	50	See Table 12
6	Beach (minor)	25m	10	10, 9
7	Beach (minor)	25m	5	12, 5
8	South	700m	75	89, 64, 72
9-16	Minor beaches	25m	35	16 for 2
17	Tropic bird	200m (difficult access)	5	Judged from pits
18-20	Minor beaches	25m each	15	Judged from pits
21	Tern or "Radbury"	500m (rough sea)	35	50 tracks
	Remainder of island		10	
		$\pm 6,665m$	Grand Total 710	

Table 11. Estimated number of female green turtles emerging per night on the various beaches of Europa Island during November-December 1970.

Date	No. females	Date	No. females
Nov. 6	45	Nov. 19	31
7	32	20	52
8	30	21	66
9	53	22	75
10	42	23	58
11	54	24	48
12	50	25	35
13	38	26	47
14	51	27	64
15	78	28	32
16	47	29	74
17	72	30	63
18	55		\bar{x} 52 per night

Table 12. Number of nesting female green turtles handled on the 500m Station Beach on Europa Island : November, 1970. These records are of females actually handled but there were always more females present than recorded. With only one worker involved it proved impossible to handle every animal and work throughout the night. Over 36 nights 851 different females were recorded on the Station Beach alone.

	n	%
Successful emergences	429	44.27
Unsuccessful emergences	462	43.96
Doubtful emergences	<u>114</u>	<u>11.76</u>
	<u>969</u>	<u>99.99</u>

Table 13. Successful and unsuccessful nesting emergences on 500m Station Beach, Europa Island: 6 November 1970 - 10th December 1970.

Interval in days	Frequency
20	1
19	4
18	5
17	9
16	19
15	25
14	64
13	50
12	46
11	9
10	1
Mean:	<u>13.84</u> days

Table 14. Recorded inter-nesting intervals for green turtle females on Europa Island: 5th November - 10th December 1970.

		Range
Europa Island	:	4000 - 9000
Tromelin Island	:	200 - 400
St. Brandon	:	200 - 600
Primeiras	:	50 - 200
		<u>4450 - 10200</u>

Table 15. Estimated annual nesting populations of green turtles at various localities in the study region.

	χ^2	df
1. Between top of transect and base of transect		
Europa (a)/Europa (c)	$p < .001^{***}$	1
Tromelin South (a)/Tromelin South (c)	$p < .02^*$	1
Tromelin North (a)/Tromelin North (c)	$p > .1$ N.S.	1
Casuarina south (a)/Casuarina South (c)	$p < .01^{**}$	1
Casuarina West (a)/Casuarina West (c)	$p < .001^{***}$	1
2. Between beaches		
Europa (a)/Tromelin South (a)	$p < .01^{**}$	1
Europa (a)/Tromelin North (a)	$p < .001^{***}$	1
Europa (a)/Casuarina South (a)	$p < .001^{***}$	1
Europa (a)/Casuarina West (a)	$p < .001^{***}$	1
Tromelin South (a)/Tromelin North (a)	$p < .001^{***}$	1
Casuarina South (a)/Casuarina West (a)	$p < .01^{**}$	1

Table 16. Observed differences between sand sample particle size composition from the islands of Europa (coral sands), Tromelin (coral sands) and Casuarina (Primeiras; mixed silica/coral sand).

	E u r o p a				T r o m e l i n			
	n	r	p	df	n	r	p	df
(a) Hatchlings								
Carapace l./carap. width	50	+ .34	> .01*	48	50	+ .70	< .001***	48
Carapace l./head width	50	+ .54	< .001***	48	50	+ .45	< .01*	48
(b) Adult Females								
Curv. carap. l./curv. carap. w.	50	+ .79	< .001***	48	44	+ .85	< .001***	42
Str. carap. l./curv. carap. l.	29	+ .96	< .001***	27	28	+ .92	< .001***	26
Str. carap. l./curv. carap. w.	29	+ .69	< .1**	27	28	+ .67	< .01**	26
Str. carap. l./plastron length	29	+ .95	< .001***	27	28	+ .74	< .001***	26
Str. carap. l./plastron width	29	+ .89	< .001***	27	28	+ .48	< .1 N.S.	26
Str. carap. l./head length	29	+ .74	< .001***	27	28	+ .64	< .001***	26
Str. carap. l./head width	29	+ .79	< .001***	27	28	+ .72	< .001***	26

Table 17. Relationships and correlation coefficients between selected measurements of green turtles in the study area.

Measurement	Mean	Europa	Island	n	\bar{x}	Tromelin	$\hat{\sigma}$	n	\bar{x}	St. Brandon	$\hat{\sigma}$	n	\bar{x}	South Africa	$\hat{\sigma}$	n
		Range	$\hat{\sigma}$			Range				Range				Range		
Skull length	21.45	20.2-23.4	1.80	10	21.2	20.4-22.6	.99	4	-	22.6	-	1	22.37	22.2-22.7	.24	4
Skull width	13.47	12.5-14.1	.47	10	13.8	13.3-14.2	.36	4	-	13.6	-	1	14.05	13.3-14.7	.60	4
Nares width	2.73	2.39-2.98	.58	10	2.88	2.82-3.00	.07	4	-	2.57	-	1	2.78	2.69-2.85	.08	4
Orbit height	4.65	4.35-4.81	.16	10	4.80	4.59-5.07	.19	4	-	4.77	-	1	4.74	4.57-4.93	.16	4
Jaw width @ symphysis	2.92	2.49-3.29	.26	10	2.82	2.63-3.08	.24	3	-	2.63	-	1	2.90	2.40-3.18	.35	4
Jaw spread between articulares	6.30	5.95-7.26	.41	10	6.54	6.06-7.16	.56	3	-	6.41	-	1	6.68	6.50-7.07	.27	4
Correlation coefficients between various parameters of female green turtle skulls.																
	r		p		df											
Length/width	+ .31		> .1		17											
Length/orbit height	+ .37		> .1		17											
Length/nares width	- .04		> 1		17											
Length/width @ symphysis	+ .55		> .02		16											
Length/jaw spread	+ .19		> .4		16											

Table 18. Selected measurements of skulls from green turtle females in the study region and their relationships.

	E u r o p a				T r o m e l i n				P r i m e i r a s			
	n	\bar{x}	Range	$\hat{\sigma}$	n	\bar{x}	Range	$\hat{\sigma}$	n	\bar{x}	Range	$\hat{\sigma}$
Diameter (mm)	28	44.7	41.6-47.2	1.50	10	44.6	42.5-46.1	1.27	40	43.8	42.7-47.5	0.82
Mass (g)	28	47.9	38.1-58.6	4.77	10	48.0	41.8-53.0	3.71	40	44.9	41.3-49.7	2.79
Clutch size	28	152	115-197	24	10	129	81-173	33	2	115	100-130	21
Clutch mass (g)	28	7259	5187-9687	1373	10	6164	4091-8650	1584	2	5176	4417-5936	1074

Table 19 (a) Data on green turtle eggs from the islands of Europa, Tromelin and the Primeiras.
 Europa: 28 samples of 10 eggs each i.e. 280 eggs.
 Tromelin: 10 samples of 20 eggs each i.e. 200 eggs.
 Primeiras: 40 eggs derived from 2 clutches.

	diff	df
Diameter	$p > .8$ N.S.	36
Mass	$p > .8$ N.S.	36
Clutch size	$p < .001^{***}$	36
Clutch mass	$p < .001^{***}$	36

Table 19 (b) Comparisons between egg data from Europa and Tromelin Islands.

Sp. No.	Date	No. Eggs	Volume (cc)	Mass(g)	Curved Carapace length
B416	17 October 1971	81	3993	4091	107.5
B425	21 October 1971	170	8551	8650	114.0
B423	21 October 1971	117	4703	4885	114.5
B427	25 October 1971	121	5772	5950	107.5
B434	27 October 1971	173	8218	8405	116.0
B439	28 October 1971	156	7051	7362	108.0
B433	28 October 1971	120	5892	6057	110.0
B432	31 October 1971	83	4250	4401	103.0
B447	4 November 1971	154	6237	6520	119.0
B448	5 November 1971	116	5116	5316	109.0

Table 20. Volume (cc) and Mass (g) of 10 green turtle clutches from Tromelin Island.

Correlation coefficient Car. L. vs Volume : + .53 p > .1 8df
Correlation coefficient Car. L. vs Mass : + .54 p > .1 8df

Shield	L	R	n	Freq. %
Post-oculars	3	3	12	100
Nuchals	1		33	100
Vertebrals	5		32	97
	6		1	3
Supra-caudals	2		33	100
Marginals	11	11	26	79
	11	12	2	6
	12	11	1	3
	12	12	4	12
Costals	4	4	33	100
Infra-marginals	4	4	8	89
	3	3	1	11
Inter-anal	Present		3	67
	Absent		2	33
Inter-gular	Present		3	67
	Absent		2	33

Table 21. Lepidosis of hawksbill turtles from various localities in the study region.

Locality	Date	Carapace Curved	Length Straight	Carapace width Curved	Straight	Plastron length	Plastron width	Head width	Head length
(a) Cape Province									
Blaauwberg Strand, C.T.	28.6.70	32.5	29.5	29.5	25.7	24.2	-	-	-
Woodstock, C.T.	14.6.70	28.5	27.2	26.0	21.5	21.3	-	-	-
Summerstrand, P.E.	1.10.68	36.8	-	30.5	-	-	-	-	-
Port Elizabeth	2.5.72	39.4	-	30.5	-	-	-	-	-
(b) Natal									
Mtunzini	5.10.71	37.1	35.2	34.5	30.3	27.2	25.8	5.5	7.8
Durban	1.2.71	58.5	55.1	54.5	44.6	44.5	38.7	8.1	10.7
Durban	8.7.71	37.5	-	36.5	-	-	-	6.8	-
Durban	6.10.71	18.4	-	14.2	-	-	-	3.1	-
Durban	13.12.71	53.0	50.4	50.0	43.2	40.1	37.6	7.2	10.7
Durban	3.3.72	40.0	37.9	38.5	32.7	30.3	28.3	5.5	-
Durban	15.9.72	40.0	38.7	38.0	33.1	31.6	29.0	5.7	8.5

Table 22. Details of stranded and net caught hawksbill turtles from the east and south coasts of South Africa.

	Juveniles (< 40cm)	Sub-adults (40-60cm)	Adults (≥60cm)
S.W. (Morondava-Androka)	1200	400	400
Diego Suarez	400+	?	40
Narinda Bay	?	?	30
N.E. Coast	?	?	100
Tamatave	40	?	?
	1600 (62.3%)	400(15.6%)	570(22.1%)
	<u>Grand total: 2500 turtles</u>		

Table 23.

The estimated numbers of hawksbill turtles killed annually in the coastal waters of Madagascar together with the percentage composition of different size classes.

Locality	Skull length	Skull width	Nostril width	Orbit height	Jaw width at symphysis	Jaw spread between articulators
Ifaty, Mad.	18.40	11.62	2.30	3.92	3.09	5.36
Morondava, Mad.	17.50	10.26	2.06	3.58	2.67	4.21
Ifaty, Mad.	16.60	9.47	1.99	3.65	3.29	4.44
Primeiras, Moz.	16.25	10.14	2.07	3.83	3.55	5.13
Durban, S.A.	12.80	7.43	1.55	3.04	2.49	3.70
Durban, S.A.	11.90	6.67	1.59	2.76	2.40	3.25
Durban, S.A.	9.70	5.04	-	2.50	1.93	2.78

Table 24. Measurements (in cm) of hawksbill turtle skulls from various localities in the study region.

Scale	Pattern	n	% Freq.	Scale	Pattern	n	% Freq.
Nuchal	1	38	76.0	Marginal	12L 12R	31	62.0
	2	12	24.0		11L 11R	7	14.0
Vertebrals	5	45	90.0		11L 12R	5	10.0
	6	5	10.0		12L 11R	4	8.0
Supra-caudals	2	50	100.0		13L 13R	2	4.0
					13L 12R	1	2.0
Costals				Post-oculars	3L 3R	32	64.0
	5L 5R	37	74.0		4L 3R	8	16.0
	6L 5R	5	10.0		3L 4R	4	8.0
	6L 6R	3	6.0		4L 4R	3	6.0
	5L 6R	2	4.0		2L 3R	1	2.0
	4L 4R	2	4.0		3L 2R	1	2.0
	6L 7R	1	2.0		2L 4R	1	2.0

Table 25. Lepidosis of a sample of 50 loggerhead hatchlings from Tongaland, Natal.

Scale	Pattern	Females ex Tongaland		Females ex Natal		Males ex Natal		Juv. ex Natal		Mozambique (unsexed)		Madagascar (unsexed)	
		n	% Freq.	n	% Freq.	n	% Freq.	n	% Freq.	n	% Freq.	n	% Freq.
Nuchal	1	29	96.6	20	95.0	13	92.9	7	97.5	4	100.0	47	97.9
	2	1	3.4	1	5.0	1	7.1	1	12.5	-	-	1	2.1
Vertebrales	4	-	-	-	-	-	-	1	12.5	-	-	-	-
	5	29	96.6	21	100.0	14	100.0	7	87.5	4	100.0	47	97.9
	6	-	-	-	-	-	-	-	-	-	-	1	2.1
	7	1	3.4	-	-	-	-	-	-	-	-	-	-
Supra-caudals	2	30	100.0	21	100.0	14	100.0	8	100.0	4	100.0	48	100.0
Costals	5L 5R	27	90.0	21	100.0	11	78.6	8	100.0	3	75.0	42	87.5
	5L 6R	1	3.3	-	-	1	7.1	-	-	-	-	1	2.1
	5L 4R	1	3.3	-	-	1	7.1	-	-	-	-	-	-
	5L 7R	-	-	-	-	-	-	-	-	-	-	1	2.1
	6L 6R	-	-	-	-	1	7.1	-	-	-	-	1	2.1
	4L 6R	-	-	-	-	-	-	-	-	1	25.0	-	-
	4L 5R	1	3.3	-	-	-	-	-	-	-	-	-	-
	4L 4R	-	-	-	-	-	-	-	-	-	-	1	2.1
Marginals	6L 5R	-	-	-	-	-	-	-	-	-	-	2	4.2
	12L 12R	22	73.3	13	61.9	12	85.7	7	87.5	3	75.0	28	60.9
	12L 11R	1	3.3	2	9.5	-	-	-	-	-	-	-	-
	11L 12R	1	3.3	2	9.5	-	-	1	12.5	-	-	6	13.0
	11L 11R	6	20.0	1	4.8	2	14.2	-	-	1	25.0	12	26.0
	12L 10R	-	-	1	4.8	-	-	-	-	-	-	-	-
	12L 13R	-	-	1	4.8	-	-	-	-	-	-	-	-
	12L 16R	-	-	1	4.8	-	-	-	-	-	-	-	-
Post-oculars	3L 3R	27	90.0	16	94.1	12	85.7	6	75.0				
	4L 3R	2	6.6	1	5.9	2	14.2	2	25.0				
	2L 3R	1	3.3	-	-	-	-	-	-				
Infra-marginals	3L 3R	26	86.6	16	88.9	12	85.7	7	87.5				
	3L 4R	2	6.6	1	5.5	-	-	1	12.5				
	4L 3R	1	3.3	1	5.5	-	-	-	-				
	4L 4R	1	3.3	-	-	2	14.2	-	-				
Inter-gular	Present	5	16.7	2	11.1	3	21.4	-	-				
	Absent	25	83.3	16	88.9	11	78.6	-	-				
Inter-anal	Present	7	23.3	3	16.7	2	14.2	-	-				
	Absent	23	76.7	15	83.3	12	85.7	-	-				

Table 26. Lepidosis of sub-adult and adult loggerheads from countries in the study region.

Bone	n	Freq.	% Freq.
Nuchal	1	31	100.00
Neurals	9	8	26.00
	10	15	48.00
	11	3	9.70
	12	4	13.00
	13	1	3.30
Supra-pygals	1	1	3.20
	2	28	90.30
	3	2	6.50
Pygal	1	31	100.00
Pleurals	8L 8R	31	100.00
Peripherals	12L 12R	31	100.00

Table 27. Osteology of 31 Loggerhead carapaces from the Natal coast (Nomenclature after Loveridge and Williams, op. cit.). Ribs enter peripherals numbered: 4,5,6,7, 8,9,11 and 12;(n=31). Of 31 carapaces investigated 2 (6.5%) had interrupted neurals. (cf. Deraniyagala, 1953:13).

(a) Carapace	Colours	n	Freq. %
(i)	Dark brown mottled or streaked with black	13	43.3
(ii)	Plain red-brown	8	26.7
(iii)	Red-brown streaked with black or dark brown	9	30.0
(b) Plastron			
(i)	Yellow	6	20.0
(ii)	Yellow-pink	7	23.3
(iii)	Dirty white	3	10.0
(iv)	Yellow-white	14	46.7
(c) Upper skin surfaces			
(i)	Dark brown/black	30	100.0
(d) Lower skin surfaces			
(i)	Yellow	8	26.7
(ii)	White	12	40.0
(iii)	Yellow-white	10	33.3

Table 28. Colour characteristics of 30 mature loggerhead females from Tongaland, Natal.

Locality	Mean c.l. (mm)	Range	N _{turtles}	N _{clutches}	Source
Solomon Islands	44.9	43.0-46.0	10	?	Carr, 1952: 394
Florida, U.S.A.	45.5	44.0-47.0	4	?	Caldwell, Carr and Hellier, 1955: 299
South Carolina, U.S.A.	45.0	38.0-50.0	398	31	Baldwin and Lofton, 1959: 342
Georgia, U.S.A.	?	46.7-52.0	5	?	Caldwell, 1962: 6
Columbia	44.6	?	?	?	Kaufmann, 1967: 70
Japan	45.8	40.0-55.0	60	5(?)	Nishimura, 1967: 22
Tongaland	44.7	38.7-48.8 (44.3-45.1)*	1004	121	

Table 29. A comparison of loggerhead hatchling length measurements from various localities.

* Range of seasonal mean size for 8 seasons in Tongaland.

	Tongaland females				Natal females			
	n	Mean	Range	\bar{s}	n	Mean	Range	\bar{s}
Curved c.l.	30	94.1	87.0-102.5	3.34	23	84.7	71.0-94.0	5.03
Straight c.l.	29	87.2	80.7-95.0	3.64	23	79.2	65.1-87.1	4.78
Curved c.w.	30	86.5	79.5-92.0	3.44	23	80.3	70.0-87.5	4.43
Straight c.w.	29	68.0	62.5-74.2	2.85	19	65.6	60.1-76.0	3.59
Plastron l.	30	66.7	60.6-72.0	2.80	18	62.4	56.0-74.5	4.14
Plastron w.	30	59.3	53.8-65.0	0.28	18	58.0	53.4-70.5	3.99
Head l.	30	19.4	17.0-21.0	1.00	18	18.0	16.2-21.6	1.63
Head w.	29	17.8	16.0-20.0	0.99	18	16.2	13.9-18.5	1.33
Mass (kg)	31	106.9	80.9-129.6	12.40	7	74.0	57.3-93.2	12.20

	Natal males				Madagascar unsexed			
	n	Mean	Range	\bar{s}	n	Mean	Range	\bar{s}
Curved c.l.	14	86.7	79.0-98.5	5.53	51	88.6	69.0-98.5	6.76
Straight c.l.	13	81.6	75.2-90.5	4.81	23	83.7	65.0-92.0	6.08
Curved c.w.	14	81.0	76.0-88.0	3.79	49	82.1	67.0-90.0	5.09
Straight c.w.	11	66.1	62.7-72.3	3.17	23	69.5	61.3-74.5	3.17
Plastron l.	12	59.8	55.8-67.0	3.06				
Plastron w.	12	58.7	55.1-64.0	3.04				
Head l.	13	18.4	16.0-20.9	1.50				
Head w.	13	16.8	14.4-18.6	1.38				
Mass (kg)	3	68.0	62.0-74.6	-				

	Mozambique unsexed				Cape unsexed			
	n	Mean	Range	\bar{s}	n	Mean	Range	\bar{s}
Curved c.l.	4	91.8	72.5-101.0	13.0	2	80.0	78.0-82.0	-
Straight c.l.	4	84.8	64.9-95.2	13.6	1	68.0	-	-
Curved c.w.	4	83.6	69.9-91.5	9.6	2	70.0	64.0-76.0	-
Straight c.w.	4	69.9	60.5-75.3	6.5	1	64.7	-	-
Plastron l.								
Plastron w.								
Head l.								
Head w.								
Mass (kg)					2	78.4	-	-

Table 30(a) Measurements of selected parameters (in cm) from loggerhead material from various localities in the study region.

	n	Mean	Range	\bar{s}
Carapace length (mm)	58	45.2	42.0-48.4	2.53
Carapace width (mm)	58	36.3	31.6-38.3	1.87
Head width (mm)	58	16.1	14.4-16.7	0.77
Mass (g)	58	22.0	17.6-24.8	2.13

Table 30(b) Measurements and mass of a sample of loggerhead hatchlings from the 1970/71 season in Tongaland, Natal (after Hughes, 1972).

Locality	n	Mean length	Range	Source
Japan	10	91.8(?)	80-101	Nishimura, 1967: 28
Georgia, U.S.A.	110	95.9*	79.4-115.0	Caldwell, Carr and Ogren, 1959: 305
S. Carolina, U.S.A.	18	92.7*	84.4-103.0	Baldwin and Lofton, 1959: 321
California, U.S.A.	1	94.0*	-	Caldwell, 1963: 568
California, U.S.A.	1	85.5*	-	Shaw, 1947: 55
Senegal	3	105.3(?)	104-108	Cadenat, 1949: 19
Tongaland	1182	86.4* (85.3-87.2)	72.8-98.5	

Table 31. A comparison of adult loggerhead carapace lengths (in cm) from various localities

* : Straight line measurement
 (?): Method of measurement unknown

Parameter	Males				Females				Sub-adults			
	n	mean	range	$\hat{\sigma}$	n	mean	range	$\hat{\sigma}$	n	mean	range	$\hat{\sigma}$
Length	9	23.2	20.6-25.0	1.47	7	22.9	21.5-24.4	1.0	10	17.4	15.0-19.8	1.38
Width	9	16.4	15.1-18.5	1.12	7	15.9	14.5-17.0	.78	10	11.9	11.0-13.7	.85
Nostril width	9	3.02	2.66-3.41	.22	7	3.1	3.0-3.26	.07	10	2.5	2.24-2.90	.17
Orbit height	9	4.96	4.60-5.42	.23	7	4.95	4.72-5.17	.17	10	4.1	3.62-4.27	.19
Jaw width at symphysis	9	5.89	5.34-6.58	.41	7	5.92	5.30-6.36	.37	10	4.4	3.83-5.00	.34
Jaw spread between articulators	9	7.24	6.40-7.70	.38	7	7.56	6.83-8.30	.48	10	6.4	5.92-6.90	.36

Table 32(a). Selected measurements (in cm) of loggerhead turtle skulls from the study region.

Parameter	females			males		
	r	p	df	r	p	df
Length/width	+.84	>.001	7	+.57	> .1	5
Length/nostril width	+.44	>.1	7	+.29	> .1	5
Length/orbit height	-.18	>.1	7	-.37	> .1	5
Length/symphysis width	+.81	>.001	7	+.88	> .001	5
Length/jaw spread	+.21	>.1	7	-.49	> .1	5

Table 32(b). Correlation coefficients between selected parameters of males and females.

Locality	Latitudenal limits of nesting	Extreme latitude of 25°C isotherm	Temperature limits of loggerhead nesting
Japan	32°N - 35°N	35°N	25° - 28°C
Burma	16°N - 17°N (?)	-	25° - 27°C
Australia	20°S - 25°S	32°S	25° - 28°C
Mediterranean Sea (Italy, Turkey, Israel)	32°N - 43°N	43°N	25°C
West Africa	10°N(?) - 35°N(?)	20°N	22° - 27°C
United States	28°N - 35°N	35°N	25° - 28°C
Colombia	10°N - 11°N	-	25° - 28°C
S.E. Madagascar	23°S - 25°S	past 25°S	26° - 27°C
South East Africa	23°S - 28°S	30°S	25° - 27°C

Table 33. Latitudenal and sea surface temperature limits of loggerhead nesting areas.

(a) Hatchlings from Tongaland

Parameter	n	r	p	df
Str. c.l./c.w.	50	+.90	>.001	48
Str. c.l./head w.	50	+.69	>.001	48
Str. c.l./mass	50	+.89	>.001	48

(b) Juveniles - unsexed ex Natal

Str. c.l./curved c.l.	8	+.79	>.02	6
Str. c.l./straight c.w.	8	+.46	>.1	6
Str. c.l./plastron l.	8	+.63	>.1	6
Str. c.l./plastron w.	8	+.54	>.1	6
Str. c.l./head l.	8	+.72	>.05	6
Str. c.l./head w.	8	+.68	>.05	6

(c) Males from Natal

Str. c.l./curved c.l.	13	+.95	>.001	11
Str. c.l./straight c.w.	13	+.80	>.001	11
Str. c.l./plastron l.	12	+.55	>.05	10
Str. c.l./plastron w.	12	+.65	>.02	10
Str. c.l./head l.	13	+.80	>.001	11
Str. c.l./head w.	13	+.63	>.02	11

(d) Females from Natal

Str. c.l./curved c.l.	18	+.98	>.001	16
Str. c.l./str. c.w.	18	+.65	>.01	16
Str. c.l./plastron l.	18	+.72	>.001	16
Str. c.l./plastron w.	18	+.86	>.001	16
Str. c.l./head l.	18	+.69	>.001	16
Str. c.l./head w.	18	+.45	>.05	16

(e) Females from Tongaland

Str. c.l./curved c.l.	30	+.92	>.001	28
Str. c.l./str. c.w.	30	+.88	>.001	28
Str. c.l./plastron l.	30	+.80	>.001	28
Str. c.l./plastron w.	30	+.83	>.001	28
Str. c.l./head l.	30	+.37	>.05	28
Str. c.l./head w.	30	+.36	>.05	28

Table 34. Correlation coefficients (r) and significance (p) between selected parameters in loggerhead turtles from the study area.

Shield	No.	Freq.	% Freq.
Nuchal	1	54	98.2
	2	1	1.8
Vertebrals	6	8	14.6
	7	41	74.6
	8	6	10.8
Supra-caudals	2	55	100.0
Costals	6L 6R	12	22.2
	6L 7R	5	9.3
	7L 6R	9	16.7
	7L 7R	20	37.0
	7L 8R	2	3.7
	8R 7L	2	3.7
	8R 8L	4	7.4
Marginals	12L 12R	49	92.5
	13L 13R	2	3.7
	13L 12R	1	1.9
	12L 13R	1	1.9
Post-oculars	3L 3R	6	100.0
Infra-marginals	4L 4R	6	85.7
	3L 3R	1	14.3

Table 35. Lepidosis of olive ridley material from the study region.

Mozambique	Carapace curved	length(cm) straight	Carapace curved	width (cm) straight	Head width (cm)	Head length (cm)	Plastron length (cm)	Plastron width (cm)	Mass (kg)
Porto Amelia	73.0	68.2	71.0	63.5	-	-	-	-	-
Porto Amelia	69.0	64.6	71.0	62.3	-	-	-	-	-
Antonio Enes	73.0	69.5	77.0	70.0	-	-	-	-	-
Antonio Enes	62.0	58.1	66.0	57.6	-	-	-	-	-
Primeira Islands	70.0	66.4	73.6	63.2	12.5	13.5	48.2	51.8	40 (Tail 24.5cm)
South Africa									
Hatchlings ex	-	4.32	-	3.41	15.6	-	-	-	0.195
Warner Beach	-	4.29	-	3.58	15.7	-	-	-	0.168
Warner Beach	-	4.35	-	3.57	15.6	-	-	-	0.193
Warner Beach	-	4.55	-	3.77	16.3	-	-	-	0.223
Warner Beach	-	4.46	-	3.50	16.1	-	-	-	0.200
Durban	53.5	49.2	57.0	47.4	8.8	10.7	38.3	38.1	17.3
Durban	68.0	63.3	70.5	62.2	-	-	-	-	-
Cape Agulhas	71.5	67.5	74.0	63.5	-	-	-	-	-
Madagascar									
Measurements	Number of specimens			Mean	\bar{s}	Range			
Carapace length (curved)	24			65.08	3.66	56.0-71.5			
Carapace length (straight)	21			60.58	3.11	52.8-66.5			
Carapace width (curved)	23			66.50	2.66	60.0-70.0			
Carapace width (straight)	21			59.73	2.39	54.9-62.7			

Table 36. Details of olive ridley material from the study region.

Locality	Length	width	nostril width	Orbit height	Jaw width at symphysis	Jaw spread between articulators
Casuarina, Mozambique	17.0	12.1	2.66	3.98	3.66	6.07
Morondava, Madagascar	16.3	11.2	2.48	3.65	3.48	5.68
Morondava, Madagascar	17.0	12.6	2.73	3.86	3.56	6.28
Morondava, Madagascar	16.7	11.2	2.60	3.79	3.44	6.07
Morondava, Madagascar	16.2	10.1	2.41	3.49	3.16	5.22
Morondava, Madagascar	16.2	11.8	2.81	3.90	3.50	6.08
Morondava, Madagascar	17.0	11.4	2.72	3.77	3.57	5.25
Morondava, Madagascar	14.2	9.6	2.28	3.40	3.06	5.16
Morondava, Madagascar	12.1	8.3	1.80	3.22	2.72	4.47
Morondava, Madagascar	16.6	11.7	2.50	3.93	3.54	5.62
Umhlanga Rocks, Natal	16.5	11.4	2.56	3.78	3.48	5.68

Table 37(a). Details of 11 unsexed olive ridley turtle skulls collected in the study

	n	r	p	df
Skull length/skull width	11	+.93	<.001***	9
Skull length/nostril width	11	+.0007	N.S.	9
Skull length/orbit height	11	+.86	<.001***	9
Skull length/jaw width at symphysis	11	+.43	N.S.	9
Skull length/jaw spread between articulators	11	+.79	<.01**	9

Table 37(b). Relationships between skull length and other parameters. All measurements in cm.

Locality	Salinity (‰)	Range of Surface Temp. (°C)	Annual Rainfall (mm)	Mangroves along Shorelines	Neritic Fauna (Prawns, etc.)	Organic content	Tides**	Spring Tidal Range (m)	Relative abundance of olive ridleys
Bay of Bengal	< 34.00	25 - 28	> 1000	abundant	abundant	high	semi-diurnal	2 - 4	abundant
Surinam	< 34.00	26 - 27	> 1000	abundant	?	high	semi-diurnal	2 - 4	abundant
Pacific S. Mexico	< 33.00	27 - 28	> 1000	abundant	?	high	semi-diurnal	2 - 4	abundant
West Africa	< 35.00	25 - 27	> 1000	abundant	?	high?	semi-diurnal	2 - 4	present
North Australia	< 35.00	27 - 29	> 1000 locally	abundant	present	high?	semi-diurnal	4+	present
South China Sea	< 33.00	25 - 28	> 1000	abundant	present	?	mixed	2 - 4	present
N. Mozambique & Tanzania	< 35.00	25 - 28	> 500	abundant locally	abundant locally	high inshore	semi-diurnal	2 - 4	present
N.W. Madagascar	< 35.00 (34.00 in summer)	24 - 28	> 1000	abundant	abundant	high inshore	semi-diurnal	2 - 4	present

Table 38. Some environmental parameters* of olive ridley concentration localities.

* data drawn from numerous sources

** tidal data from Pattullo, 1966

	Count	Freq.	% Freq.	Costa Rica
Neural ridge	26	2	1.5	1.8
	27	5	3.8	5.3
	28	7	5.3	8.8
	29	12	9.1	31.6
	30	30	22.7	17.5
	31	15	11.4	19.3
	32	20	15.2	12.3
	33	20	15.2	1.8
	34	12	9.1	-
	35	7	5.3	1.8
	36	2	1.5	-
		<u>132</u>	<u>100.1</u>	<u>100.2</u>
Right costal ridge	27	3	2.3	-
	28	5	3.9	-
	29	10	7.7	-
	30	24	18.5	-
	31	26	20.0	3.5
	32	17	13.1	1.8
	33	21	16.2	10.5
	34	8	6.2	22.8
	35	9	6.9	24.6
	36	4	3.1	10.5
	37	1	.8	12.3
	38	1	.8	10.5
	39	1	.8	1.8
	40	-	-	1.8
		<u>130</u>	<u>100.3</u>	<u>100.1</u>
Chin	11	5	4.1	-
	12	8	6.6	-
	13	20	16.4	-
	14	35	28.7	5.3
	15	29	23.8	16.1
	16	10	8.2	21.4
	17	9	7.4	35.7
	18	5	4.1	14.3
	19	1	.8	5.4
	20	-	-	1.8
		<u>122</u>	<u>100.1</u>	<u>100.0</u>
Nuchal	9	2	1.5	-
	10	4	3.1	-
	11	20	15.3	-
	12	30	22.9	3.5
	13	29	22.1	14.0
	14	25	19.1	26.3
	15	11	8.4	35.1
	16	9	6.9	10.5
	17	1	.8	10.5
		<u>131</u>	<u>100.1</u>	<u>99.9</u>

Table 39. Selected scale counts from leatherback hatchlings*, Tongaland; compared with similar counts from Costa Rica** (data from Carr and Ogren, 1959:27).

* Sample from 14 clutches

** Sample from 2 clutches

(a) Hatchlings from Tongaland

	n	Mean	Range	\bar{x}
Carapace length (mm)	131	58.7	54.8-63.4	1.83
Carapace width (mm)	124	39.3	36.3-43.5	1.23
Head width (mm)	45	17.8	16.9-18.6	0.37
Mass (g)	47	37.3	27.5-41.0	1.78

(b) Adult females from Tongaland (cm)

Carapace length (curved)	122	161.1	133.5-178.0	7.0
Carapace length (straight)	8	154.0	146.5-165.0	6.42
Carapace width (curved)	120	115.6	101.5-127.0	6.5
Carapace width (straight)	8	87.9	83.5-95.3	5.1
Head width	17	22.2	20.3-25.2	1.4

(c) Specimens from other localities (measurements in cm)

Locality	Date	Sex	c.l. curved	c.l. straight	c.w. curved	c.w. straight	pl. length	pl. width	head width	head length	mass (kg)	remarks
Ramsgate, Natal	7/7/70	F	160.5	153.2	118.0	85.8	117.0	80.3	23.7	27.0	340.0	697 well developed eggs
Chaka's Rock, Natal	17/7/70	F	149.0	144.0	109.0	75.0	121.0	-	-	-	-	-
Mtunzini, Natal	29/12/71	F	170.0	160.1	124.0	90.6	123.7	-	24.6	29.0	409.0	1015 well developed eggs
Durban, Natal	18/2/71	F	123.0	117.5	88.0	64.0	91.1	53.1	18.7	21.1	155.4	see text for details of mass
Cape Town	1/5/73	?	119.0	114.0	87.0	66.0	94.0	-	18.0	-	150.0	48km offshore, netted
Cape Town	5/2/73	?	133.5	-	93.0	-	-	-	-	-	-	12km offshore, netted
Cape Town	4/9/71	Juv.	-	76.0	-	46.0	47.0	-	-	-	27.3	Caught at sea
Laaiplek, Cape	18/6/69	F	170.2	157.5	119.4	93.4	-	-	24.8	28.6	646.0	12km offshore, netted in 30 f.
Saldanha Bay, Cape	6/8/69	M	162.0	155.0	-	84.0	-	-	24.0	29.5	320.0	Tail projected 38cm past tip of carapace.

Table 40. Details of leatherback turtles from the study area

Locality	Mean	Range	σ	No. hatchlings	No. clutches	Source
Colombia	60.4	58.6-62.0	-	7	1?	Kaufmann, 1971:92
Trinidad	67.0	66.0-68.0	-	2	1?	Bacon, 1970:216
French Guiana	65.0	-	-	12	?	Bacon, <i>ibid.</i>
Costa Rica	65.0	-	-	74	2	Carr and Ogren, 1959:18 and 24
Surinam	58.3	56.0-60.0	-	25	1	Pritchard, 1969a:129
Tongaland	58.7	54.8-63.4	1.83	131	14	

Table 41. Straight carapace length measurements of leatherback hatchlings from various localities.

Season	Number new tags	Number recoveries	Total observed	% recovered	Estimated population
1963/64	19	-	19	-	80+*
1964/65	11	-	11	-	-
1965/66	24	2	26	7.7	50
1966/67	3	2	5	40.0	8
1967/68	18	-	18	-	18+
1968/69	14	5	19	26.3	19+
1969/70**	18	10	28	35.7	77
1970/71**	11	6	17	35.3	26
1971/72**	34	5	39	12.8	55
1972/73**	17	4	21	19.0	35

Table 42. Total numbers of female leatherback turtles handled during 10 seasons in Tongaland, with the estimated total nesting population for each season.

* McAllister, et.al. (1965:32). Almost certainly an overestimation.

** These seasons estimations based on complete, thorough monitoring.

Locality	Date	Sex	Skull length	Skull width	orbit height	nostril width	width at symphysis	Jaw spread; internal between articulators
Durban	18/2/71	Juv.	21.5	17.6	5.53	4.60	1.28	11.43
Ramsgate	7/7/70	F	26.7	23.0	6.12	5.28	1.93	13.43
Chaka's Rock	17/7/70	F	27.0	21.2	6.38	5.87	1.60	15.27

Table 43. Details of 3 leatherback skulls from Natal (in cm)

Season	Duration of tagging programme	Number tagged	Mean measurements of sample in Tongaland			Spec. No.	Locality Recovered	Date	Distance (km)	Age in days		Measurements		
			c.l.(mm)	c.w.(mm)	Mass(g)					Min.	Max.	c.l.	c.w.	mass
1972	27 Jan-1 Mar. (33 days)	5000	45.1	36.9	20.0	A	Port Elizabeth	1 May	1100	61	- 92	57.0	54.2	45.3
1973	15 Jan-10 Mar. (54 days)	5250	44.3	36.3	19.1	B	Durban	13 Feb.	400	4	- 28	49.0	39.0	22.6+
						C	Port Elizabeth	20 Feb.	1100	7	- 36	52.0	47.0	29.0
						D	Port Elizabeth	7 Apr.	1100	28	- 75	65.0	60.5	49.9
						E	Cape Agulhas	27 Apr.	1650	48	- 102	52.5	51.5	32.0
						F	Cape Agulhas	27 Apr.	1650	48	- 102	52.8	49.5	32.7

Table 44. Details of 6 notched loggerhead hatchlings recovered at various localities along the east and south coasts of South Africa.

Species	Localities	Date	Measurements	
			Carapace length (mm)	Carapace width (mm)
Loggerhead	Bhanga Nek, Tongaland	5 March 1971	60.0	54.9
	Port Elizabeth	28 March 1968	101.6	-
	Port Elizabeth	28 March 1968	110.0	-
	Port Elizabeth	11 August 1968	112.0	102.0
	George, Cape.	28 December 1968	219.0	202.0
Leatherback	Cape Agulhas	2 April 1968	100.1	74.8
Green	Port Elizabeth	12 September 1969	190.0	156.0
Hawksbill	Durban	5 November 1971	180.0	140.0

Table 45. Unseasonal and unusual strandings of juvenile sea turtles in the study region.

Date	Time	Total Number hatchlings	Number taken by crabs	% Kill
24 January 1973	0020	25	4	16.0
15 February 1973	2200	91	2	2.2
16 February 1973	2300	61	2	3.3
16 February 1973	2315	92	3	3.3
16 February 1973	2340	135	2	1.5
17 February 1973	2100	94	0	0
17 February 1973	2150	90	0	0
18 February 1973	0015	130	1	0.7
18 February 1973	2115	84	3	3.6
18 February 1973	2215	75	5	6.7
				Mean: 3.7

Table 46. The incidence of ghost crab (Ocypode spp.) predation on loggerhead hatchlings in Tongaland.

Number of hatchlings	Stomach contents
5	Nothing
8	Fine grit only
8	Grit; feathers (1x36mm; 1x18mm and 15mm; 1x10mm; 1x21mm; 1x9mm)
2	Fragments of algae (sp.); piece of bark 5mmx3mm.
2	Grit; spherical 1mm plastic beads
2	Pieces of fine plastic sheet (both pieces about 30mm long and 20mm at widest point)
9	Gelatinous material - <u>Physalia</u> (?).
1	Clearly <u>Physalia physalis</u>

Table 47. Stomach contents of 37 loggerhead hatchlings stranded on Cape Agulhas

Size class (mm)	M o n t h s											
	J	F	M	A	M	J	J	A	S	O	N	D
60 - 61.9	-	X	-	-	-	-	X	-	-	-	-	-
62 - 63.9	-	-	-	-	-	-	-	X	-	-	X	-
64 - 65.9	-	-	X	-	-	-	-	X	-	X	X	-
66 - 67.9	-	X	-	-	-	-	X	-	-	-	-	-
68 - 69.9	-	-	-	-	-	-	-	-	-	-	-	-
70 - 71.9	-	-	-	-	-	-	-	-	-	-	-	-
72 - 73.9	-	-	-	-	-	-	-	-	-	-	X	-
74 - 75.9	-	-	X	-	2	-	X	-	-	-	-	-
76 - 77.9	-	-	X	-	-	X	-	-	-	X	X	-
78 - 79.9	-	-	-	X	X	-	X	X	-	X	-	X
80 - 81.9	3	-	X	X	-	-	X	-	-	-	X	-
82 - 83.9	X	-	2	X	-	-	X	-	2	-	-	-
84 - 85.9	-	-	-	-	-	-	-	-	-	X	-	2
86 - 87.9	X	-	-	-	-	-	X	-	-	-	-	-

Table 48. Size classes (straight carapace length) of loggerhead turtles found along the Natal coast during various months of the year.

Carapace length	Mollusca (%)	Echinoderma (%)	Porifera (%)	Crustacea (%)	Ascidiaceae (%)	Coelenterata (%)	Miscellaneous (%)	Sample Mass (g)	Remarks and principal articles
60.5	3.0	-	-	-	-	-	97.0	25.0	Sugar cane; bark; plastic strip; <u>Janthina</u>
62.0	37.8	-	-	-	-	62.2	-	18.7	<u>Porpita</u> spp.
62.2	21.0	68.9	-	-	-	-	10.0	14.7	<u>Prionocidaris baculosa</u> (the slate-pencil urchin); plastic bag.
63.9	-	-	-	61.6	-	38.4	-	61.5	<u>Paguristes</u> spp.
64.0	69.4	-	-	-	-	-	30.6	12.4	<u>Janthina</u> ; <u>Spirula</u> skeletons; Pteropoda shells.
64.7	7.9	-	-	47.0	41.6	-	3.7	267.0	<u>Pagurus</u> spp.; <u>Pyura stolonifera</u> (?); pieces of glass
65.0	0.2	-	-	-	-	-	99.8	15.5	Bark, plastic bag; <u>Janthina</u>
66.0	11.6	-	-	14.6	-	63.3	11.0	42.4	<u>Physalia</u> (?); <u>Janthina</u>
67.0	76.0	-	-	7.1	-	-	16.9	22.6	See table 50
72.9	-	-	-	6.0	-	-	94.0	16.6	Fragments of Pagurids; grit
77.0	36.5	-	-	55.3	-	-	8.2	151.6	<u>Pagurus arresor</u> (?); see table 50
78.5	100.0	-	-	-	-	-	-	9.7	See table 50
78.5	8.8	-	-	57.0	-	-	34.2	33.9	<u>Janthina</u> ; <u>Lepas</u> spp.; bark; carapace shields of hatchling loggerhead
79.6	59.8	-	-	40.2	-	-	-	71.7	<u>Janthina</u> ; <u>Spirula</u> shells
80.6	68.7	-	-	4.1	-	-	27.4	87.5	See table 50
81.0	26.6	-	22.9	22.2	-	-	28.4	1114.0	See table 50 ; Pagurids
81.3	100.0	-	-	-	-	-	-	6000.0	<u>Perna perna</u>
83.3	70.8	9.0	-	18.5	-	-	1.8	85.0	See table 50
84.0	29.0	20.0	-	8.4	-	-	42.6	389.9	See table 50
84.2	26.7	38.8	-	1.0	-	-	33.4	825.0	See table 50
85.0	90.0	-	-	10.0	-	-	-	320.0	See table 50
86.0	-	-	-	76.8	-	-	23.2	398.0	<u>Pagurus arresor</u>
86.7	-	-	-	100.0	-	-	-	2.0	Fragments
87.0	57.2	0.4	-	13.4	-	-	29.0	898.8	See table 50
87.2	52.8	-	-	35.1	-	-	12.1	93.3	See table 50
89.0	15.5	51.1	-	7.7	-	-	25.7	585.2	See table 50 ; <u>Prionocidaris baculosa</u>
Means:	38.5	7.5	0.8	23.3	1.7	6.6	21.6	-	

Table 49. The stomach contents of 26 loggerhead turtles from the South African coast.
The percentage contributions of each phylum expressed in terms of mass.

- 1 Bufonaria crumenoides (Plate 21)
Ficus subintermedius (Plate 21)
- 2 Babylonia pintado
Tonna variegata
Lyria ponsonbyi
Bullia similus
- 3 Limaria fragilis
Ficus ficus
Harpa major
Astrea andersoni
- 4 Nassarius kraussianus
Harpa davidus
- 5 Rapana rapiformis
Perna perna
Charonia lampas pustulata
Latirus abnormis
Pintada radiata
Pecten spp.
Conus spp.
- 6 Cymatium labiosum
Bursa granularis
Harpa amouretta
Mayena australasia gemmifera
Anitica spp.
Marginella pipenata
Murex falax
Action spp.
Dupliclaria spp.
Polinices didyma
Glycimeris queketti
Vepricardium asiaticum
Pinna spp.

Table 50. Species list of littoral and benthic Mollusca taken from the stomachs of loggerhead turtles. Listed in order of frequency.

Specimen 1 - 12												
Article	1	2	3	4	5	6	7	8	9	10	11	12
<u>Gelidium cartilagineum</u>	49.2	60.4	95.2	50.5	94.6	-	25.4	-	-	-	73.0	8.8
<u>Gelidium amanzii</u>	-	30.0	-	-	-	91.2	-	-	-	100.0	-	-
<u>Codium duthieae</u>	31.1	1.9	4.8	28.3	-	7.8	70.0	-	2.2	-	26.0	-
<u>Codium platylobium</u>	-	-	-	-	-	-	2.3	-	-	-	-	-
<u>Caulerpa filiformis</u>	18.4	7.7	-	5.5	5.3	0.9	2.4	96.5	76.5	-	-	90.1
<u>Halimeda cuneata</u>	1.4	-	-	-	-	-	1.0	0.1	0.3	-	-	-
<u>Ulva</u> spp.	-	-	-	-	-	-	-	-	-	-	-	0.1
<u>Cladophora capensis</u>	-	-	-	-	-	-	-	3.0	-	-	-	-
<u>Kirchenpaneria pinnata</u>	-	-	-	-	-	-	-	0.4	-	-	-	-
Unidentifiable	-	-	-	15.7	-	-	-	-	21.0	-	1.0	1.0

Table 51. Stomach contents of 12 green turtles from the coast of Natal. Percentages expressed in terms of mass.

Carapace L.	Detail		Carapace L.	Detail	
60.5	Nothing		80.0	Nothing	
62.0	<u>Lepas</u> sp. (Plate 22)		80.6	<u>Chelonibia</u> sp.	
62.2	Nothing		80.7	<u>Chelonibia</u> sp.	
63.9	Nothing		81.0	Nothing	
64.0	<u>Lepas</u> sp.	18% <u>Lepas</u> sp.	81.0	Nothing	
64.0	Nothing	18% <u>Chelonibia</u> sp.	81.0	<u>Chelonibia</u> sp.	
64.2	Nothing	64% No epizoites	81.1	Nothing	
64.7	Nothing		81.3	Nothing	
65.0	<u>Chelonibia</u> sp.		82.0	Nothing	47.4% <u>Chelonibia</u> sp.
66.0	Nothing		83.0	<u>Chelonibia</u> sp.	52.6% No epizoites
67.0	<u>Chelonibia</u> sp.		83.3	<u>Chelonibia</u> sp.	
			83.8	Nothing	
72.9	Nothing		84.0	<u>Chelonibia</u> sp.	
75.5	Nothing		86.0	Nothing	
76.1	Nothing		86.7	<u>Chelonibia</u> sp.	
76.4	Nothing		87.0	<u>Chelonibia</u> sp.	
76.5	Nothing		87.1	Nothing	
77.0	<u>Chelonibia</u> sp.		87.2	<u>Chelonibia</u> sp.	
77.9	Nothing	21.4% <u>Chelonibia</u> sp.	89.0	Nothing	
78.5	Nothing	78.6% No epizoites			
78.5	Nothing				
78.5	<u>Chelonibia</u> sp.				
78.5	<u>Chelonibia</u> sp.				
78.5	Nothing				
79.0	Nothing				
79.6	Nothing				

N.B. Tongaland females: 73% Chelonibia sp.
27% No epizoites

Table 52. Epizoites on the carapaces of 44 loggerhead turtles from Natal.

Tag No.	Date last seen in Tongaland	Date recovered	Time interval (days)	Locality recovered	Distance (km)	Minimum distance per day (km)
T81	30 Dec. 1965	16 March 1966(?)	76	Kilwa Masoka, Tanzania	2640	35
T59	11 Jan. 1966	3 April 1967	82	Mikindani, Tanzania	2400	29
A49	28 Dec. 1969	27 Jan. 1970	30	Warner Beach, Natal	430	14
A165	5 Dec. 1970	9 Feb. 1971	66	Kilwa Masoka, Tanzania	2640	40
A868	8 Jan. 1971	17 Nov. 1971	313	Lourenco Marques, Moz.	120	0.4
B72	2 Dec. 1971	9 Aug. 1972	251	Lourenco Marques, Moz.	120	0.5
A30	17 Dec. 1969	19 Feb. 1973	1060	Zanzibar Channel	2880	2.7

Table 53. Some extra-nesting area recoveries of loggerhead turtles tagged in Tongaland.

Tag. no.	Locality tagged	Date last seen	Date recovered	Time interval (days)	Locality recovered	Distance (km)	Minimum distance travelled per day
(a) Green turtles							
A246	Europa Island	6 Nov. '70	25 Dec. '70	48	Farafangana, Madagascar	1200	25 km
A421	Europa Island	12 Nov. '70	3 Jul. '71	234	Ambaro Bay, Madagascar	1400	6 km
A521	Europa Island	29 Nov. '70	15 Oct. '72	685	Morembe, Madagascar	320	-
A443	Europa Island	8 Dec. '70	18 Sept. '73	965	Tulear, Madagascar	400	-
(b) Leatherback							
B235	Tongaland	7 Dec. '71	10 Dec. '72	369	Beira, Mozambique	1000	-
B236							

Table 54. Details of recoveries of tagged green turtles and a tagged leatherback turtle from Tongaland.

Season	Number of turtles encountered	Period of absence												Calloused %		Percentage remigrations of turtles handled
		1yr.	%	2yr.	%	3yr.	%	4yr.	%	5yr.	%	6yr.	%			
1964/65	223	3	1.4	-	-	-	-	-	-	-	-	-	-	-	-	1.3
1965/66	200	5	2.5	9	4.5	-	-	-	-	-	-	-	-	-	-	7.0
1966/67	221	3	1.4	16	7.2	3	1.4	-	-	-	-	-	-	-	-	9.9
1967/68	293	5	1.7	12	4.1	4	1.4	9	3.1	-	-	-	-	11	3.8	14.0
1968/69	184	-	-	3	1.6	3	1.6	5	2.7	1	0.5	-	-	16	8.7	15.2
1969/70	285	-	-	-	-	-	-	1	0.4	1	0.4	4	1.4	68	23.9	26.0
1970/71	241	8	3.3	-	-	-	-	-	-	1	0.4	2	0.8	70	29.1	33.6
1971/72	321	10	3.1	18	5.6	-	-	-	-	-	-	1	0.3	101	31.5	40.5
1972/73	262	6	2.3	41	15.7	9	3.4	-	-	-	-	-	-	67	25.6	47.0
<u>Totals</u>		<u>40</u>	<u>21.9</u>	<u>99</u>	<u>54.1</u>	<u>19</u>	<u>10.4</u>	<u>15</u>	<u>8.2</u>	<u>3</u>	<u>1.6</u>	<u>7</u>	<u>3.8</u>			

Table 55. Details of loggerhead remigrations to the Tongaland beaches.

Tag No.	Original Season		Interval (years)	Recovery 1		Interval (years)	Recovery 2		Interval (years)	Recovery 3		Number of Seasons Nested
	Date	Loc.**		Date	Loc.		Date	Loc.		Date	Loc.	
S/yellow 42	17 Dec. '63	2.4 S	1	10 Dec. '64	4.0 S	1	10 Dec. '65	4.0 S	-	-	-	3
S/Black 38	17 Nov. '64	2.8 S	1	21 Dec. '65	8.0 S	2	11 Nov. '67	11.2 S	-	-	-	3
S/Black 47	23 Nov. '64	3.2 N	1	8 Dec. '65	4.8 N	1	2 Nov. '66	6.8 N	2	21 Nov. '68	2.4 N	4
S/Black 71	24 Nov. '64	6.4 S	2	12 Dec. '66	7.2 S	2	13 Dec. '68	4.8 S	-	-	-	3
S/Black 90	29 Nov. '64	1.6 N	2	21 Dec. '66	8.4 S	5	19 Dec. '71	2.4 S	-	-	-	3
L/Red T72*	-	-	1	28 Dec. '65	5.2 N	2	7 Dec. '67	3.6 N	-	-	-	3
A25*	-	-	?	19 Dec. '69	5.6 N	1	16 Dec. '70	5.2 N	2	5 Dec. '72	8.8 N	4
A129	1 Nov. '69	6.4 S	1	13 Nov. '70	6.4 S	1	7 Dec. '71	5.6 S	-	-	-	3
A946	23 Dec. '70	6.0 S	1	8 Dec. '71	7.2 S	1	24 Nov. '72	10.0 S	-	-	-	3
A963*	had a broken 1964/65 tag.		6?	5 Jan. '71	4.8 S	2	6 Dec. '72	4.8 S	-	-	-	3

Table 56. Details of 10 loggerhead turtle multiple remigrations to Tongaland.

* Denotes that turtle had been tagged previously but had lost original tag.

** Denotes distance (km) north or south of Bhanga Nek camp.

In addition to the above at least 29 females have nested in 3 separate seasons in Tongaland.

Season	Number of turtles encountered	Period of absence								Calloused %		% remigrations of turtles handled
		1 yr.	%	2 yr.	%	3 yr.	%	4 yr.	%			
1964/65	13	1	7.7	-	-	-	-	-	-	-	-	7.7
1965/66	26	-	-	2	7.7	-	-	-	-	-	-	7.7
1966/67	5	-	-	2	40.0	-	-	-	-	-	-	40.0
1967/68	18	-	-	-	-	-	-	-	-	-	-	-
1968/69	19	-	-	-	-	4	21.0	1	5.3	-	-	26.3
1969/70	28	-	-	3	10.7	-	-	2	7.1	5	17.9	35.7
1970/71	17	-	-	3	17.7	-	-	-	-	2	11.8	29.4
1971/72	39	-	-	2	5.1	-	-	-	-	3	7.7	12.8
1972/73	21	-	-	1	4.7	-	-	-	-	3	14.3	19.1
	Totals	1	2.9	13	38.2	4	11.8	3	8.8	13	38.2	

Table 57. Details of leatherback remigrations to the Tongaland beaches.

Tag. No.	Original Season		Interval (years)	Recovery 1			Interval (years)	Recovery 2			Number of seasons nested
	Date	Locality		Date	Locality			Date	Locality		
S/Blue 16	19 Jan. '64	27.2 S	1	3 Dec. '64	.8 N		2	3 Jan. '67	10 S		3
S/Yellow 19	10 Dec. '63	1.2 N	2	30 Dec. '65	1.6 N						2
S/Green 24	23 Dec. '63	27.2 S	2	25 Jan. '66	19.6 S						2
L/Blue T36	19 Dec. '64	2.0 N	2	3 Dec. '66	19.6 S						2
L/Green T22	31 Jan. '66	5.6 S	3	13 Jan. '69	20.8 S		2	18 Nov. '70	9.6 S		3
L/Yellow T65	3 Jan. '66	19.1 S	3	12 Jan. '69	10.0 S		2	3 Jan. '71	6.4 N		3
L/Yellow T79	8 Feb. '66	13.6 S	3	8 Jan. '69	12.8 S						2
L/Red T87	29 Dec. '65	5.2 N	4	21 Jan. '70	.4 S		2	22 Dec. '71	1.6 N		3
L/Red T93	30 Dec. '65	2.8 N	4	28 Dec. '69	3.6 S		2	19 Dec. '71	7.2 N		3
R/Yellow 5085	26 Dec. '67	4.0 N	2	9 Jan. '70	10.4 S						2
R/Yellow 4627	11 Jan. '68	6.0 N	2	4 Dec. '69	4.8 N						2
R/Yellow 4652	13 Dec. '67	20.8 S	2	12 Nov. '69	10.4 S						2
R/Yellow 4415	8 Jan. '69	6.4 N	2	21 Nov. '70	8.8 N						2
A951	28 Dec. '70	35.2 S	2	6 Jan. '73	36.8 S						2

Table 58. Details of 15 leatherback turtle multiple remigrations to Tongaland. (Distances as in Table 56)

Tag No.	Season	Interval (Yrs)	First site encountered	Date	Within season recoveries				
					1	2	3	4	5
A6	1969/70		3.6 S	14 Dec.	-	-	-	-	-
	1972/73	3	4.0 S	8 Dec.	-	-	-	-	-
A11	1969/70		2.8 S	15 Dec.	6.0 S	1.2 S	0.8 N	-	-
	1972/73	3	4.4 N	27 Nov.	4.0 S	2.4 N	5.6 S	-	-
A24*	1969/70		4.8 N	17 Dec.	-	-	-	-	-
	1972/73	3	3.6 N	28 Nov.	-	-	-	-	-
A25*	1969/70		5.6 N	19 Dec.	-	-	-	-	-
	1970/71	1	5.2 N	16 Dec.	-	-	-	-	-
	1972/73	2	8.8 N	5 Dec.	7.2 N	-	-	-	-
A41	1969/70		2.8 N	27 Dec.	-	-	-	-	-
	1972/73	3	3.2 N	24 Dec.	-	-	-	-	-
A44	1969/70		4.4 S	27 Dec.	-	-	-	-	-
	1972/73	3	1.6 N	5 Jan.	4.4 S	-	-	-	-
A63	1969/70		6.4 N	8 Jan.	-	-	-	-	-
	1972/73	3	8.4 N	20 Nov.	-	-	-	-	-
A72	1969/70		5.6 N	13 Jan.	-	-	-	-	-
	1972/73	3	11.6 N	21 Dec.	-	-	-	-	-
A74	1969/70		.8 N	28 Dec.	-	-	-	-	-
	1972/73	3	4.0 N	4 Dec.	7.2 S	-	-	-	-
A98	1969/70		3.6 S	24 Jan.	-	-	-	-	-
	1972/73	3	2.4 N	28 Nov.	3.2 N	4.0 S	-	-	-

Table 59. Renesting localities of 56 loggerhead females in 2 or more nesting seasons.

*Denotes turtle was tagged previously but had lost tag.

Tag No.	Season	Interval (Yrs)	First site encountered	Date	Within season recoveries				
					1	2	3	4	5
A112*	1970/71		2.8 N	10 Nov.	5.6 S	2.0 N	-	-	-
	1972/73	2	8.4 S	13 Dec.	6.4 S	-	-	-	-
A124	1970/71		3.2 N	13 Nov.	3.2 N	-	-	-	-
	1972/73	2	3.2 N	13 Dec.	3.2 N	2.4 N	-	-	-
A163*	1970/71		4.0 N	21 Nov.	6.4 N	-	-	-	-
	1972/73	2	2.4 N	2 Dec.	2.4 N	-	-	-	-
A164*	1970/71		4.4 N	21 Nov.	5.2 N	-	-	-	-
	1972/73	2	3.2 N	10 Nov.	8.0 N	8.0 N	-	-	-
A169*	1970/71		10.8 N	21 Nov.	-	-	-	-	-
	1972/73	2	0.8 N	2 Dec.	8.8 N	-	-	-	-
A172	1970/71		2.8 N	21 Nov.	1.2 N	-	-	-	-
	1972/73	2	4.0 S	25 Nov.	2.4 N	2.8 N	3.2 N	-	-
A184	1970/71		5.6 S	23 Nov.	-	-	-	-	-
	1972/73	2	2.8 N	5 Nov.	-	-	-	-	-
A187	1970/71		1.2 S	23 Nov.	6.4 S	-	-	-	-
	1972/73	2	4.8 N	12 Dec.	-	-	-	-	-
A197	1970/71		25.2 S	27 Nov.	7.2 S	-	-	-	-
	1972/73	2	7.6 S	25 Nov.	7.2 S	4.8 N	7.2 S	7.2 S	-
A704*	1970/71		4.8 S	1 Dec.	-	-	-	-	-
	1972/73	2	28.4 S	2 Dec.	-	-	-	-	-
A715	1970/71		6.0 S	10 Dec.	-	-	-	-	-
	1972/73	2	6.4 S	23 Nov.	3.6 S	-	-	-	-
A734	1970/71		6.4 S	3 Jan.	-	-	-	-	-
	1972/73	2	10.0 S	12 Jan.	-	-	-	-	-
A736	1970/71		4.4 N	3 Jan.	-	-	-	-	-
	1972/73	2	48.0 S	11 Jan.	-	-	-	-	-
A742*	1970/71		29.6 S	13 Jan.	36.8 S	-	-	-	-
	1972/73	2	7.2 S	20 Dec.	-	-	-	-	-

Table 59. Renesting localities of 56 loggerhead females in 2 or more nesting seasons.

*Denotes turtle was tagged previously but had lost tag.

Tag No.	Season	Interval (Yrs)	First site encountered	Date	Within season recoveries				
					1	2	3	4	5
A802	1970/71		2.0 N	2 Dec.	-	-	-	-	-
	1972/73	2	3.6 N	7 Dec.	-	-	-	-	-
A808	1970/71		4.4 N	2 Dec.	-	-	-	-	-
	1972/73	2	11.6 N	19 Dec.	12.4 N	-	-	-	-
A827	1970/71		3.2 N	8 Dec.	-	-	-	-	-
	1972/73	2	5.2 N	6 Dec.	2.8 N	-	-	-	-
A838	1970/71		3.2 S	13 Dec.	-	-	-	-	-
	1972/73	2	4.4 S	20 Nov.	4.0 S	3.6 S	-	-	-
A839*	1970/71		4.4 S	13 Dec.	-	-	-	-	-
	1972/73	2	1.6 S	11 Dec.	0.4 S	-	-	-	-
A845*	1970/71		5.2 N	17 Dec.	-	-	-	-	-
	1972/73	2	4.0 N	12 Jan.	6.0 N	-	-	-	-
A863	1970/71		6.0 N	5 Jan.	-	-	-	-	-
	1972/73	2	5.6 N	12 Dec.	4.8 N	-	-	-	-
A865	1970/71		5.6 S	6 Jan.	-	-	-	-	-
	1972/73	2	6.0 S	26 Nov.	6.0 S	-	-	-	-
A869	1970/71		2.4 N	15 Jan.	-	-	-	-	-
	1972/73	2	2.0 N	24 Dec.	2.0 N	-	-	-	-
A915*	1970/71		2.8 N	7 Dec.	-	-	-	-	-
	1972/73	2	2.4 S	15 Dec.	-	-	-	-	-
A916*	1970/71		3.2 N	7 Dec.	-	-	-	-	-
	1972/73	2	3.6 N	5 Dec.	1.6 N	2.8 N	-	-	-
A917*	1970/71		4.4 N	7 Dec.	6.8 N	6.0 N	-	-	-
	1972/73	2	4.8 N	8 Dec.	6.8 N	6.0 N	-	-	-

Table 59. Renesting localities of loggerhead females in 2 or more nesting seasons.

*Denotes turtle was tagged previously but had lost tag.

Tag No.	Season	Interval (Yrs)	First site encountered	Date	Within season recoveries				
					1	2	3	4	5
A919*	1970/71		7.2 N	7 Dec.	6.0 N	-	-	-	-
	1972/73	2	6.8 N	13 Dec.	-	-	-	-	-
A921*	1970/71		4.0 N	7 Dec.	-	-	-	-	-
	1972/73	2	5.2 N	12 Dec.	4.0 N	2.8 N	-	-	-
A923	1970/71		2.4 N	7 Dec.	-	-	-	-	-
	1972/73	2	2.4 N	7 Nov.	3.6 N	2.8 N	2.8 N	-	-
A927	1970/71		4.4 S	10 Dec.	5.2 S	-	-	-	-
	1972/73	2	.8 N	17 Dec.	-	-	-	-	-
A932	1970/71		4.4 N	11 Dec.	6.0 N	-	-	-	-
	1972/73	2	5.2 N	5 Dec.	5.6 N	-	-	-	-
A939*	1970/71		3.6 N	16 Dec.	-	-	-	-	-
	1972/73	2	3.6 N	12 Dec.	3.2 N	4.4 N	-	-	-
A941	1970/71		6.0 N	16 Dec.	3.6 N	-	-	-	-
	1972/73	2	2.8 N	30 Nov.	5.2 N	8.0 N	6.4 N	-	-
A942	1970/71		6.4 N	16 Dec.	-	-	-	-	-
	1972/73	2	4.0 N	10 Dec.	6.0 N	-	-	-	-
A945	1970/71		5.4 S	21 Dec.	-	-	-	-	-
	1972/73	2	6.0 S	15 Dec.	-	-	-	-	-
A946	1970/71		6.0 S	23 Dec.	-	-	-	-	-
	1971/72	1	7.2 S	8 Dec.	7.2 S	-	-	-	-
	1972/73	1	10.0 S	24 Nov.	-	-	-	-	-

Table 59. Renesting localities of loggerhead females in 2 or more nesting seasons.

* Denotes turtle was tagged previously but had lost tag.

Tag No.	Season	Interval (Yrs)	First site encountered	Date	Within season recoveries				
					1	2	3	4	5
A947	1970/71		0.4 S	27 Dec.	-	-	-	-	-
	1972/73	2	6.0 S	29 Nov.	5.6 S	-	-	-	-
A948	1970/71		6.4 S	27 Dec.	-	-	-	-	-
	1972/73	2	7.6 N	12 Dec.	7.2 S	-	-	-	-
A959	1970/71		6.4 N	29 Dec.	-	-	-	-	-
	1972/73	2	4.4 N	23 Nov.	6.4 N	6.8 N	-	-	-
A961	1970/71		3.6 N	4 Jan.	2.8 N	-	-	-	-
	1972/73	2	4.8 N	25 Nov.	5.6 N	3.6 N	-	-	-
A963*	1970/71		4.8 S	5 Jan.	-	-	-	-	-
	1972/73	2	4.8 S	6 Dec.	-	-	-	-	-
B126	1971/72		9.2 S	25 Dec.	4.8 S	-	-	-	-
	1972/73	1	4.4 S	11 Nov.	2.4 N	-	-	-	-
B135	1971/72		8.4 N	3 Jan.	-	-	-	-	-
	1972/73	1	10.4 N	6 Dec.	7.2 N	-	-	-	-
B137*	1971/72		6.0 S	4 Jan.	-	-	-	-	-
	1972/73	1	5.6 S	23 Nov.	4.8 S	7.2 S	-	-	-
B203*	1971/72		5.2 N	4 Dec.	-	-	-	-	-
	1972/73	1	5.6 N	28 Nov.	4.8 N	-	-	-	-
B214	1971/72		3.2 N	8 Dec.	-	-	-	-	-
	1972/73	1	7.2 N	27 Nov.	6.0 N	-	-	-	-

Table 59. Renesting localities of loggerhead females in 2 or more nesting seasons.

* Denotes turtle was tagged previously but had lost tag.

Season	Tag Nos.	Locality of original encounter	Recoveries			Season	Tag Nos	Locality of original encounter	Recoveries		
			1	2	3				1	2	3
1964/65	T7gr.	.8N*	0.4N	0.8N	-	1970/71	A152/153	9.6S	24.0S	-	-
	S/blu.28	14.4S	13.6S	-	-		A706/707	26.4S	26.0S	32.0S	-
	S/bla.32	4.8S	0.4N	0.4N	-		A709/712	31.2S	.8N	-	-
1965/66	T57Y	18.4S	18.4S	-	-		A952/953	28.8S	22.4S	-	-
	T64Y	19.2S	20.0S	-	-		A954/955	27.2S	6.0S	-	-
	T65Y	19.6S	9.6S	-	-	1971/72	B3	6.0S	19.6S	-	-
	T71R	1.2N	12.0S	1.2S	1.2S		B20/21	13.2S	18.4S	-	-
	T93R	2.8N	4.8S	-	-		B77/78	30.4S	30.0S	-	-
	T70W	1.2S	0.4N	9.2S	-		B84/85	17.6S	20.0S	28.0S	-
1967/68	T5G.	19.6S	5.6S	-	-		B104/105	28.8S	13.2S	-	-
	4652/72	20.8S	19.2S	21.6S	-		B174/175	1.2N	7.6N	-	-
1968/69	4360/61	9.6S	9.6S	-	-		B313/314	23.6S	31.2S	-	-
	4384/85	10.8S	10.4S	-	-		B328/331	16.4S	8.0N	-	-
	4387/88	12.8S	5.6S	2.4N	1.2N		B351/352	32.0S	26.0S	-	-
	4407/09	1.2N	17.6S	-	-		A45/47	7.2N	6.8N	-	-
	4432/33	8.4S	15.2S	13.2S	-		A102/103	1.6N	1.2N	-	-
	4469/71	12.8S	18.0S	-	-	1972/73	C10/11	4.4S	10.4N	8.4S	-
	4472/74	21.6S	21.6S	-	-		C52/53	2.0N	1.2N	2.4N	-
	4475/76	18.0S	17.6S	-	-		C71/72	21.6S	18.4S	-	-
	4481/83	10.4S	20.4S	-	-		C73/74	36.8S	2.4N	1.6N	-
	4563/65	14.4S	21.6S	-	-		C81/82	17.6S	3.6S	-	-
	4584/86	14.4S	20.0S	-	-		C112/113	6.4S	5.6N	-	-
1969/70	4670/71	30.0S	39.2S	-	-		C182/183	2.0N	5.6S	1.2N	-
	6225/26	4.8N	5.2S	14.4S	-		C202/-	4.4N	13.6S	-	-
	2280/2810	8.0N	1.2N	-	-		C228/229	.4N	5.2N	5.6S	1.2S
	2556/59	9.6S	6.4S	-	-		C232/233	1.6N	18.4S	-	-

Table 60. Details of all within season recovery records of leatherback females in Tongaland 1963-1973

*Distances in km north or south of the Bhanga Nek camp

Curv. carap. l. size class	New turtles	%	Remigrant turtles	%	Size class %	Curv. carap. l. size class	New turtles	%	Remigrant turtles	%	Size class %
<u>1965/66 Season</u>						<u>1970/71 Season</u>					
Up to 85cm	3	100.0	0	-	2.6	Up to 85cm	4	80.0	1	20.0	3.3
86 - 90	24	96.0	1	4.0	21.4	86 - 90	19	68.0	9	32.0	18.3
91 - 95	47	92.0	4	8.0	43.6	91 - 95	44	71.0	18	29.0	40.5
96 - 100	31	97.0	1	3.0	27.4	96 - 100	38	76.0	12	24.0	32.7
101 +	6	100.0	0	-	5.0	101 +	6	75.0	2	25.0	5.2
	<u>111</u>		<u>6</u>				<u>111</u>		<u>42</u>		
<u>1966/67 Season</u>						<u>1971/72 Season</u>					
Up to 85cm	4	100.0	0	-	2.5	Up to 85cm	6	100.0	0	-	1.9
86 - 90	29	88.0	4	12.0	20.5	86 - 90	32	71.0	13	29.0	14.0
91 - 95	57	92.0	5	8.0	38.5	91 - 95	87	57.0	65	43.0	47.4
96 - 100	42	79.0	11	21.0	32.9	96 - 100	50	48.0	53	52.0	32.1
101 + cm	9	100.0	0	-	5.6	101 +	10	72.0	4	28.0	4.6
	<u>141</u>		<u>20</u>				<u>185</u>		<u>135</u>		
<u>1967/68 Season</u>						<u>1972/73 Season</u>					
Up to 85cm	5	100.0	0	-	1.9	Up to 85cm	4	67.0	2	33.0	2.4
86 - 90	47	87.0	7	13.0	20.1	86 - 90	26	63.0	15	37.0	16.5
91 - 95	100	92.0	9	8.0	40.7	91 - 95	50	47.0	57	53.0	43.2
96 - 100	84	93.0	6	17.0	33.6	96 - 100	44	54.0	37	46.0	32.7
101 + cm	8	80.0	2	20.0	3.7	101 +	7	54.0	6	46.0	5.2
	<u>244</u>		<u>24</u>				<u>131</u>		<u>117</u>		
<u>1968/69 Season</u>						<u>Overall size class percentages</u>					
Up to 85cm	4	100.0	0	-	3.1	Up to 85cm	-	2.4%	33		
86 - 90	20	100.0	0	-	15.3	86 - 90	-	17.6%	246		
91 - 95	40	91.0	4	9.0	33.6	91 - 95	-	42.0%	587		
96 - 100	41	72.0	16	28.0	43.5	96 - 100	-	33.3%	466		
101 + cm	2	33.0	4	67.0	4.6	101 +	-	4.7%	66		
	<u>107</u>		<u>24</u>						<u>1398</u>		

Table 61. Size class composition of 7 seasonal nesting populations of loggerhead females in Tongaland.

Curved carapace l. size class	1965/66		1966/67		1967/68		1968/69		1970/71		1971/72		1972/73		Totals	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Up to 140cm	-	-	-	-	-	-	-	-	-	-	1	2.6	-	-	1	0.8
141 - 150	1	4.4	-	-	1	6.7	1	5.6	1	10.0	3	7.7	1	4.8	8	6.3
151 - 160	7	30.4	2	100.0	7	46.7	7	38.9	3	30.0	17	43.6	12	57.1	55	43.0
161 - 170	10	43.5	-	-	7	46.7	7	38.9	6	60.0	15	38.5	8	38.1	53	41.4
171 +	5	21.7	-	-	-	-	3	16.7	0	-	3	7.7	0	-	11	8.6
Totals	23	100.0	2	100.0	15	100.1	18	100.1	10	100.0	39	100.1	21	100.0	128	100.1

Table 62. Composition in size classes of 7 seasonal nesting populations of leatherbacks in Tongaland.

Month	Season	Loggerheads				Mean Sea Temp. °C	Leatherbacks			
		Nests recorded	% of season total	Taggings	% of season total		Nests recorded	% of season total	Taggings	% of season total
November	1969/70	500	26.91	111	38.20	24.3	94	27.49	7	25.93
	1970/71	529	30.74	94	39.00	24.3	49	23.90	3	16.67
	1971/72	381	21.03	60	18.70	21.7	71	20.17	6	15.39
	1972/73	367	29.96	93	35.63	24.0	59	28.37	6	28.57
December	1969/70	807	43.43	135	47.40	26.0	123	35.49	10	37.05
	1970/71	805	46.78	117	48.60	26.0	76	37.07	11	61.11
	1971/72	775	42.77	160	49.80	24.3	132	37.50	13	33.33
	1972/73	462	37.71	140	53.64	25.3	80	38.46	12	57.14
January	1969/70	551	29.66	39	14.40	26.0	125	36.55	10	37.04
	1970/71	387	22.48	30	12.50	26.3	80	39.03	4	22.22
	1971/72	656	36.20	101	31.50	27.0	149	42.33	20	51.28
	1972/73	396	32.33	28	10.73	25.7	69	33.17	3	14.29

Table 63. Monthly tagging, nesting and sea surface temperature records in Tongaland for the seasons 1969/70, 1970/71, 1971/72 and 1972/73.

Phase	Season	Sea surface temperature (°C)	Mean inter-nesting interval (days)	Number observations
1 November-November	1969/70	24.0	15.8	38
	1970/71	24.5	16.1	14
	1971/72	21.5	17.7	7
	1972/73	24.0	17.1	13
2 November-December	1969/70	24.5	15.5	66
	1970/71	24.5	15.1	46
	1971/72	22.0	16.6	37
	1972/73	24.4	16.0	49
3 December-December	1969/70	26.0	14.7	78
	1970/71	26.0	15.1	62
	1971/72	23.5	15.2	69
	1972/73	25.3	14.8	92
4 December-January	1969/70	26.5	14.2	66
	1970/71	25.5	15.0	38
	1971/72	24.5	15.1	99
	1972/73	25.7	14.0	65
5 January-January	1969/70	26.0	13.6	32
	1970/71	26.3	14.3	12
	1971/72	27.0	13.9	48
	1972/73	25.8	13.8	29
Mean inter-nesting intervals		1969/70 14.8 days	Mean sea surface temperatures	1969/70 25.4°C
		1970/71 15.1 days		1970/71 25.4°C
		1971/72 15.7 days		1971/72 23.7°C
		1972/73 15.1 days		1972/73 25.0°C

Table 64. Mean inter-nesting intervals of loggerhead females during four seasons in Tongaland; compared with the corresponding sea surface temperatures.

Locality	Tag No.	Outward crawl	Excavation of nest cavity	laying time	No. eggs	Covering time	Return crawl	Total time
Europa Island	A327	10	45	28	153	51	10	144
Tromelin Island	B416	?	38	22	81	72	11	143
Primeiras Islands	A506	5	48	31	130	31	6	121

Table 65. Details of the duration (minutes) of green turtle nesting activity from three localities in the study region.

		Loggerheads					Leatherbacks							
(a) Bulk nest records	Total No. nests	Estimated total No. females			Mean No. nests/turtle		Total No. nests	Estimated total No. females			Mean No. nests/turtle			
1969/70	1860	466			3.99		364	47			7.75			
1970/71	1725	410			4.21		216	26			8.31			
1971/72	1831	502			3.65		373	55			6.78			
1972/73	1225	301			4.07		218	35			6.23			
(b) Individual nest records	No. nests per female					Total females encountered		No. nests per female					Total females encountered	
	5	4	3	2	1		7	6	5	4	3	2	1	
1969/70	20	35	38	30	162	285	-	1	-	-	1	2	22	26
1970/71	4	26	35	32	144	241	1	-	1	3	-	-	12	17
1971/72	17	32	57	53	162	321	-	2	1	1	5	2	28	39
1972/73	15	45	49	46	107	262	-	1	1	1	3	2	13	21
(c) No. eggs/clutch	Mean	range		̄	No. clutches			Mean	range		̄	No. clutches		
	113.6	69 - 173		25	290			104	60 - 160		25.6	59		
(d) Size	Mean	̄		No. eggs			Mean	̄		No. eggs				
	40.9	1.7		260			53.07	1.49		165				
(e) Incubation period	46.0 - 67.0 days						62.5 - 72.0 days							

Table 66. A summary of nest and egg data from loggerhead and leatherback turtles from Tongaland during the 1969/70, 1970/71, 1971/72 and 1972/73 seasons.

Size of ova	Left ovary	Right ovary
0.0 - 5.0 mm	44 653	98 404
6.0 - 10.0 mm	11	7
11.0 - 15.0 mm	17	15
16.0 - 20.0 mm	10	10
21.0 - 25.0 mm	19	23
26.0 - 30.0 mm	8	21
31.0 - 35.0 mm	6	9
36.0 - 40.0 mm	7	6

Table 67. Ova counts from an adult female loggerhead from Tongaland.

	No. eggs/ clutch	Infertile eggs	Fertile/ unhatched	Hatchlings Live	Hatchlings in nest Dead	Hatchlings emerged	Total No. hatchlings	Fertility %	Hatching success %	Emergence success %
(1) Loggerheads; Tongaland. (n=72 clutches)										
Mean	105.3	18.8*	4.53*	0.5*	0.33*	81.21	82.0	82.7	78.6	77.8
Range	39-154	0-113	0-63	0-7	0-4	0-130	0-132	0-100	0-98.7	0-98.7
S.D.	21.7	27.0*	8.71*	1.31*	0.82*	32.1	32.4	22.9	26.0	25.9
(2) Leatherbacks; Tongaland. (n=39 clutches)										
Mean	103.7	20.1*	3.7*	4.41*	2.85*	71.9	79.3	79.6	76.2	68.9
Range	55-142	4-70	0-31	0-24	0-23	5-114	18-121	21.4-96.2	20.2-96.2	5.6-93.2
S.D.	20.8	17.2*	5.8*	5.45*	5.6*	24.0	22.9	16.4	15.7	18.6
(3) Green turtles; Europa Island. (n=27 clutches)										
Mean	142	8.7*	14.2*	7.78*	0.89*	110.2	118.7	93.9	84.3	77.6
Range	75-238	0-30	0-98	0-20	0-8	50-196	67-197	82.3-100.0	41.1-98.9	30.9-98.9
S.D.	35.1	8.2*	20.02*	6.9*	1.8*	37.7	34.12	5.0	13.08	15.62
(4) Green turtles; Tromelin Island. (n=30 clutches)										
Mean	124.6	9.13*	19.2*	3.3*	4.5*	88.7	96.3	92.2	76.34	69.84
Range	79-230	1-37	0-71	0-19	0-50	32-196	38-196	57.5-99.4	34.1-98.8	28.7-97.7
S.D.	31.5	8.55*	20.5*	5.17*	10.66*	40.75	39.05	8.38	20.64	22.05

Table 68. The fertility and hatching success of loggerhead, leatherback and green turtle clutches in the study area.

(*)N.B. The distribution of these data is strongly skewed but the data does not fit a Poisson distribution.

Size class	Number	Estimated gross mass	Estimated value	
			Fmg.	Rands
Juveniles	2245(15)	33675	1 683 750-00	4 209-38
Sub-adults	1166(100)	116600	5 830 000-00	14 575-00
Adults	3411(170)	579870	28 993 500-00	72 483-75
Totals	6822	730145	35 507 250-00	91 268-13

Table 69. The annual green turtle harvest in the south western region of Madagascar in estimated numbers, mass in kilograms and monetary value at 100 Fmg. (R0.25) per kilogram. Figures in parentheses indicate the mass of each group individual.

Year	J	F	M	A	M	J	J	A	S	O	N	D
1957	55	31	86	38	39	38	38	4	2	55	77	102
1958	93	61	-	10	39	41	14	5	11	43	36	62
1959	95	-	78	58	-	-	-	-	-	8	11	12
1960	44	-	12	17	-	-	5	-	7	-	11	10
1961	74	22	42	41	37	17	-	21	6	43	69	41
1962	71	77	33	15	18	32	3	-	9	21	24	27
1963	-	116	53	57	7	22	1	2	-	5	3	8
1964	6	5	-	52	24	32	19	34	22	35	96	91
1965	54	56	58	39	3	1	34	-	-	8	8	10
1966	11	15	18	12	4	5	10	26	25	55	70	114
1967	25	76	85	44	-	-	-	2	3	12	17	4
1968	18	83	19	24	-	-	3	2	1	9	7	18
1969	33	36	39	12	10	50	30	28	38	8	52	27
1970	21	29	11	8	73	25	21	2	48	-	33	165
1971	134	38	28	15	-	-	-	-	-	-	1	-
Totals	734	645	562	442	218	263	178	126	172	302	515	691
Means	49	43	38	30	15	18	12	8	12	20	34	46

Table 70. Monthly catches of green turtles on the St. Brandon Islands, 1957-1971.

Island	Presence of suitable beach	Number of tracks observed
Albatross	Yes (1 continuous)	-
North Island	Yes (1 continuous)	100 +
Puits à Eau	Yes (2 separate)	5 +
Poulailler	No	-
Raphaël	Yes (1 small)	-
Little Raphaël	No	-
Sirene	Yes (continuous)	25
Pearl	Yes (continuous)	56
Frigate	Yes (continuous)	+ 50 (assumed)
Paul	No	-
Tortue	Yes (continuous)	15
Avoquer	Yes (continuous)	-
Coco	Yes (continuous)	4
East Dagone	Yes (continuous)	19
West Dagone	Yes (continuous)	14
Long	Yes (continuous)	26
Big Capitaine	Yes (continuous)	-
Little Capitaine	Yes (very coarse gravel)	6
Big South Island	Yes (continuous)	51
Little South Island	Yes (continuous)	-
Point de Requin	Yes (continuous)	<u>10</u>
		<u>+375</u> tracks

Table 71. Summary of nesting beaches and observed turtle tracks seen on the islands of St. Brandon during November, 1971.

Area	Turtle nesting species	Present status	Administrating State Dept.	Recommendation
(a) <u>South Africa</u> Tongaland coast.	Loggerheads, leatherbacks	Efficiently protected	Natal Parks Board	Park status
(b) <u>Mozambique</u> Paradise Islands Maritime Park.	Green turtles, loggerheads	Officially protected	Servicos Veterinaria	-
Maputo Reserve coast	Loggerheads, leatherbacks	No protection	-	Park status
Primeiras Islands	Green turtles, hawksbills	No protection	-	Park status
Querimba Islands	Green turtles, hawksbills and olive ridleys (?)	No protection	-	Park status
(c) <u>Madagascar</u> Nosy anambo	Green turtles, hawksbills	Technically protected but no surveillance.	Department des Pêche Maritime	Redeclared with park status
Nosy Iranja	"	"	"	"
Chesterfield Island	"	"	"	"
Nosy Trozona	"	"	"	"
Nosy Ve	"	"	"	"
Saint Luce area near Fort Dauphin	Loggerheads	No protection	-	Park status
Vohemar-Sambava coast	Hawksbills	"	-	Park status
(d) <u>Reunion and its dependencies</u> Europa Island	Green turtles	Nature Reserve Status	Dept. Meteorologie National	Park status
Juan do Nova	Greens and hawksbills	"	"	"
Iles Glorieuses	"	"	"	"
Tromelin	"	"	"	"
(e) <u>Mauritius and its dependencies</u> North Island (St. Brandon)	Green turtles	Privately protected	Mauritius Fishing Development Co.	Park status
Frigate Island (St. Brandon)	Green turtles	Not protected	-	"
Pearl Island (St. Brandon)	Green turtles	Not protected	-	"

Table 72. Areas in the South western Indian Ocean which, because of the presence of nesting sea turtles, would benefit from formal protection; adequately protected areas are included in the list.

Country	Region	Species
Mozambique	(1) The coast between Inhaca and Ponto do Oro	Loggerheads and leatherbacks
	(2) The coast between Zavora and Toffa	Loggerheads and leatherbacks
	(3) Antonio Enes	Olive ridley and greens
Madagascar	(1) Around St. Luce near Fort Dauphin	Loggerheads
	(2) Barren Islands	Green turtles
	(3) The north east coast between Vohemar and Sambava	Hawksbills
Mauritius	(1) On St. Brandon if egg robbing cannot be stopped effectively.	Green turtles

Table 73. Localities in the study region where egg gathering and sale to a central hatchery might prove a valuable conservation step if formal protection is impractical.

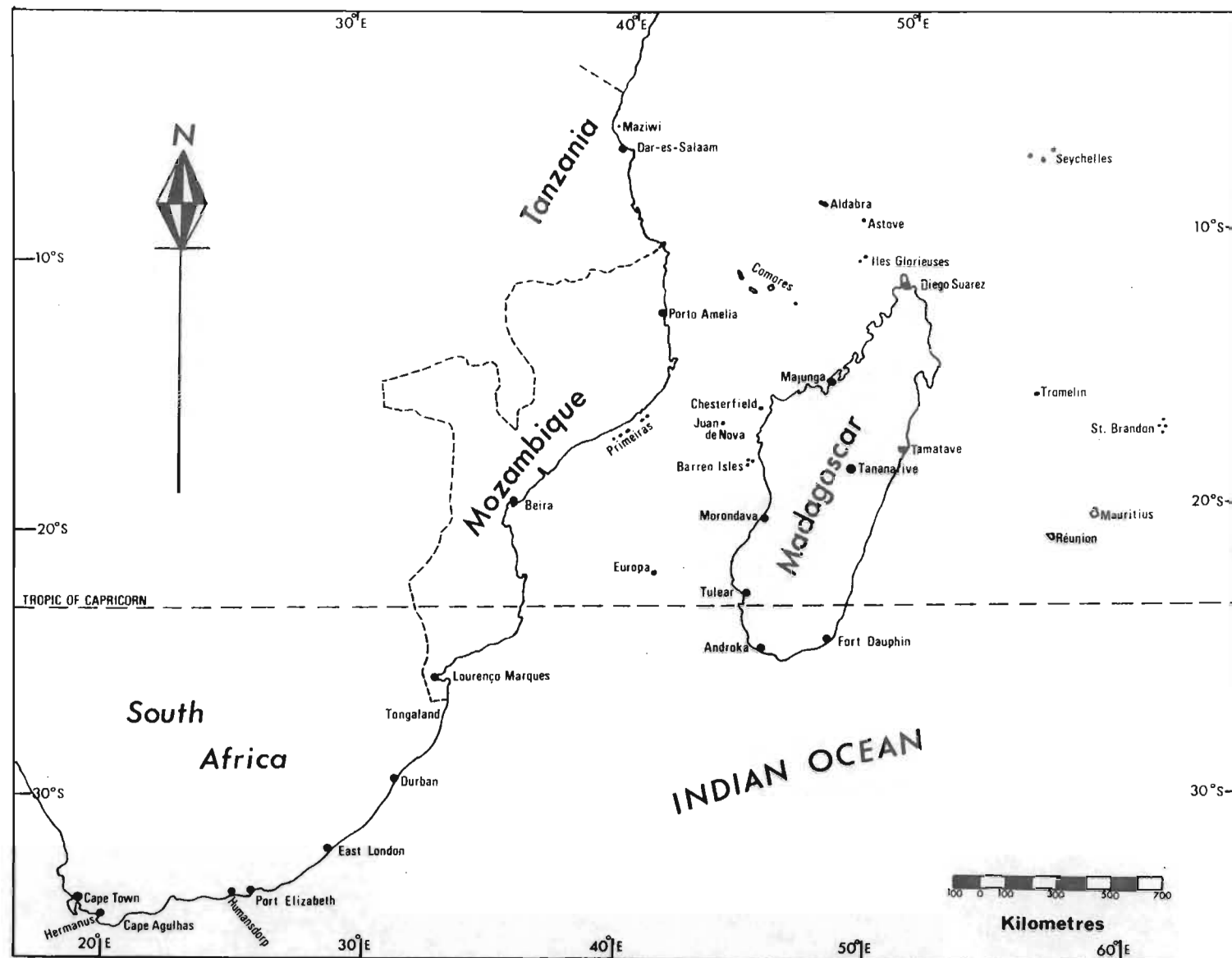


Figure 1. The south east African study region.

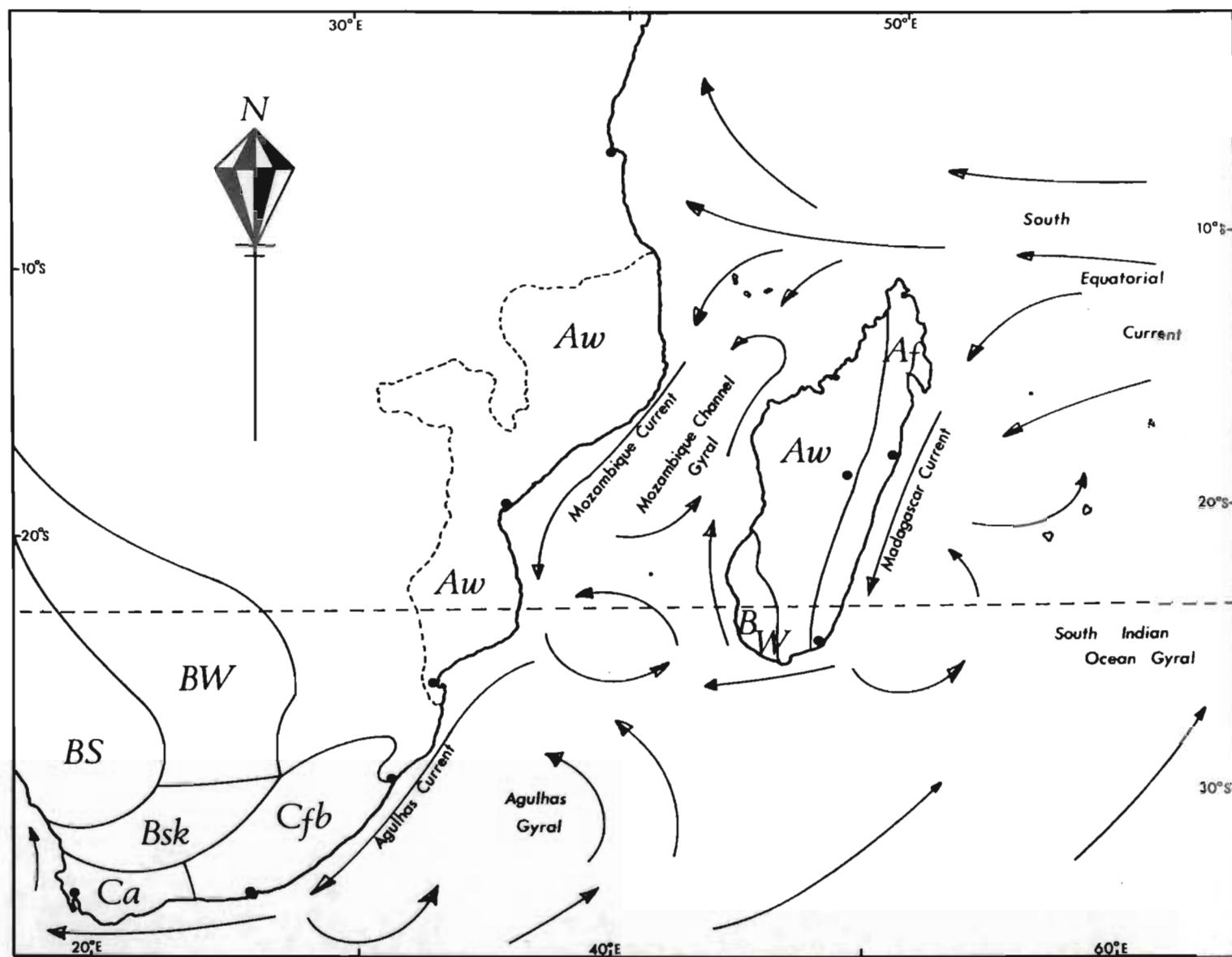


Figure 2. The study region showing the climates of the land masses (after Stamp, 1966) and the oceanic circulation of the south western Indian Ocean (data from numerous sources)

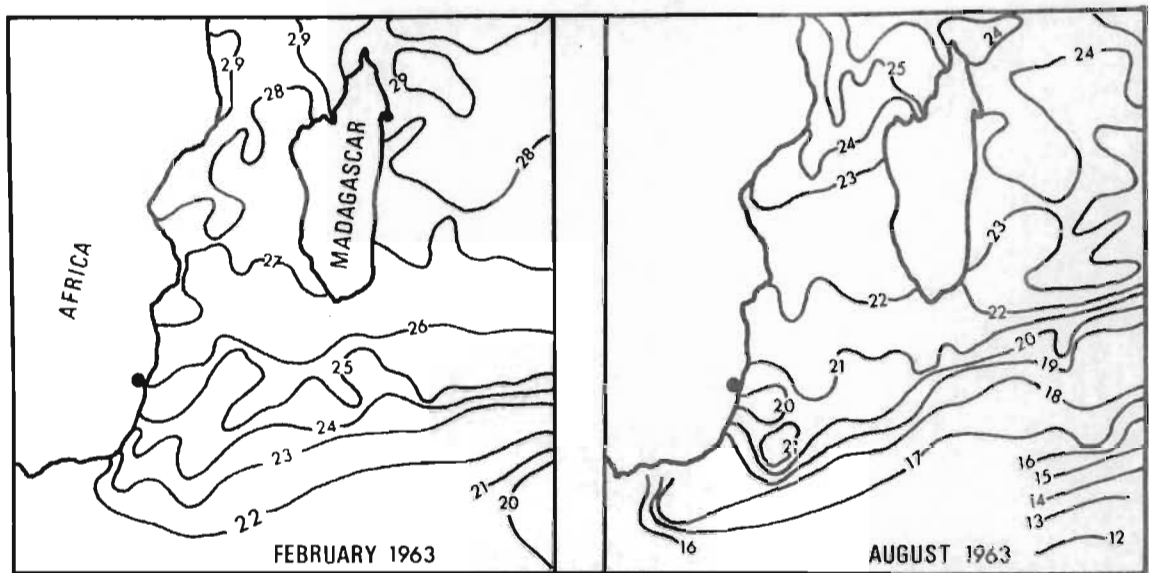


Figure 3. Sea surface temperatures for the study region during February and August, 1963 (after Wyrski, 1972).

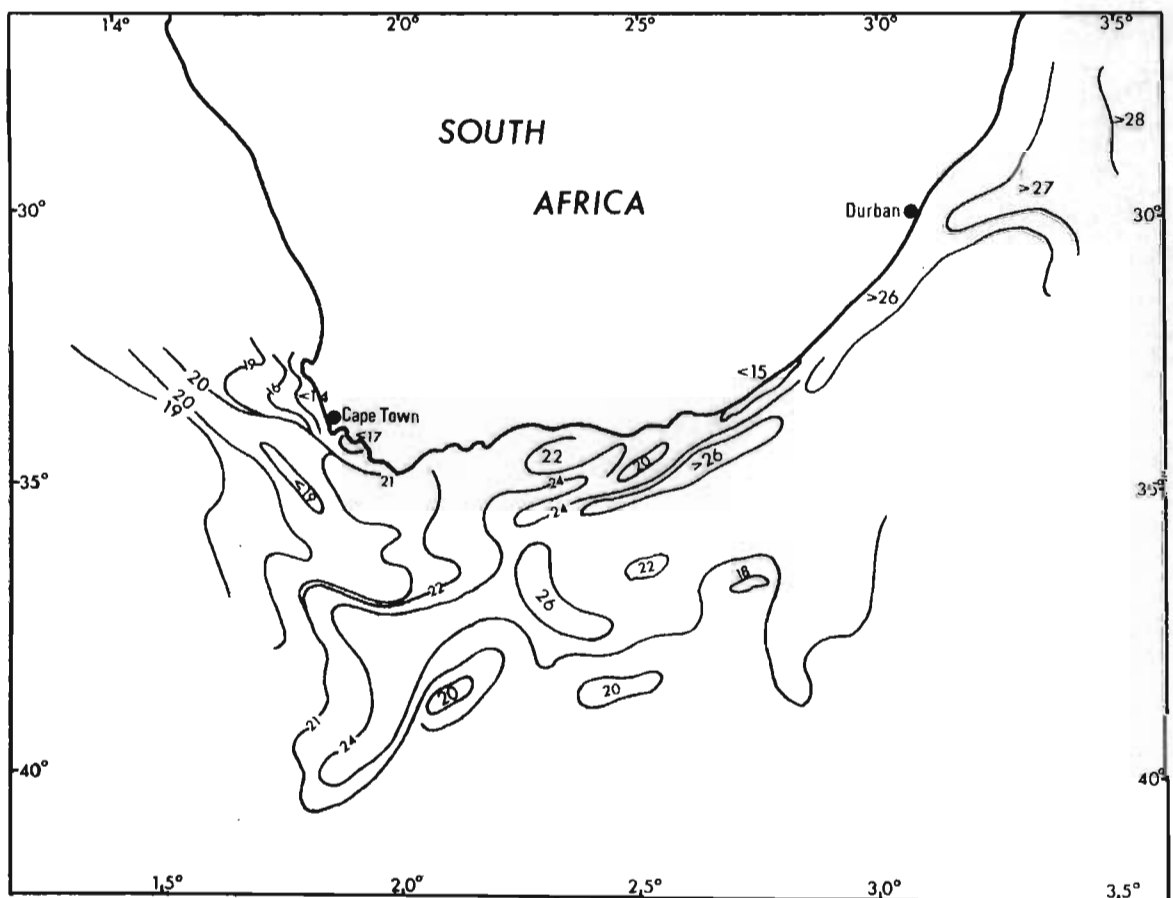


Figure 4. Sea surface temperatures off the south coast of Africa, 6-24 March, 1969 (simplified after Bang, 1970).

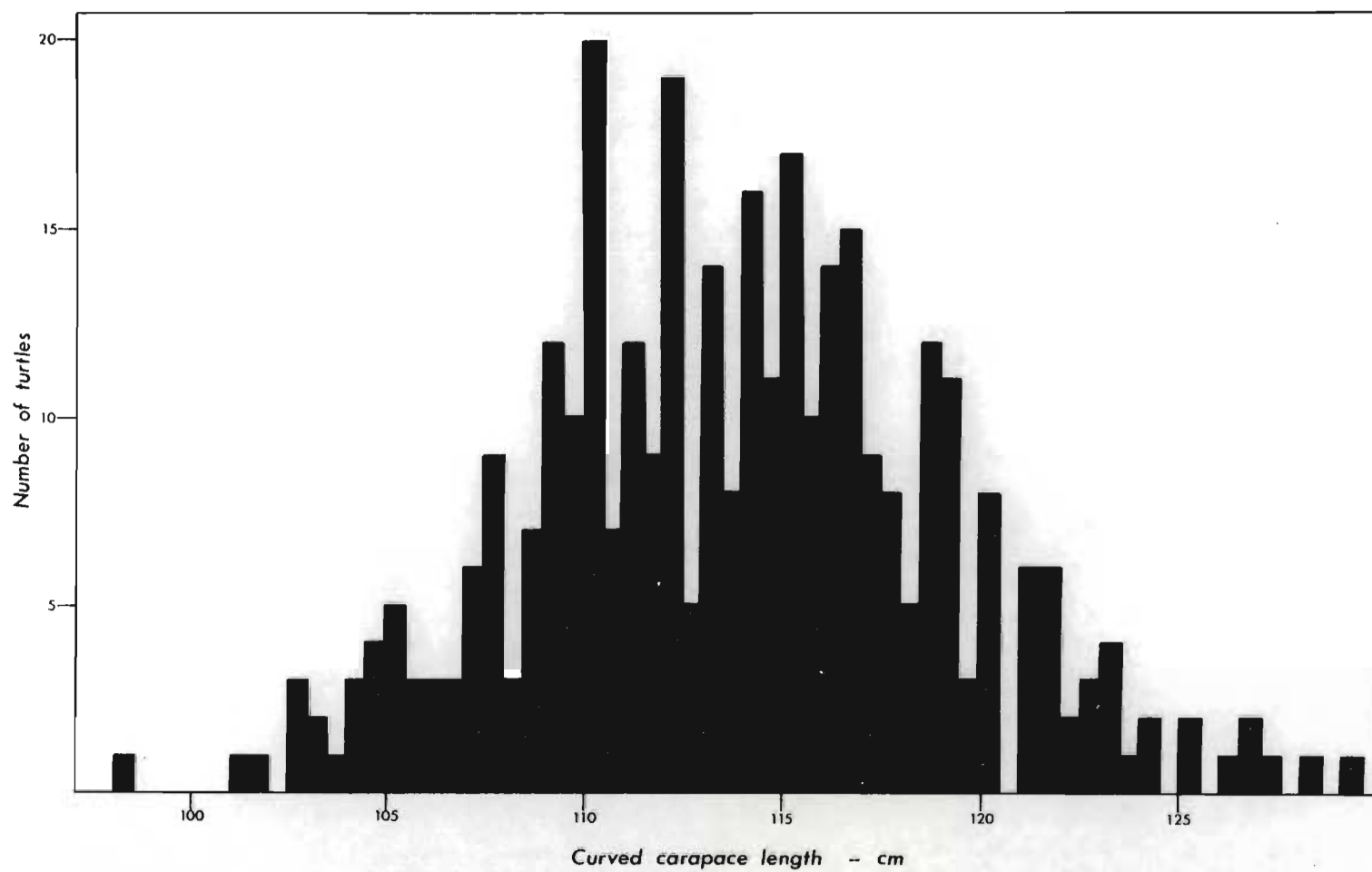


Figure 5. Curved carapace length distribution of nesting female green turtles on Europa Island; November-December, 1970.

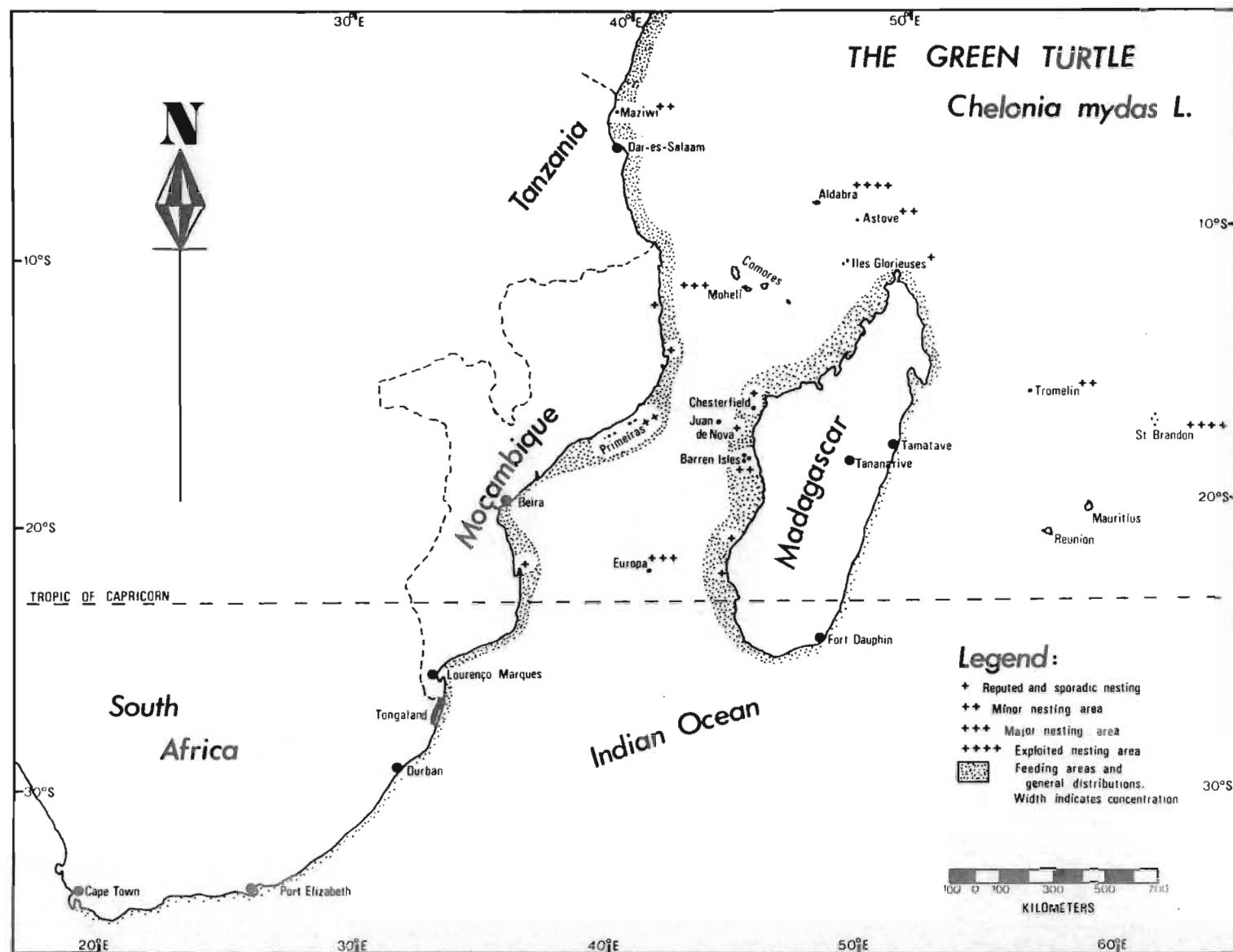


Figure 6. The distribution and nesting areas of the green turtle *Chelonia mydas* in the study region. Width of stippling indicates relative abundance.

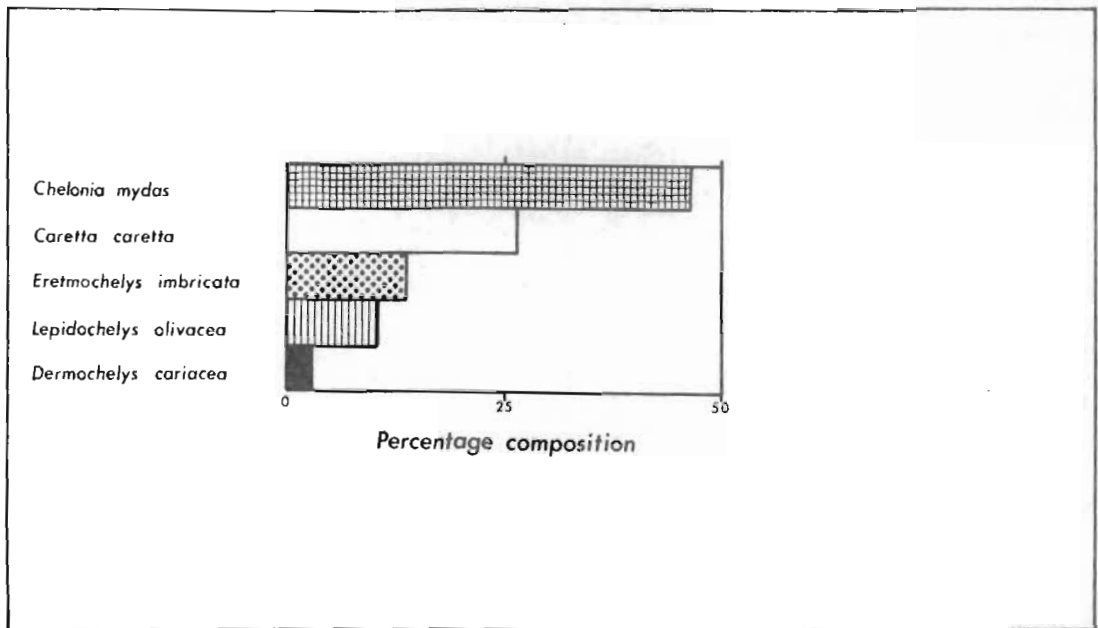


Figure 7. The approximate species composition of the sea turtle population in the study region.

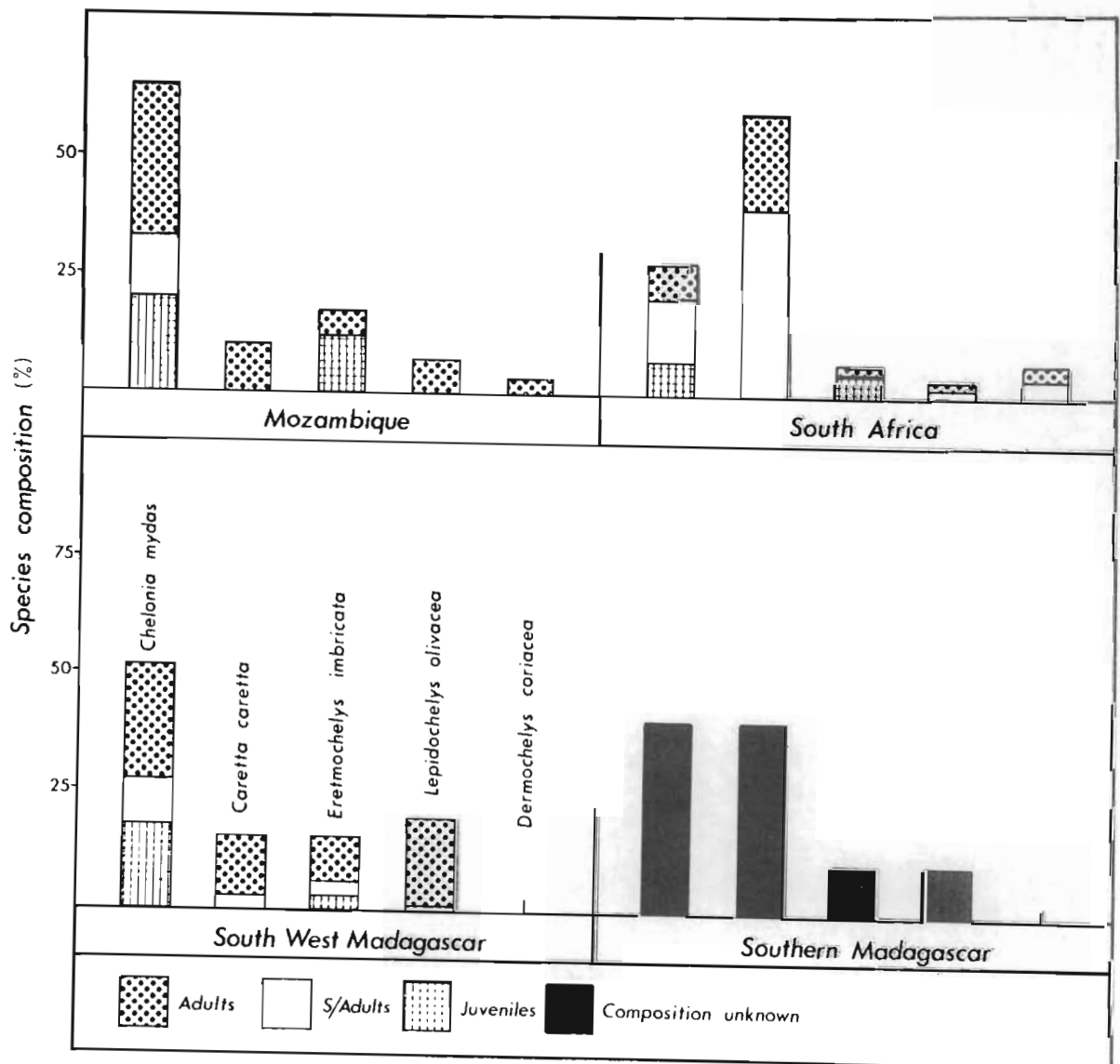


Figure 8. The approximate species composition of the sea turtles found off; (a) South Africa, (b) Mozambique and (c) Madagascar (southern and western regions).

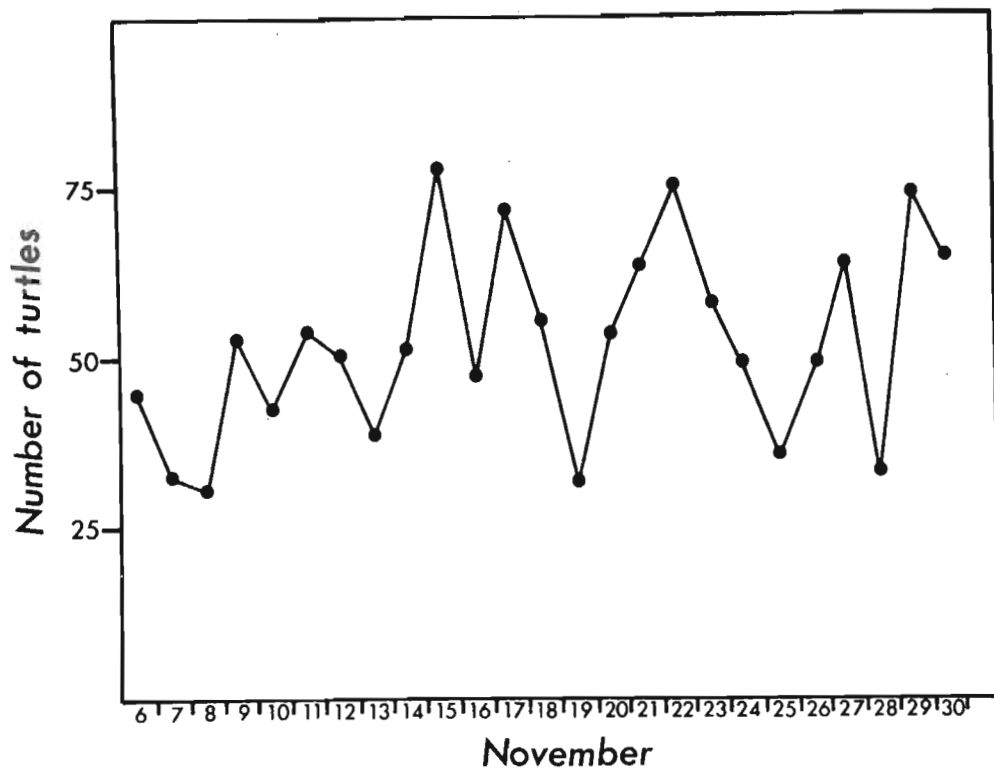


Figure 9. The number of nesting green turtle females encountered nightly on the 500m Station beach, Europa Island; 6-30 November, 1970.

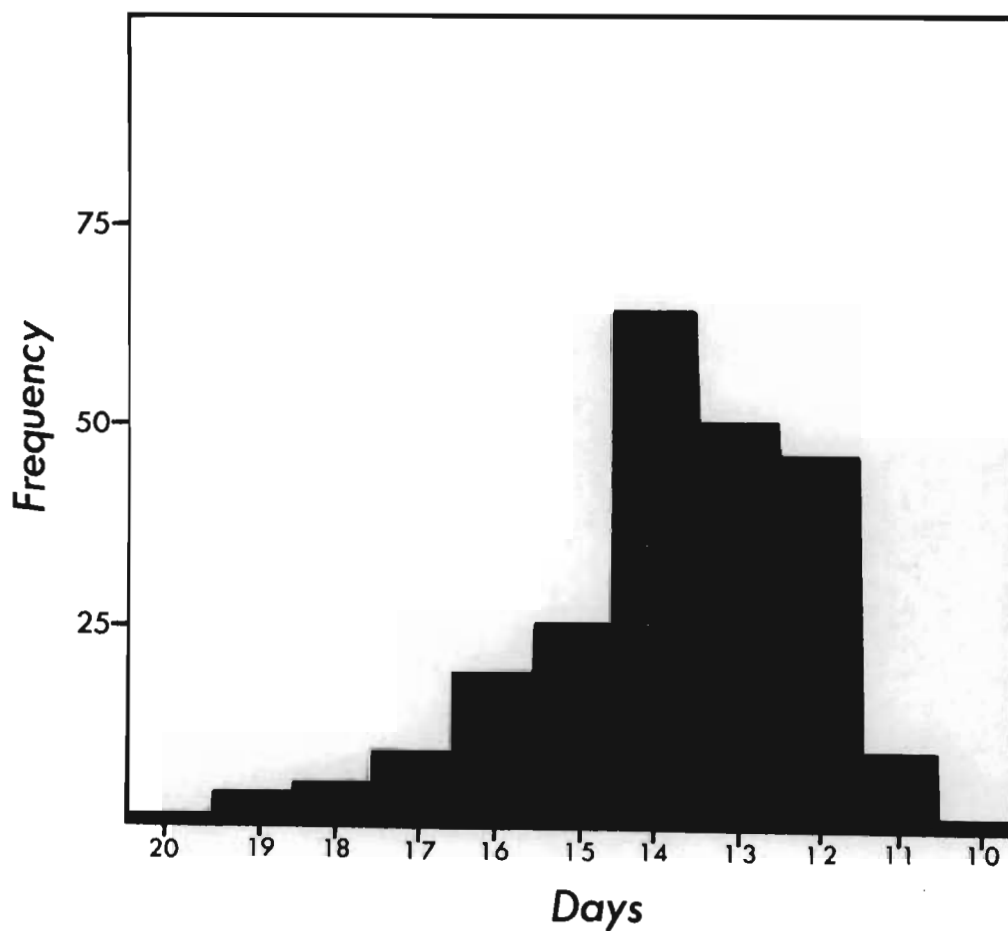


Figure 10. Internesting intervals recorded from tagged female green turtle emergences on Station beach, Europa Island; November, 1970.

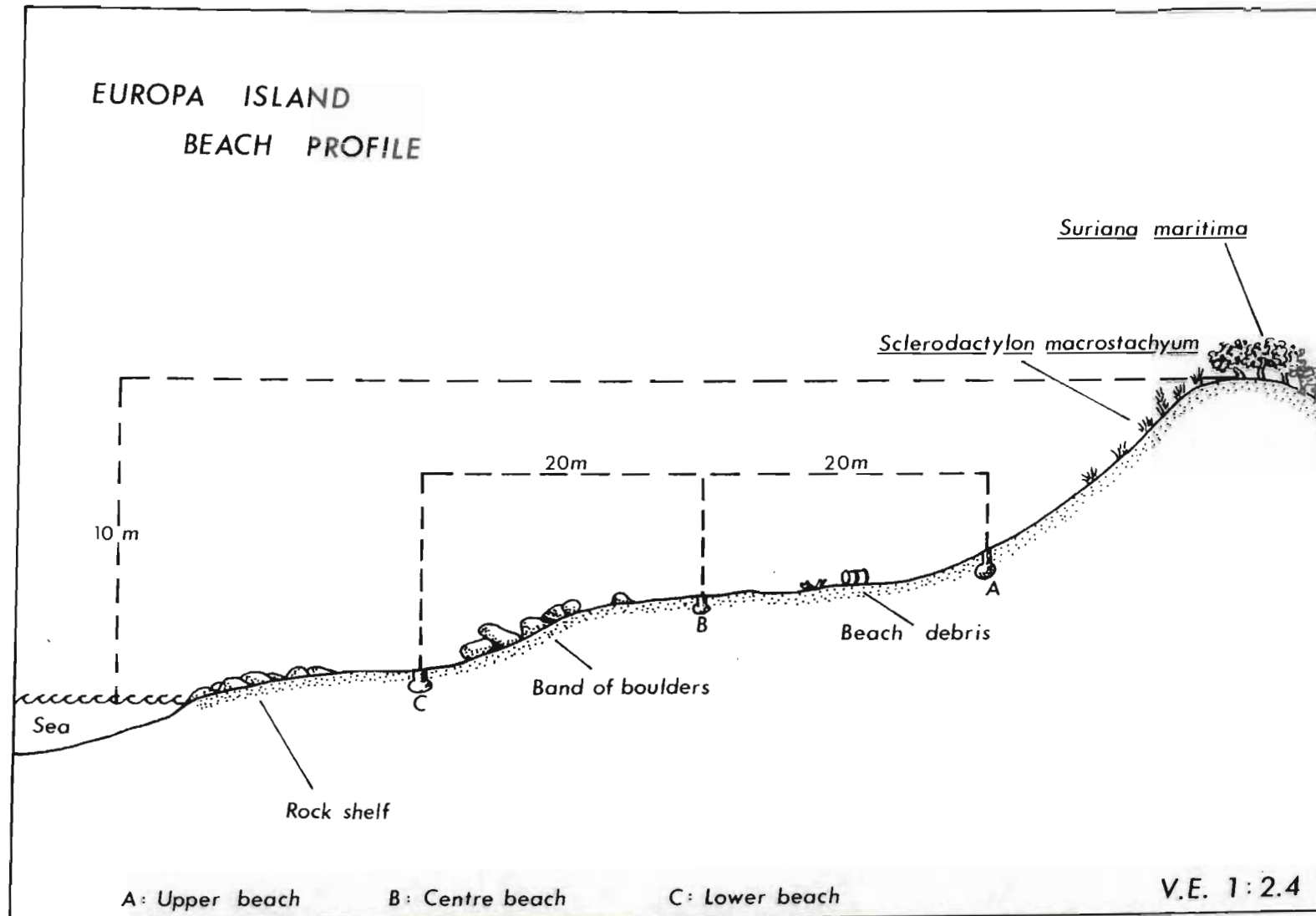


Figure 11. Profile of Station beach, Europa Island showing sites from which sand samples were taken.

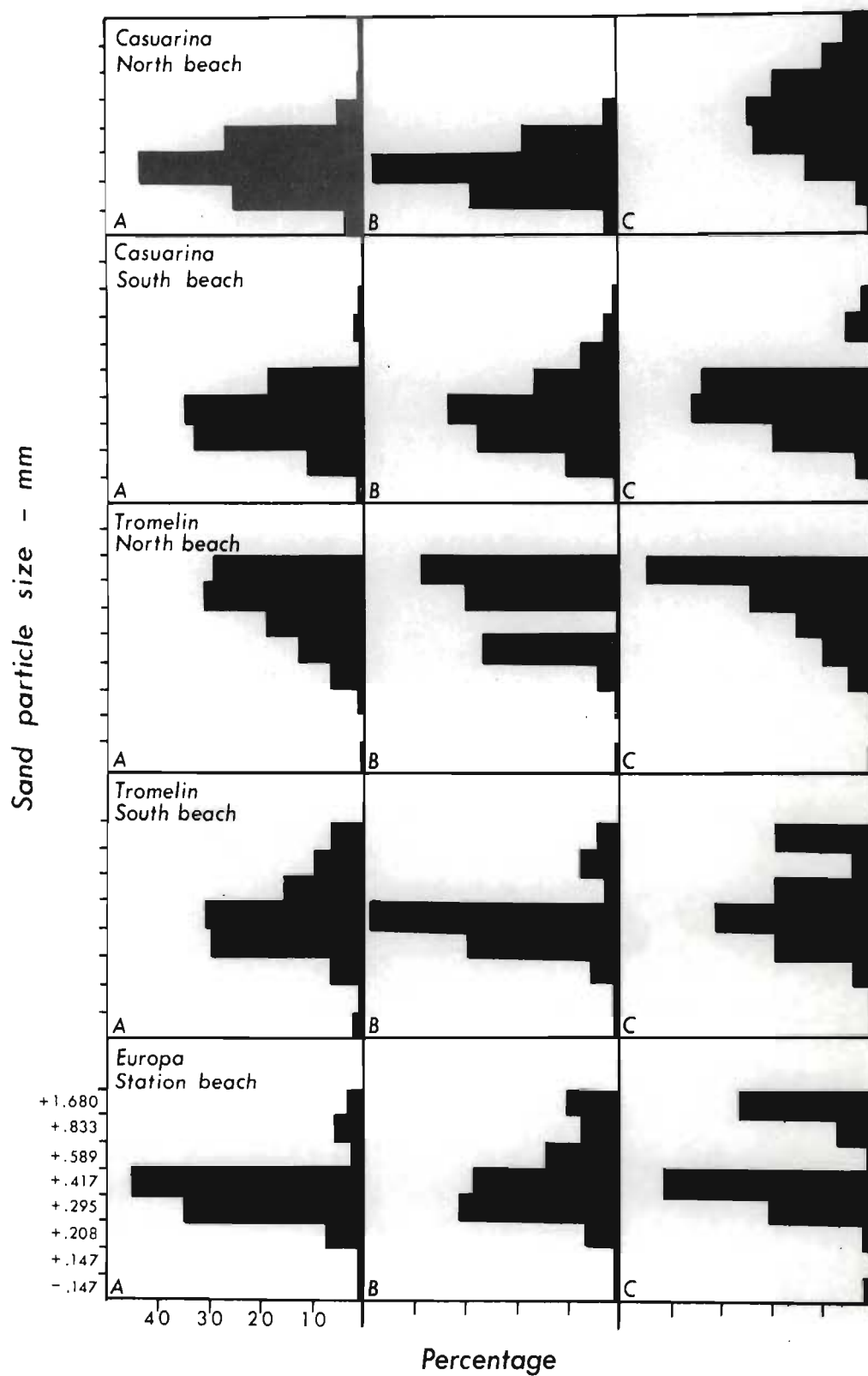


Figure 12. Histograms of the sand particle composition of 15 samples of beach sand from 5 green turtle nesting beaches in the study area.

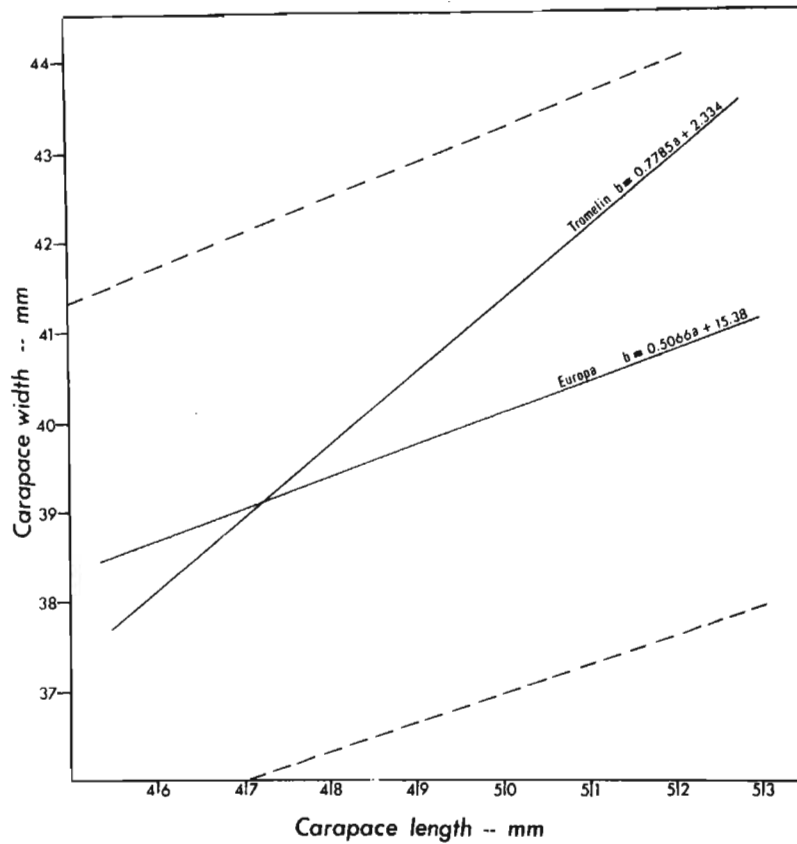


Figure 13. The relationship between straight carapace length and straight carapace width in a sample of 50 green turtle hatchlings from Europa Island, November 1970, with 95% confidence limits. The relationships between these parameters for a sample of 50 hatchlings from Tromelin Island, (October, 1971) is also included.

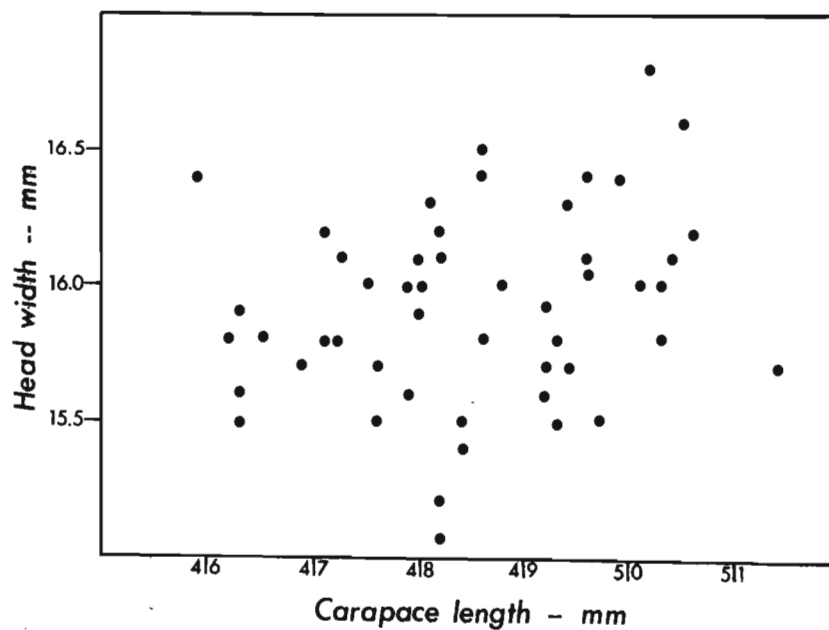


Figure 14. The relationship between straight carapace length and straight head width in a sample of 50 green turtle hatchlings from Europa Island, November, 1970.

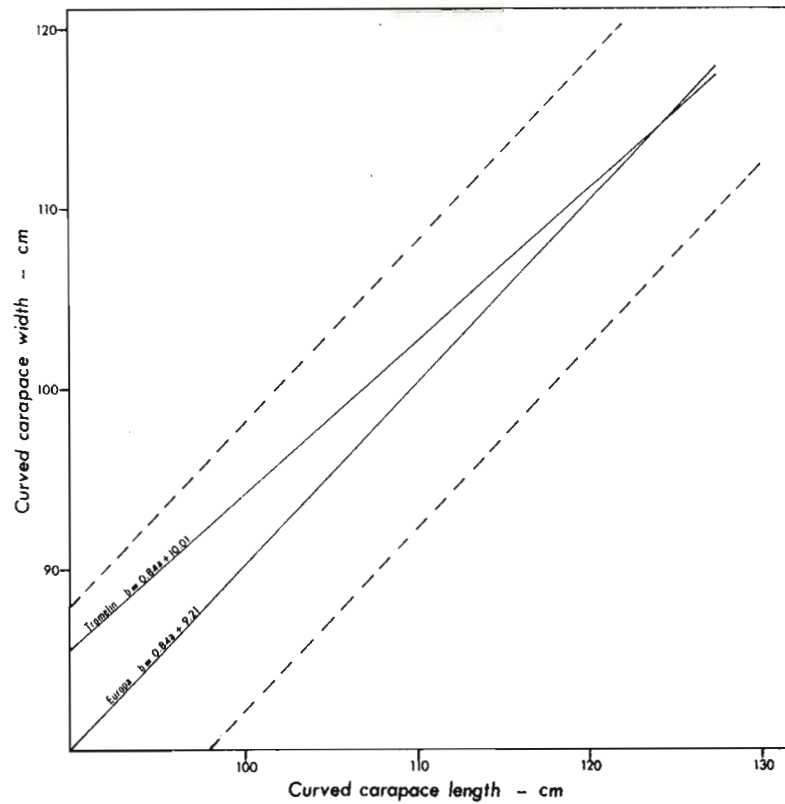


Figure 15. The relationship between the curved carapace length and curved carapace width in a sample of 50 adult green turtle females from Europa Island, November, 1970, with 95% confidence limits. The same relationship in a sample of 44 females from Tromelin Island (October, 1971) is also included.

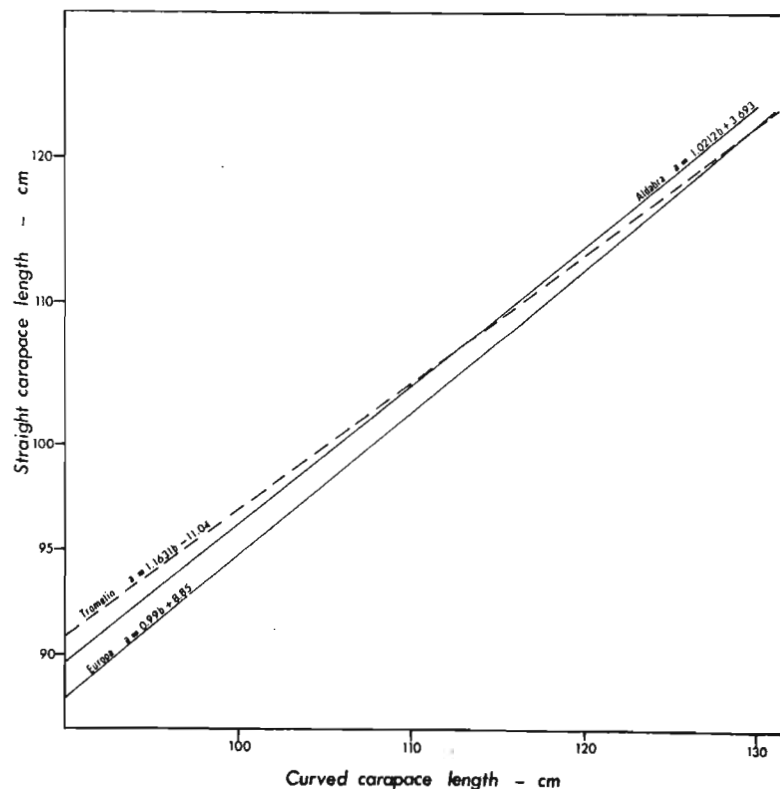


Figure 16. The relationship between straight and curved carapace length in a sample of 29 adult green turtle females from Europa Island, November, 1970. Relationships between the same parameters in green turtle females from Tromelin (n=28) and Aldabra (n=?) are also included.

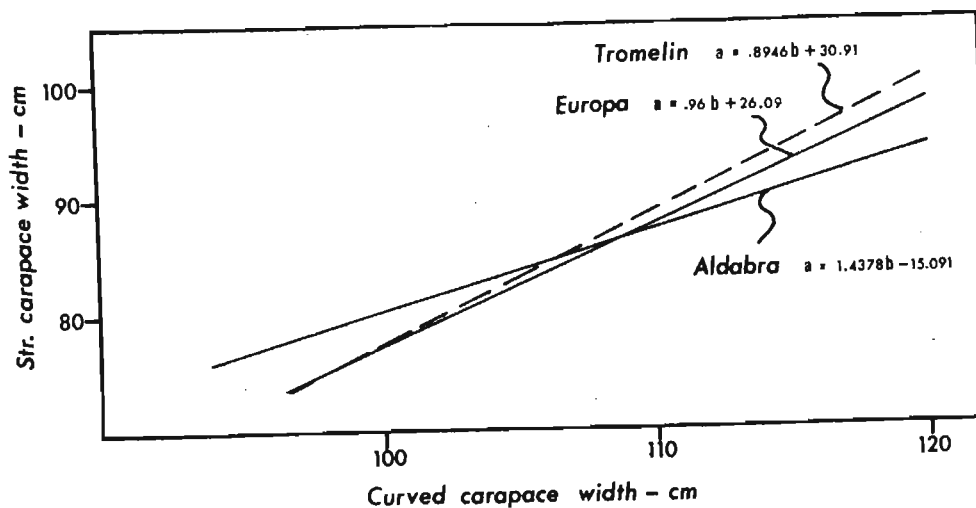


Figure 17. The relationship between straight carapace width and curved carapace width in green turtle females from Europa Island (n=29), Tromelin (n=28), and Aldabra (n=?).

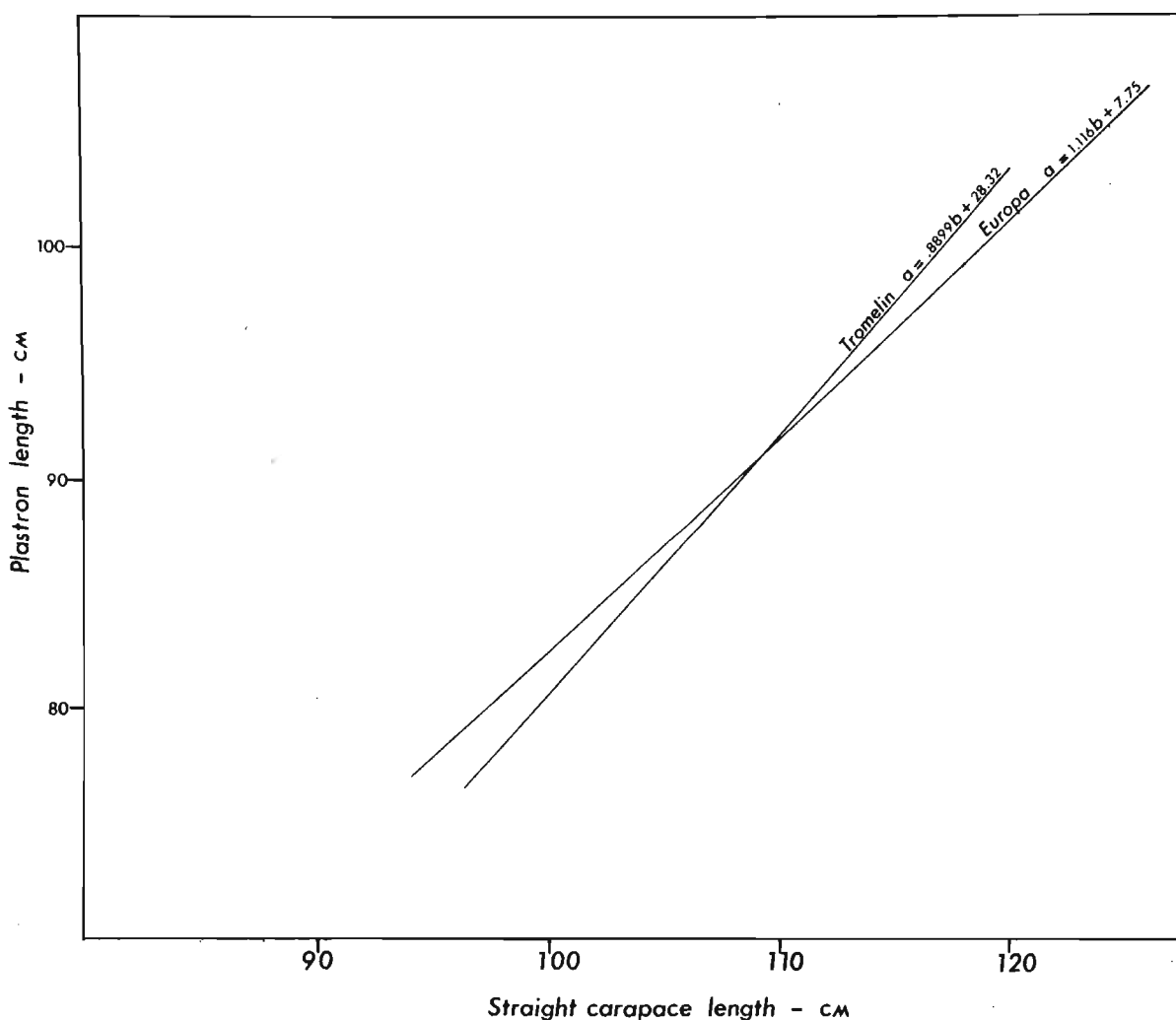


Figure 18. The relationship between straight carapace length and straight plastron length in adult green turtle females from Europa Island (n=29) and Tromelin Island (n=28).

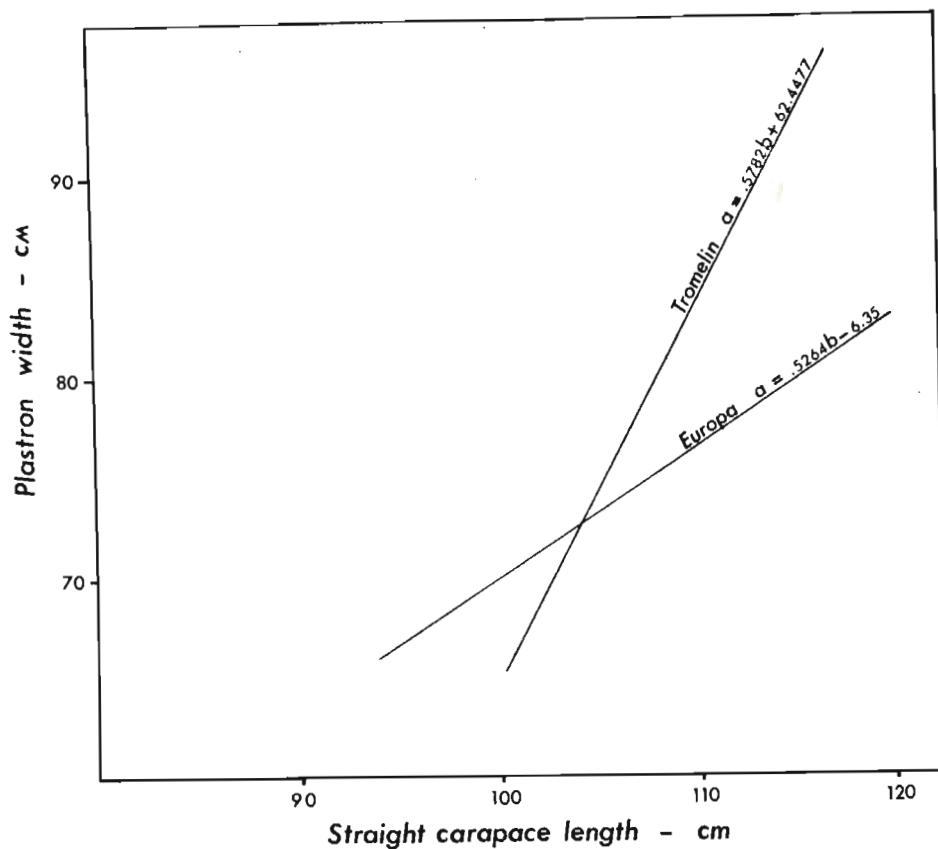


Figure 19. The relationship between straight carapace length and straight plastron width in adult green turtle females from Europa Island (n=29), and Tromelin Island (n=28).

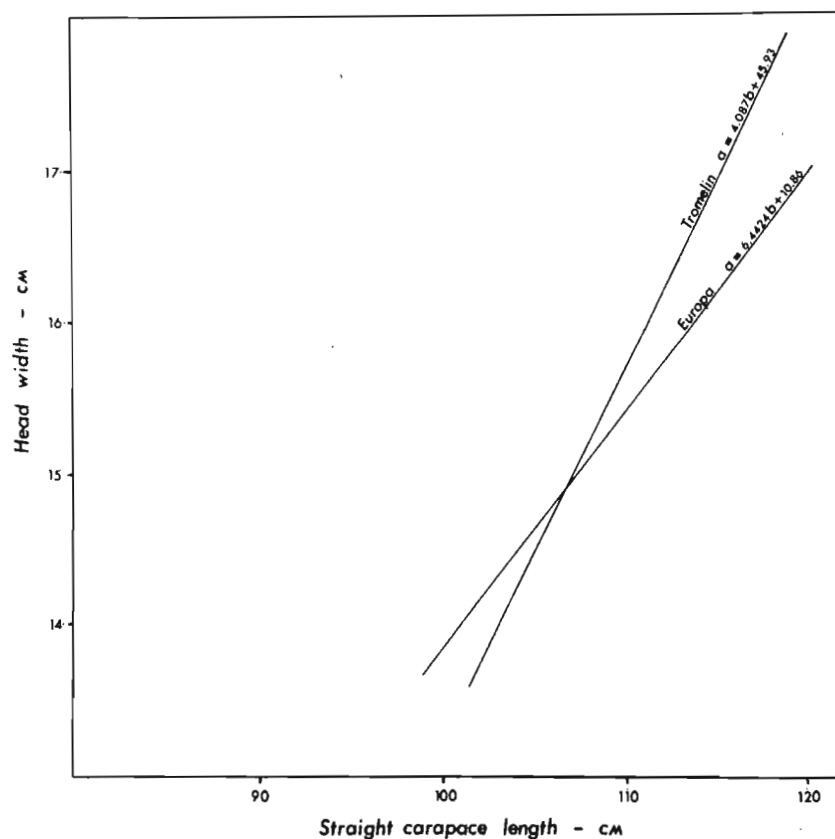


Figure 20. The relationship between straight carapace length and straight head width in adult green turtle females from Europa Island (n=29), and Tromelin Island (n=28).

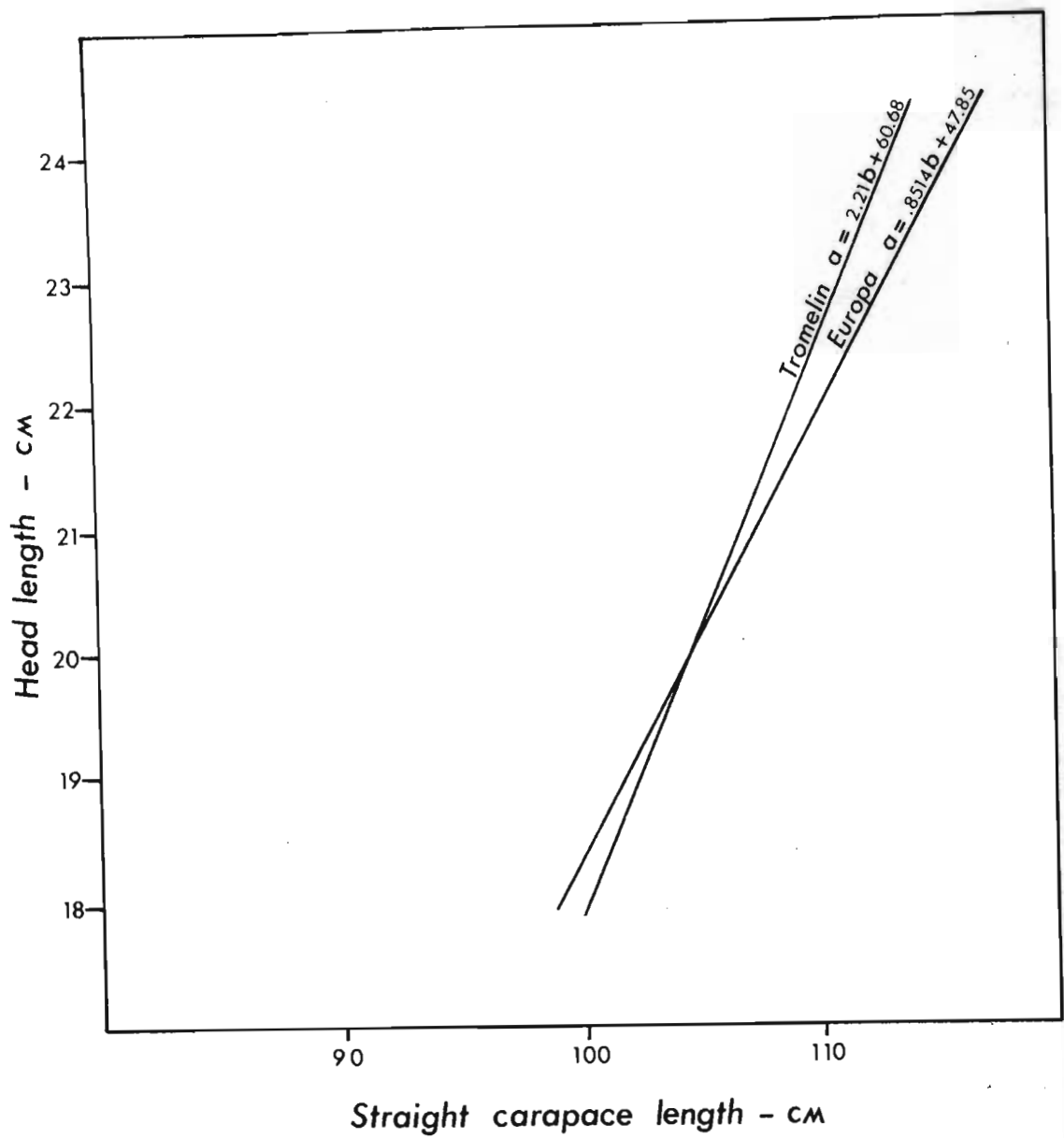


Figure 21. The relationship between straight carapace length and curved head length in adult green turtle females from Europa Island (n=29) and Tromelin Island (n=28).

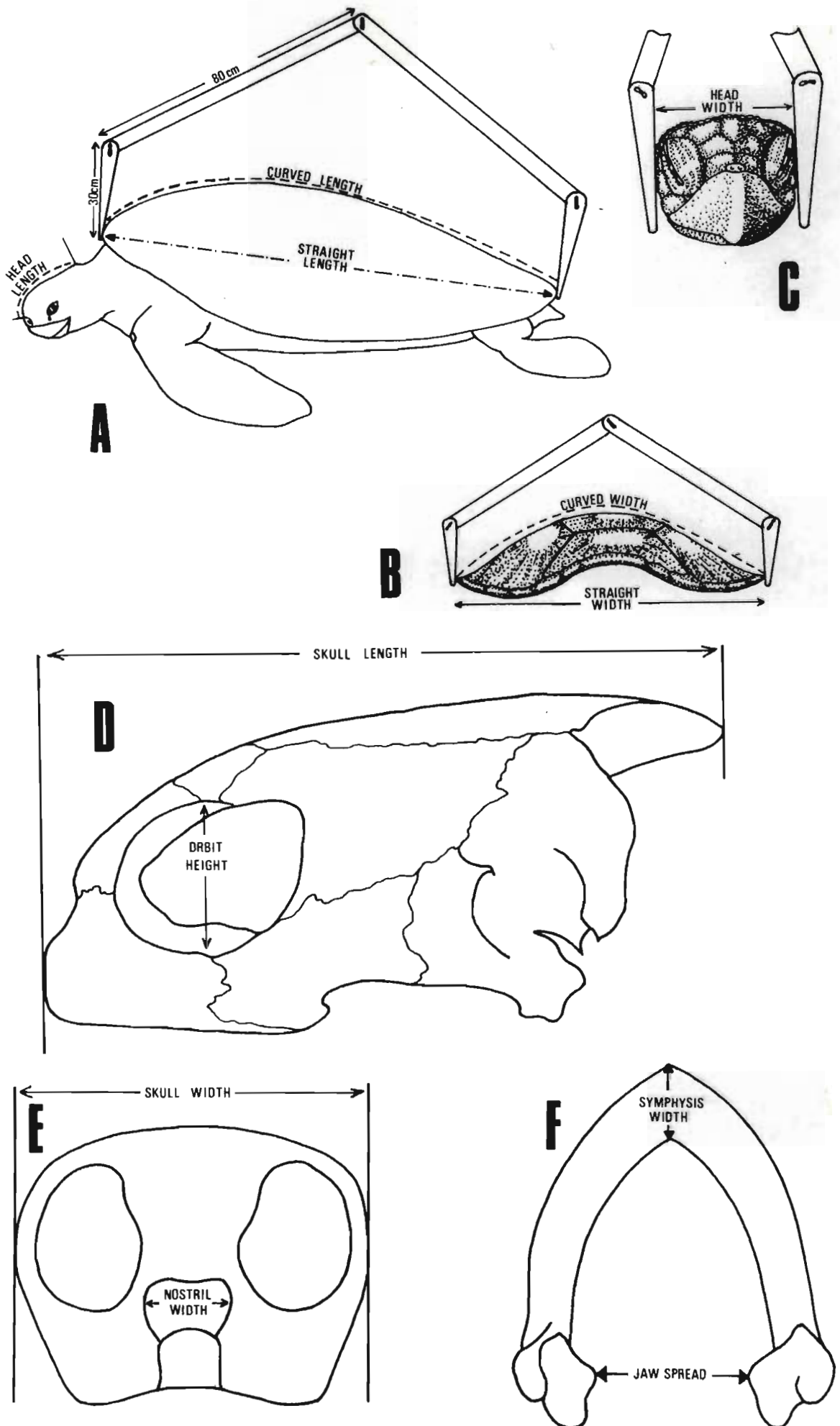


Figure 22. Skull, head and body measurements used in the present study.

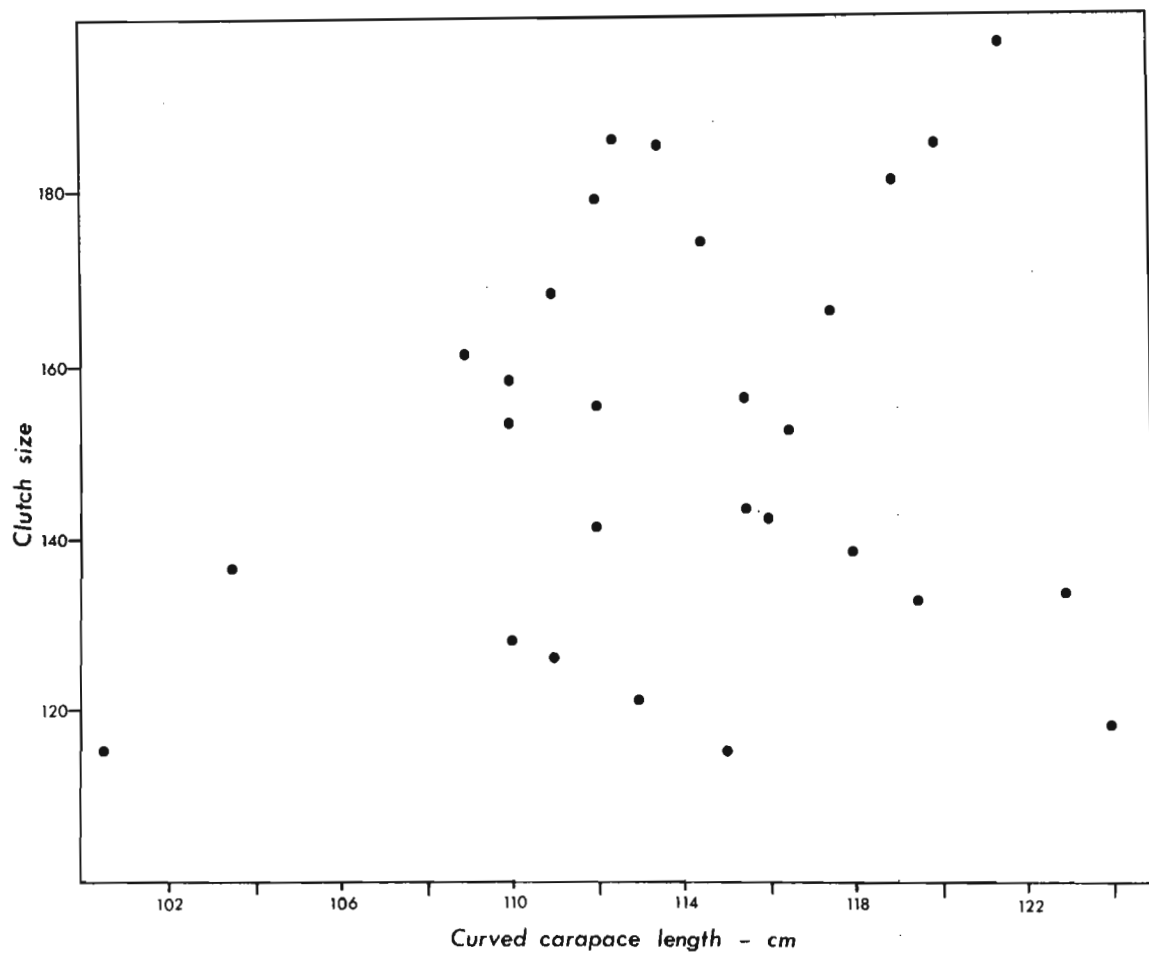


Figure 23. The relationship between curved carapace length and egg clutch size in green turtles from Europa Island, November, 1970 (n=28).

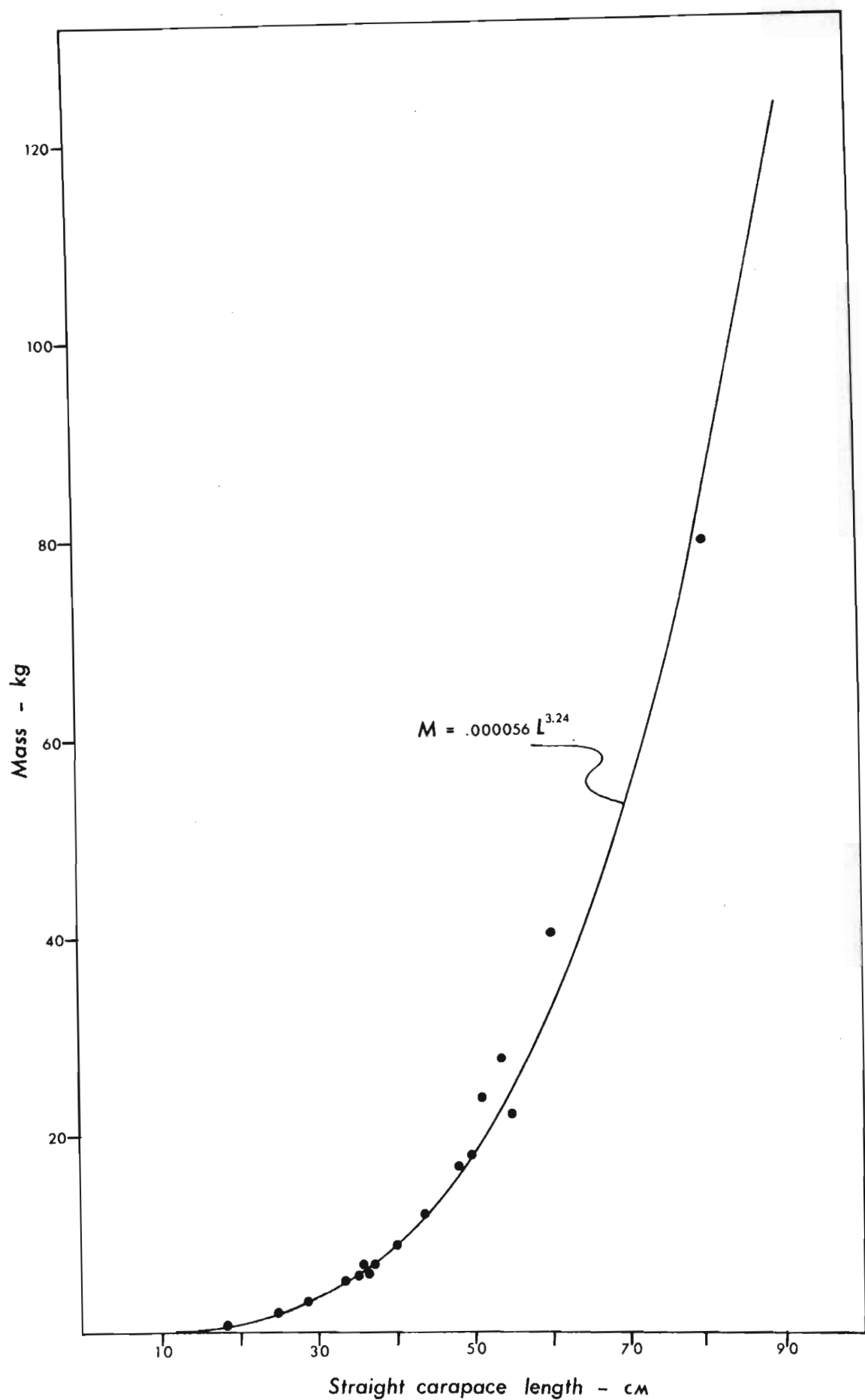


Figure 24. The relationship between straight carapace length and mass in the hawksbill turtle in the study region.

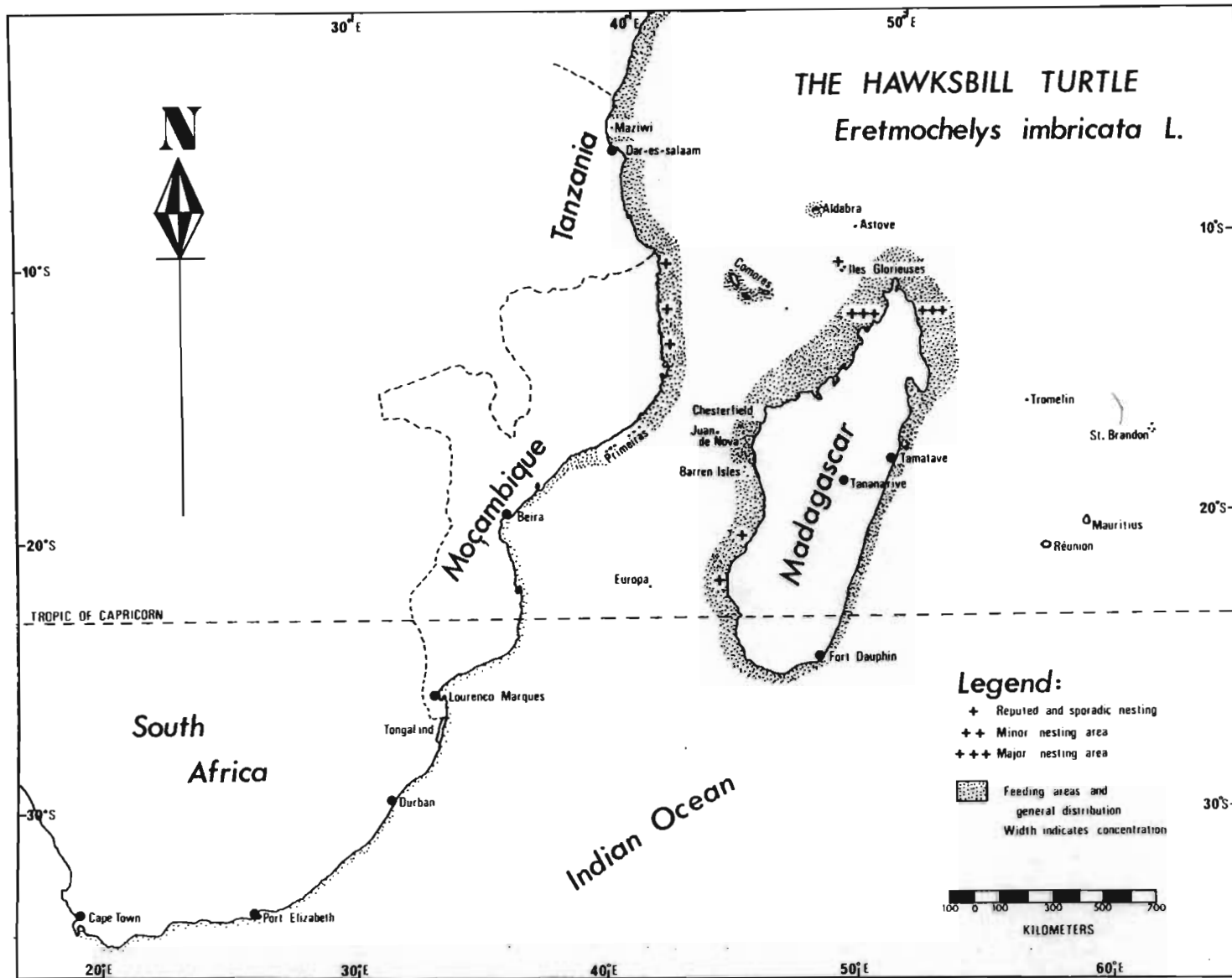


Figure 25. The distribution and nesting areas of the hawksbill turtle *Eretmochelys imbricata* in the study region. Width of stippling indicates relative abundance.

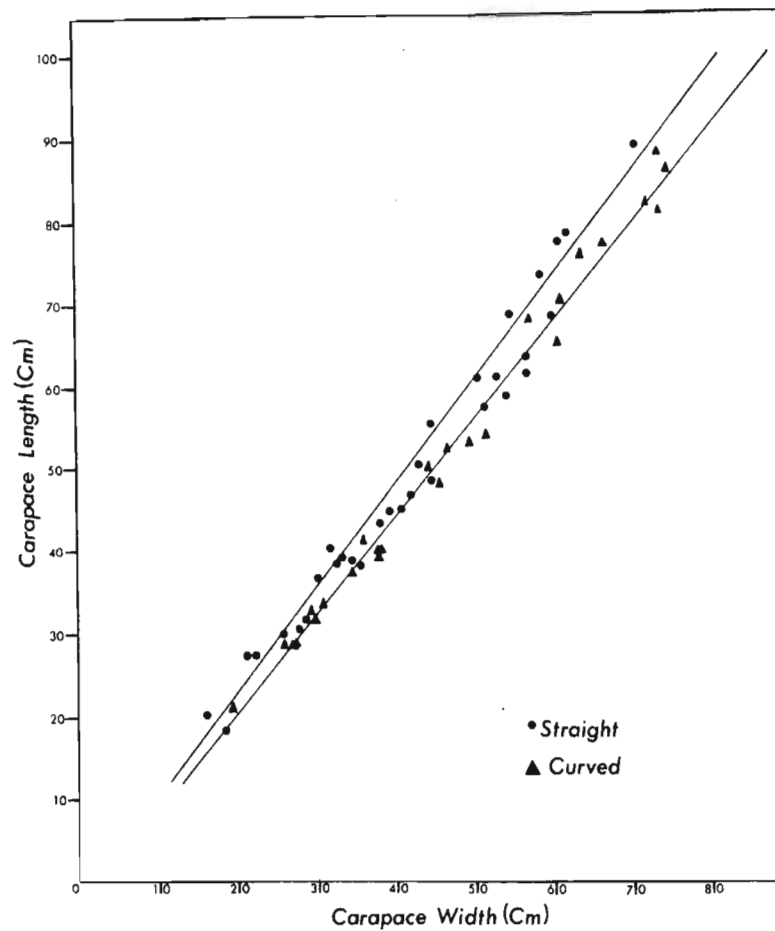


Figure 26. The relationships between curved carapace length/curved carapace width, and straight carapace length/straight carapace width in hawksbill turtles from the study region.

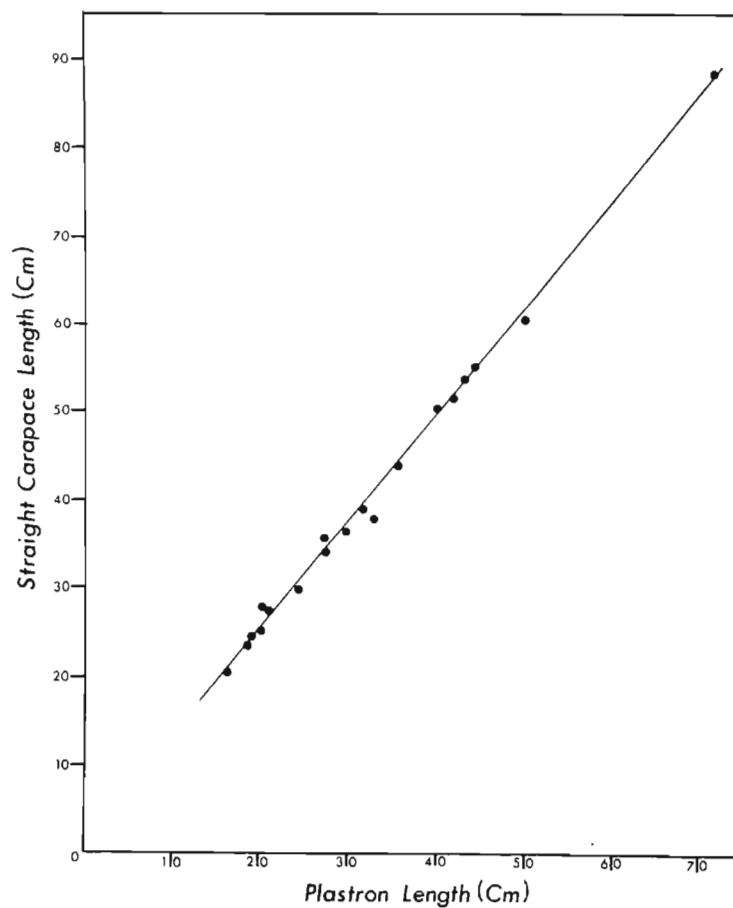


Figure 27. The relationship between straight carapace length and plastron length in the hawksbill turtle.

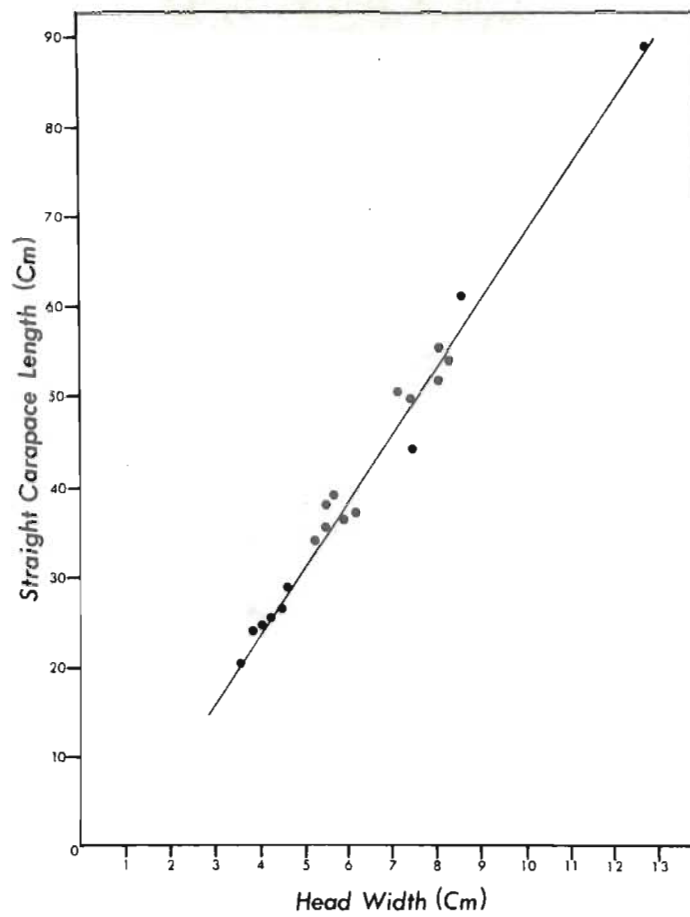


Figure 28. The relationship between straight carapace length and head width in the hawksbill turtle.

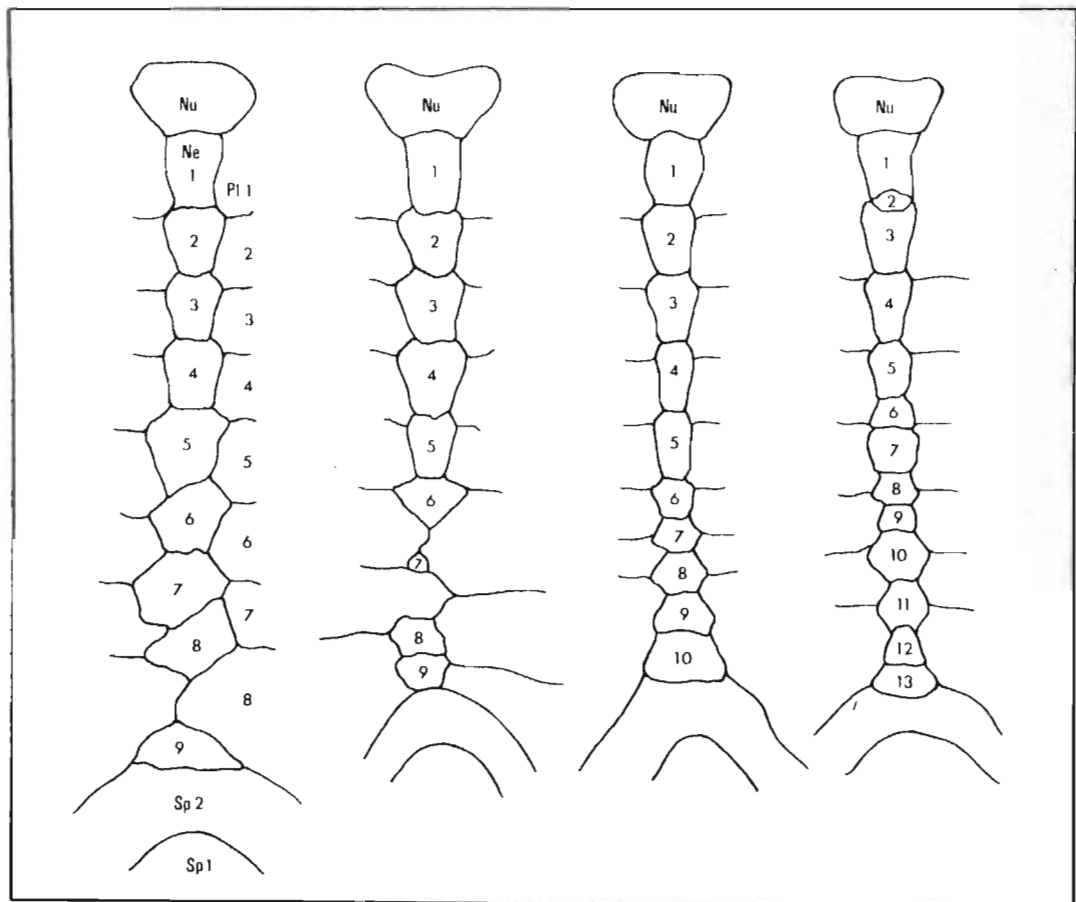


Figure 29. Four examples of neural bone patterns in loggerhead carapaces from the Natal coast.

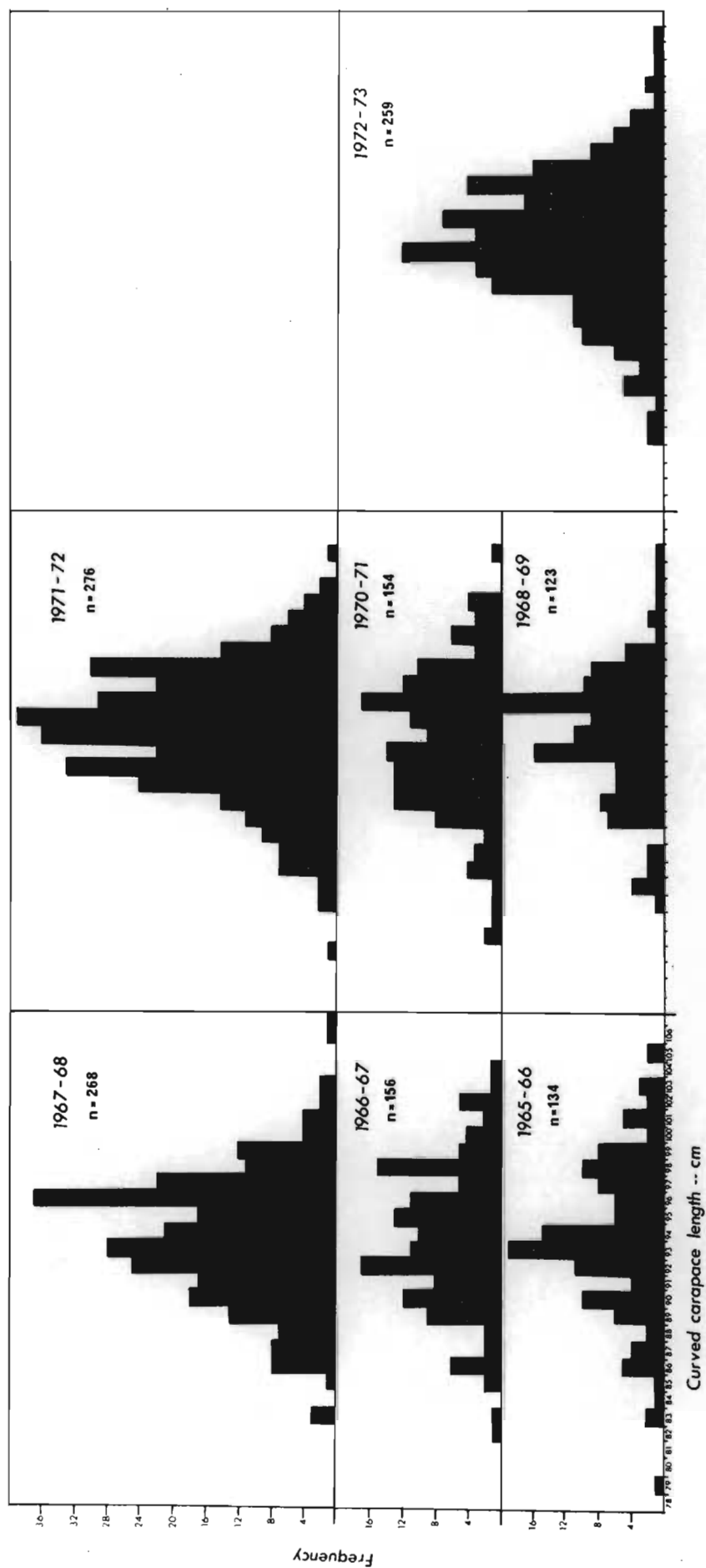


Figure 30. The size distribution of nesting loggerhead females in seven seasons in Tongaland, Natal.

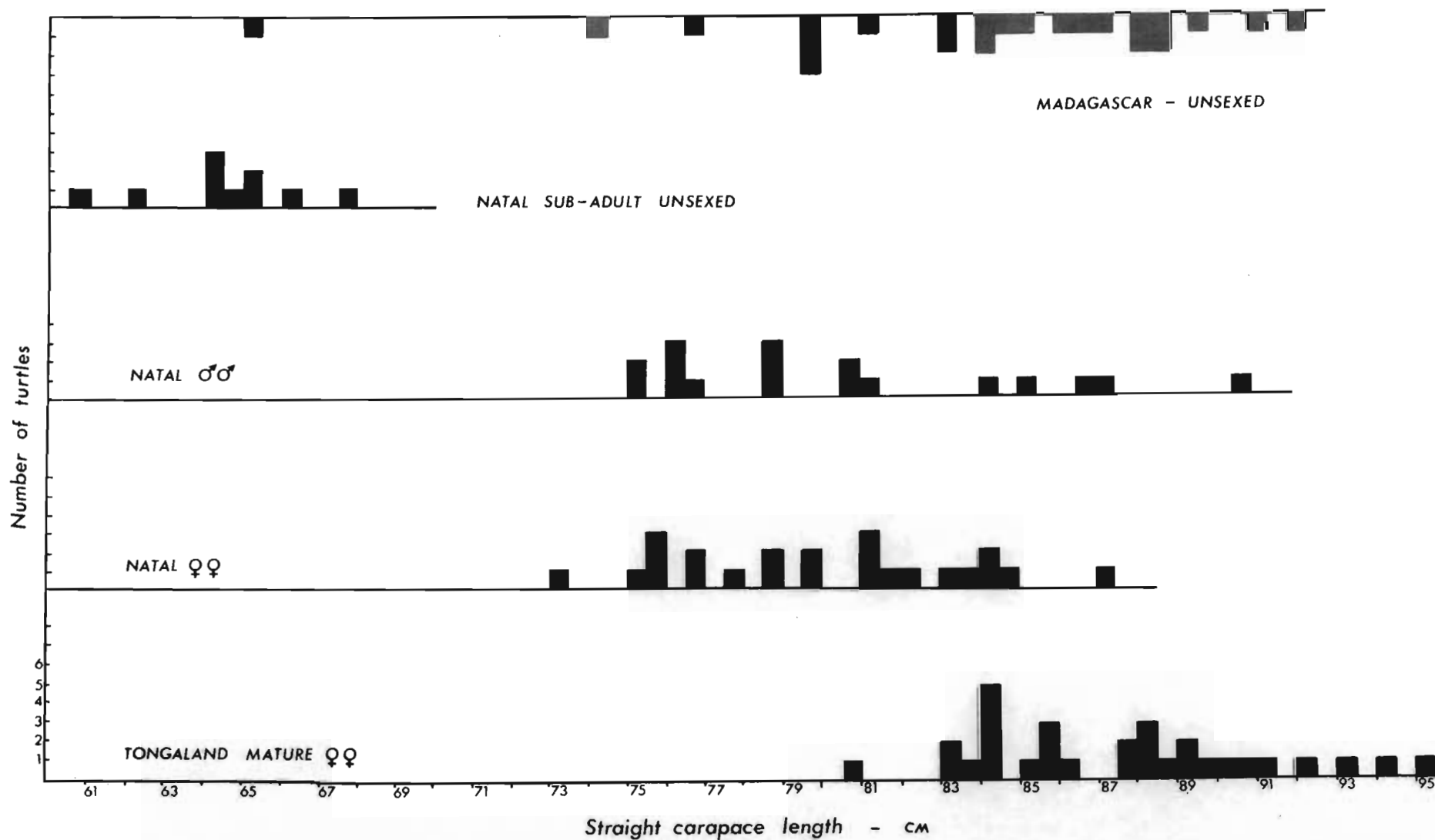


Figure 31. The size distribution of loggerhead material examined in Natal (males, females and young sub-adults), a sample of mature females from Tongaland, and unsexed material from Madagascar.

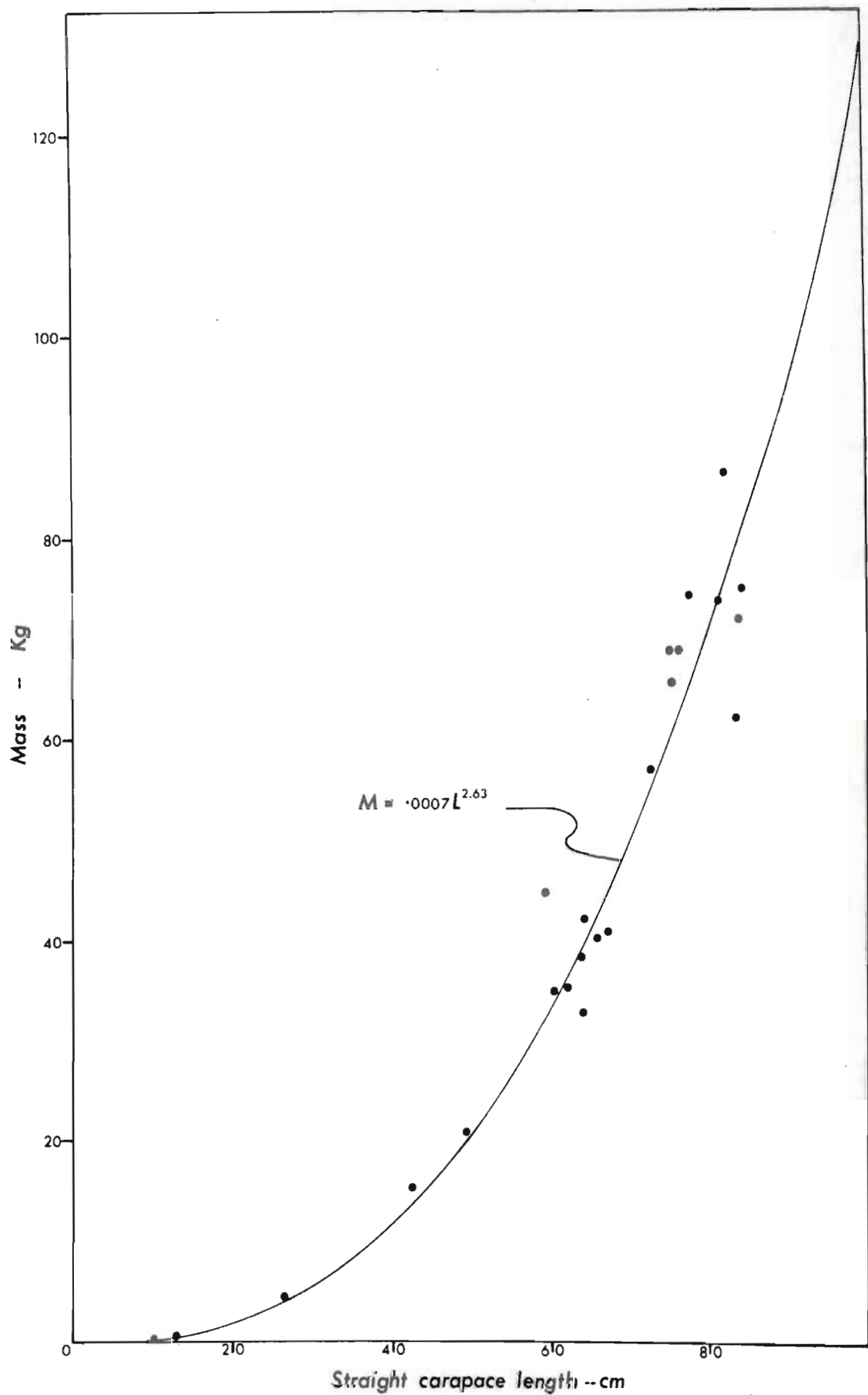


Figure 32. The length-mass relationship in loggerhead turtles from the Natal coast.

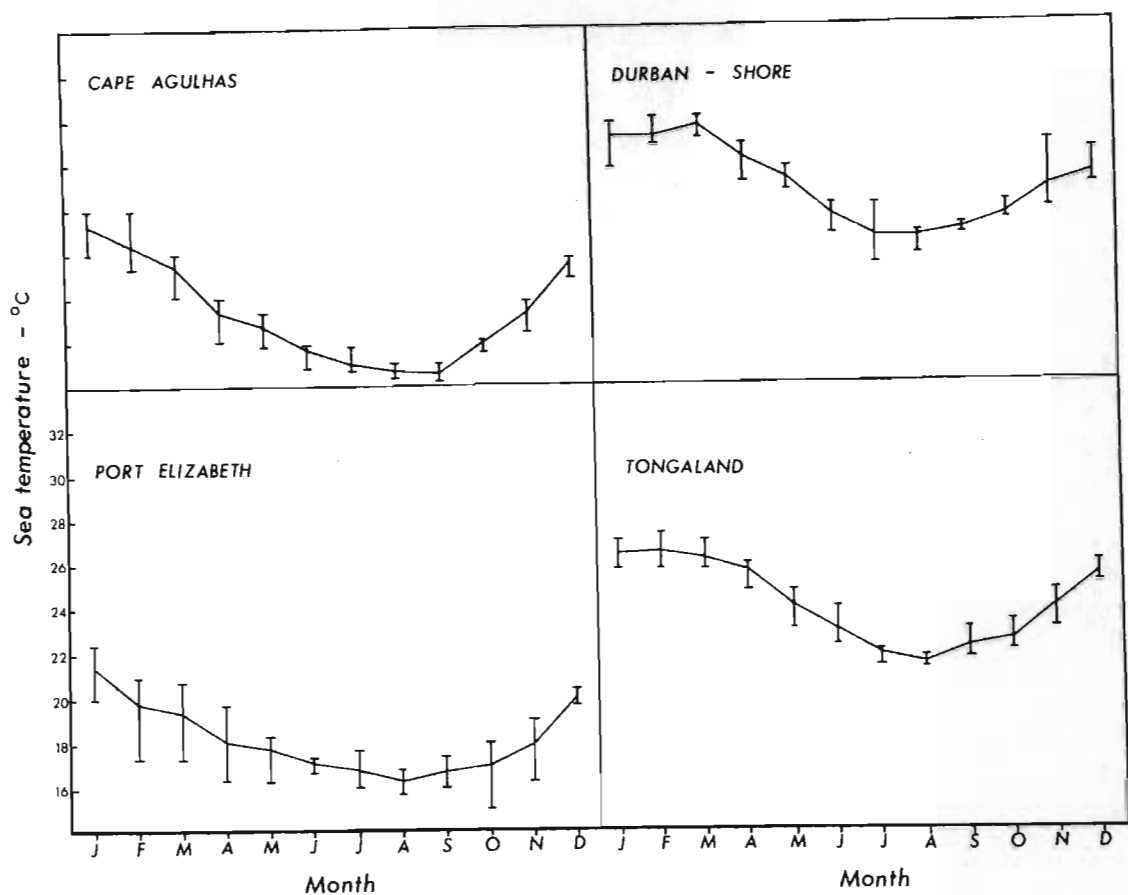


Figure 33. Mean monthly sea shore temperatures at four localities on the east and south coasts of South Africa. Vertical bars indicate ranges from 1969-1972 inclusive.

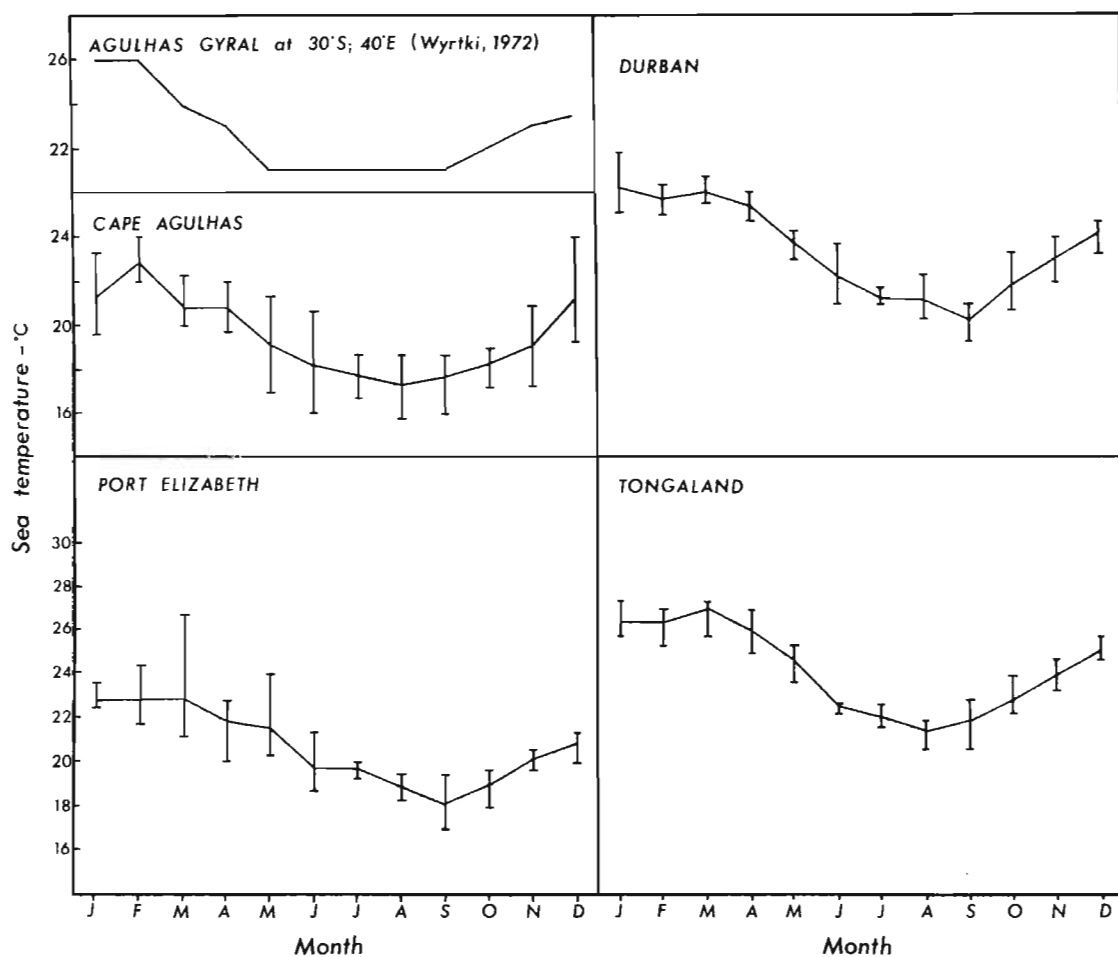


Figure 34. Mean monthly sea temperatures 150 nautical miles offshore four localities on the east and south coasts of South Africa, and in the centre of the Agulhas Gyrals. Vertical bars indicate ranges

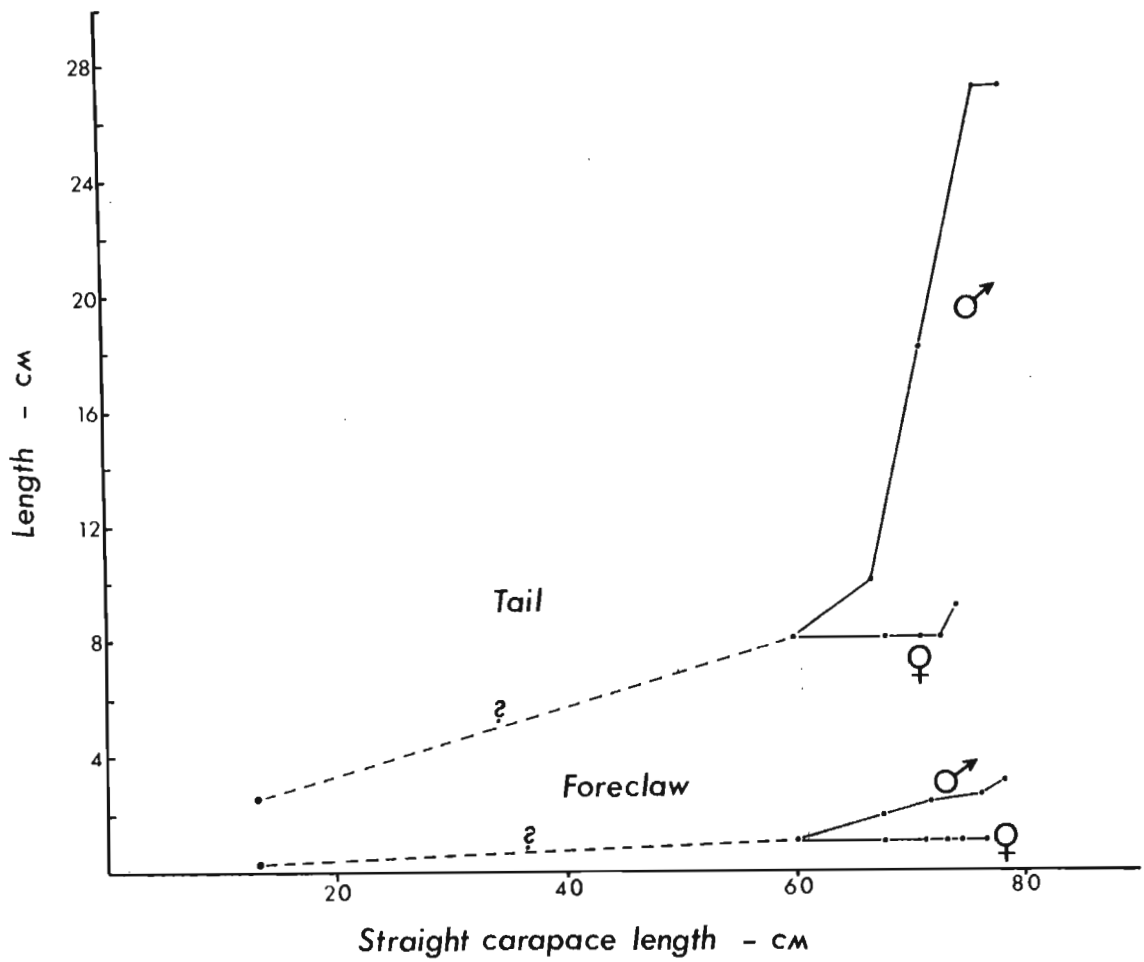


Figure 35. Tail and claw growth differences in one male and one female loggerhead turtle from the Durban Aquarium.

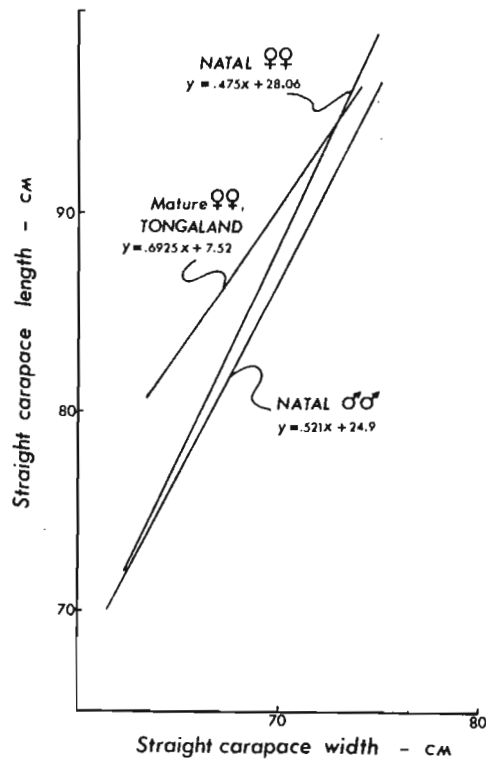


Figure 36. The relationship between straight carapace length and straight carapace width in Natal coast males and females, and mature Tongaland females.

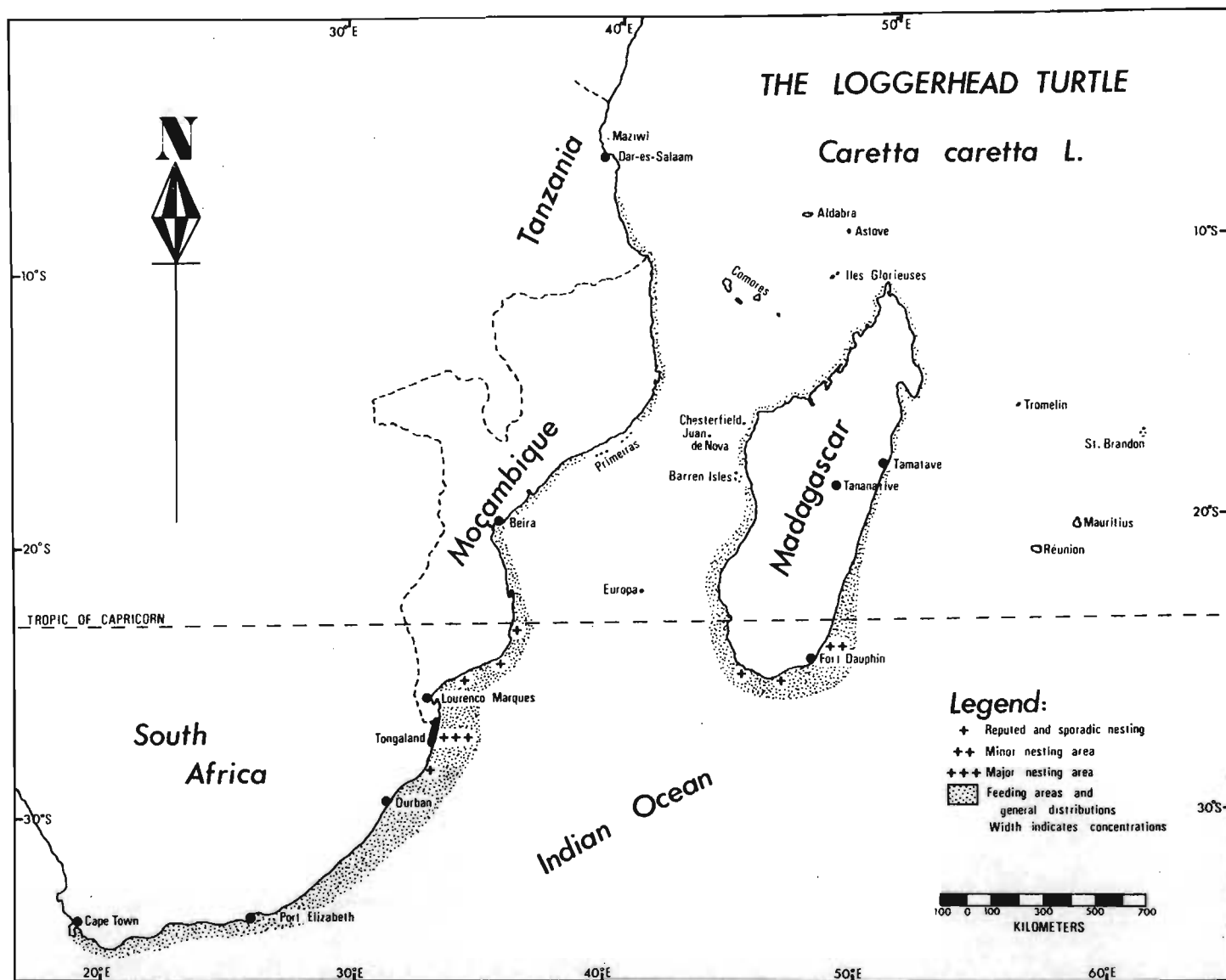


Figure 37. The distribution and nesting areas of the loggerhead turtle *Caretta caretta* in the study region. Width of stippling indicates relative abundance.

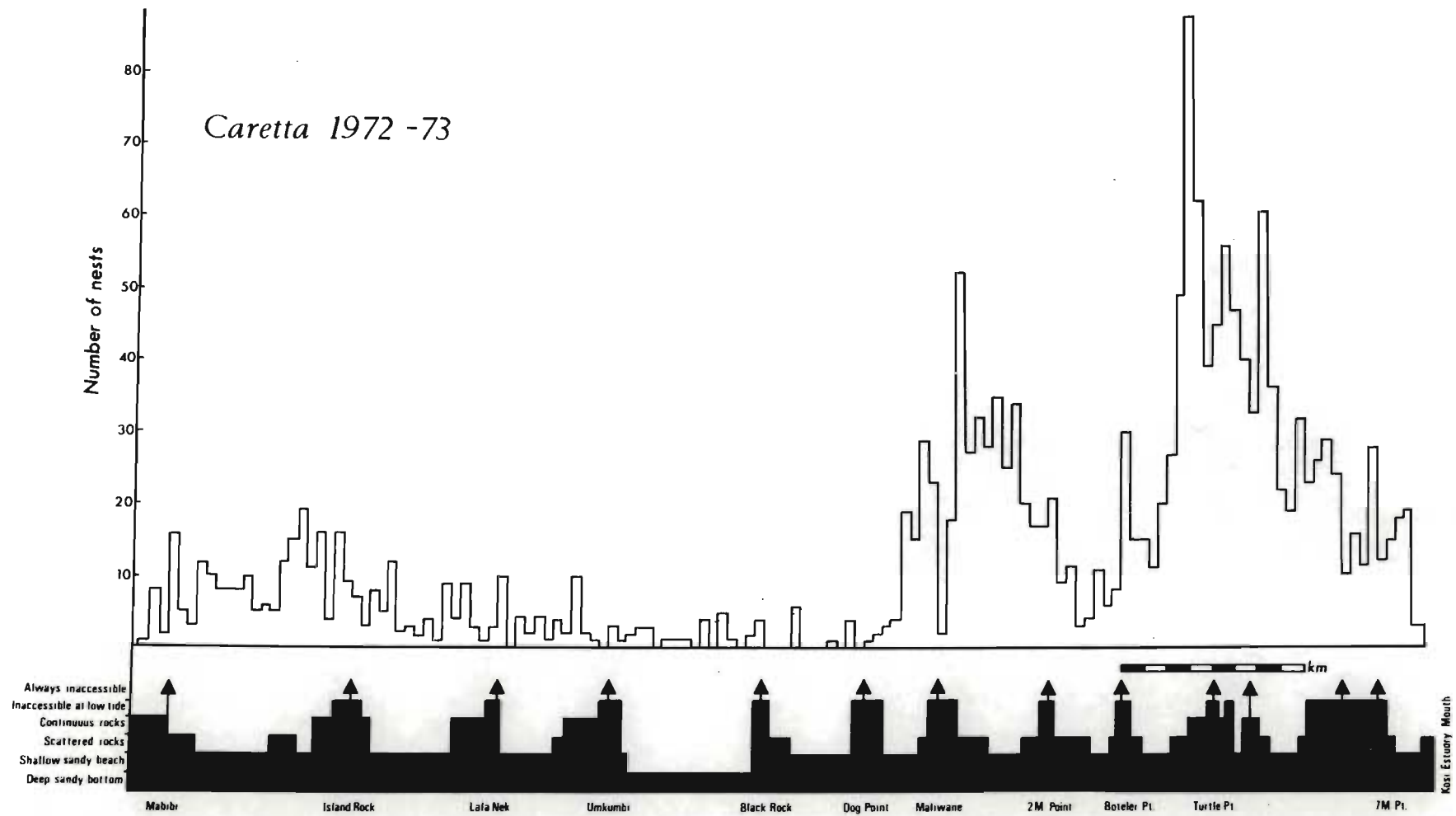


Figure 38. Loggerhead nesting activity during the 1972/73 season along the Tongaland study region showing the nature of the littoral zone.

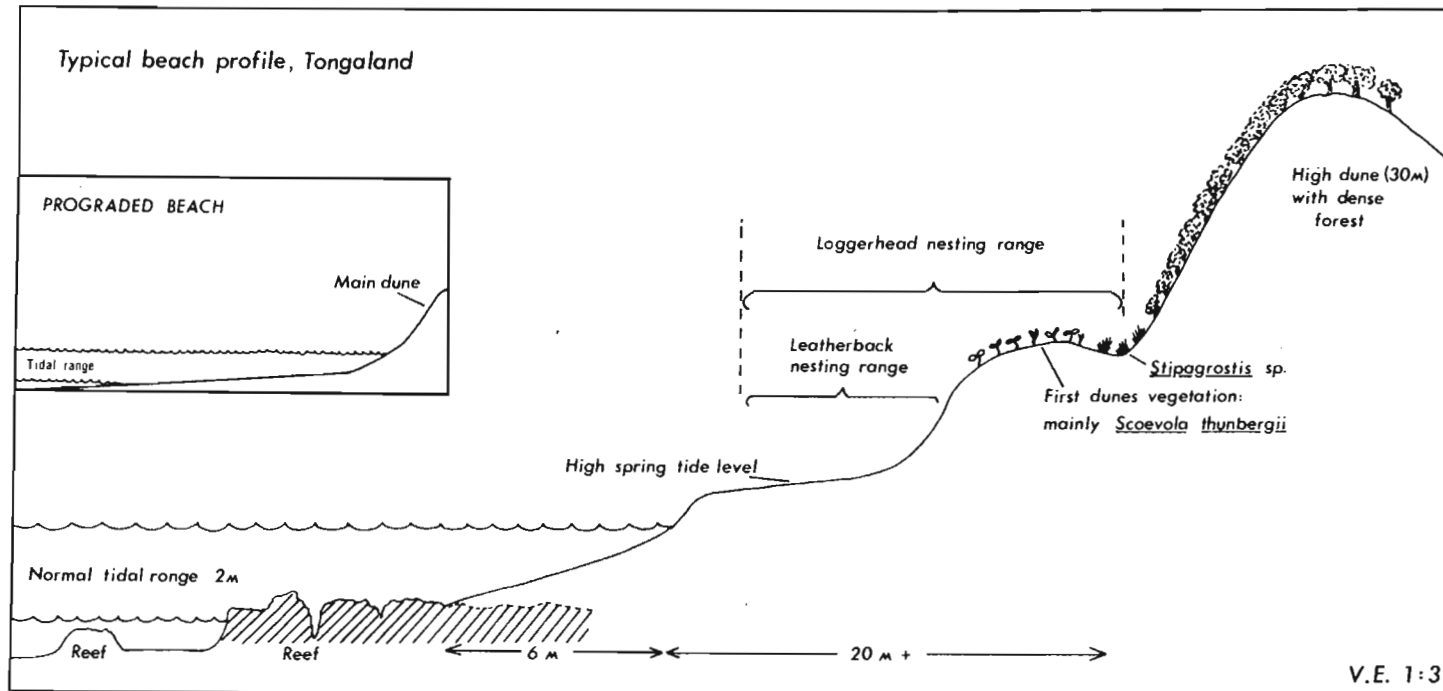


Figure 39. An example of a typical retrograded beach in Tongaland, heavily utilized by nesting turtles. An example of the less common prograded beach type is inset.

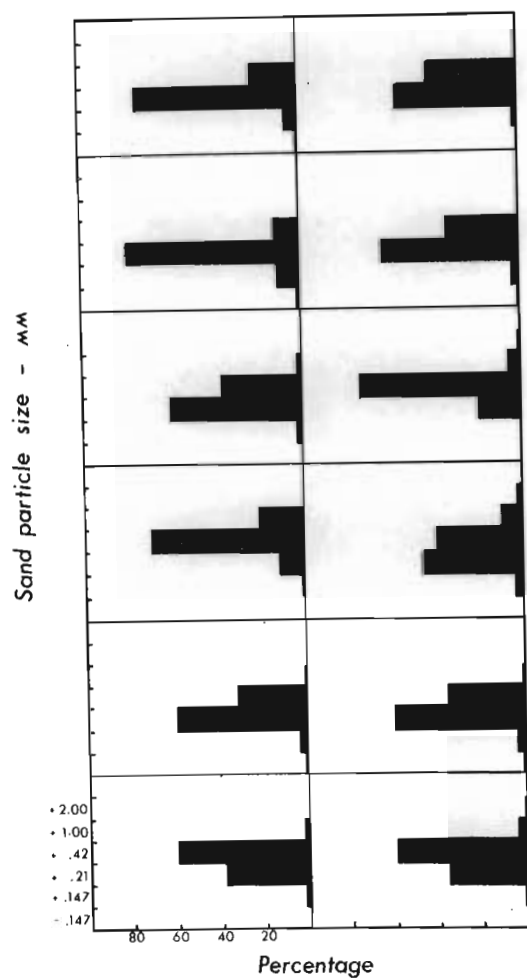


Figure 40. Sand particle sizes from samples taken at 12 sites along the Tongaland protected zone.

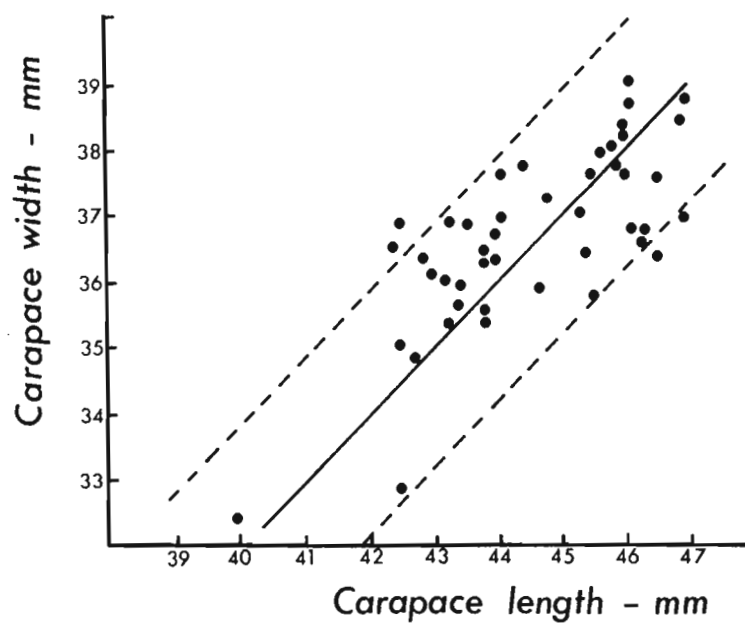


Figure 41. The relationship between carapace length and width in a sample of 50 loggerhead hatchlings from Tongaland.

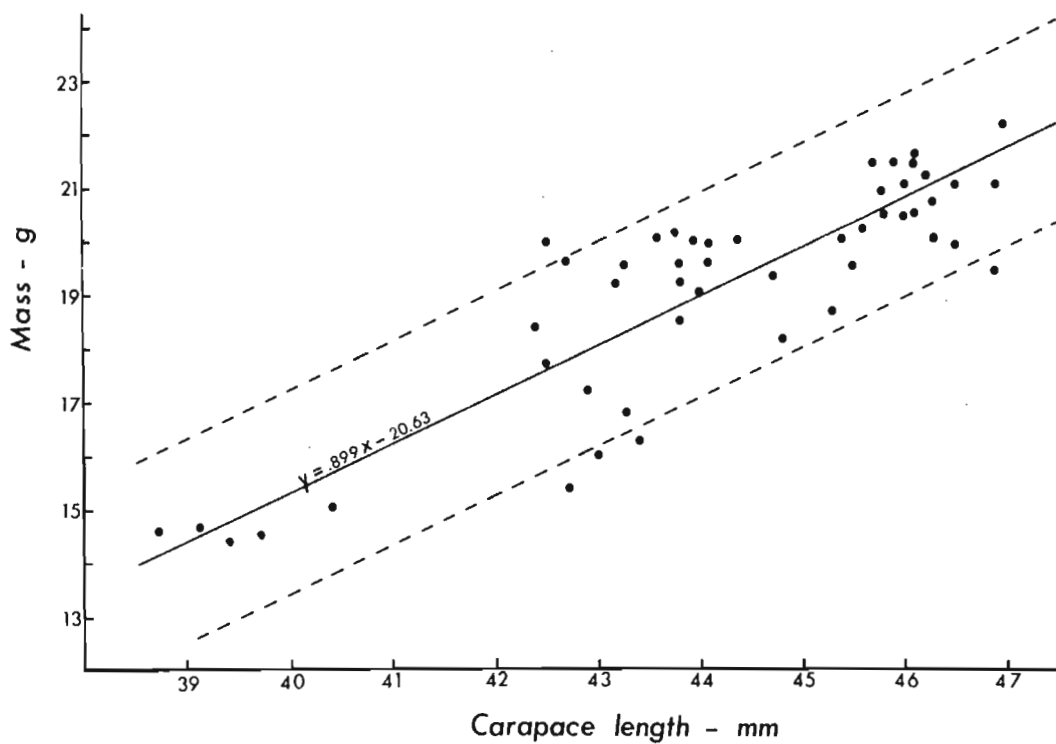


Figure 42. The relationship between carapace length and mass in a sample of 50 loggerhead hatchlings from Tongaland.

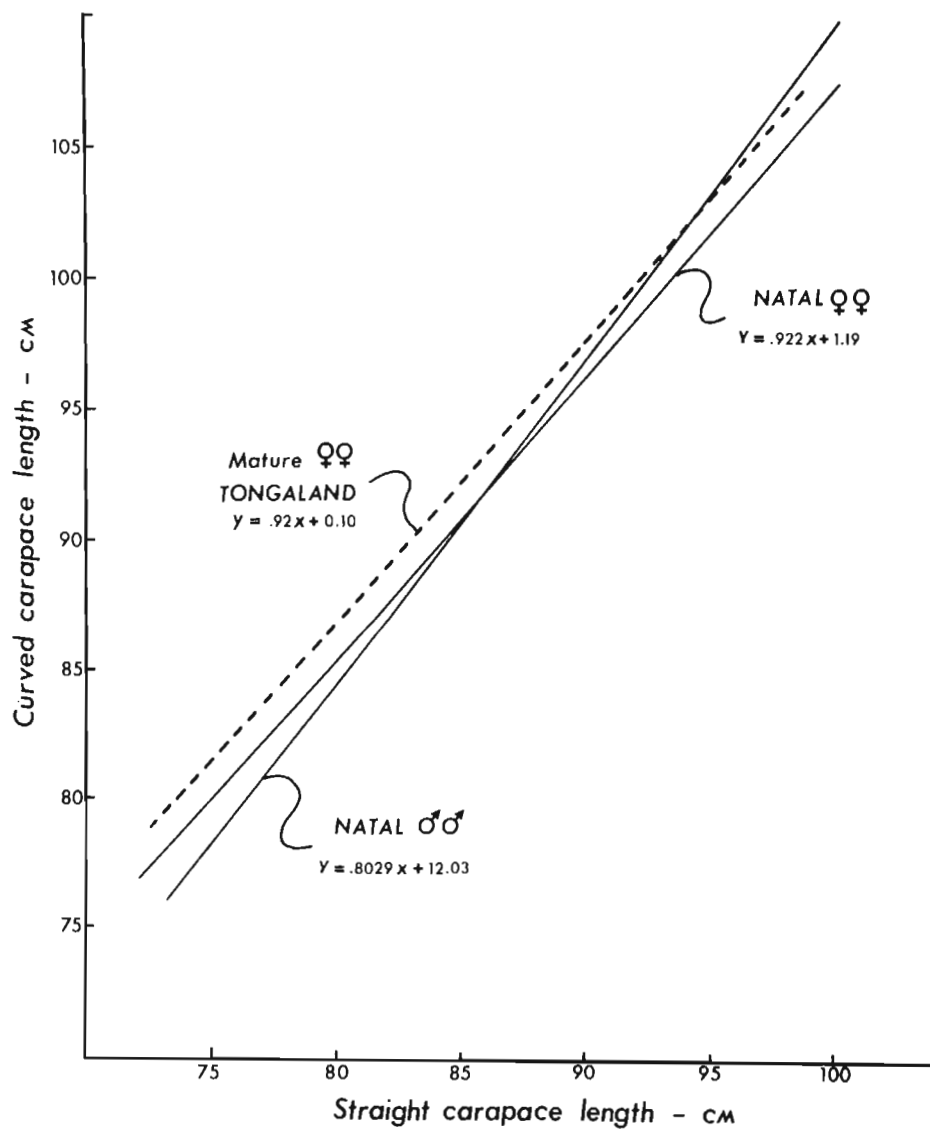


Figure 43. The relationship between curved carapace length and straight carapace length in sub-adult male and female loggerheads from Natal, and mature loggerhead females from Tongaland.

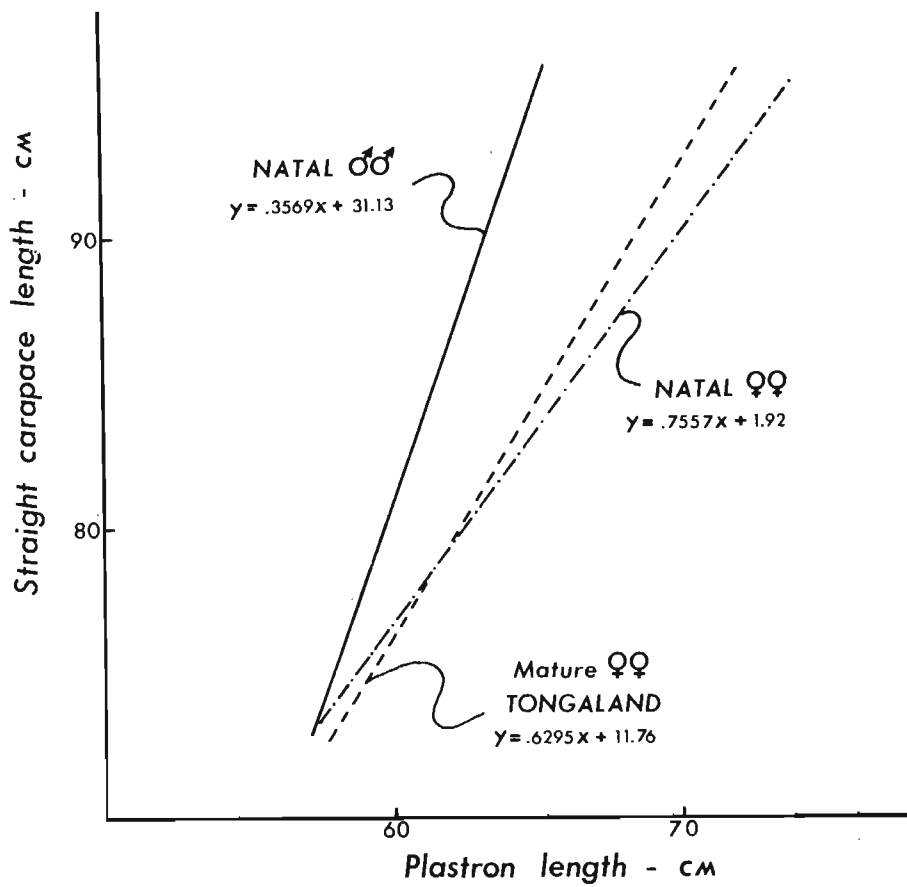


Figure 44. The relationship between straight carapace length and plastron length in sub-adult male and female loggerheads from Natal, and mature female loggerheads from Tongaland.

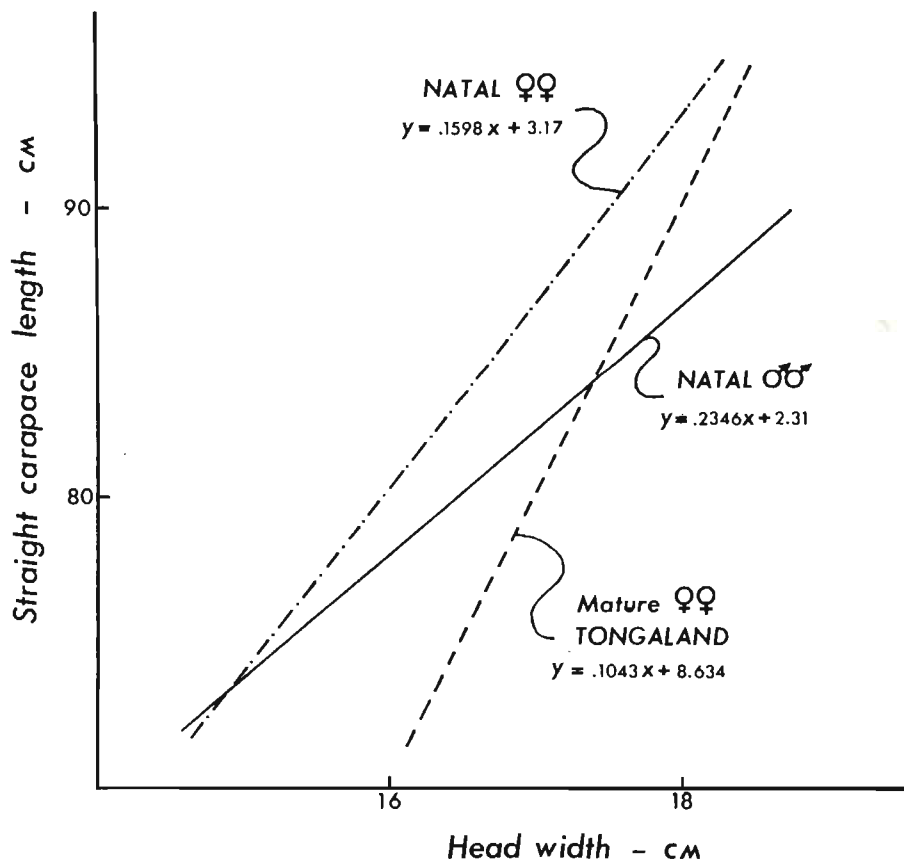


Figure 45. The relationship between straight carapace length and head width in sub-adult male and female loggerheads from Natal, and mature female loggerheads from Tongaland.

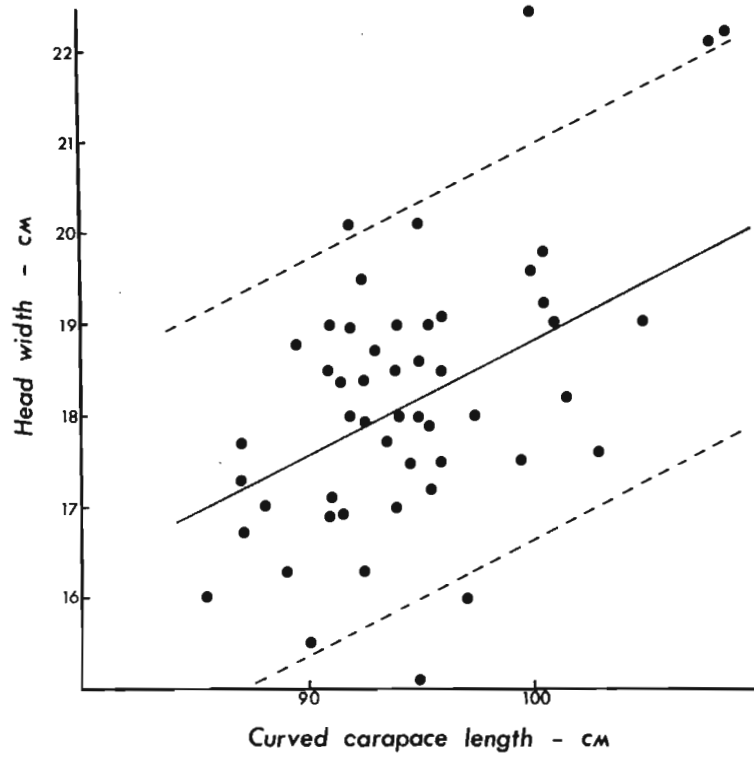


Figure 46. The relationship between curved carapace length and head width in a sample of 50 mature loggerhead females from Tongaland.

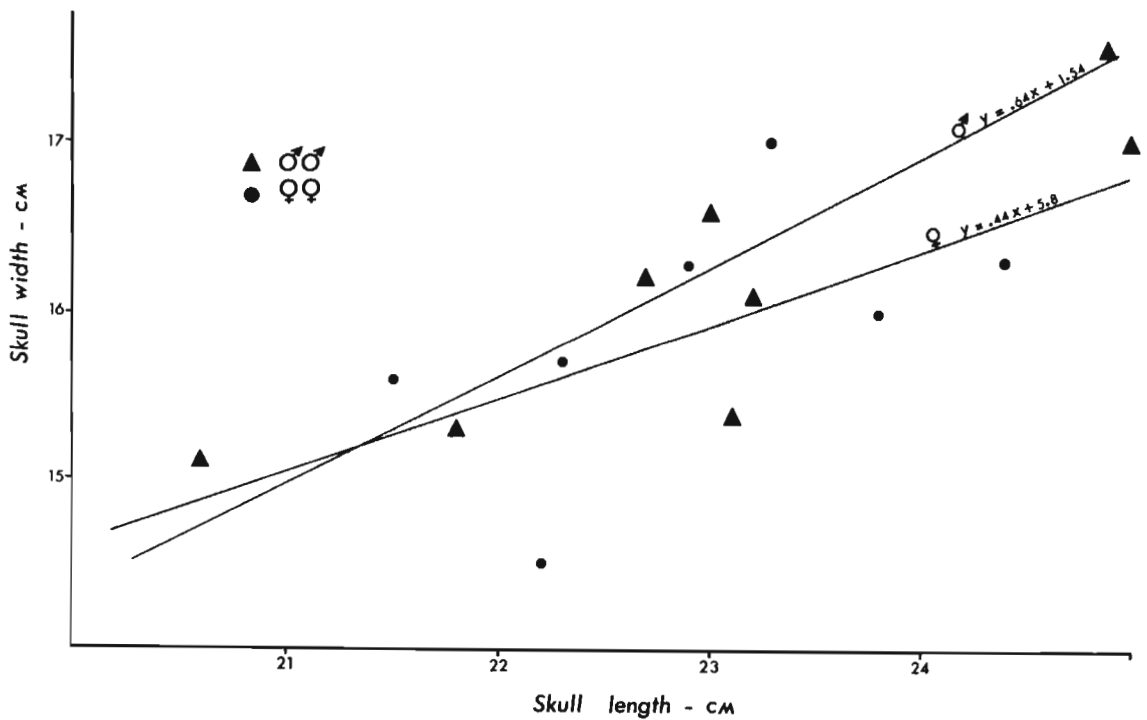


Figure 47. The relationship between skull length and skull width in male and female loggerhead turtles.

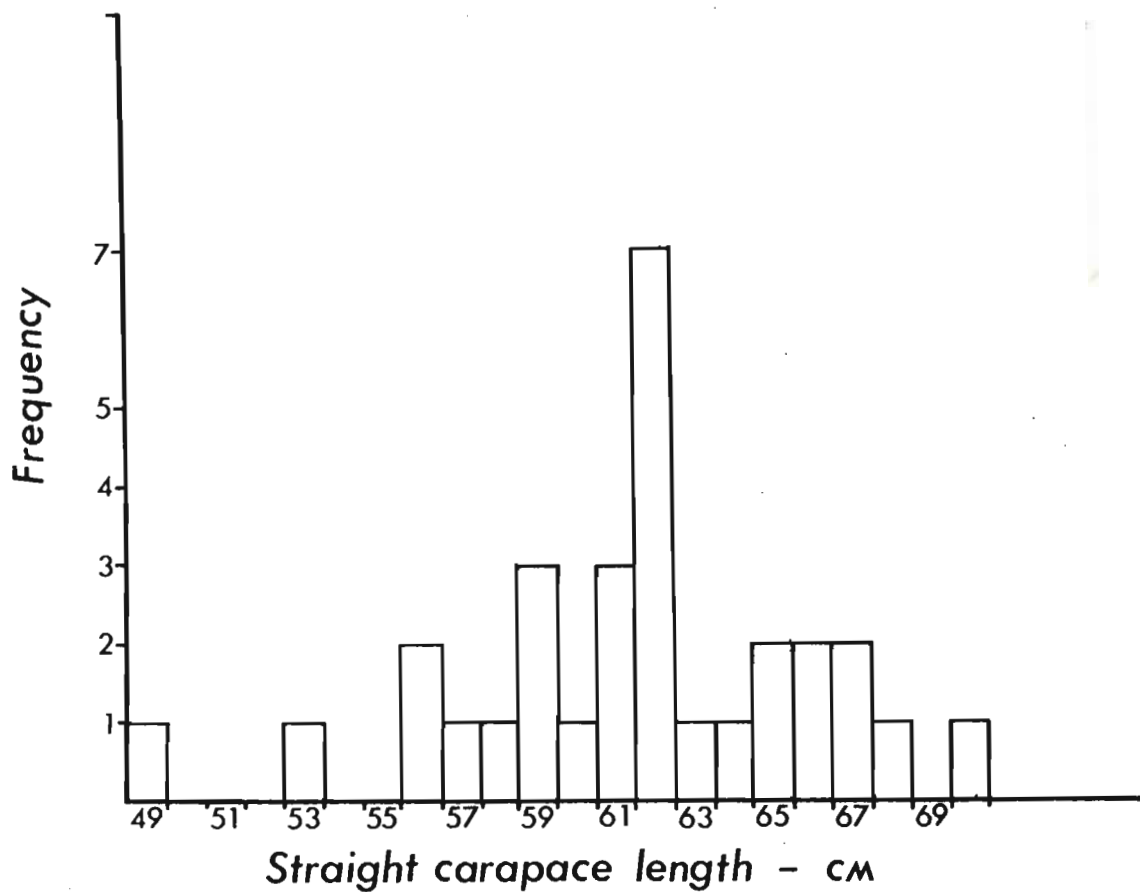


Figure 48. The size distribution (straight carapace length) of olive ridley turtles from the study region.

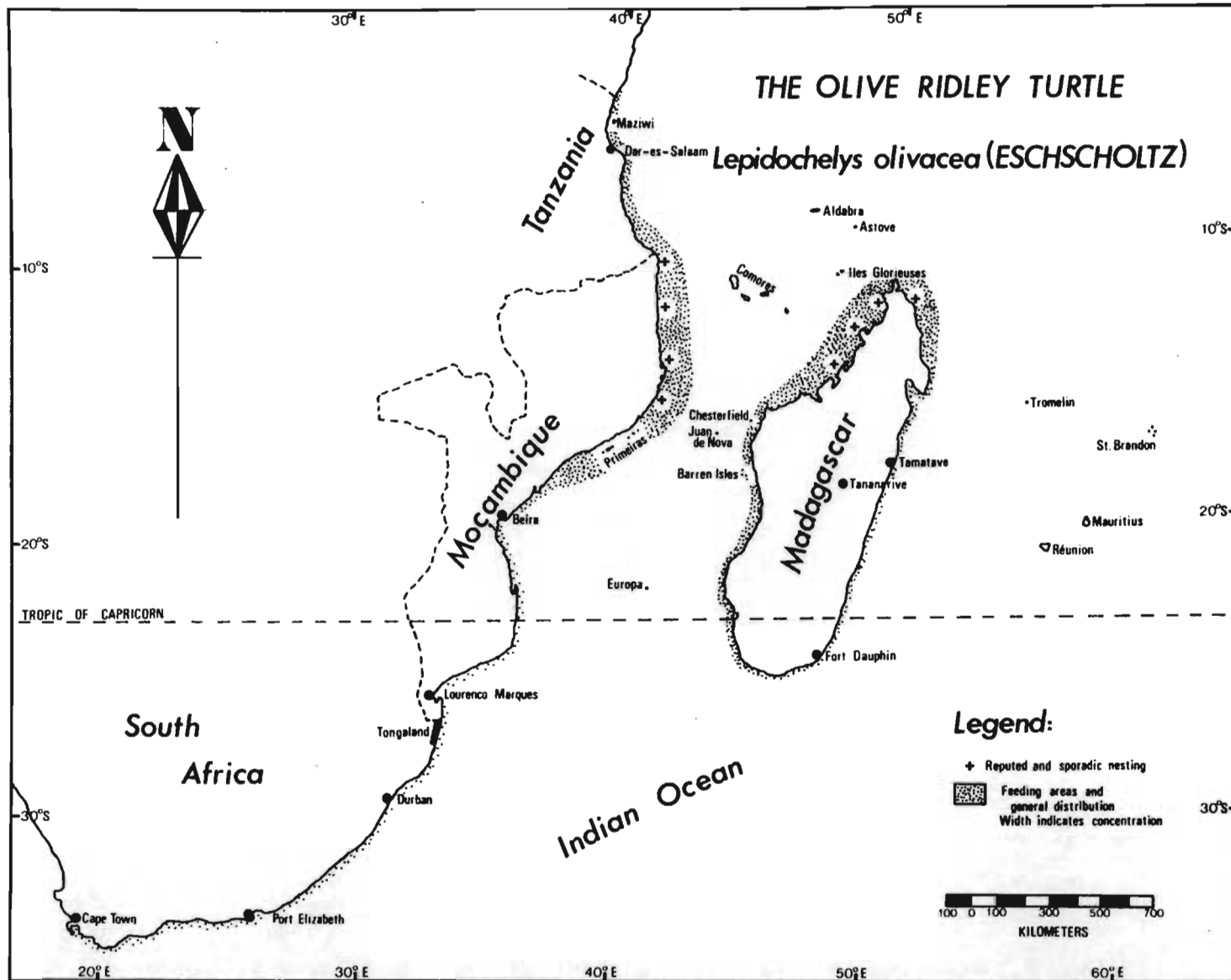


Figure 49. The distribution and nesting areas of the olive ridley turtle Lepidochelys olivacea in the study region. Width of stippling indicates relative abundance.

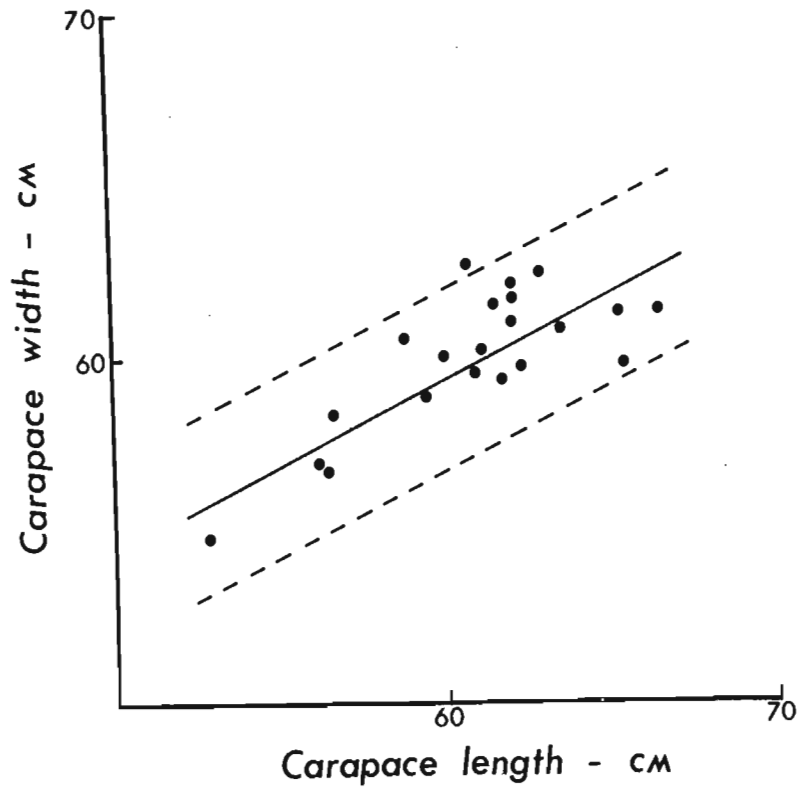


Figure 50. The relationship between straight carapace length and width in olive ridley material from the study region.

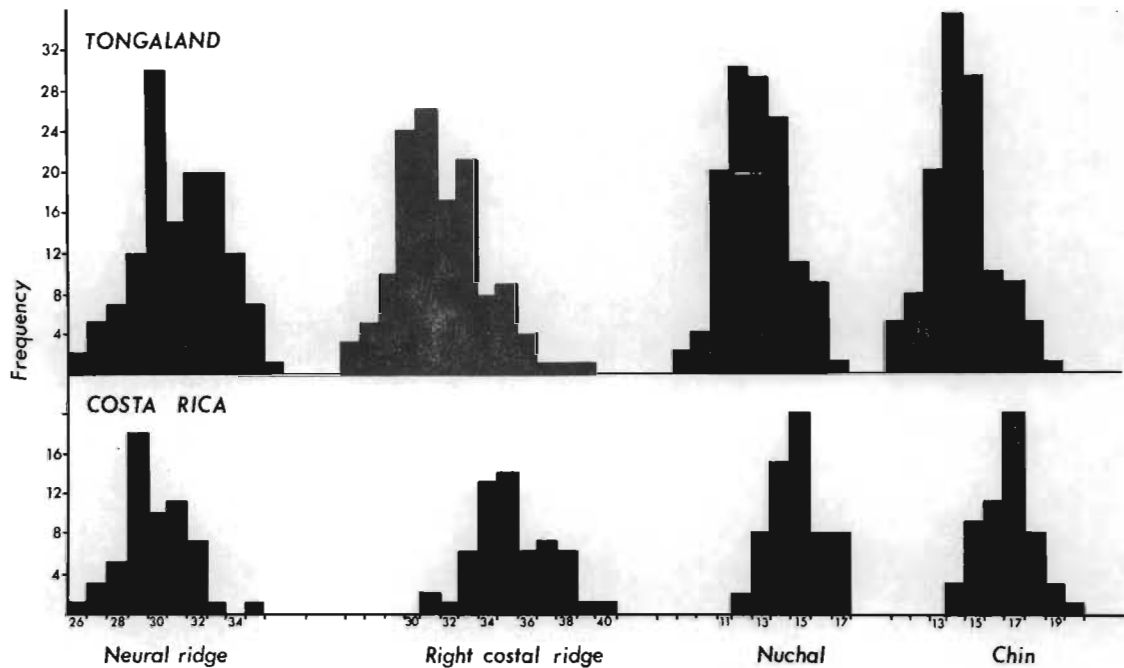


Figure 51. The frequency of four different scale counts in a sample of leatherback hatchlings from 14 clutches in Tongaland, compared with counts from a sample of 84 hatchlings drawn from two clutches in Costa Rica.

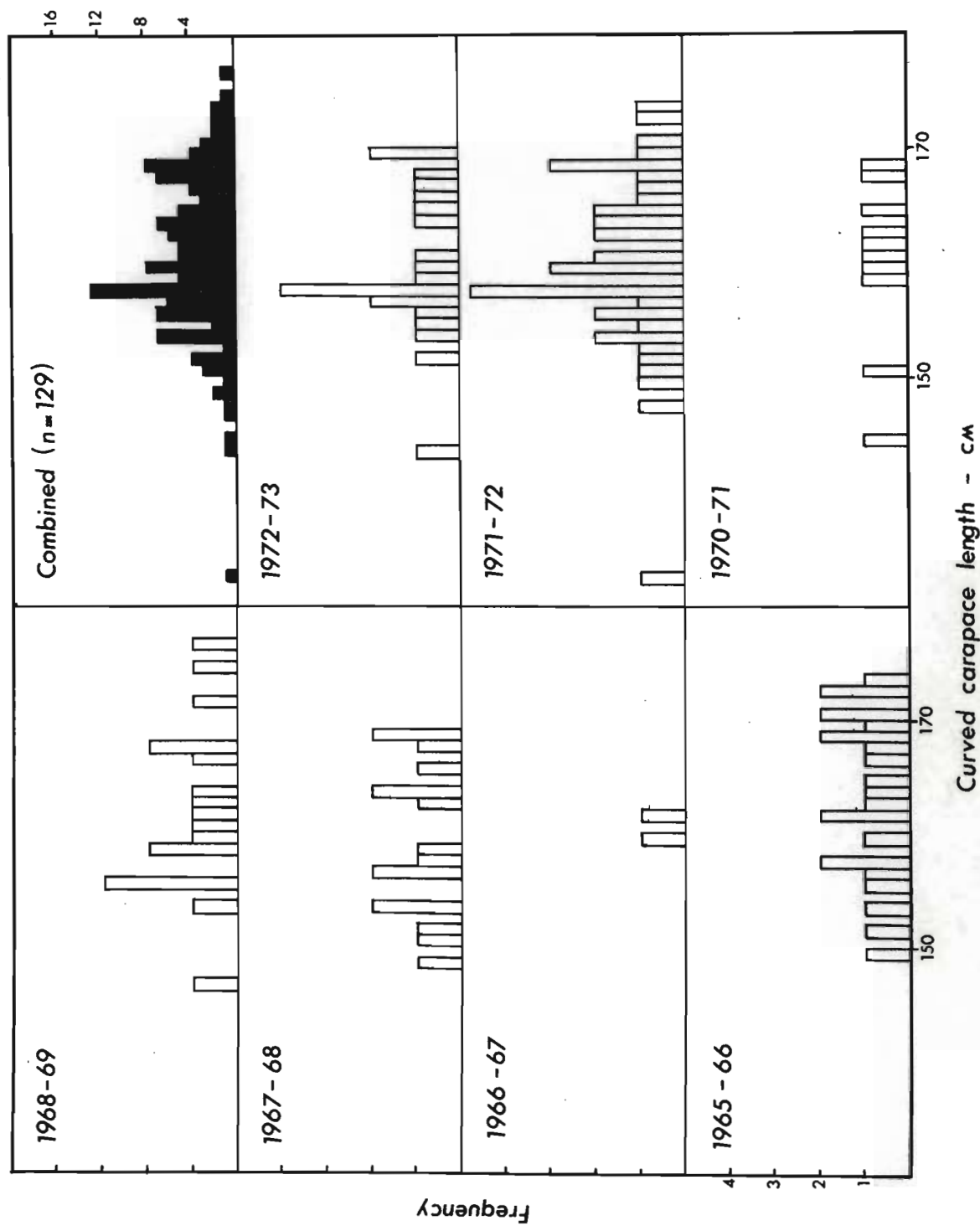


Figure 52. The curved carapace length distribution of leatherback turtles in 7 seasons in Tongaland; and the combined size distribution.

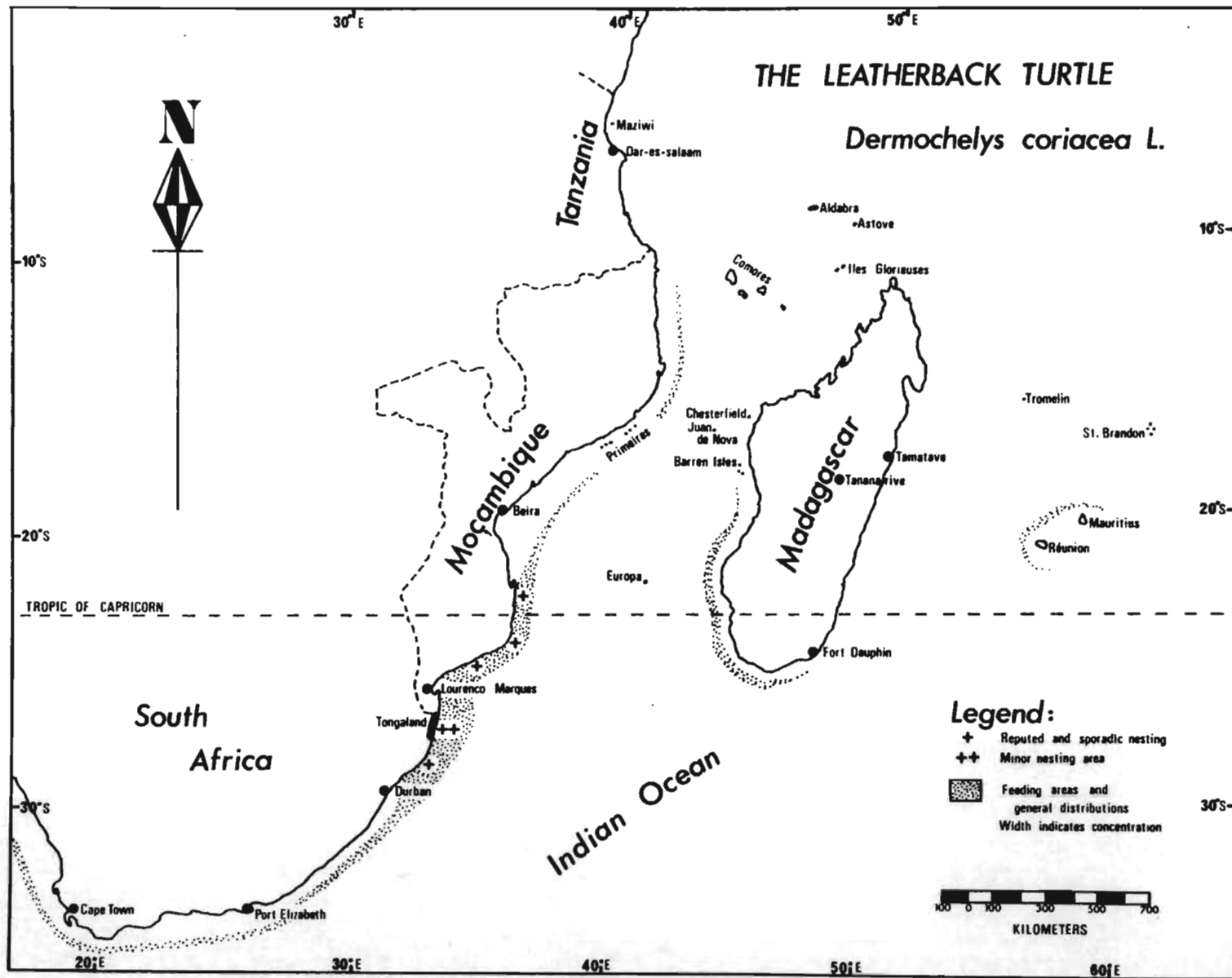


Figure 53. The distribution and nesting areas of the leatherback turtle *Dermochelys coriacea* in the study region. Width of stippling indicates relative abundance.

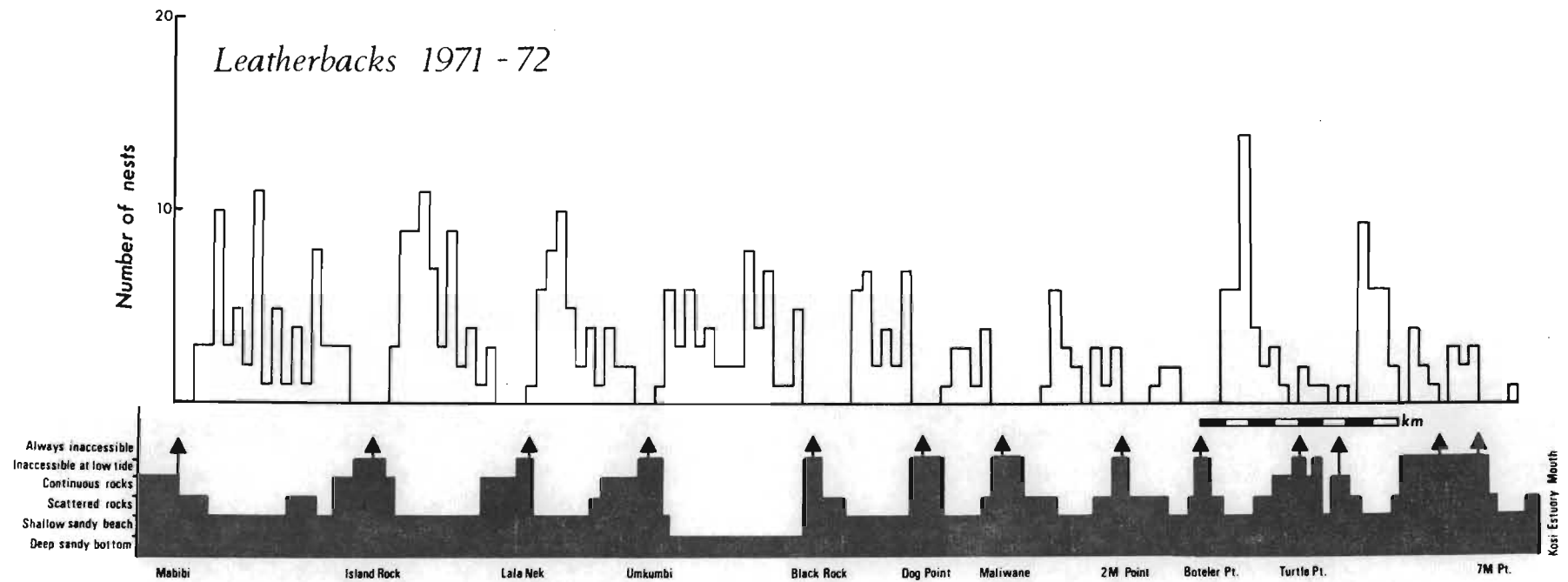


Figure 54. Leatherback nesting activity during the 1971/72 season in Tongaland showing the nature of the littoral zone.

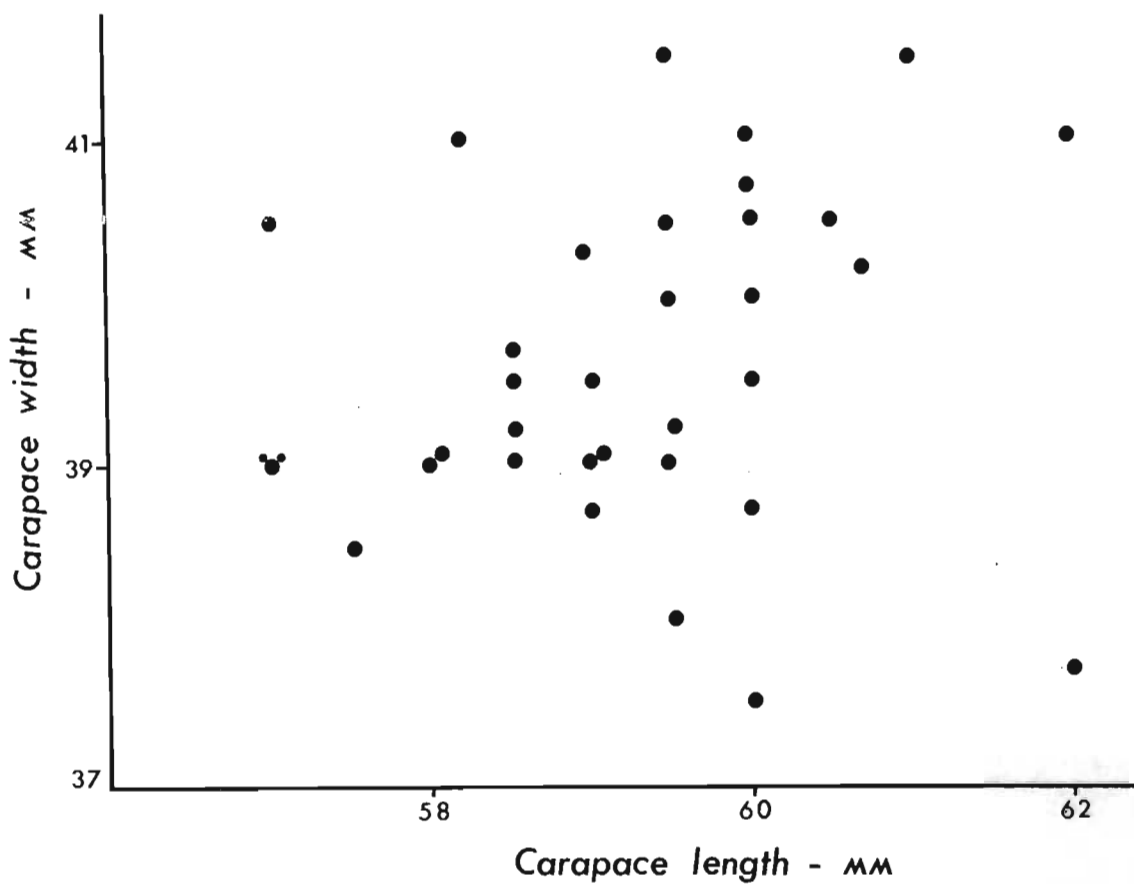


Figure 55. The relationship between carapace length and width in a sample of 38 leatherback hatchlings from Tongaland.

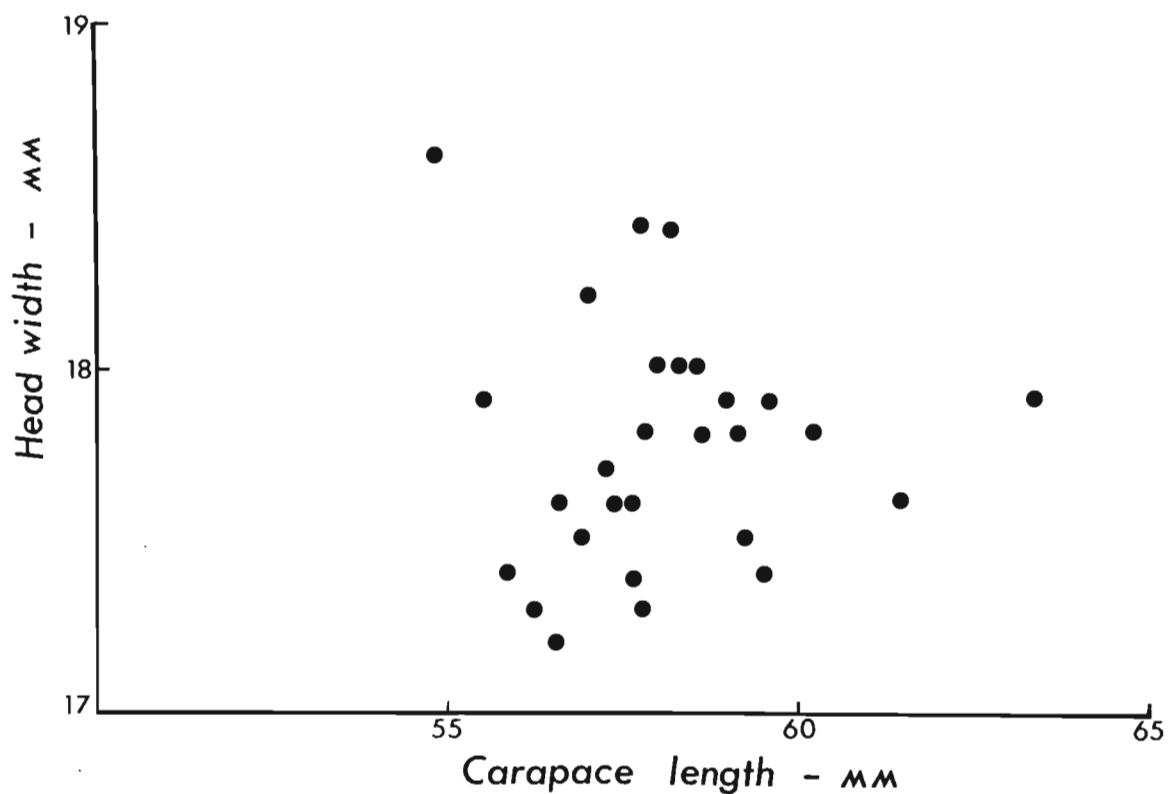


Figure 56. The relationship between carapace length and head width in a sample of 28 leatherback hatchlings from Tongaland.

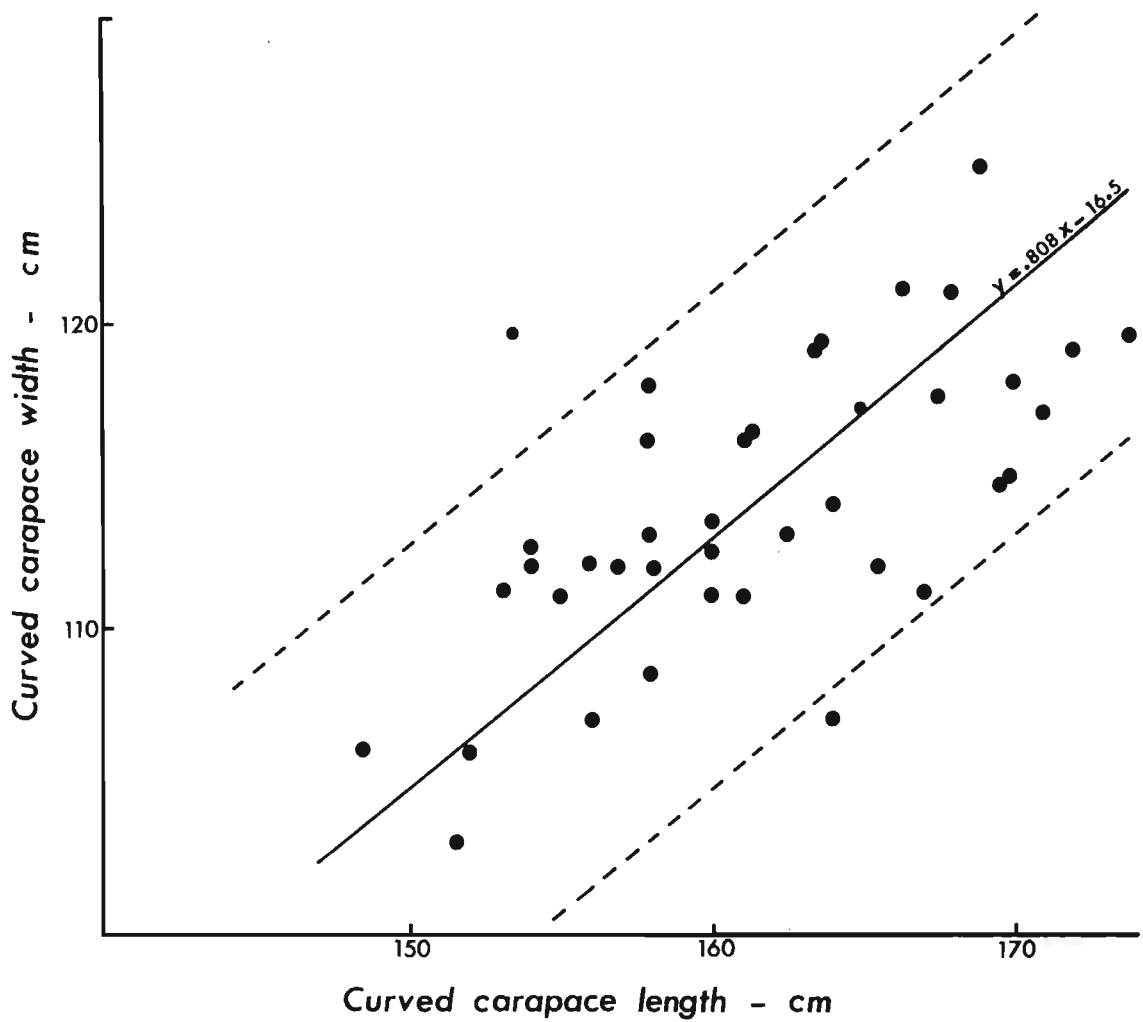


Figure 57. The relationship between curved carapace length and curved carapace width in a sample of 40 leatherback females from Tongaland.

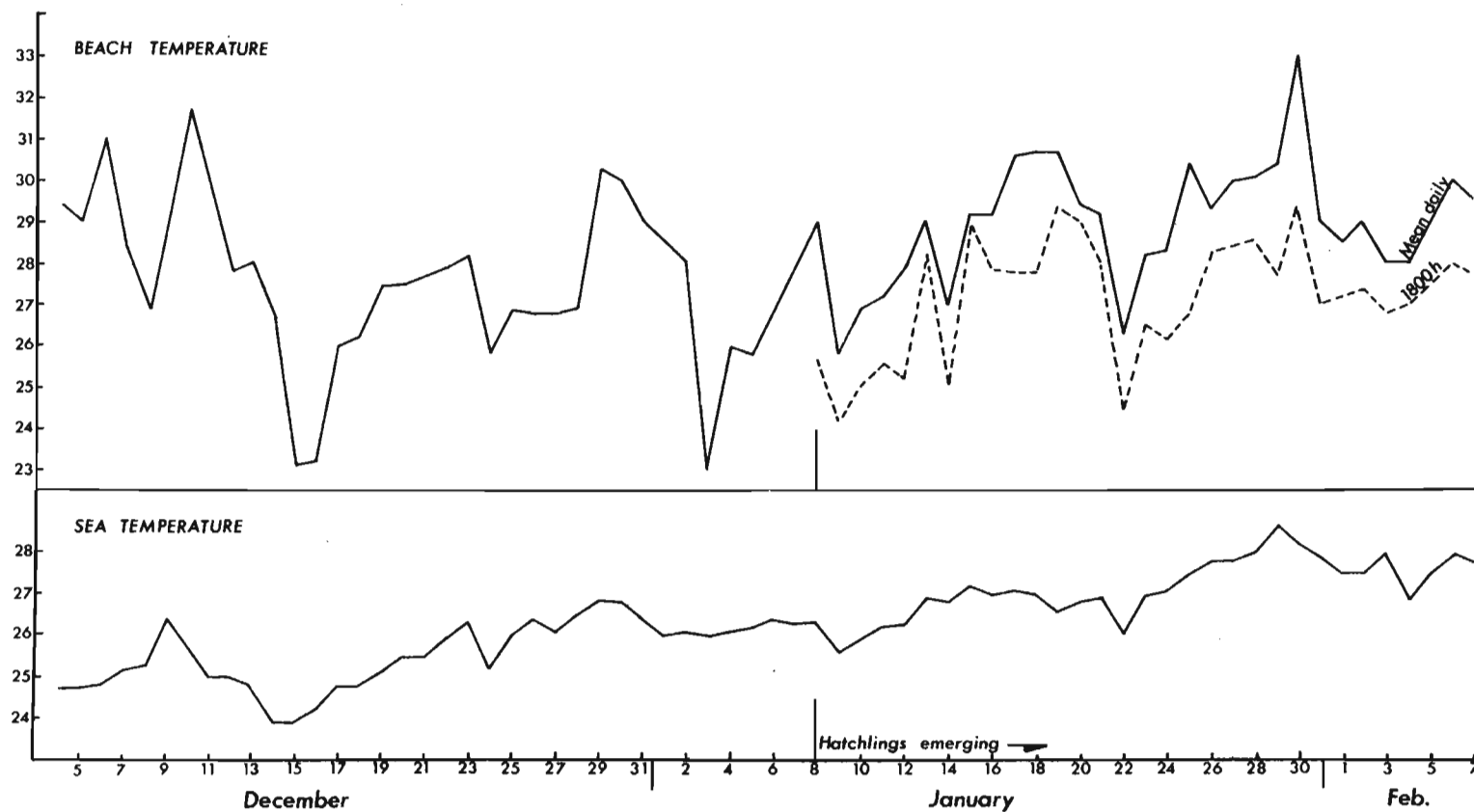


Figure 58. Mean daily sea surface and beach surface temperatures at Bhanga Nek (Boteler Point), Tongaland during part of the 1966/67 season (December 4th-February 7th). The Beach surface temperature at 1800 hrs. from the 8th January is shown as a broken line.

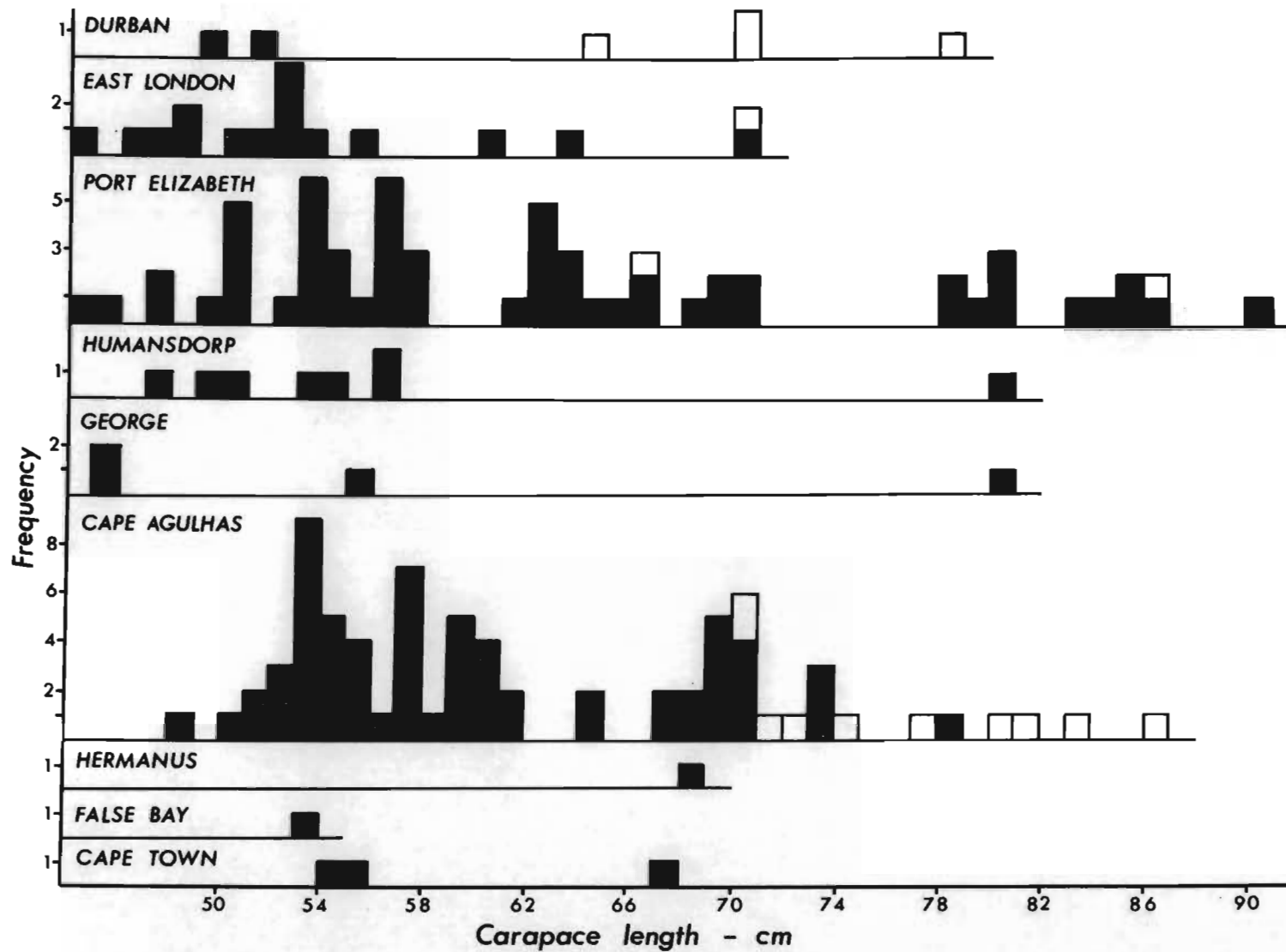


Figure 59. Size distribution of loggerhead (solid blocks) and leatherback (open blocks) hatchlings stranded at various localities in South Africa.

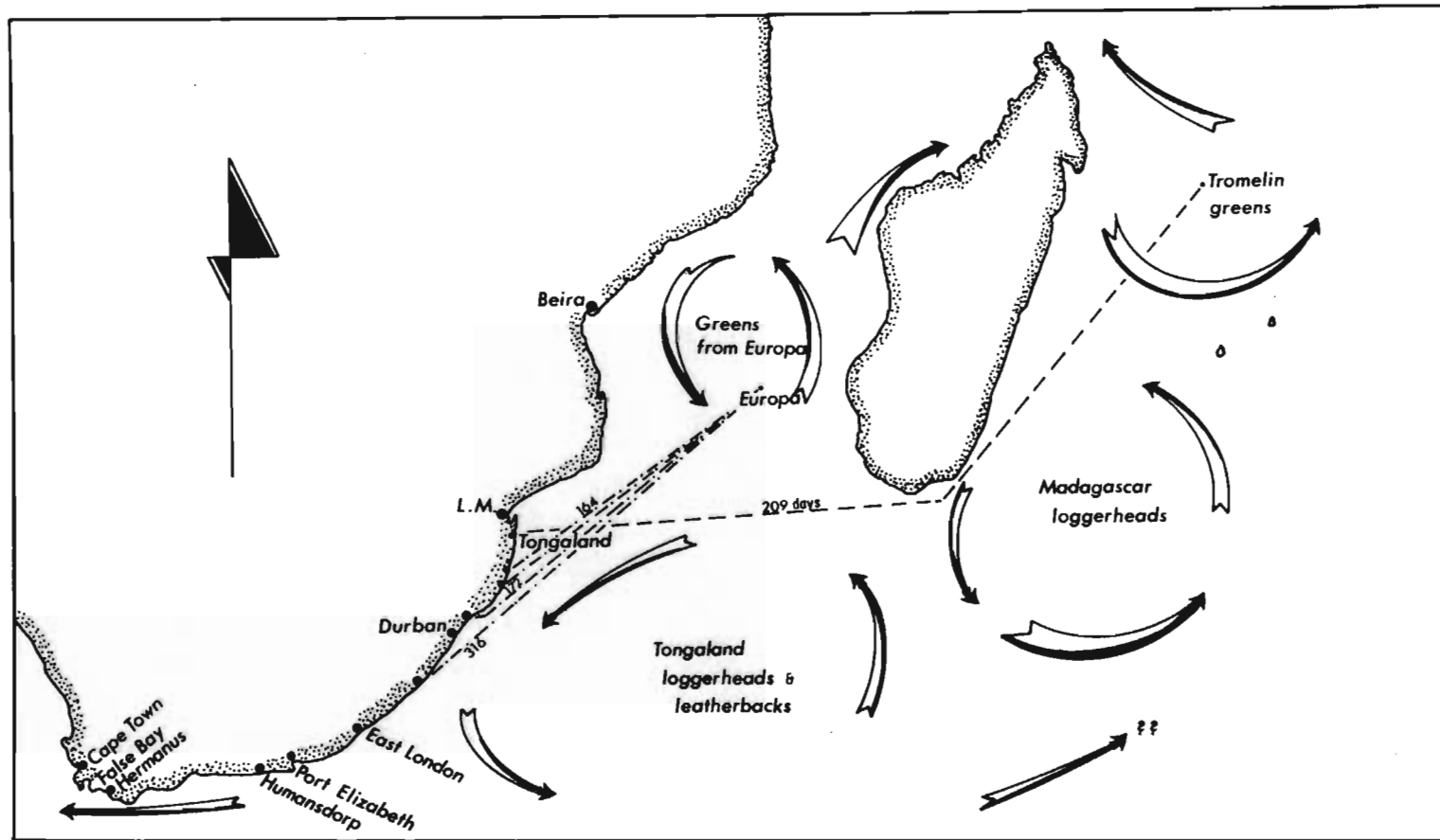


Figure 60. The study region showing localities of hatchling strandings in South Africa; release and recovery points of drift cards released during the present study; and the hypothetical distribution of turtle hatchlings from known nesting areas.

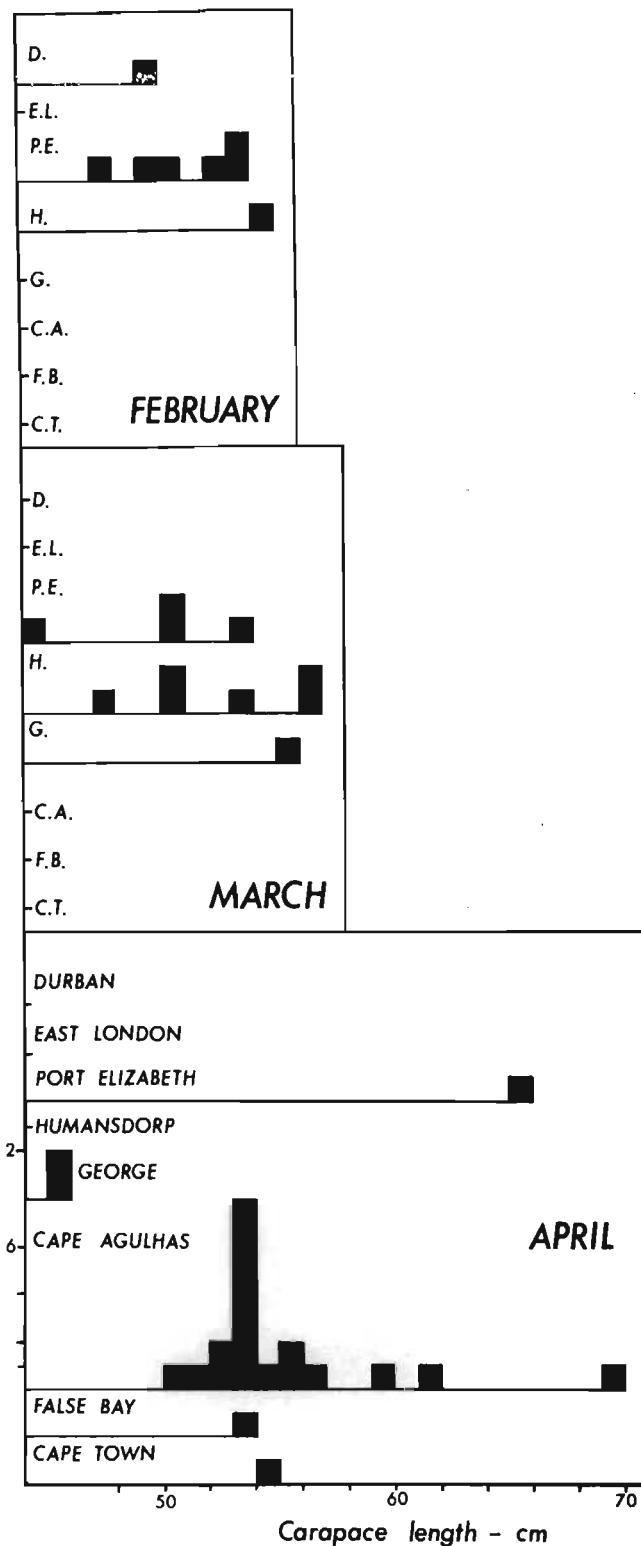


Figure 61. The size distribution of loggerhead hatchlings stranded in South Africa during February, March and April, 1973.

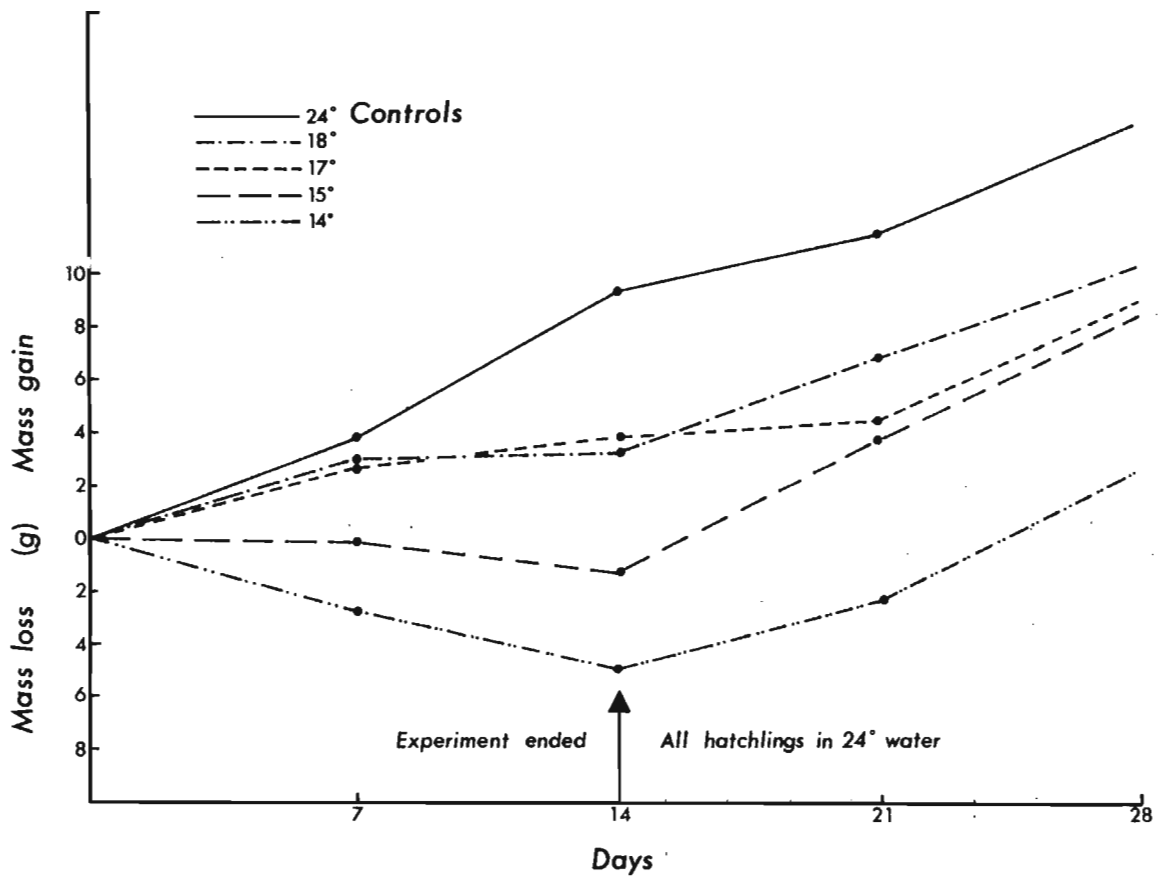


Figure 62. The response, expressed as mass changes, of 5 groups of loggerhead hatchlings to different temperature regimes.

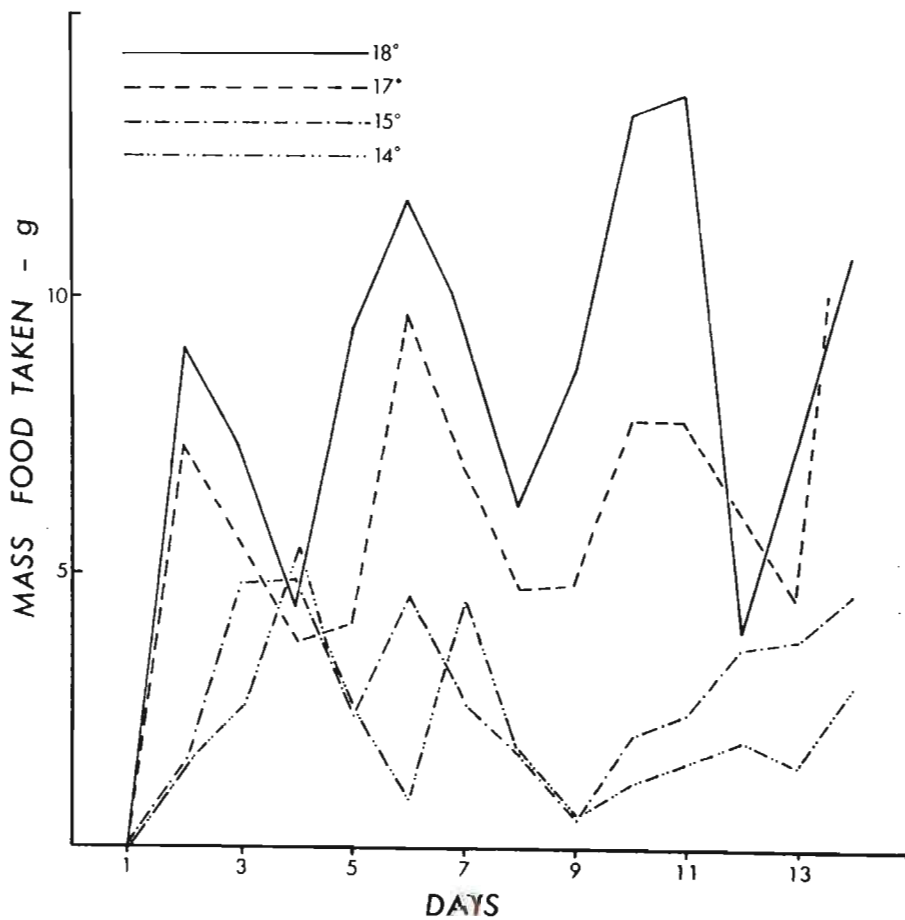


Figure 63. Daily food intake of experimental loggerhead hatchlings in different temperature regimes.

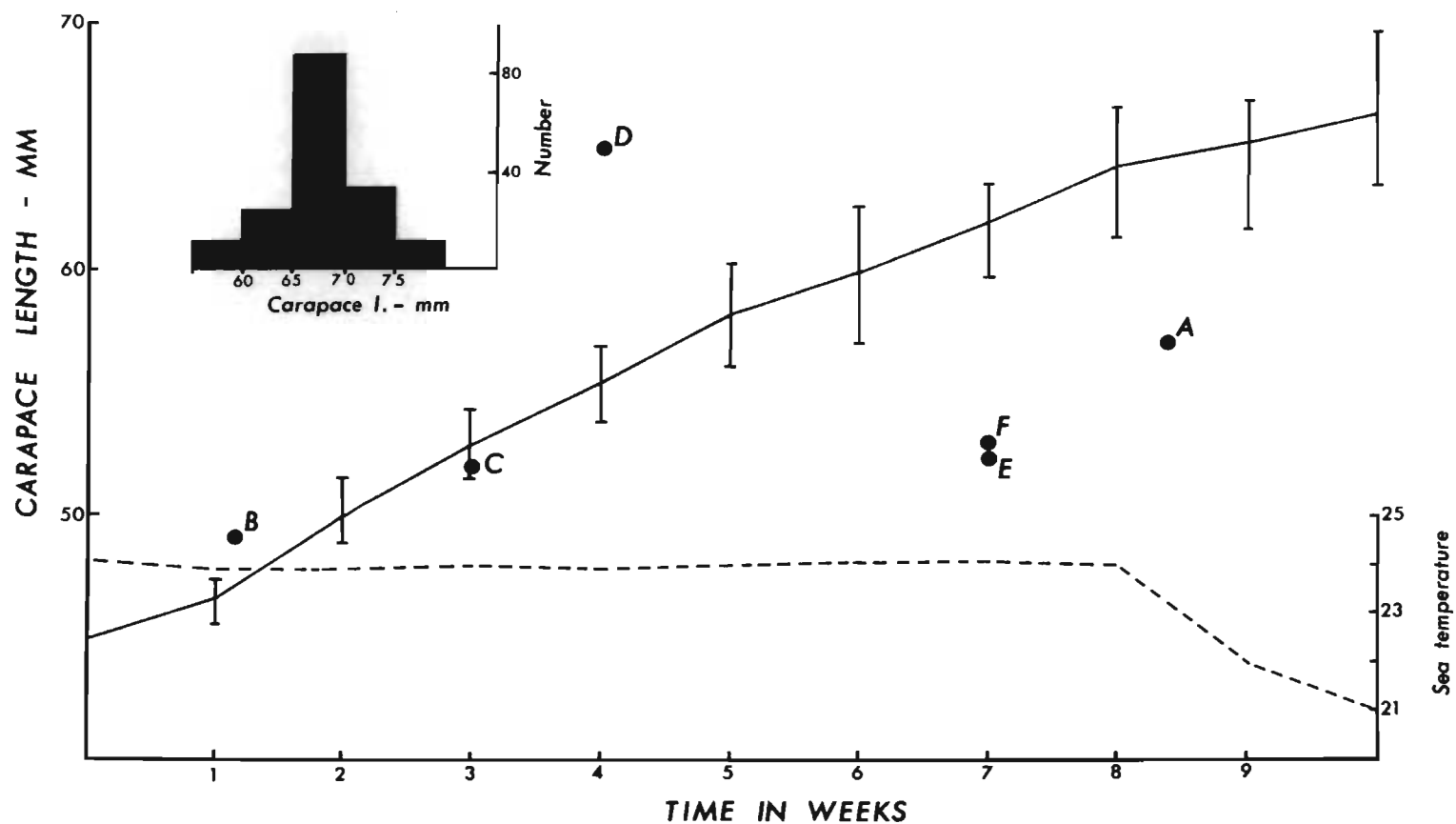


Figure 64. The mean growth rate of a sample of 200 loggerhead hatchlings kept at the Durban Aquarium. Vertical bars indicate ranges. The mean weekly sea temperature is shown as a broken line. Inset is the range of sizes in 168 hatchlings at 12 weeks. Recovered notched hatchlings labelled A-F are shown at their minimum possible age.

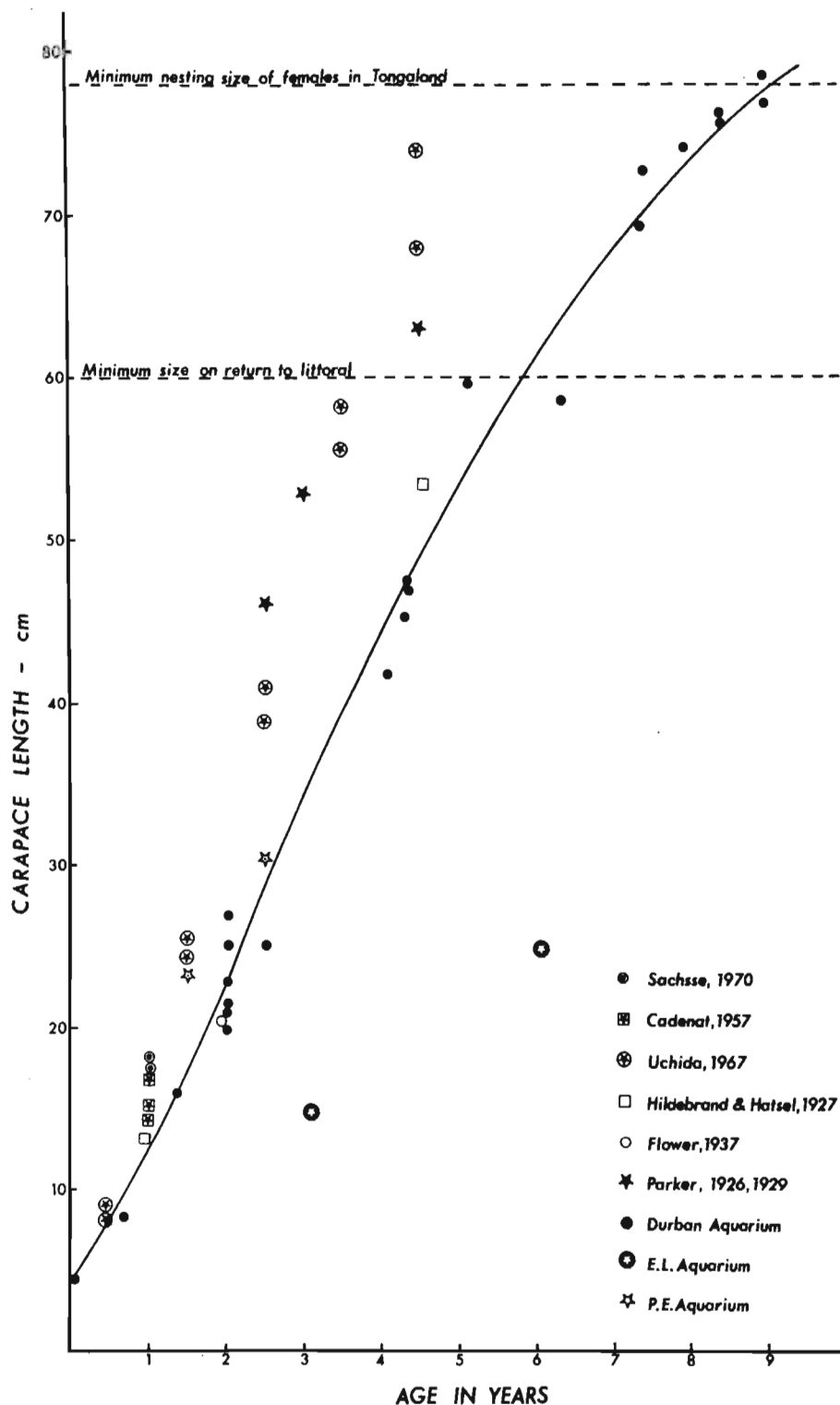


Figure 65. An approximate growth curve for the loggerhead turtle based on data from captive turtles from the Durban Aquarium. Growth rates reported by other investigators are included for comparison.

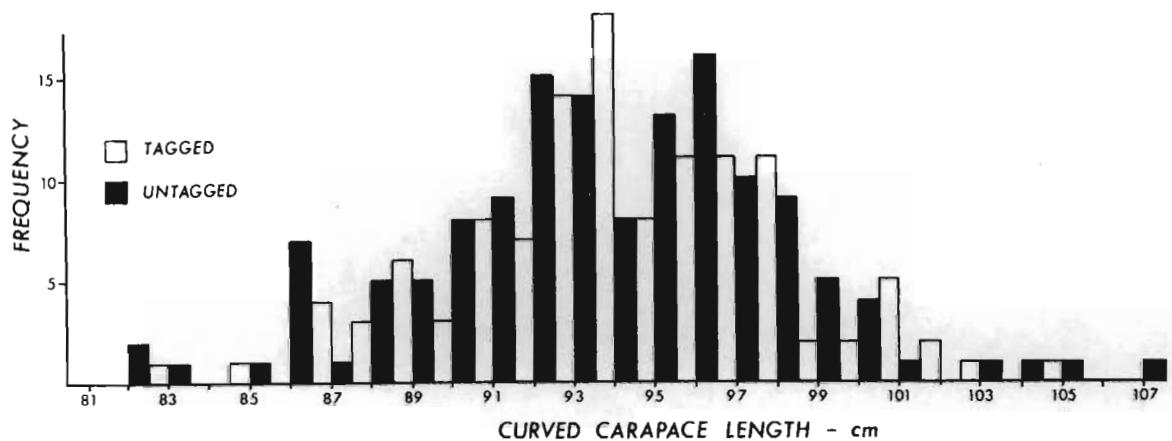
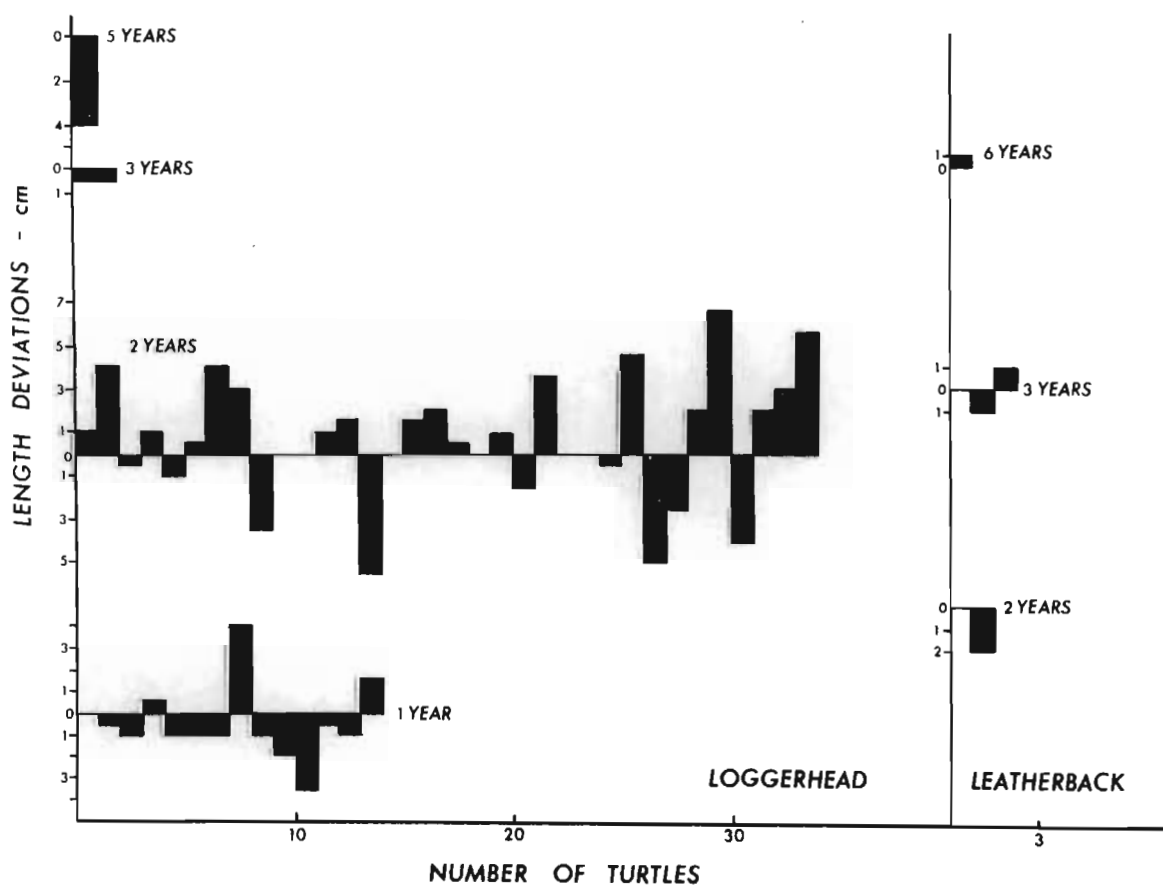


Figure 66. The size distribution of tagged and untagged loggerhead females in Tongaland during the 1972/73 season.



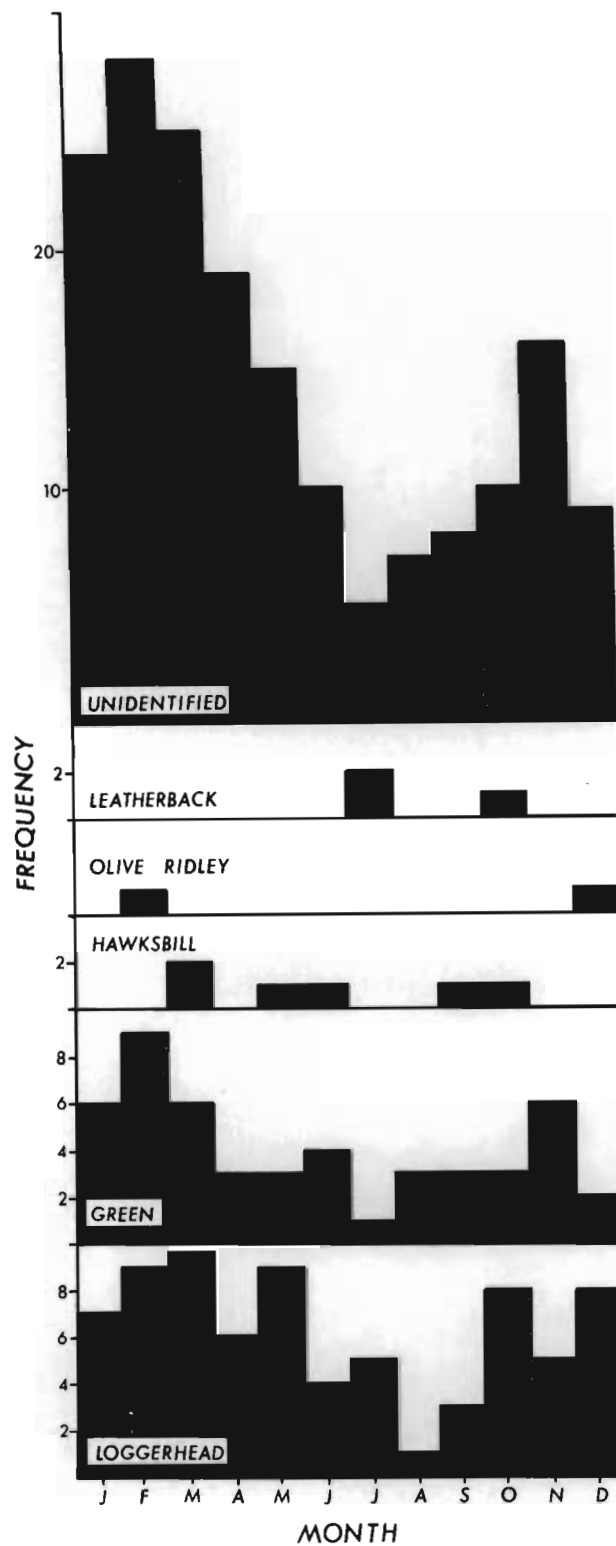


Figure 68. The catches of loggerhead turtles, and other species, in the anti-shark net-work along the Natal coast; 1965-1973.

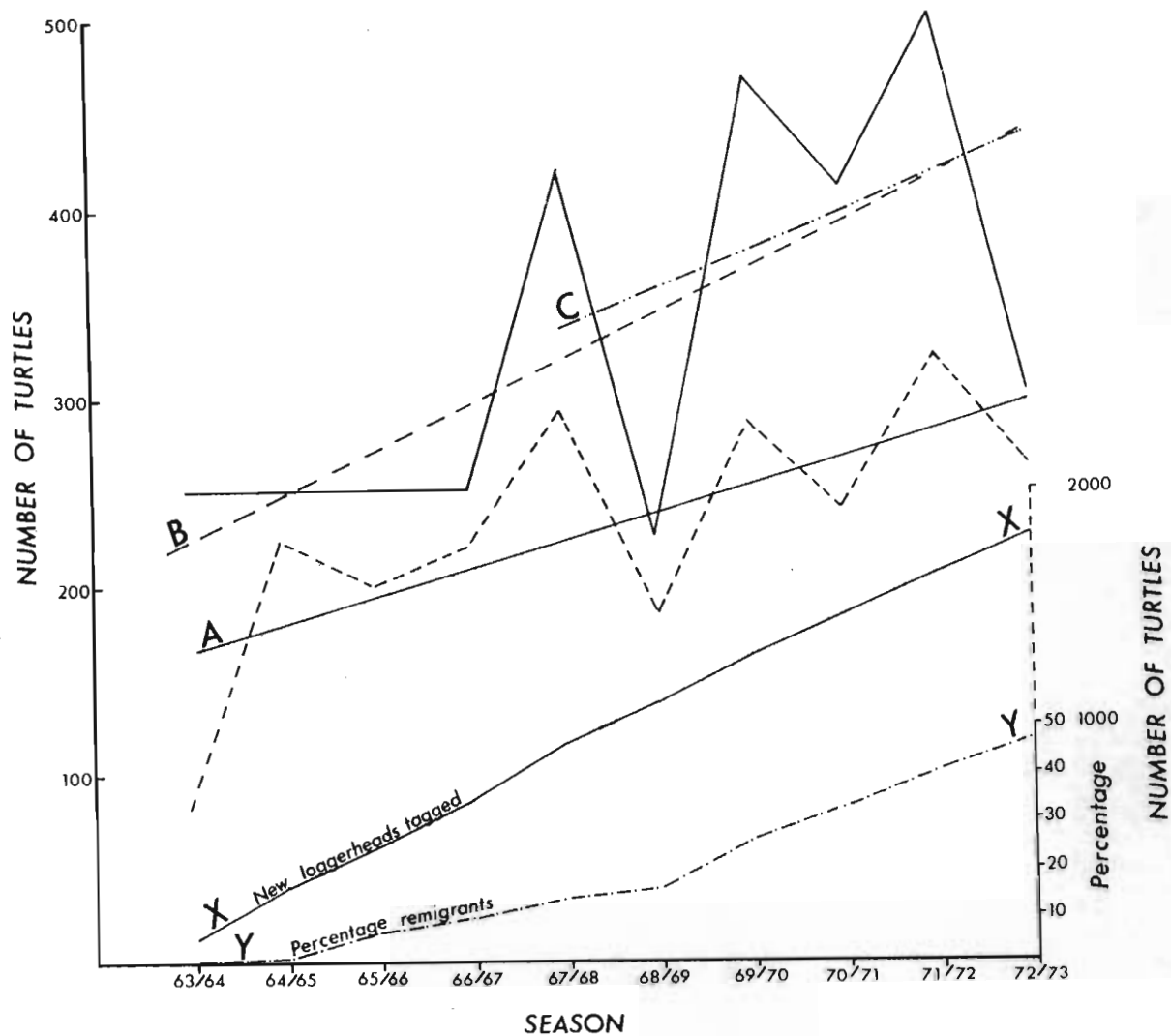


Figure 69. (i) The estimated total annual nesting populations of female loggerhead turtles in the Tongaland protected area; 1963-1972 (solid line) with trend lines B and C (see text).
 (ii) The seasonal totals of loggerhead females encountered since 1963 (broken line) with trend line A.
 (iii) The cumulative number of new females tagged since 1963 (line X).
 (iv) The increasing percentage of remigrant loggerhead females found each season since 1964 (line Y).

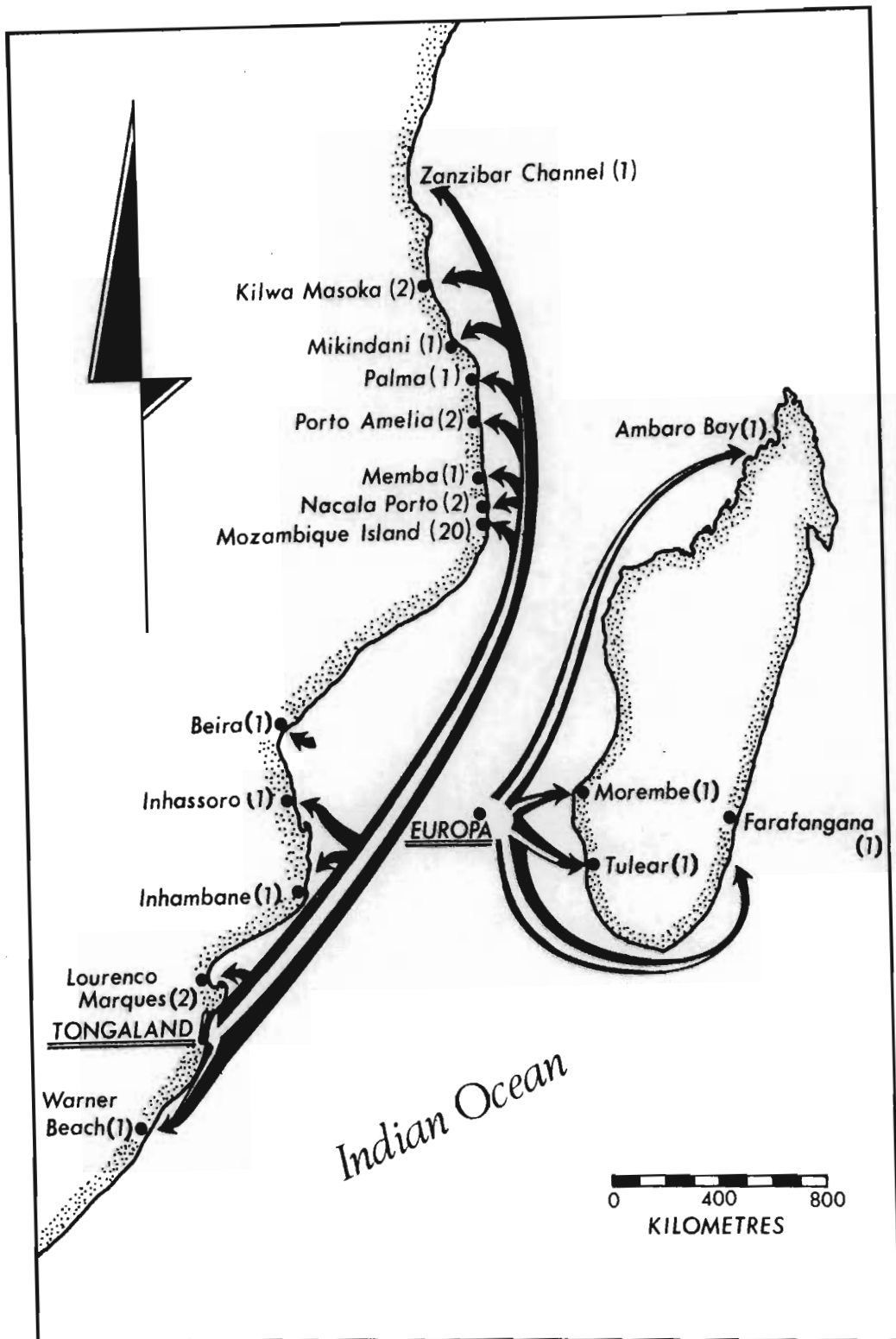


Figure 70. Extra-nesting area recoveries of loggerhead turtles tagged in Tongaland; and of green turtles tagged on Europa Island. One leatherback turtle, tagged in Tongaland, has been recovered near Beira.

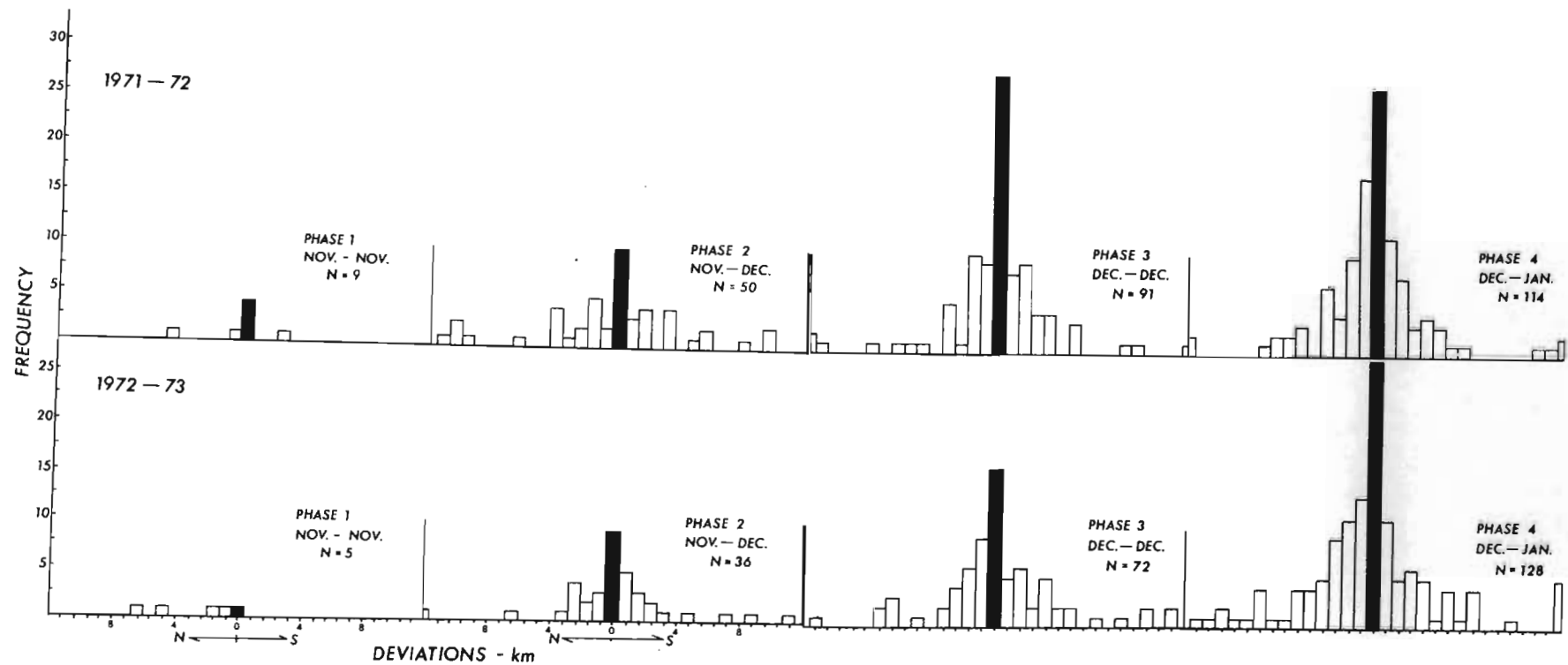


Figure 71. The spatial intervals between emergences of loggerhead turtles during two seasons in Tongaland.

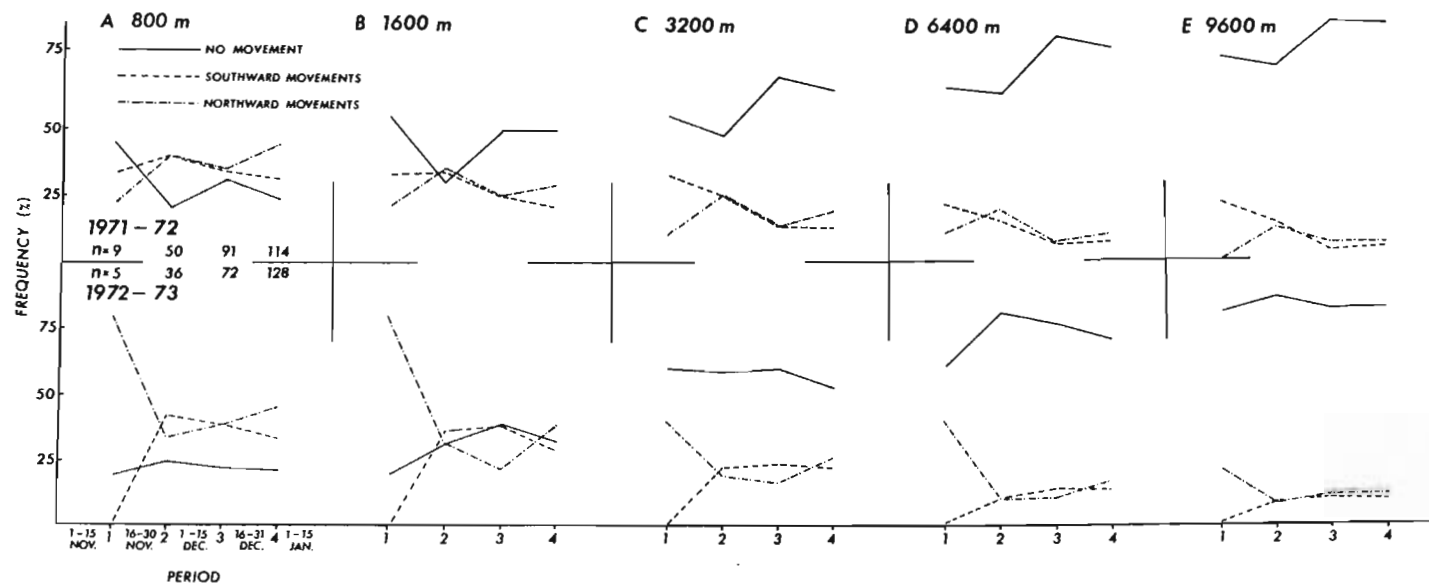


Figure 72. The movement and site tenacity of loggerhead females during the 1971/72 seasons and 1972/73 seasons expressed as percentages at four phases of each season (see text) and at five zonal widths.

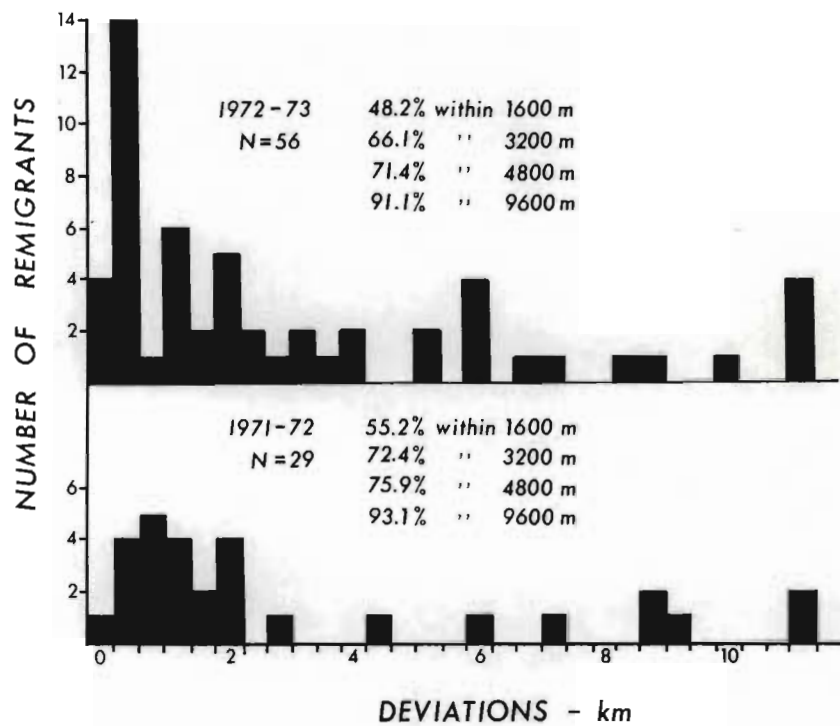


Figure 73. Deviations in km from the site of original encounter of remigrant loggerhead females from the 1971/72 and 1972/73 seasons.

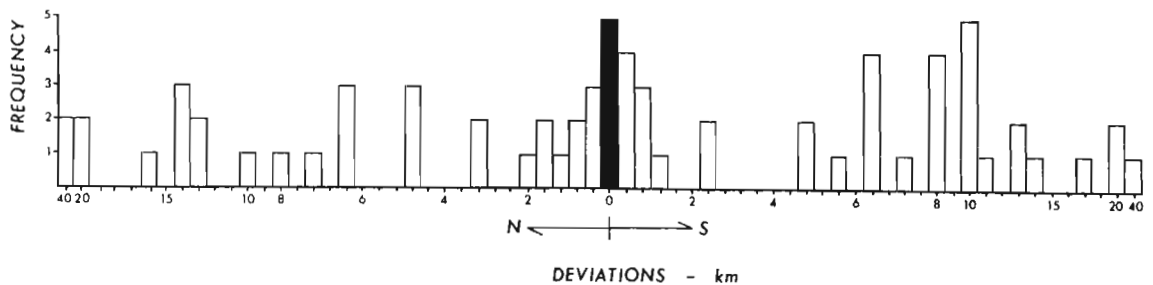


Figure 74. Deviations in km between the emergences of leatherback turtles in Tongaland; 1963-1973.

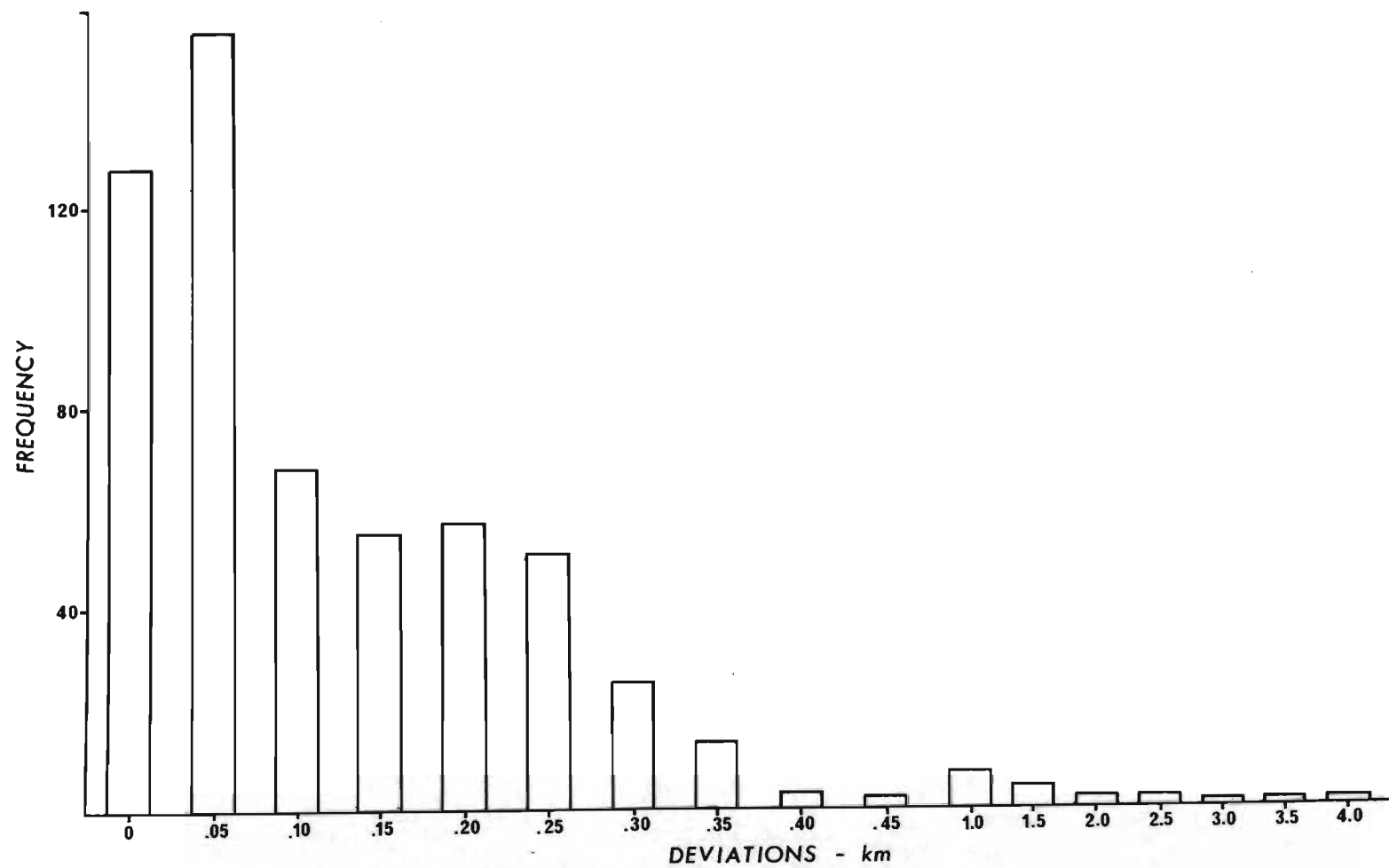


Figure 75. Observed deviations (in km) of green turtle females from the site of their previous emergence on Europa Island, November to December, 1970.

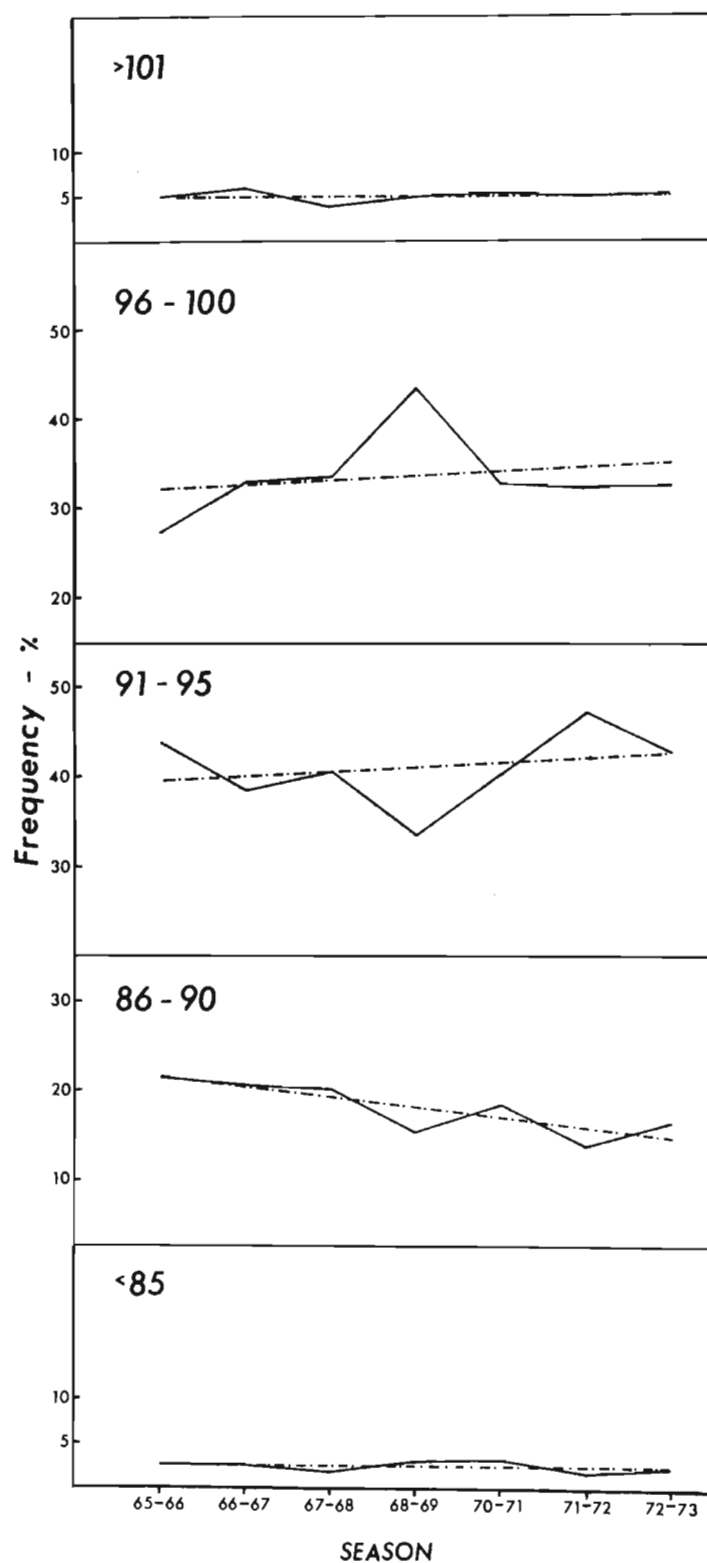


Figure 76. Size class compositions, with trendlines, of seven seasonal nesting populations of loggerhead females in Tongaland.

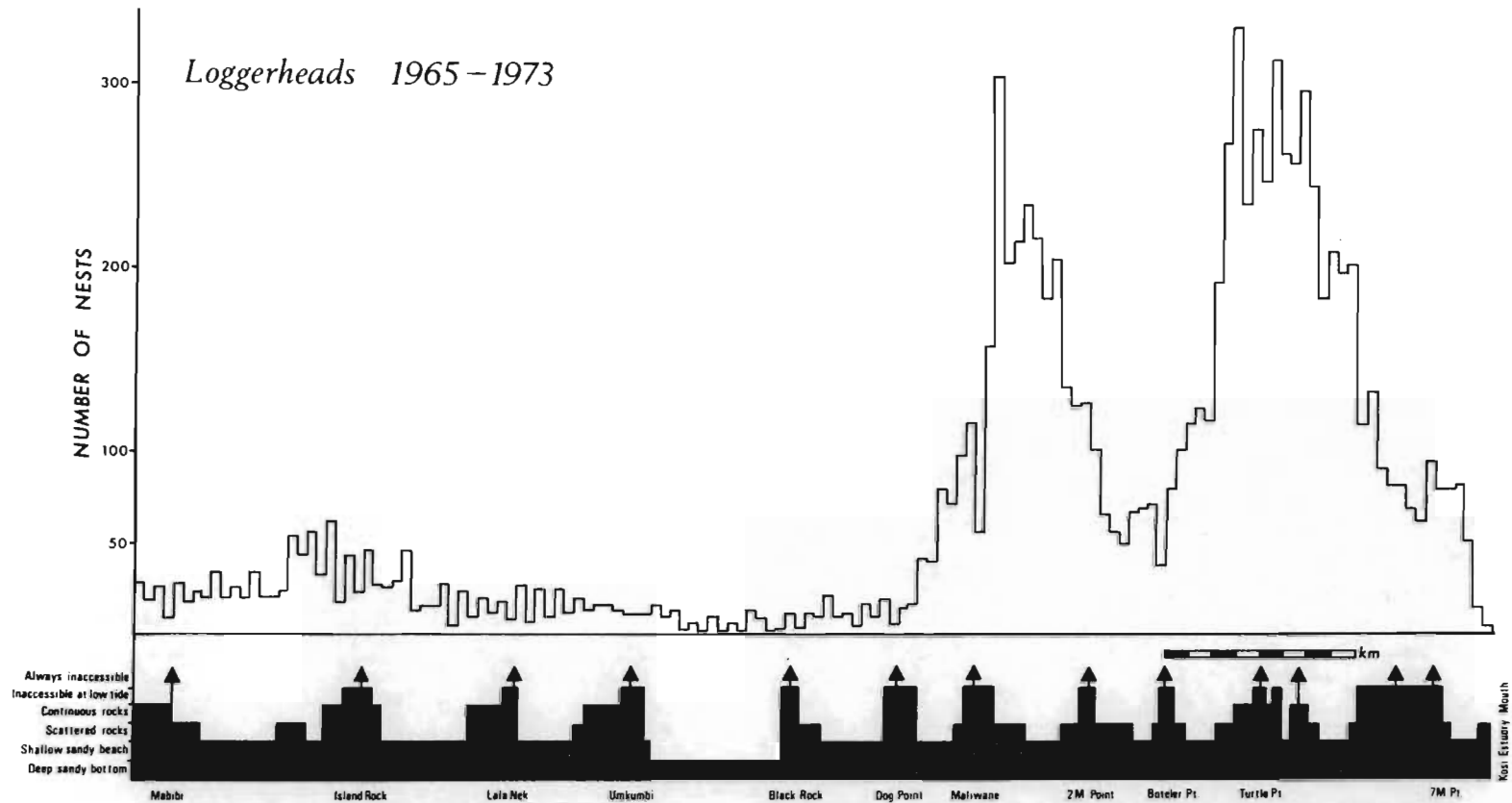


Figure 77. Loggerhead nesting activity in 8 seasons from 1965/66 to 1972/73. Distances in 400m intervals.

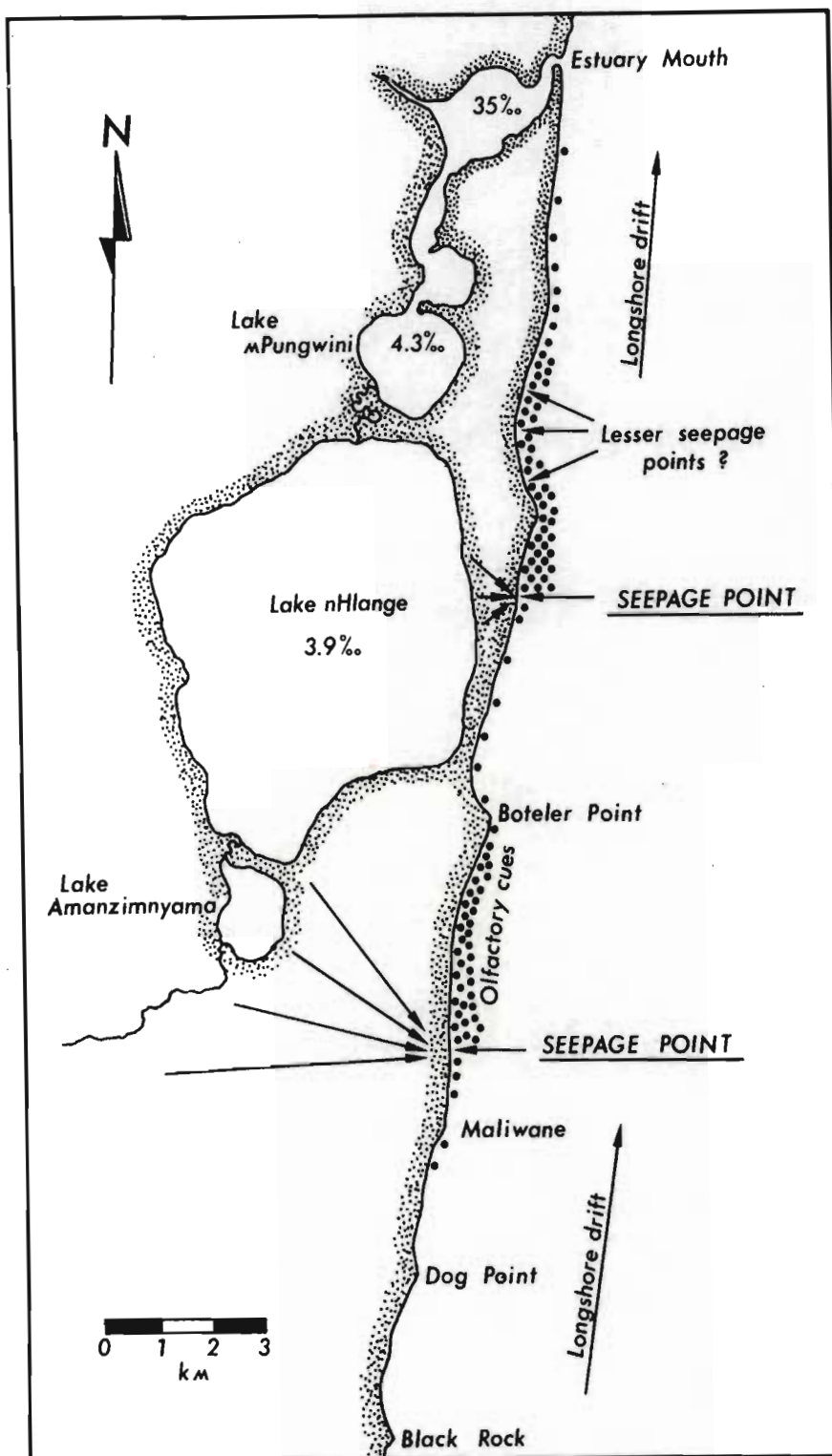


Figure 78. The high density loggerhead nesting areas in Tongaland showing their position in relation to the Kosi Bay lake system with the hypothetical seepage points and northward distribution of the olfactory cue (see text for details).

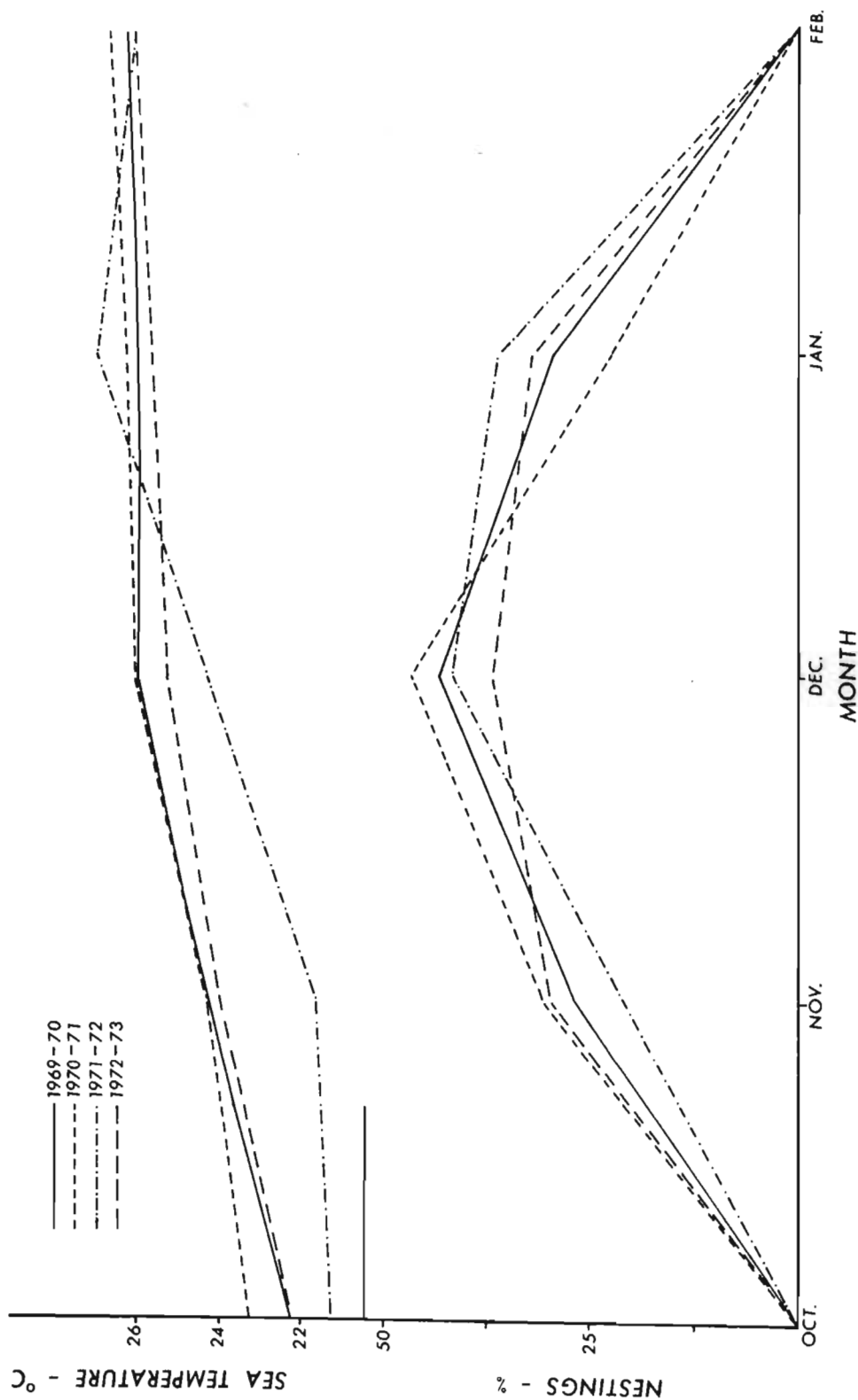


Figure 79. Monthly loggerhead nesting records, expressed as percentages for the seasons 1969/70, 1970/71, 1971/72 and 1972/73 compared with the corresponding mean monthly sea surface temperature records.

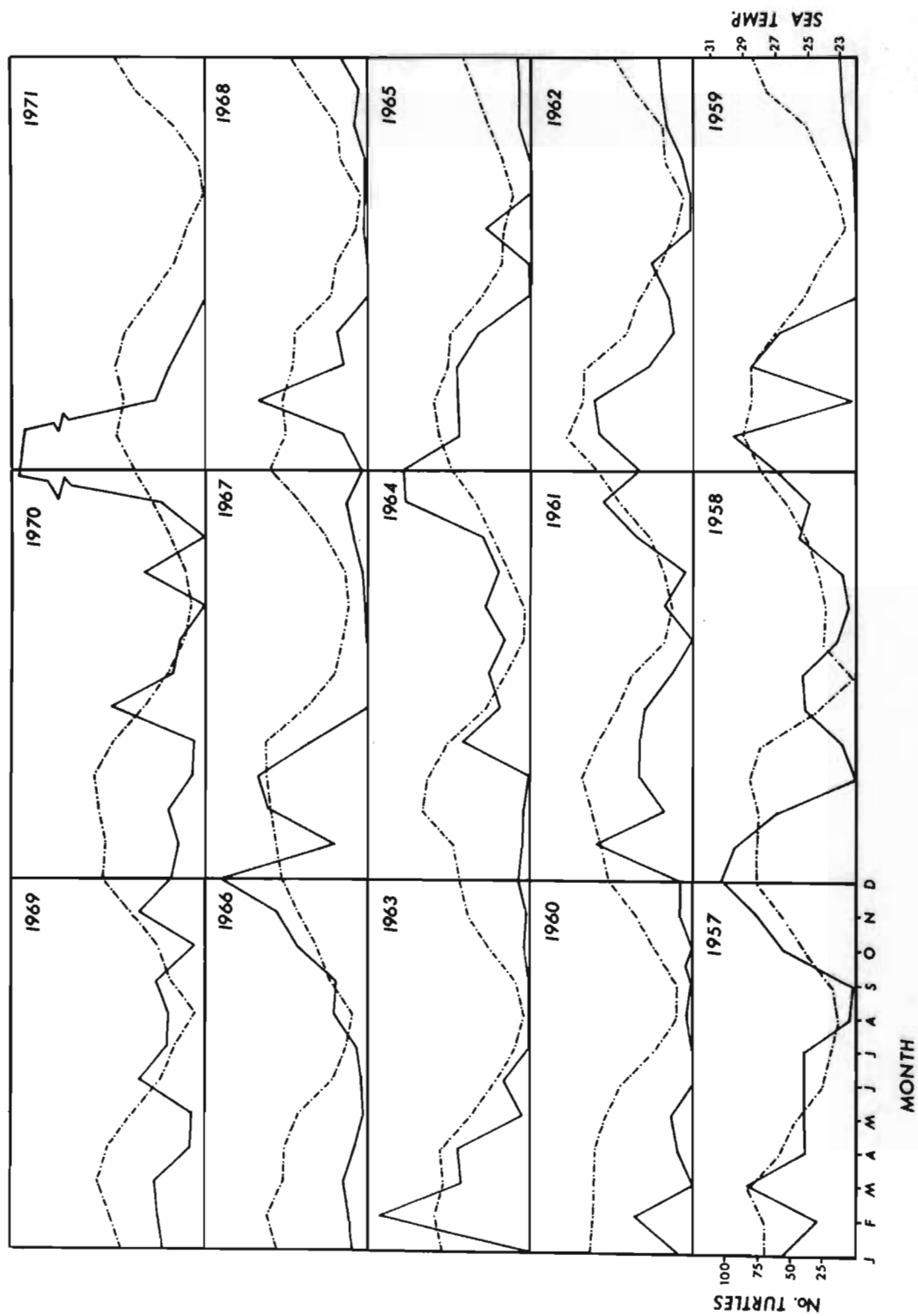


Figure 80. The monthly distribution of sea surface temperatures over 15 years (broken line) with the monthly green turtle exploitation figures (solid line) from the St. Brandon Islands.

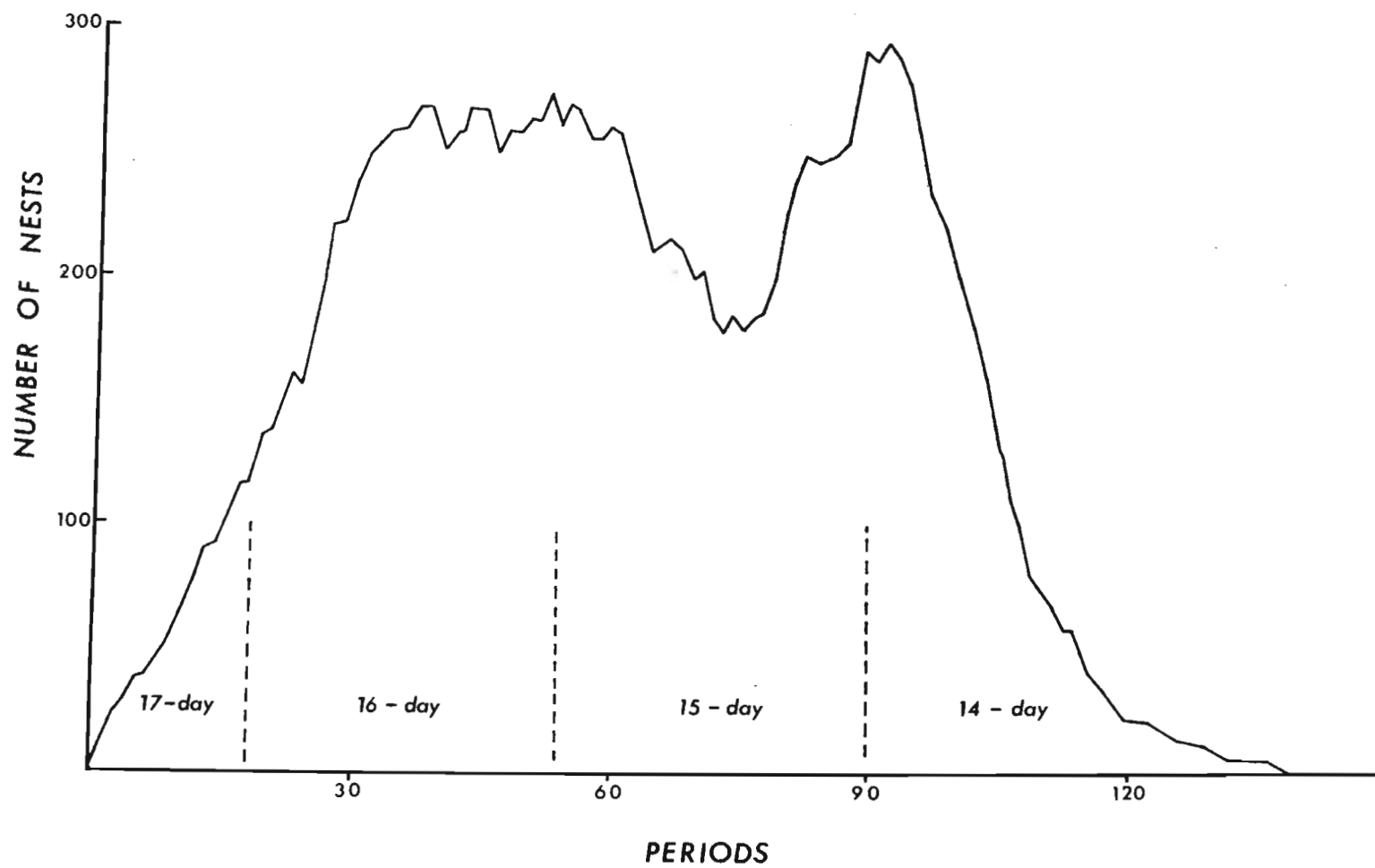


Figure 81. The cumulative nesting records of loggerhead females for the 1972/73 season. See text for details.

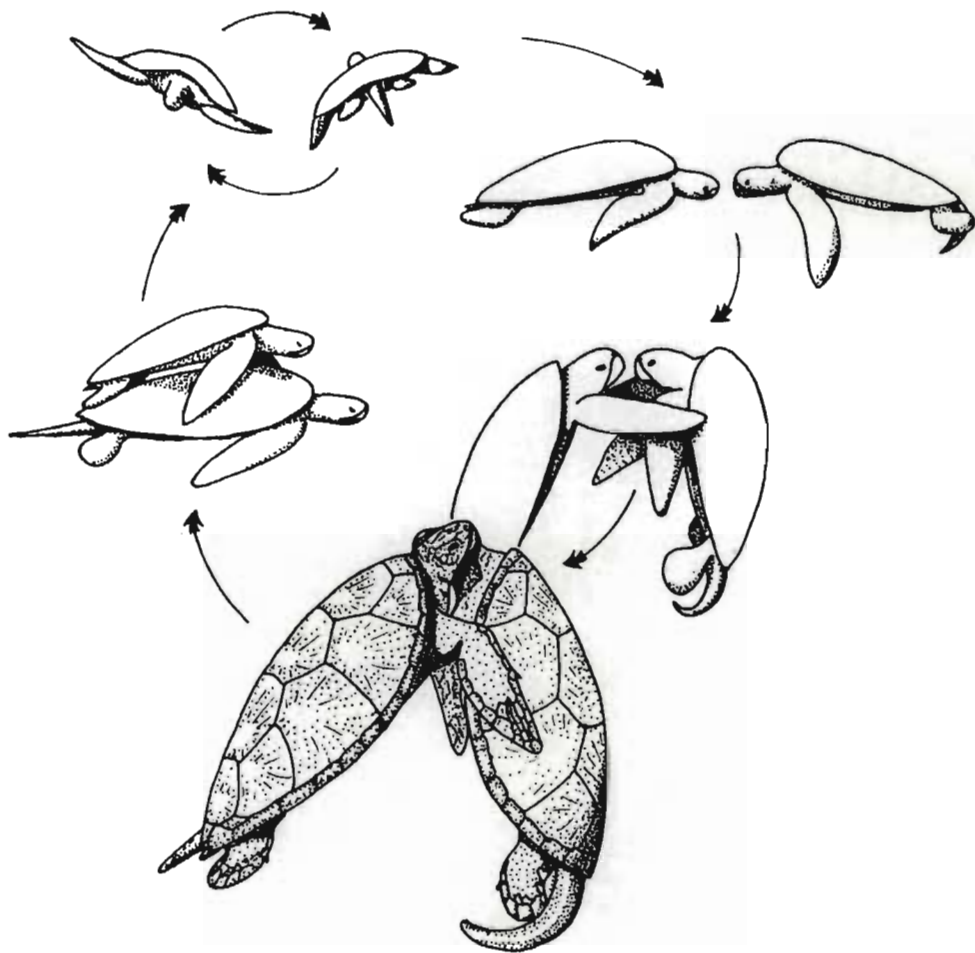


Figure 82. Five stages in the possible courtship behaviour of green turtles at Europa Island.

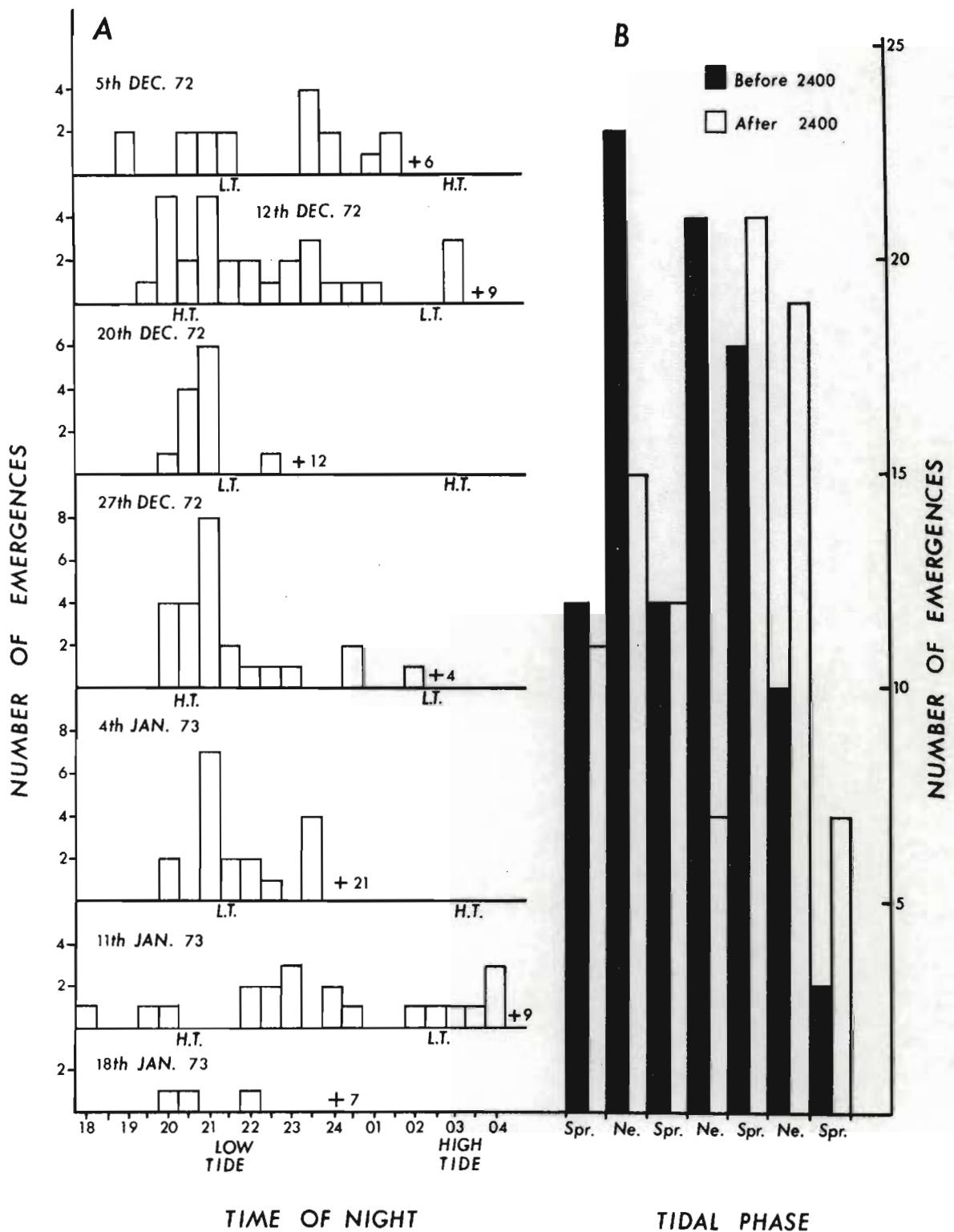


Figure 83. The distribution of loggerhead nesting activity on the peak spring and full neap tide periods during December, 1972 and January, 1973. A, the exact time of emergence; B, expressed as before and after midnight.

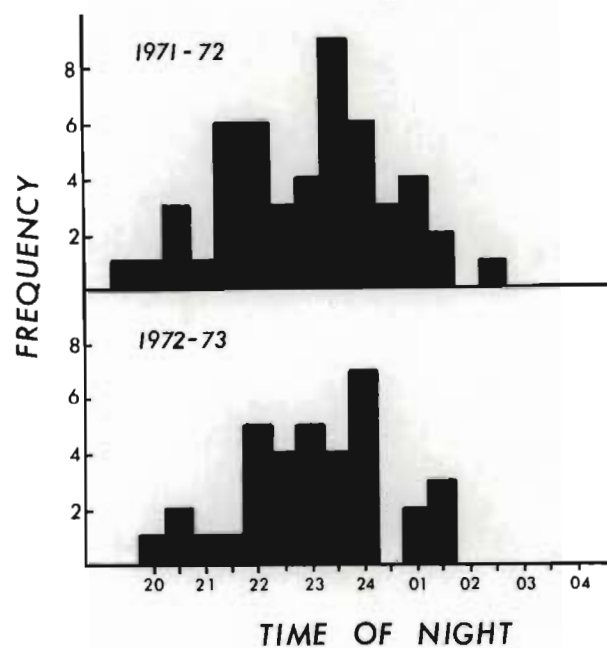


Figure 84. The frequency of leatherback nesting emergences in Tongaland during the 1971/72 and 1972/73 seasons.

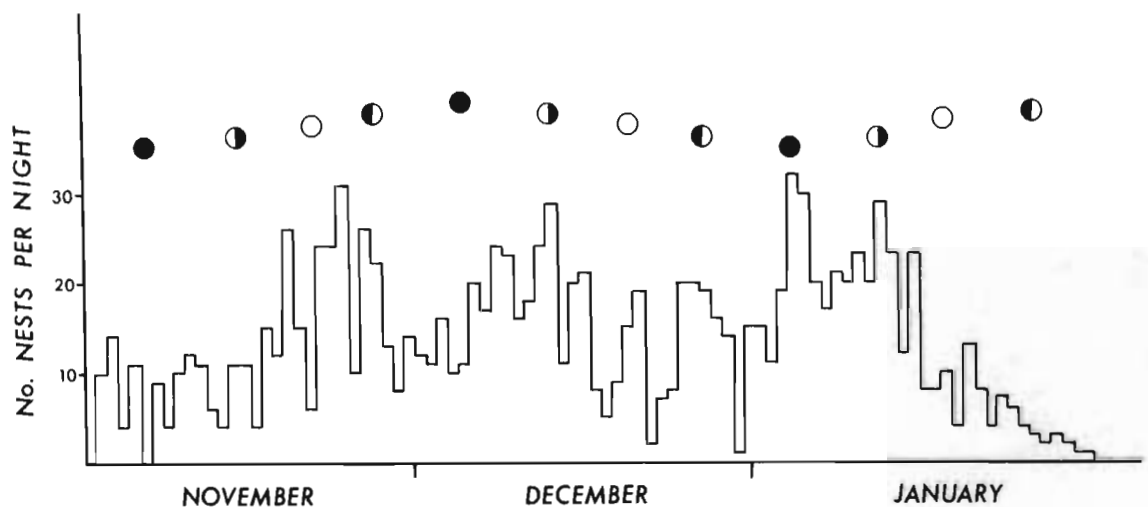


Figure 85. The nightly nesting activity of loggerheads during the 1972/73 season, with the moon phases in November, December and January.

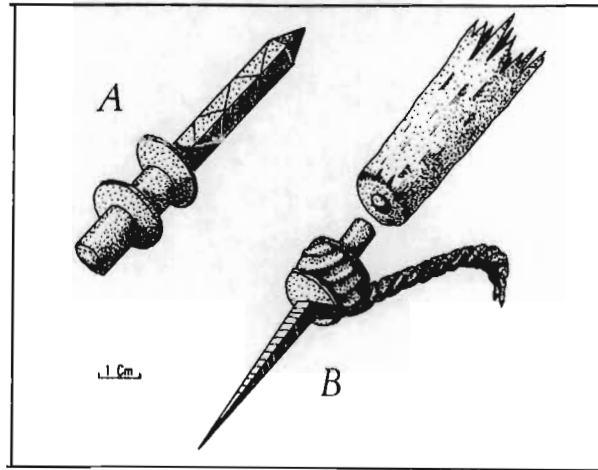


Figure 86. The Johnkin harpoon. A. The harpoon head as purchased in Mauritius; B. An example of a harpoon head after being altered by fishermen.

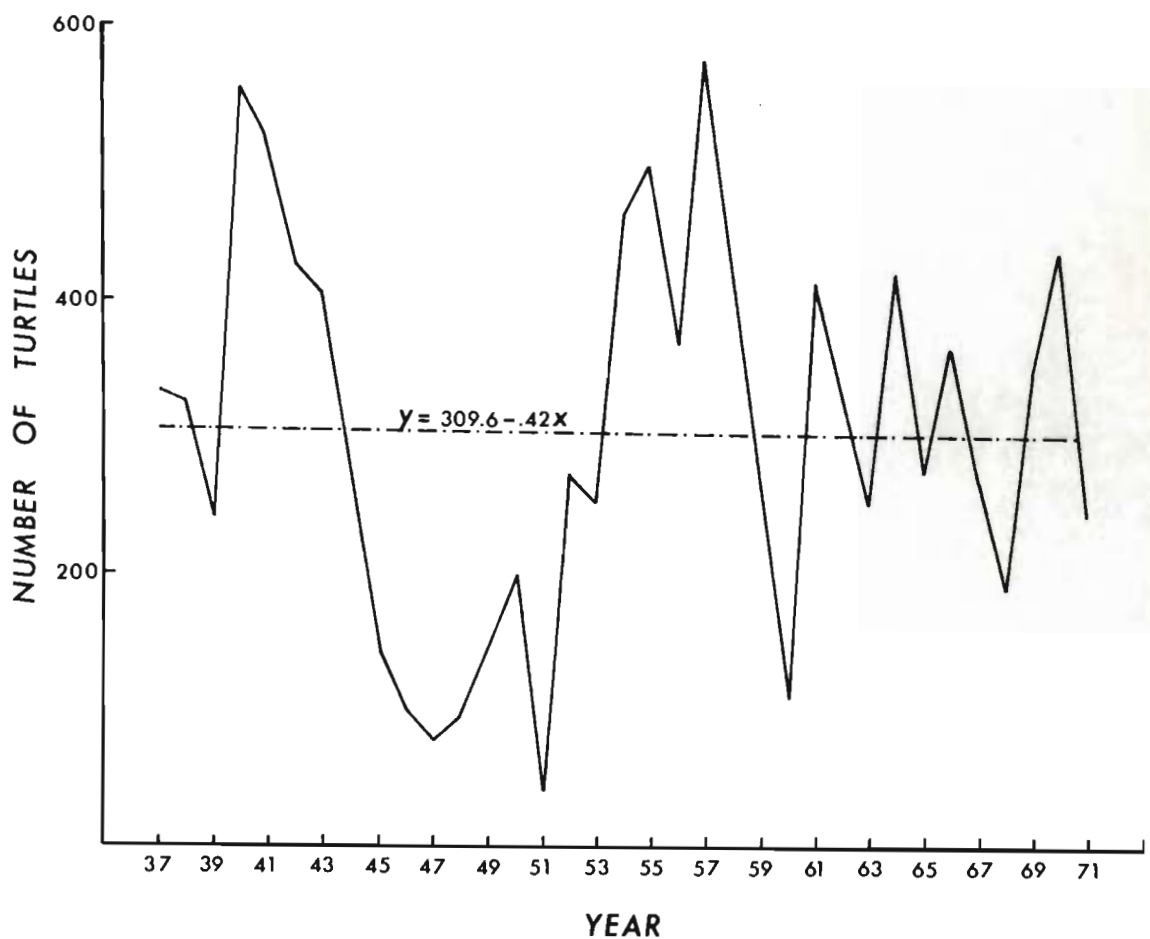


Figure 87. The annual green turtle catch on the St. Brandon Islands since 1937.

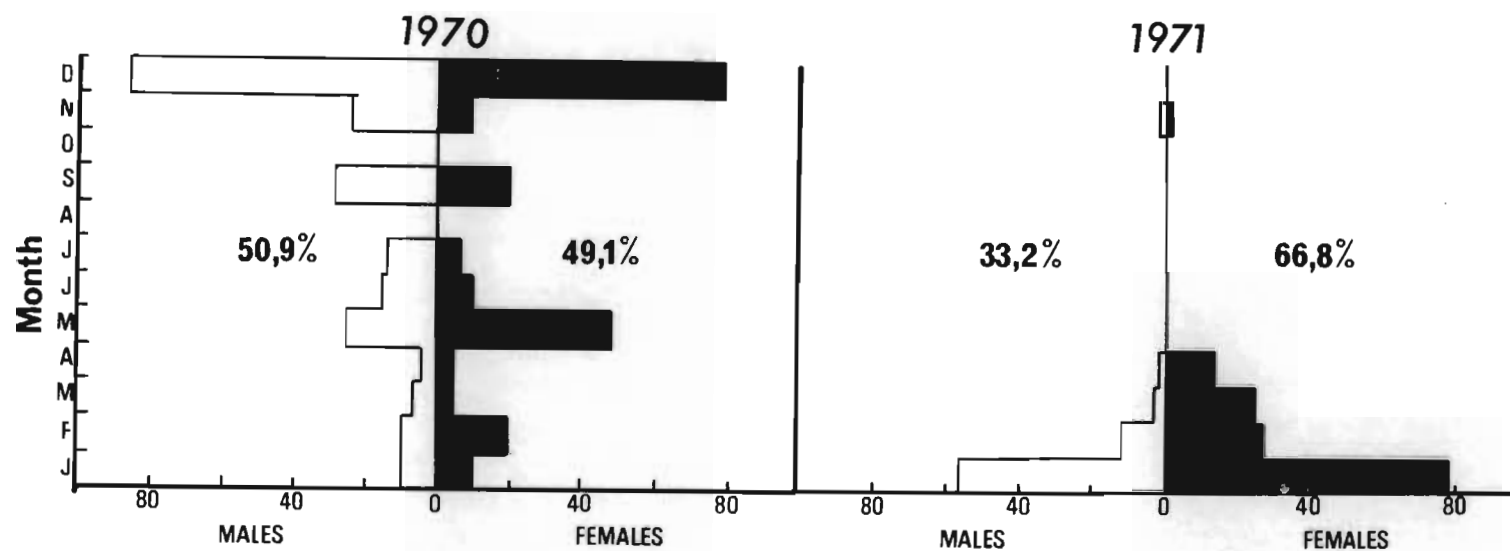


Figure 88. The sex ratios of green turtle catches on St. Brandon during 1970 and 1971.

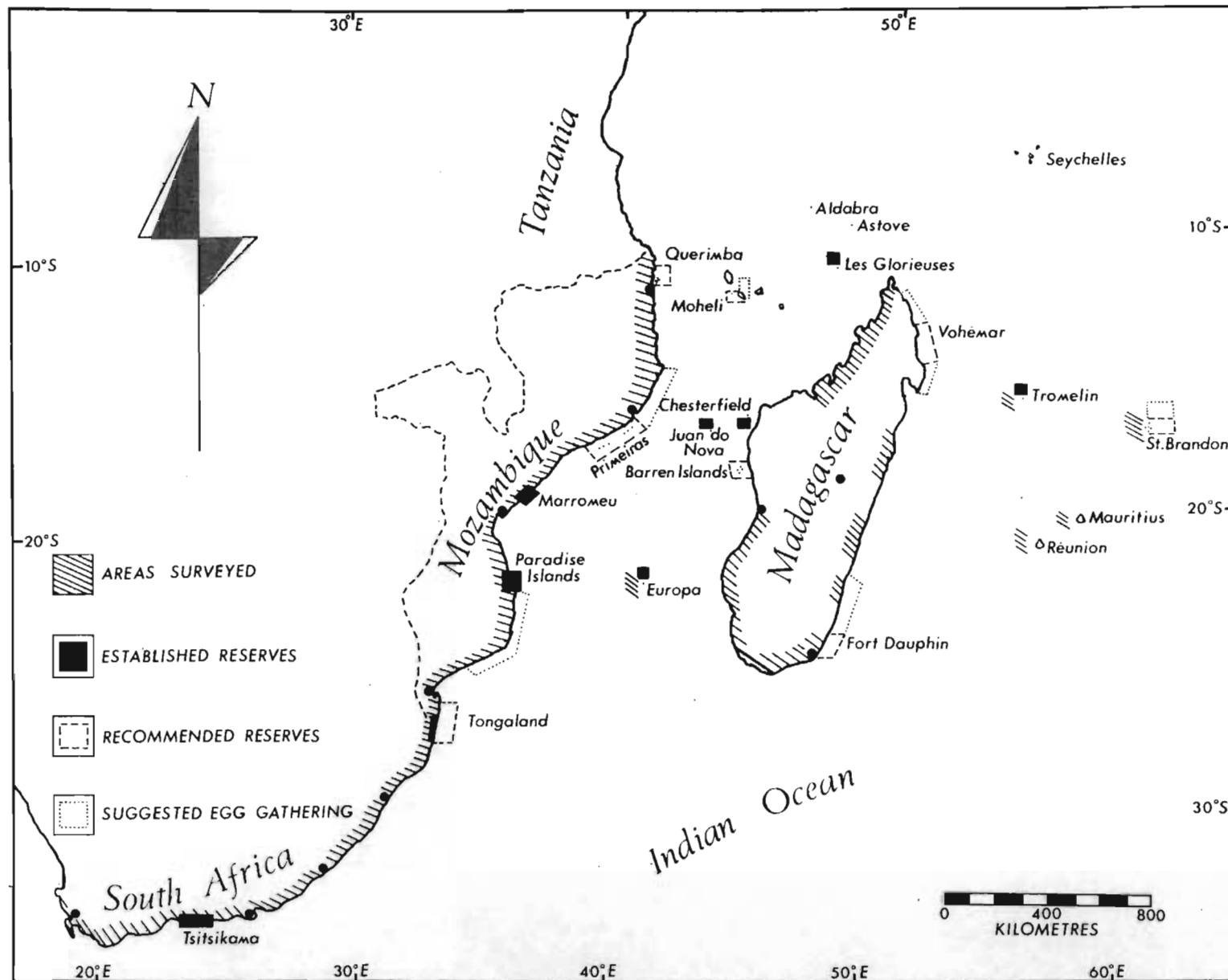


Figure 89. The current conservation situation in the study region with recommendations.

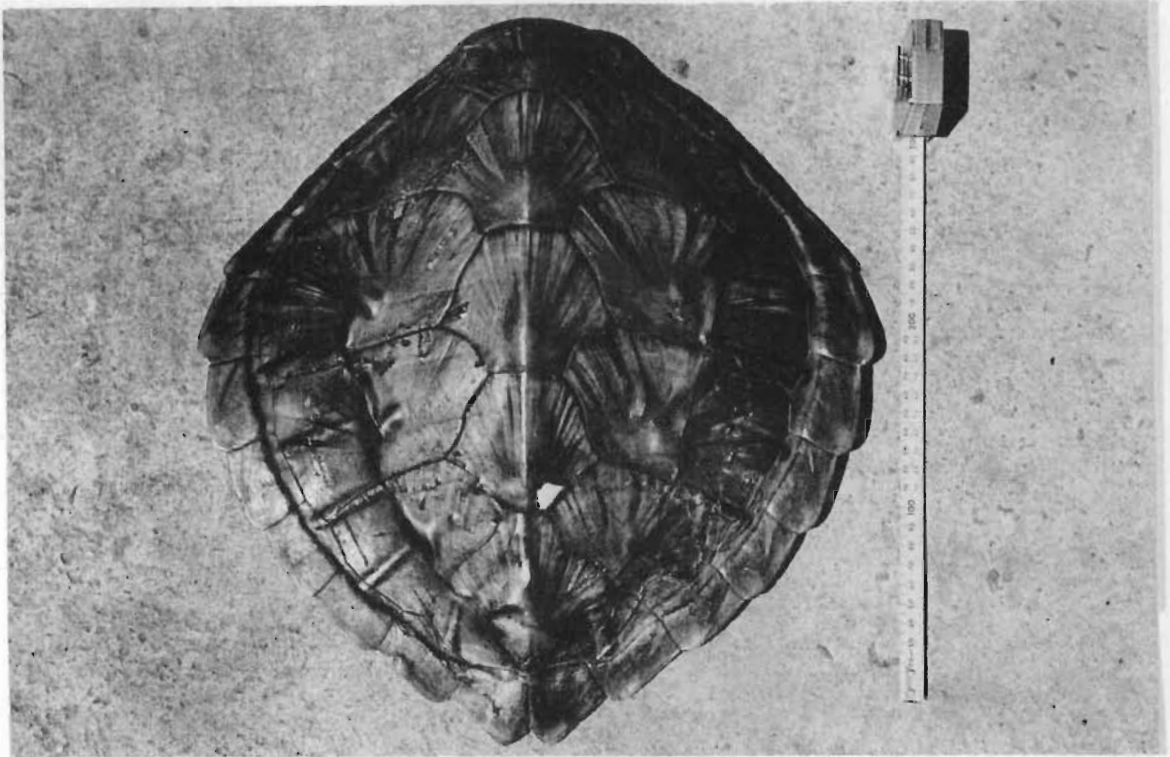


Plate 1. Carapace of juvenile green turtle showing semi-serrate margin.

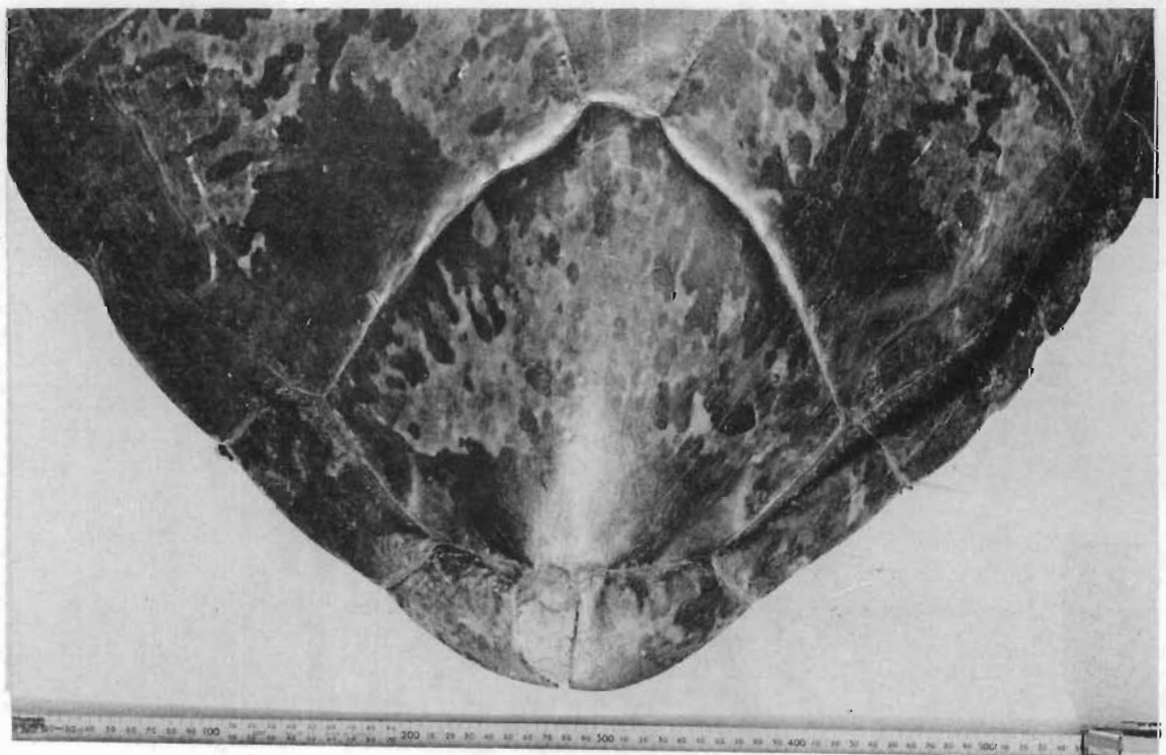


Plate 2. Posterior of adult green turtle carapace showing smooth margin.

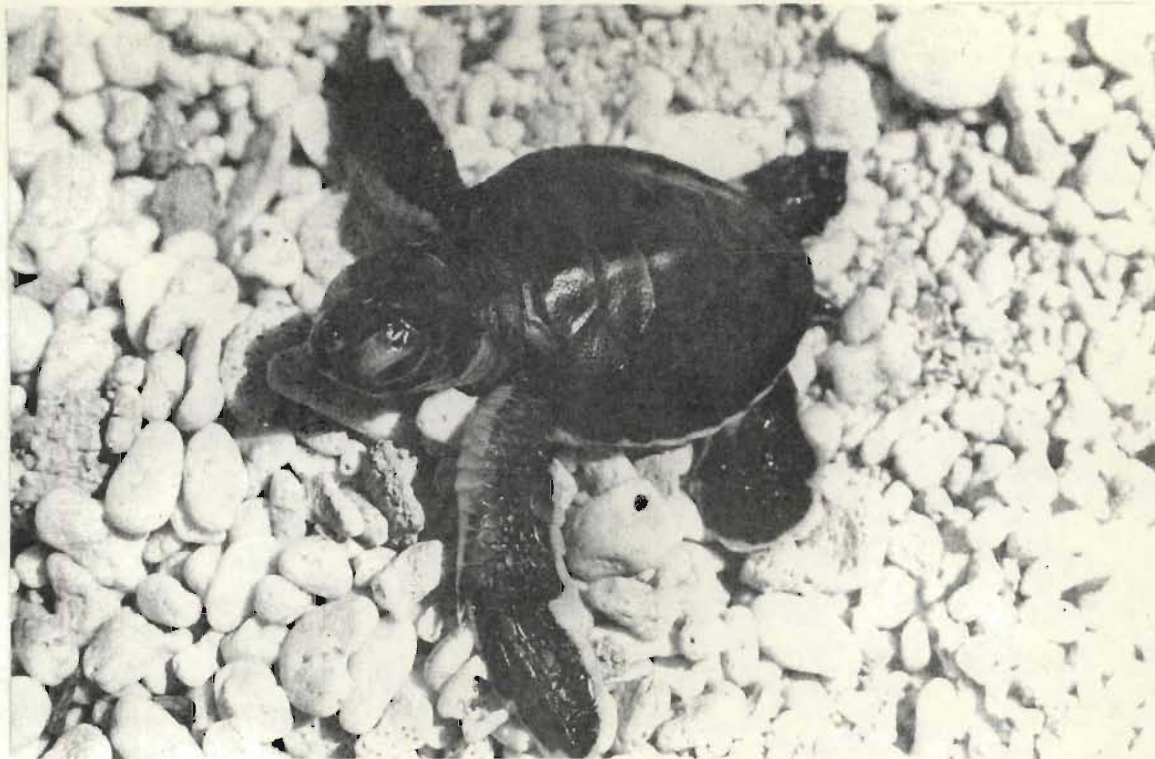


Plate 3. Typical green turtle hatchling from the study region.



Plate 4. A typical green turtle juvenile from the study region.



.Plate 5. An atypical juvenile green turtle carapace from eastern Madagascar.



Plate 6. A pair of copulating green turtles on Tromelin Island showing the similarities in carapace colouring and pattern between male and female.



Plate 7. Blonde type of juvenile hawksbill colouring.

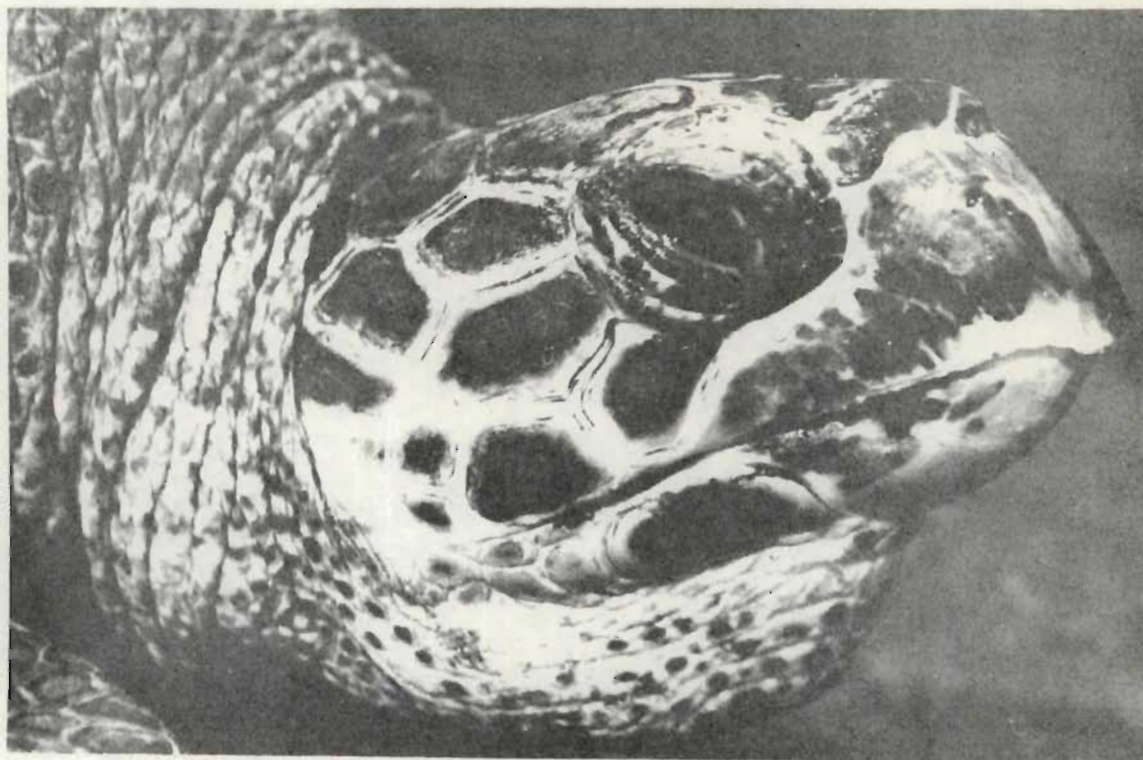


Plate 8. Head of hawksbill turtle showing head scales clearly outlined in yellow-white.

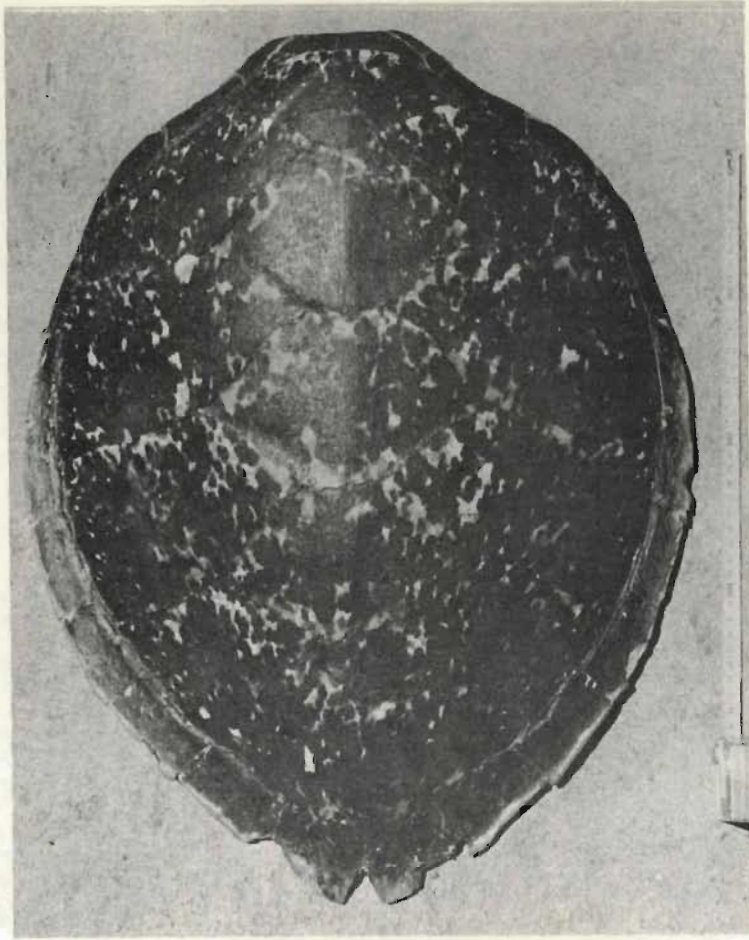


Plate 9. The carapace of a sub-adult hawksbill from the study region showing the dark phase.



Plate 10. A sub-adult loggerhead from the Natal Coast showing the golden-yellow coloration of the plastron and undersurfaces.

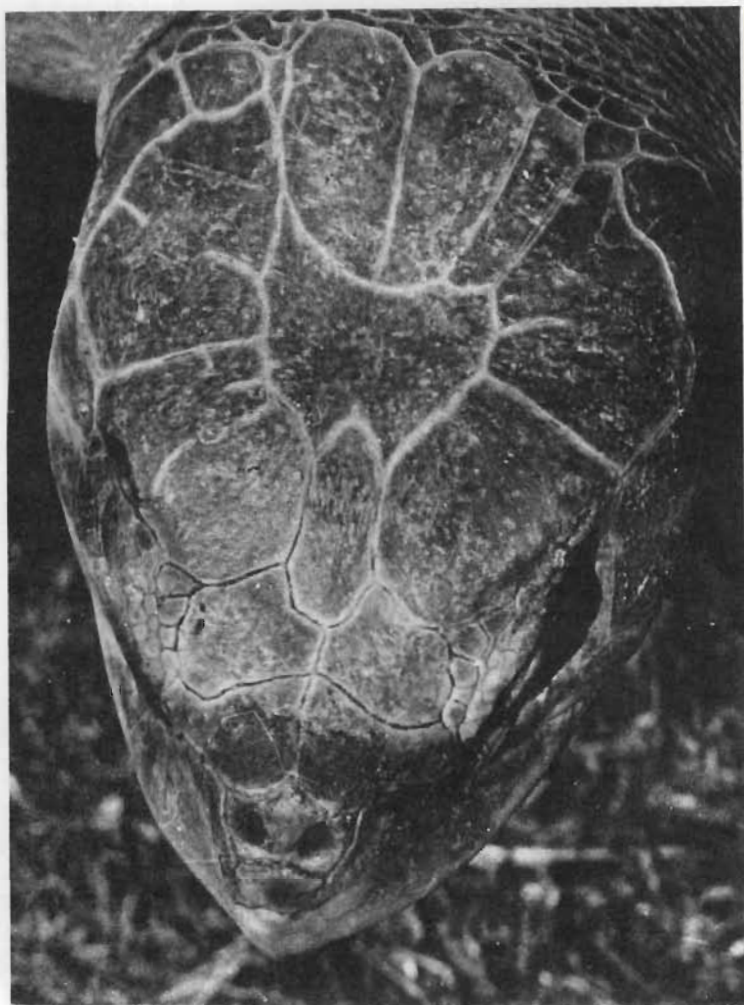


Plate 11. Head shield pattern of olive ridley from northern Mozambique.

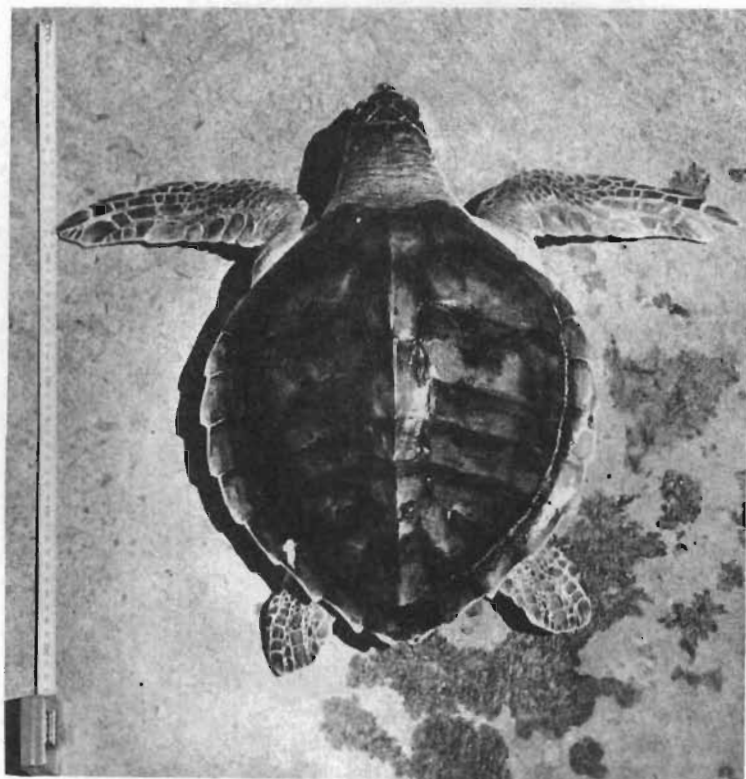


Plate 12. Juvenile olive ridley from the Durban Aquarium.

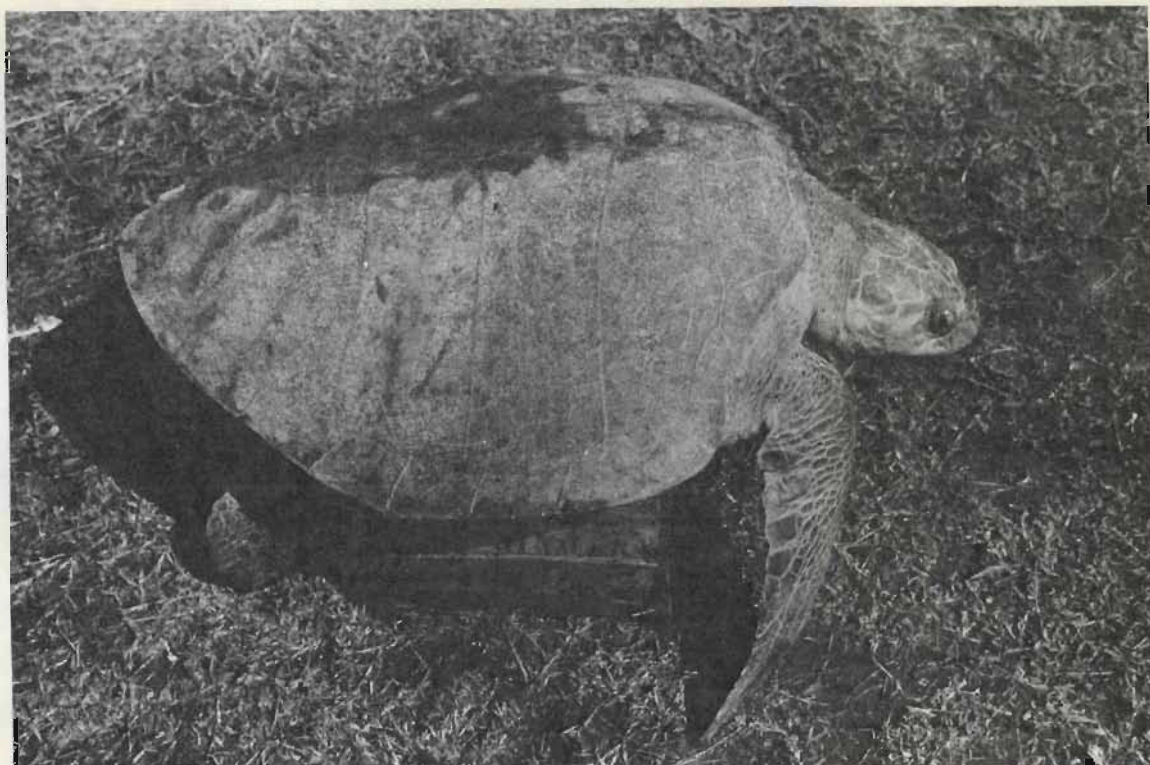


Plate 13. Adult olive ridley from Northern Mozambique.



Plate 14. A typical leatherback hatchling from Tongaland.

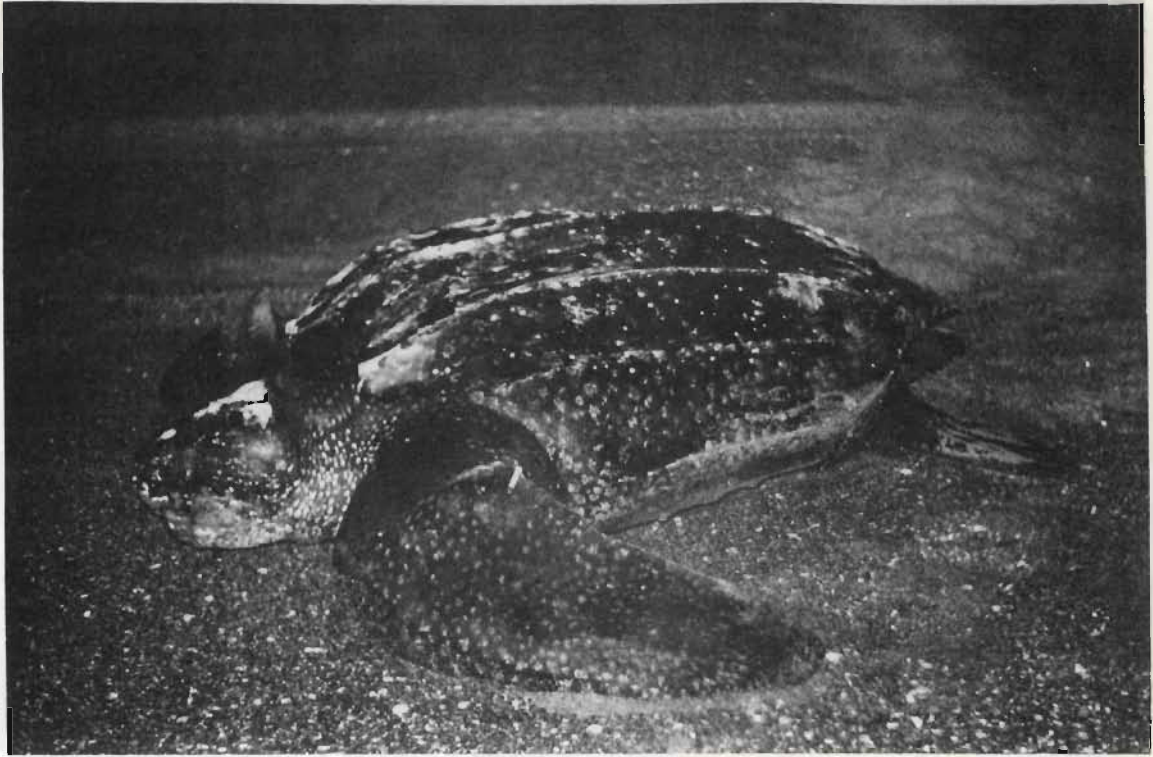


Plate 15. A typical adult female leatherback from Tongaland.



Plate 16. A typical loggerhead hatchling from Tongaland showing the notching site during the 1972/73 season.



Plate 17. Hermit crabs Caenobites sp. on the beach at Europa Island, November 1970.



Plate 18. The goose necked barnacle Conchoderma virgatum on the hind flipper of a leatherback hatchling stranded at Cape Agulhas.

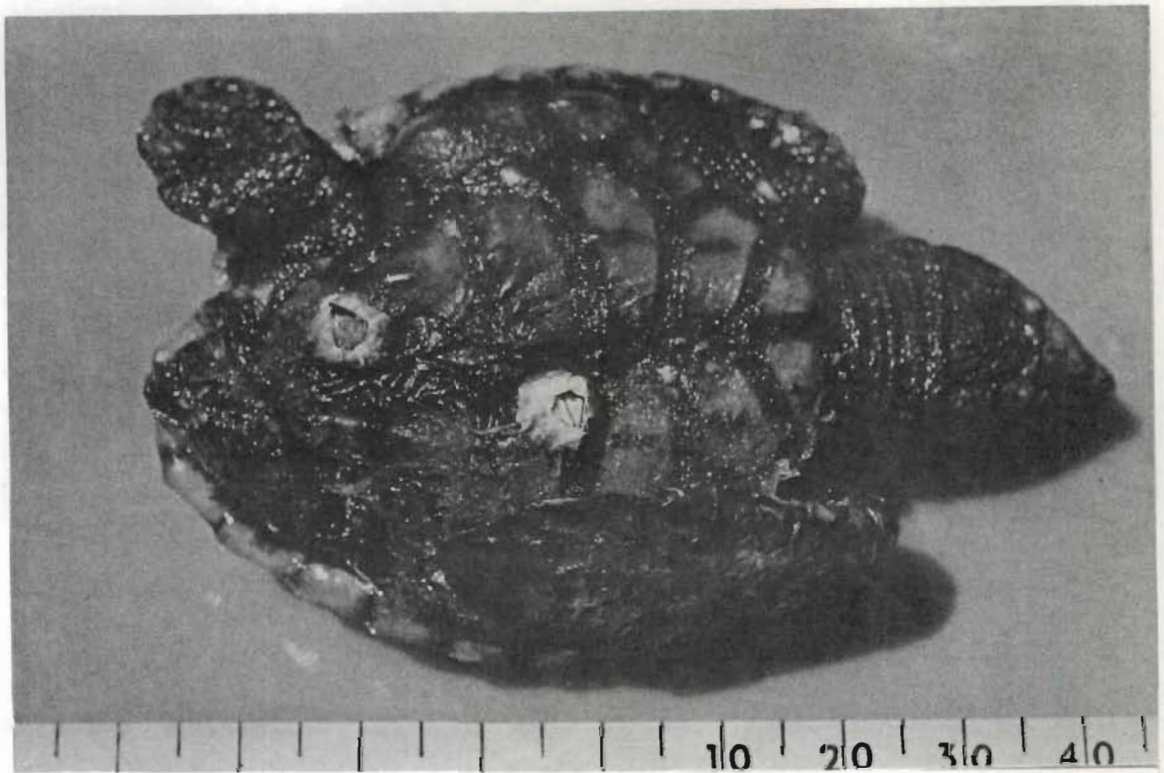


Plate 19. Acorn barnacles Balanus sp. on the plastron of a loggerhead hatchling stranded at Cape Agulhas.

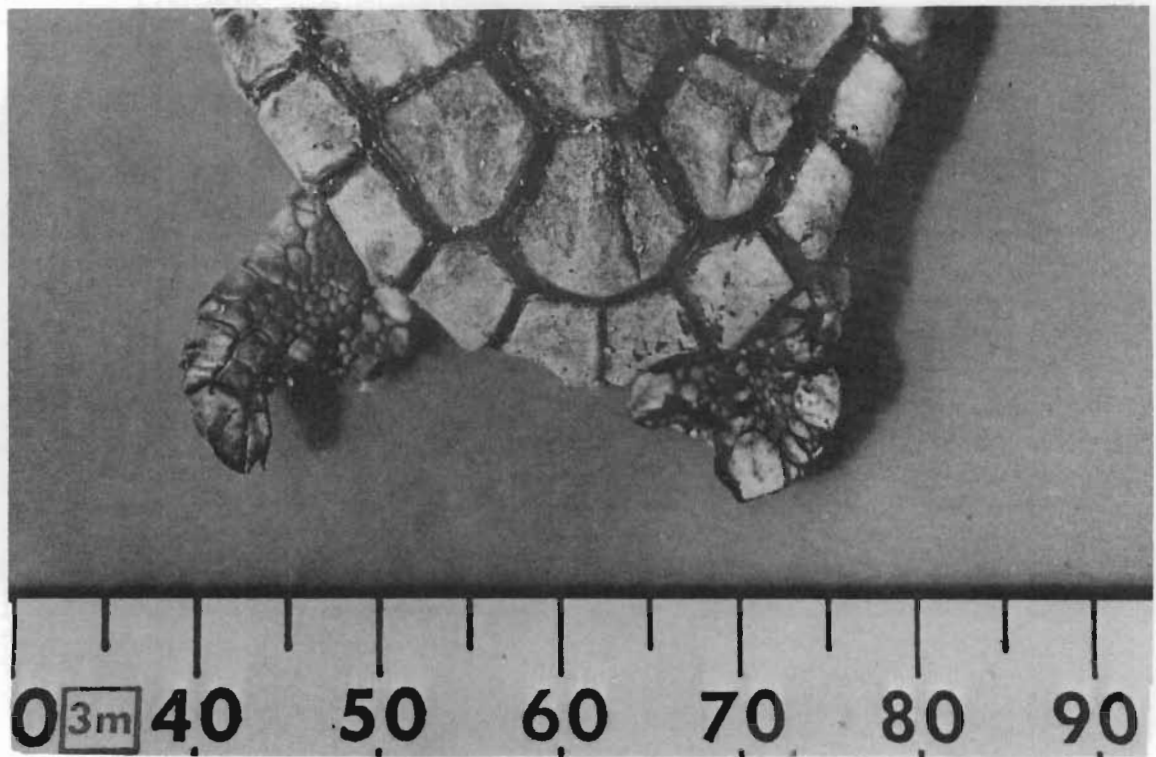


Plate 20. Crescent shaped injuries to the hindflippers of a loggerhead hatchling stranded at Cape Agulhas.

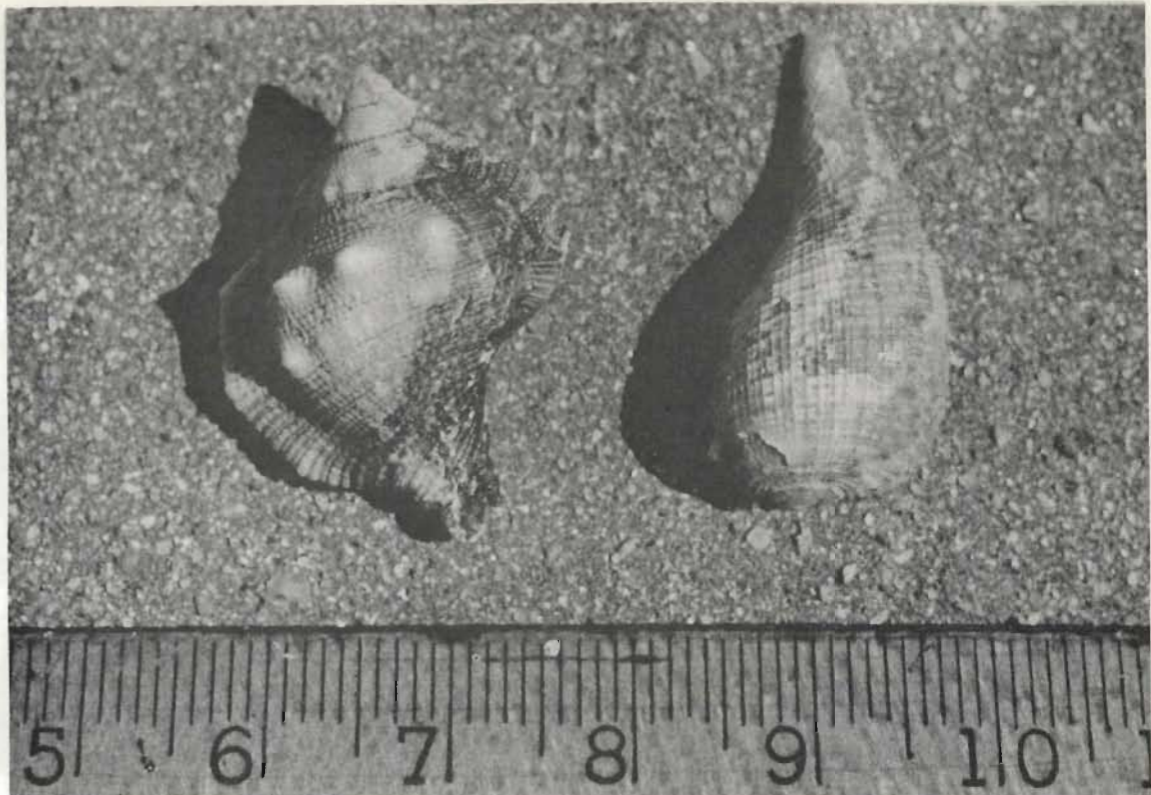


Plate 21. The most common species of Mollusca from the stomachs of loggerhead turtles along the Natal coast: Left, Bufonaria crumenoides; right, Ficus subintermedius.

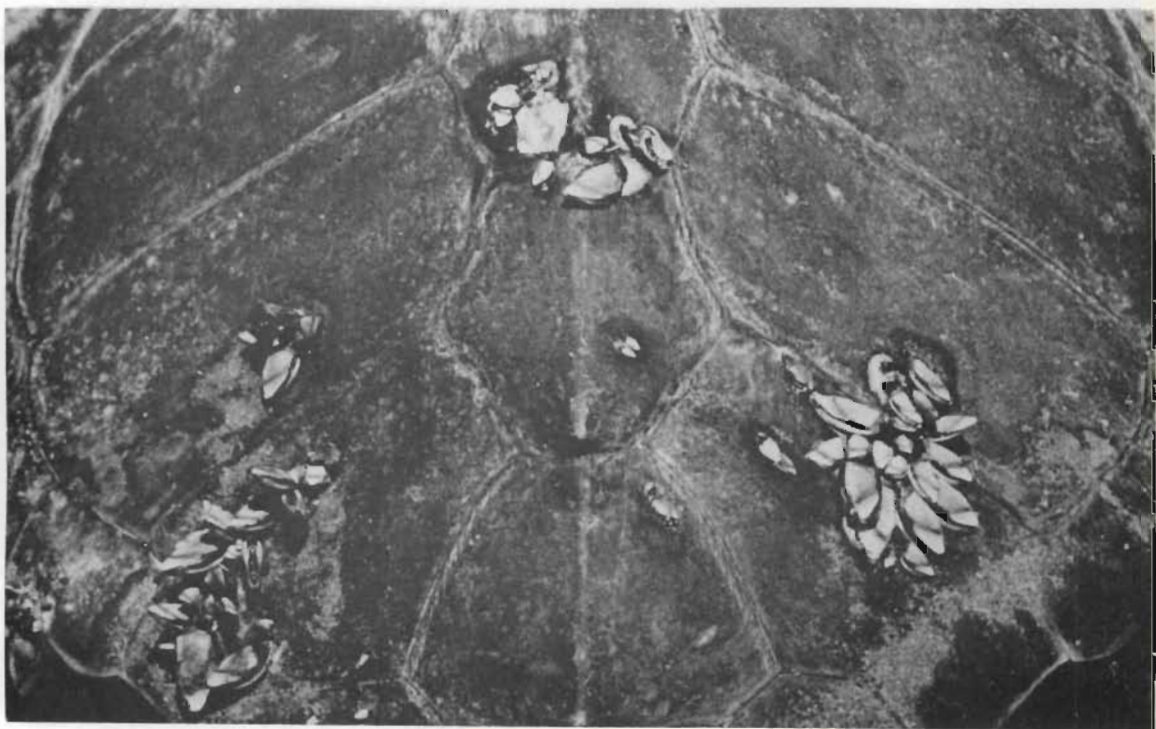


Plate 22. Lepas sp. barnacles on a sub-adult loggerhead from the Natal coast.