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The Sea Turtles of South-East Africa

I. Status, morphology and distributions

by

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Contents

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 over-exploitation 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 by local Moslems 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 Lougnon, 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 series of papers 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 these papers have 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.

The first paper in the two part series is concerned with the description and distribution of each of the five species occurring in the study region. Part 2 will describe the life cycle, migratory behaviour and reproductive potential of the loggerhead turtle and will include some data on the leatherback and green turtles in the study region.

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 series 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 (Fig. 1) 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) (Fig. 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; Fig. 1), Tromelin Island (15°51'S, 54°25'E; Fig. 1) and the St. Brandon Archipelago or the Cargados Carajos Shoals (between 16° and 17°S, 60°E; Fig. 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. Lougnon, 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 gyrals 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 temperatures 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.

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, 1969). 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, 1971).

Salinities within the study region vary from $35^{\circ}/_{00}$ to $35.5^{\circ}/_{00}$; an exception being found in north-western Madagascar which, during January and February, has salinities lower than $34.5^{\circ}/_{00}$ (Wyrtki, 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 infra-marginal 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; 1967 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.

1970 *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); *icahu, pateri, casa* (Makua); *usa* (Chimani); *hassa* (Shangane); *sinembo* (Shangane for juveniles); *ifudu* (Zulu); *fano, fanojoaty* (Vezo, Mahefaly, Antandroy, N. Sakalava); *tsakoy* (Sakalava); *fanohara* (Sakalava for juveniles); *fanorua* (Antonosy).

Peter's (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 dependent 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 (Plate 1) 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.

(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. 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.

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 weighed 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 3. Plastron length and width measurements were taken using calipers and these methods are not illustrated. See also legend of 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 51.9 mm, 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 Fig. 4). Loveridge and Williams (1957: 477) quote him as giving a mass 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 (*a*)).

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 4) 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 5 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 algaes are readily eaten 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 6 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 (Fig. 7).

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 main land 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. Maximum recorded seasonal population 502.

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 Fig. 8) and when 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 Fig. 9).

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).

$$\text{i.e.} \quad = 710 \times \frac{44}{100} \times 14$$
$$= 4\,374 \text{ females}$$

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 7 000 (Hughes, 1971c: 117). Table 15 shows the estimated annual numbers of nesting green turtles on some of the nesting areas.

Beach preference and nesting areas

Figure 5 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 10 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 1 000 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:

Mesh size number	*Mesh size (mm)*
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 11 shows the results graphically. Differences between upper level samples (*a*) and lower level samples (*c*) of every transect were tested for using X^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, Fig. 11) 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 12 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 13 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 14 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 15 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: $\frac{\text{Curved C.L.}}{\text{Straight C.L.}} = 1.08$ (Europa); 1.06 (Aldabra))

Figure 16 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 17 to 20 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 Fig. 3 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 (Fig. 21) 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 1843

Species: *Eretomochelys 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); *fanohara* (Northern Sakalava, Vezo); *fanojaty* (South Sakalava); *fanotanga* (Antonosy); *inhama* (Chimani); *inhapa, ngapa, xicore, mamba* (Makua); *sissassumbanga* (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. 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 5).

Sub-adult and adult carapace colouring mainly darker in tone some almost black with yellow blotches (Plate 6); 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 22 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 139.1kg (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 23 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: Fig. 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 6 and in Figure 7 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 2 500 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 (2,5kg = 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 7.

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 23 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 24 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 25 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 26 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 1 600km. 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; 1964 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); *ulongosi* (Zulu, Thonga); *eluvi, rufi* (Makua, Swahili); *ngambu* (Shangane); *sinyola* (Sisonga); *amphombo* (Vezo, Sakalava, Mahefaly, Antandroy); *fanomena, fanovema* (Antonosy); *tsiasara*, (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; frontoparietal 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 innermost of which becomes recessed and gradually reduced in size through time until maturity when it is barely visible;~~

tail short in juveniles until 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 serrate 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 27.

In the bony carapaces nuchal always one; neurals highly variable but most commonly 10 only occasionally interrupted by pleurals; suprapygals 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 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, Plate 7).

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 colouring, 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 [illegible]mm. 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 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 28 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 American 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 28 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 29 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 30 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 30. 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 appropciate 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. 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 31 and 32 are presented. Figure 31 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 32 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 32 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 Wyrtki (1971).

It can be seen that the length/mass relationship expressed in Figure 30 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 61,0 and 67,0cm (6-7 years of age) when the tail and claws of the male started to lengthen perceptibly. Figure 33 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 (Fig. 42) 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 34) 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 (Table 32b).

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 35 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 Maugé, a member of the Legendre expedition, that this may have been a misidentification, there being confusion between juvenile greens and loggerheads.

From Figure 7 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 56 km protected area in Tongaland, Natal some 1790 loggerhead females have been tagged over the past ten years. Recovery rates have reached the 47% level so it is possible that approximately 4 000 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 region. 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 36 shows a composite picture of the littoral zone of the Tongaland nesting beaches and Figure 37 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 (Fig. 37) and the flatter prograded type (inset Fig. 37), 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 36 the 6.8km (4¼ 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 38 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 Fig. 36). 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 in a subsequent publication (Hughes, in press (*b*)). 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 (Fig. 38) 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 39 shows the relationship between carapace length and carapace width in a sample of 50 loggerhead hatchlings from Tongaland. Figure 40 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-ADULT 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 41 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 34 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 34 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 42 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 43 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 44 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 43 showed that males apparently have larger heads in relation to the carapace length than females. Figure 45 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 Fig. 30) of 120kg.

Such enlarged heads are not restricted to the males. Figure 44 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 supernumery 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: Fig. 3: 17; Nishimura *op. cit.*, Fig. 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 27 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). Deriniyagala'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 1½ 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 Hughes, in press (*b*)). 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. 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 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 severly limited, therefore the differences must arise during the juvenile and subadult 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 Madeira. Around Madeira they occur in substantial numbers and a thousand or more are captured and slaughtered each year (Brongersma, 1968: 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 Europe:	6 000km in 1-2 years
Europe via Azores to America:	10 400km in 3-5 years (?)
Total distance:	16 400km 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 8 000km 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 is mainly negative but there are some positive data. Tongaland loggerheads are swept southwards by the Agulhas Current (see Hughes, in press (*b*)) 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 Madeira 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.*) sites 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, she can never attain the same dimensions as that of her American counterparts.

The olive ridley turtle

Genus *Ledipochelys* 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* (Porguese); *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: Fig. 3: 130) (Plate 8) 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 9); 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 28.5 cm; 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 olivacious 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 9).

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.

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 46 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 47 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 the olive ridley occurs in the Seychelles and adds that it does not occur in Aldabra.

Figure 6 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 47 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 48 shows the relationship between straight carapace length and straight carapace width. The formula for converting curved carapace length into straight carapace length is:

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

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 $34\,^{\circ}/_{00}$ over an extensive area during the summer months. This is the only locality in the study region in which such salinities are found (Wyrtki, 1971).

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 Bé was taken in an experimental prawn trawl at 110 metres (Dr. A. Crosnier, Director, O.R.S.T.O.M., Nossi Bé, *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 Hughes, in press *b*).

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 1812.

Species: *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; 1964 Bass and McAllister, 287; 1965 McAllister, Bass and van Schoor, 13; 1966 Minton, 59; 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); *leerrug 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 identation, 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 49 shows the frequency of scale counts in a sample of leatherback hatchlings from Tongaland. Plate 10 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 11); 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 10).

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 11).

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 were 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 50 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 (197 lb: 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 (Fig. 50), 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 Laalplek remains as one of the heaviest leatherbacks on record at 646kg. 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 35.00mm 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 1 015 eggs and ova which weighed approximately 28.9kg. 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:

	Mass (kg)	*% of total*
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
	155.25	100.1

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 51 shows the distribution and apparent 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 apparent 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.

Beach preference and nesting areas

Figure 51 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 latitudenal 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 gentle 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 Fig. 52).

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 38 (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 52 is a schematic presentation of the nature of the offshore seabed in Tongaland (see also Fig. 36) 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:

		n	%	
Obstruction free approaches	Deep water	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		15	4.0	
Total successful nesting emergences		371	100.0	

Although a deep water approach section is shown in Figure 52, 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 Figs. 36 and 52) 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 ($p < .9$, Fig. 53), as is the relationship between carapace length and head width

($p < .9$, Fig. 54). The carapace length-mass relationship is somewhat more positive (Hughes, 1971b: 21, Fig. 8).

In adult females laying in Tongaland the carapace length-width relationship still displays variations but somewhat less so than in hatchlings (Fig. 55) 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:

Carapace length $y = 0.8x + 23.01$ ($p < .001$)
Carapace width $y = 0.682x + 7.49$ ($p < .02$)

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 Hughes, in press (*b*) and Pritchard, *op. cit.*: 23, 24-25). The numbers of clutches laid by each female seems consistent throughout their range.

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. 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 Hughes, in press (*b*)) 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 Carribean; 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 hatchinglings 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.

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Tables
Pages 50 to 80

			Europa	Tromelin
Shields	L	R	% Freq. (n=200)	% Freq. (n=172)
Post-oculars	2	2	3.5	3.0
	2	3	1.5	2.0
	3	2	0.5	2.0
	3	3	13.5	15.0
	3	4	8.0	2.0
	4	3	8.5	9.0
	4	4	47.5	52.0
	4	5	8.0	2.0
	5	4	5.0	1.0
	5	5	3.0	1.0
	3	5	0.5	0.0
	4	2	0.5	0.0
	2	4	0.0	2.0
			100.0	100.0
Nuchals	1		87.5	87.2
	2		12.5	12.8
			100.0	100.0
Vertebrals	4		0.5	0.0
	5		83.0	93.0
	6		13.0	5.0
	7		1.5	0.6
	8		1.5	0.6
	9		0.5	0.6
			100.0	99.8

			Europa	Tromelin
Shields	L	R	% Freq. (n=200)	% Freq. (n=172)
Marginals	9	11	0.0	0.6
	10	10	1.0	0.0
	11	10	3.0	1.7
	10	11	1.5	0.6
	11	11	84.0	93.0
	12	11	3.0	0.6
	11	12	4.0	2.0
	12	12	3.5	0.6
	11	13	0.0	0.6
			100.0	99.7
Costals	4	4	85.5	96.3
	4	5	6.5	0.6
	5	3	0.5	0.0
	5	4	4.0	1.2
	5	5	2.5	0.0
	6	5	0.5	0.0
	6	6	0.5	0.0
			100.0	100.1
Infra-marginals	3	3	0.5	1.2
	3	4	1.5	1.2
	4	3	1.0	0.0
	4	4	88.5	89.5
	4	5	2.0	3.5
	5	4	3.0	1.2
	5	3	0.5	0.0
	5	5	3.0	3.5
			100.0	100.1

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. % Freq.	n.	Tromelin % Freq.	n.	St. Brandon % Freq.	n.	Mozamb. % Freq.	n.	S. Africa % Freq.	n.	Madag. % Freq.	n.	$\bar{x}$	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	15	100	3	92.57	89
Inter-anal	absent	97	30	100	29	100	2	100	9	94	15	100	3	98.50	89

Table 2. Lepidosis of green turtles *Chelonia mydas* from various localities in S.E. Africa.

		Concen-		Colours		
Locality	Sex	tration	Base colour	Streaks	Spots	Density*
Europa Island	♂	Black	Olive-green	—	Black	Dense
Tromelin Island	♂	—	Olive-green	—	Black	Dense
Durban	♂	—	Olive-green	Black	Black	Dense
Europa Island	♀	Brown	Red-brown	Browns	Brown	Medium
Europa Island	"	—	Red-brown	—	Browns	Medium
Europa Island	"	—	Olive	—	Black	Sparse
Europa Island	"	—	Dark Olive	—	Black	Medium
Europa Island	"	—	Dark brown	—	Bl. & Br.	Dense
Europa Island	"	Brown	Dark brown	Browns	—	Dense
Europa Island	"	—	Olive-grey	—	Bl. & Br.	Medium
Europa Island	"	Brown	Grey-brown	Browns	—	Medium
Europa Island	"	—	Olive-green	—	Black	Sparse
Europa Island	"	—	Pale-brown	—	Black	Dense
Europa Island	"	Brown	Pale-brown	Browns	—	Medium
Europa Island	"	—	Pale-brown	Browns	Brown	Medium
Europa Island	"	Brown	Pale-brown	Browns	Brown	Medium
Europa Island	"	—	Brown	—	Brown	Dense
Europa Island	"	—	Olive brown	—	Brown	Dense
Europa Island	"	Brown	Olive-brown	Occasional	Brown	Sparse
Europa Island	"	—	Olive-brown	Dark brown	—	Dense
Europa Island	"	Black	Olive-green	—	Black	Medium
Europa Island	"	Black	Olive-green	—	Black	Dense
Europa Island	"	Black	Olive-green	—	Black	Medium
Europa Island	"	Black	Olive-green	—	Black	Medium
Europa Island	"	—	Olive	—	Black	Sparse
Tromelin Island	"	Brown	Olive-green	Browns	—	Medium
Tromelin Island	"	—	Pale brown	—	Bl. & Br.	Dense
Primeira Island	"	Brown	Olive-brown	Browns	—	Medium
Primeira Island	"	Black	Olive-green	Black	Black	Sparse
Primeira Island	"	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.

	Tromelin Mean	Range	$\hat{\sigma}$	Europa Mean	Range	$\hat{\sigma}$	Differences (df: 98)
Carapace length (mm)	48.62	46.2-51.9	1.62	48.49	45.8-51.4	1.37	p. >0.6 N.S.
Carapace width (mm)	40.16	35.9-44.4	2.00	39.86	35.3-42.5	1.95	p. >0.5 N.S.
Head width (mm)	16.13	15.4-16.9	0.67	15.92	15.0-16.8	0.35	p. >0.05 N.S.
Mass (g)	23.96	19.8-29.4	2.56	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 Island	48.49	45.8 — 51.4	50	20	
Tromelin Island	48.62	45.2 — 51.8	50	17	
Aldabra and Astove	50.00	—	184	4	Frazier, 1971: 381
Yemen	46.90	44.0 — 48.4	20	1	FAO, 1988: 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, 1969a: 95
Ceylon	—	49.0 — 54.0	?	?	Deraniyagala, 1939: 229
Galapagos Islands	46.20	41.0 — 49.6	29	?	Pritchard, 1971a: 8
Mean:	48.91	Overall Range: 44.0 — 57.0			

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					
	Mean	Range	$\hat{\sigma}$	n	Mean	Range	$\hat{\sigma}$	n	Diff.	DI.
Carapace length (curved)	113.66	98.0-128.0	4.69	60	110.84	98.0-127.0	6.60	44	p. >.01	92
Carapace length (straight)	106.47	95.5-120.5	5.69	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	59.7- 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. >.06	57
Plastron width	74.42	68.1- 80.7	3.60	30	72.52	68.6- 76.5	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	—	—	13.4	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	1 925	56	2 451	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		Leather-back	
	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‡	46	12.0†	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	1km	60	96, 58
2	Lagoon 2	1km	50	40, 68
3	Reef and Lagoon 3	2.5km	350	460, 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	10 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	
		±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	70		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 831 different females were recorded on the Station Beach alone.

	n	%
Successful emergences	429	44.27
Unsuccessful emergences	462	43.96
Doubtful emergences	114	11.76
	969	99.99

Table 13. Successful and unsuccessful nesting emergences on 500m Station Beach, Europa Island: 6 November — 10th December, 1970.

Interval in days	Frequency
20	1
19	4
18	5
17	9
16	19
15	25
14	54
13	60
12	46
11	9
10	1
	Mean: 13.84 days

Table 14. Recorded inter-nesting intervals for green turtle females on Europa Island: 5th November—10th December, 1970.

	Range
Europa Island	4 000 — 9 000
Tromelin Island	200 — 400
St. Brandon	200 — 600
Primeiras	50 — 200
	4 450 — 10 200

Table 15. Estimated annual nesting populations of green turtles at various localities in the study region.

	X^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).

	Europa				Tromelin			
	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	+.69	<.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	Europa Island				Tromelin				St. Brandon				South Africa			
	Mean	Range	$\hat{\sigma}$	n	$\bar{x}$	Range	$\hat{\sigma}$	n	$\bar{x}$	Range	$\hat{\sigma}$	n	$\bar{x}$	Range	$\hat{\sigma}$	n
Skull length	21.48	20.2-23.4	1.00	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	0.47	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	0.58	10	2.86	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	0.16	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	0.26	10	2.82	2.63-3.08	.24	3	—	2.63	—	1	2.90	2.40-3.18	.35	4
Jaw spread between articulars	6.30	5.95-7.26	0.41	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.

	Europa					Tromelin				Primeiras		
	n	$\bar{x}$	Range	$\hat{\sigma}$	n	$\bar{x}$	Range	$\hat{\sigma}$	n	$\bar{x}$	Range	$\hat{\sigma}$
Diameter (mm) . . .	28	44.7	41.8-47.2	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	116	100-130	21
Clutch mass (g) .	28	7 259	5 187-9 587	1 373	10	6 164	4 091-8 650	1 564	2	5 176	4 417-5 936	1 074

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
B419	17 October 1971	81	3 993	4 091	107.6
B425	21 October 1971	170	8 551	8 650	114.0
B423	21 October 1971	117	4 703	4 885	114.5
B427	25 October 1971	121	5 772	5 950	107.5
B434	27 October 1971	173	8 218	8 405	116.0
B439	28 October 1971	156	7 051	7 362	108.0
B433	28 October 1971	120	5 892	6 057	110.0
B432	31 October 1971	83	4 250	4 401	103.0
B447	4 November 1971	154	6 237	6 520	119.0
B448	5 November 1971	115	5 116	5 316	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 Length Curved	Carapace Length Straight	Carapace width Curved	Carapace width Straight	Plastron length	Plastron width	Head width	Head length
(a) Cape Province									
Blaauwberg Strand, C.T.	28.5.70	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	6.10.71	37.1	35.2	34.5	30.3	27.2	25.8	5.5	7.6
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	—	35.5	—	—	—	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	37.8	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)	1 200	400	400
Diego Suarez	400+	?	40
Narinda Bay	?	?	30
N.E. Coast	?	?	100
Tamatave	40	?	?
	1 600 (62.3%)	400 (15.6%)	570 (22.1%)
		Grand total: 2 500 turtles	

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 articulars
Italy, Mad.	18.40	11.62	2.30	3.92	3.09	5.36
Morondava, Mad.	17.60	10.20	2.06	3.58	2.67	4.21
Italy, Mad.	16.60	9.47	1.99	3.85	3.29	4.44
Primeiras, Moz.	18.25	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
					11L 12R	5	10.0
Vertebrals	5	45	90.0		12L 11R	4	8.0
	6	5	10.0		13L 13R	2	4.0
					13L 12R	1	2.0
Supra-caudals	2	50	100.0				
				Post-oculars	3L 3R	32	64.0
Costals	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 n	Females ex Tongaland % Freq.	Females ex Natal n	Females ex Natal % Freq.	Males ex Natal n	Males ex Natal % Freq.	Juv. ex Natal n	Juv. ex Natal % Freq.	Mozambique (unsexed) n	Mozambique (unsexed) % Freq.	Madagascar (unsexed) n	Madagascar (unsexed) % Freq.
Nuchal	1	29	96.6	20	95.0	13	92.9	7	87.5	4	100.0	47	97.9
	2	1	3.4	1	5.0	1	7.1	1	12.5	—	—	1	2.1
Vertebrals	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
	6L 5R	—	—	—	—	—	—	—	—	—	—	2	4.2
Marginals	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	—	—	5	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	15	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 and12; (n = 31). Of 31 carapaces investigated 2 (6.5%) had interrupted neurals. (*cf.* Deraniyagala, 1953: 13).

Colours	n	Freq. %
(a) Carapace		
(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, 1962a : 8
Colombia	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)*	1 004	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	$\hat{\sigma}$	n	Mean	Range	$\hat{\sigma}$
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	16.2-21.5	1.53
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	$\hat{\sigma}$	n	Mean	Range	$\hat{\sigma}$
Curved c.l.	14	86.7	79.0-90.5	5.53	51	88.6	69.0-98.5	6.70
Straight c.l.	13	81.5	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	40	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	$\hat{\sigma}$	n	Mean	Range	$\hat{\sigma}$
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	60.6-76.3	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	$\hat{\sigma}$
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, 1972b).

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: 306
S. Carolina, U.S.A.	18	92.7*	84.4-103.0	Baldwin and Lofton, 1959: 321
California, U.S.A.	1	84.0*	—	Caldwell, 1963: 568
California, U.S.A.	1	85.5*	—	Shaw, 1947: 65
Senegal	3	105.3 (?)	104-108	Cadenat, 1949: 19
Tongaland	1 182	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	14.6-17.0	.76	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	4.72-6.17	.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 articulars	9	7.24	6.40-7.70	.38	7	7.58	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.

	females			males		
Parameter	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 loggerhd. 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.L. 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.

Parameter	n	r	p	df
(a) Hatchlings from Tongaland				
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	+.40	>.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	+.96	>.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	14.5
	7	41	74.6
	8	6	10.9
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 length (cm)		Carapace width (cm)		Head width (cm)	Head length (cm)	Plastron length (cm)	Plastron width (cm)	Mass (kg)
	curved	straight	curved	straight					
Porto Amelia	73.0	68.2	71.0	53.6	—	—	—	—	—
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	1.58	—	—	—	0.195
Warner Beach	—	4.29	—	3.58	1.57	—	—	—	0.168
Warner Beach	—	4.35	—	3.57	1.56	—	—	—	0.193
Warner Beach	—	4.55	—	3.77	1.63	—	—	—	0.223
Warner Beach	—	4.46	—	3.50	1.61	—	—	—	0.200
Durban	53.5	49.2	57.0	47.4	8.8	10.7	38.3	38.1	17.3
Durban	69.0	63.3	70.5	62.2	—	—	—	—	—
Cape Agulhas	71.5	67.5	74.0	63.5	—	—	—	—	—

Madagascar

Measurements	Number of specimens	Mean	0	Range
Carapace length (curved)	24	65.08	3.95	56.0-71.5
Carapace length (straight)	21	60.58	3.11	52.8-65.6
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 articulars
Casuarina, Mozam.	17.0	12.1	2.66	3.98	3.66	6.07
Morondava, Madagas.	16.3	11.2	2.48	3.65	3.48	5.68
Morondava, Madagas.	17.0	12.6	2.73	3.86	3.56	6.28
Morondava, Madagas.	16.7	11.2	2.60	3.79	3.44	6.07
Morondava, Madagas.	16.2	10.1	2.41	3.49	3.16	5.22
Morondava, Madagas.	16.2	11.8	2.81	3.90	3.50	6.08
Morondava, Madagas.	17.0	11.4	2.72	3.77	3.57	5.25
Morondava, Madagas.	14.2	9.6	2.28	3.40	3.06	5.16
Morondava, Madagas.	12.1	8.3	1.80	3.22	2.72	4.47
Morondava, Madagas.	16.6	11.7	2.50	3.93	3.54	5.62
Umhlanga Rocks, Ntl.	16.5	11.4	2.56	3.70	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 articulars. .	11	+.79	<.01**	9

Table 37 (*b*). Relationships between skull length and other parameters. All measurements in cm.

Locality	Salinity (°/$_{oo}$)	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	>1 000	abundant	abundant	high	semi-diurnal	2 - 4	abundant
Surinam	<34.00	26 - 27	>1 000	abundant	?	high	semi-diurnal	2 - 4	abundant
Pacific S. Mexico . . .	<33.00	27 - 28	>1 000	abundant	?	high	semi-diurnal	2 - 4	abundant
West Africa	<35.00	25 - 27	>1 000	abundant	?	high?	semi-diurnal	2 - 4	present
North Australia . . .	<35.00	27 - 29	>1 000 locally	abundant	present	high?	semi-diurnal	4+	present
South China Sea . . .	<33.00	25 - 28	>1 000	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	>1 000	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	—
		132	100.1	100.2
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	0.8	12.3
	38	1	0.8	10.5
	39	1	0.8	1.8
	40	—	—	1.8
		130	100.3	100.1

Table 39 (continued)

	Count	Freq.	%Freq.	Costa Rica
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	0.8	5.4
	20	—	—	1.8
		122	100.1	100.0
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	0.8	10.5
		131	100.1	99.9

Table 39. Selected scale counts from leatherback hatchlings,* Tongaland; compared with similar counts from Costa Rica† (data from Carr and Ogren, 1959: 77).

* Sample from 14 clutches.

† Sample from 2 clutches.

(a) Hatchlings from Tongaland	n	Mean	Range	$\hat{\sigma}$
Carapace length (mm)	131	58.7	54.8-53.4	1.83
Carapace width (mm)	124	39.3	38.3-43.5	1.23
Head width (mm)	45	17.6	16.9-18.6	0.37
Mass (g)	47	37.3	27.5-41.0	1.79

(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)	130	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, Ntl.	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	1 015 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	56.0	94.0	—	18.0	—	150.0	48 km offshore, netted
Cape Town	5.2.73	?	133.5	—	93.0	—	—	—	—	—	—	12 km offshore, netted
Cape Town	4.9.71	Juv.	—	75.0	—	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	28.8	646.0	12 km offshore, netted in 30 fathoms
Saldanha Bay, C.P.	6.8.69	M	162.0	155.0	—	84.0	—	—	24.0	29.5	320.0	Tail projected 35cm past tip of carapace

Table 40: **Details of leatherback turtles from the study area.**

Locality	Mean	Range	$\hat{\sigma}$	No. hatchlings	No. clutches	Source
Colombia	60.4	58.6-62.0	—	7	1?	Kaufmann, 1971b: 92
Trinidad	67.0	66.0-68.0	—	2	1?	Bacon, 1970: 216
French Guiana	65.0	—	—	12	?	Baco, *ibid.*
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	54.9-63.4	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	28
1971/72†	34	5	39	12.8	55
1972/73†	17	4	21	19.0	38

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 articulars
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	1.80	15.27

Table 43. Details of 3 leatherback skulls from Natal (in cm).

Figures

Pages 82 to 144

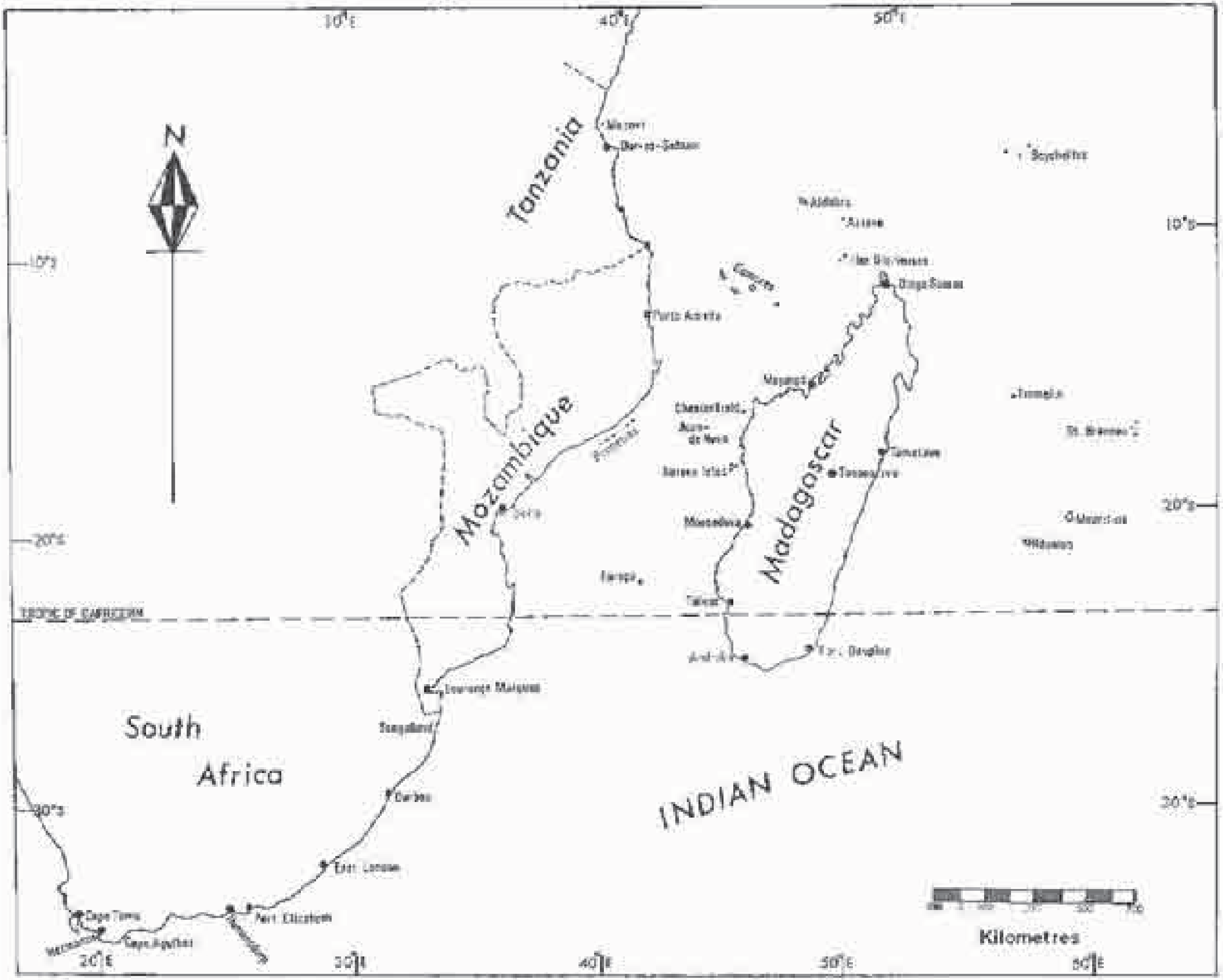

Fig. 1. The south-east African study region.

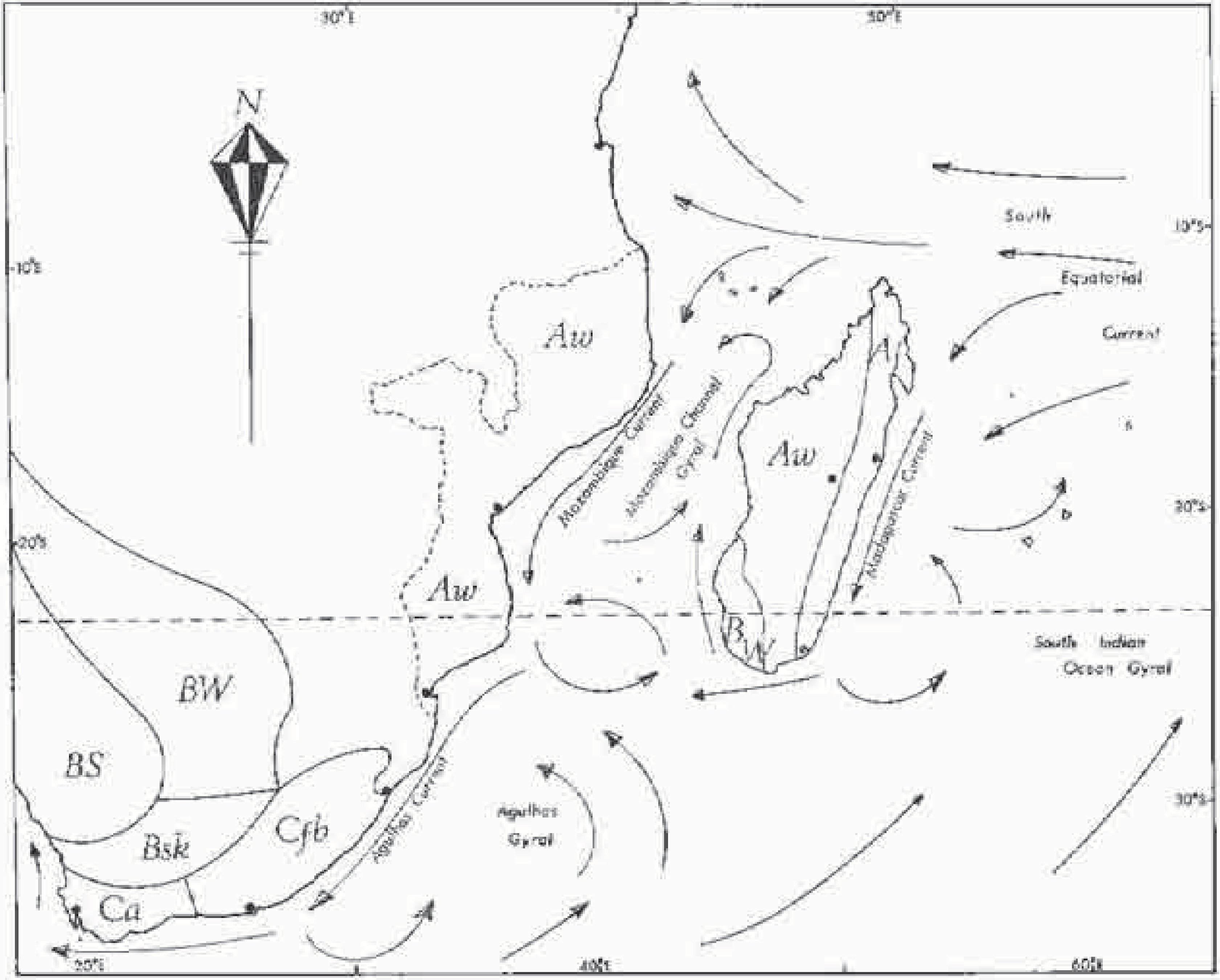

Fig. 2: **The** study region showing the climates of the land masses (after Stamp, 1966) and the oceanic circulation of the south-western Indian Ocean (data from numerous sources)

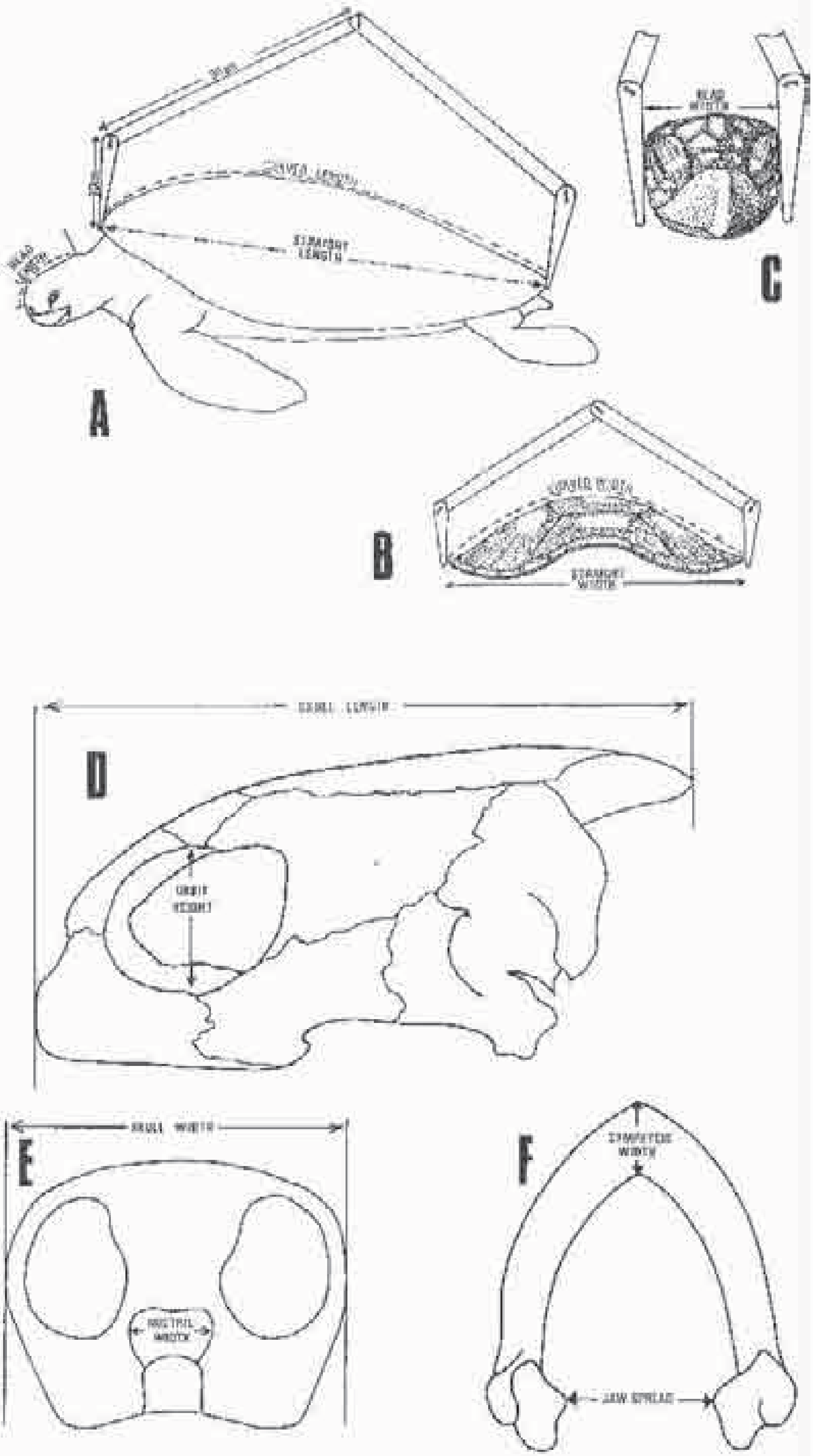

Fig. 3. Skull, head and body measurements used in the present study.

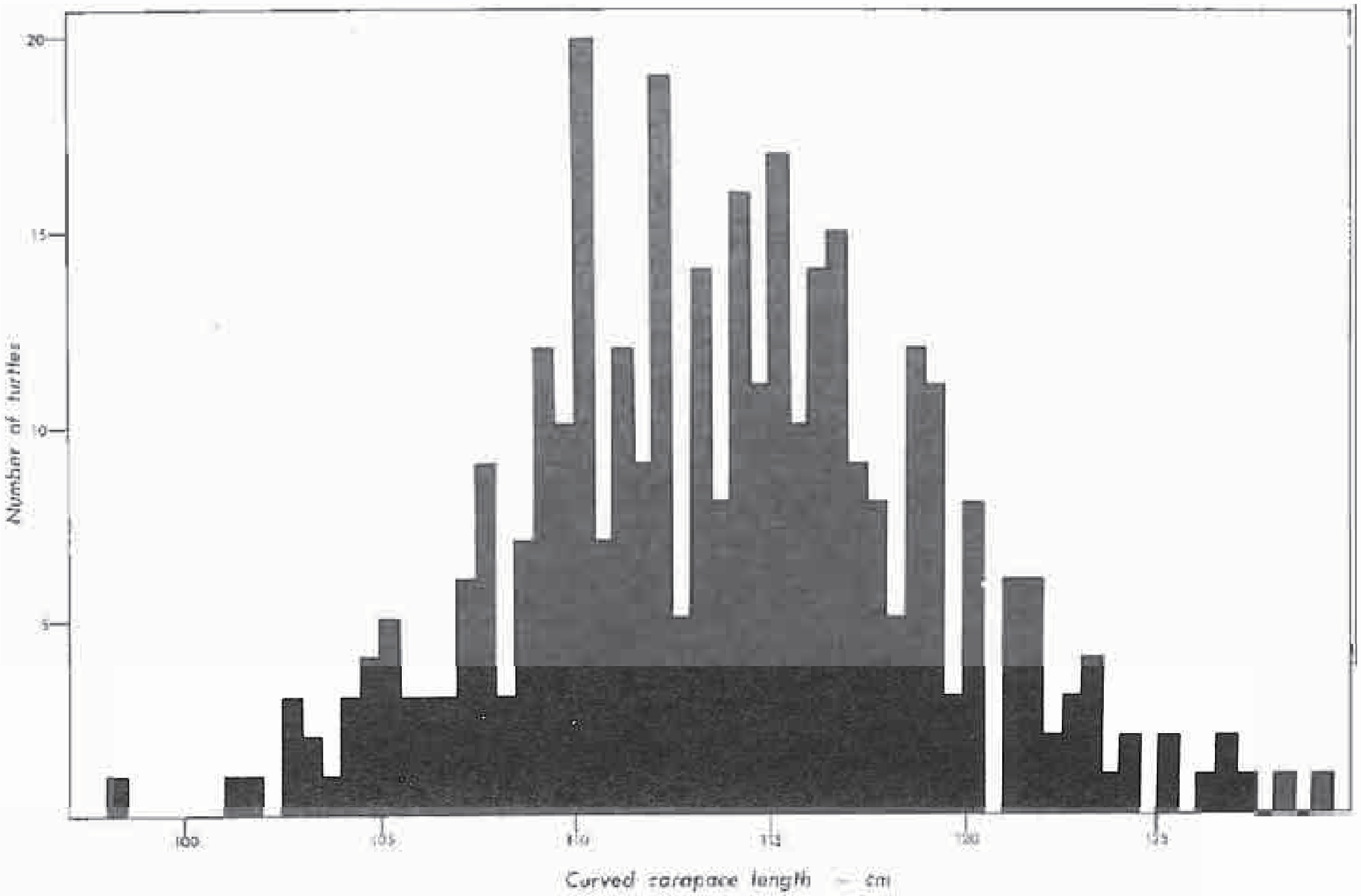

Fig. 4. Curved carapace length distribution of nesting female green turtles on Europa Island; November-December, 1970.

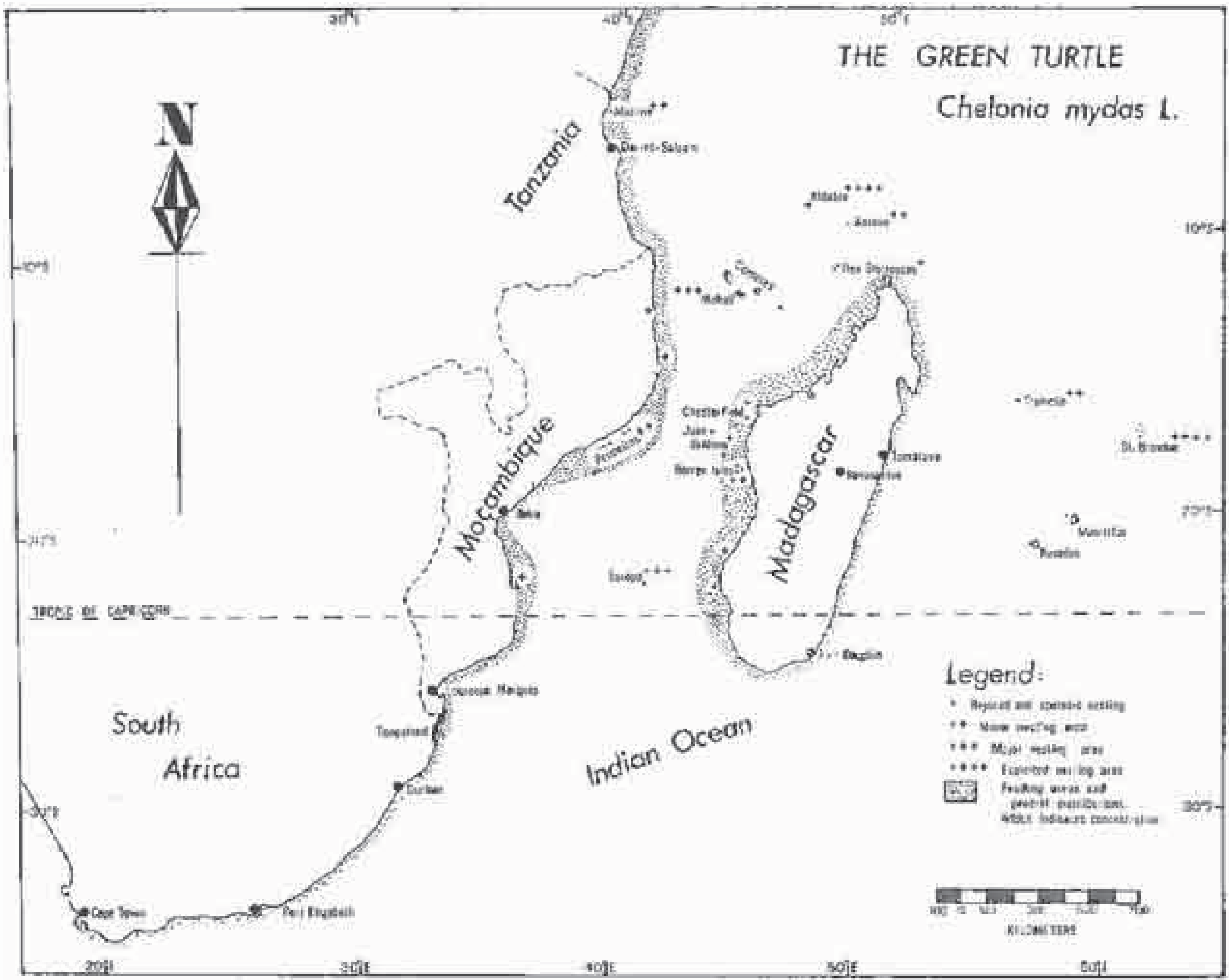

Fig. 5. The distribution and nesting areas of the green turtle *Chelonia mydas* in the study region. Width of stippling indicates relative abundance.

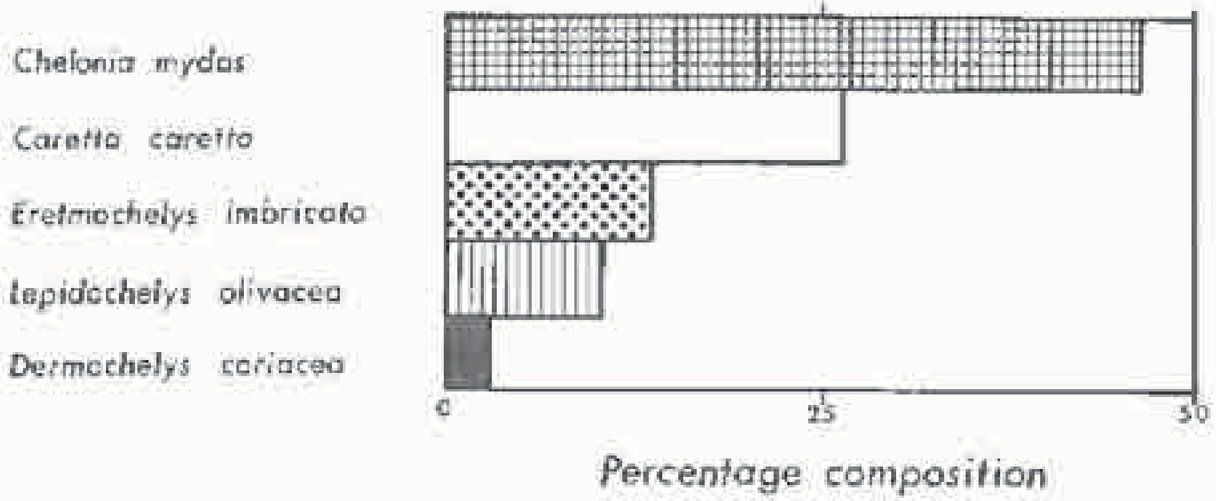

Fig. 6. The approximate species composition of the sea turtle population in the study region.

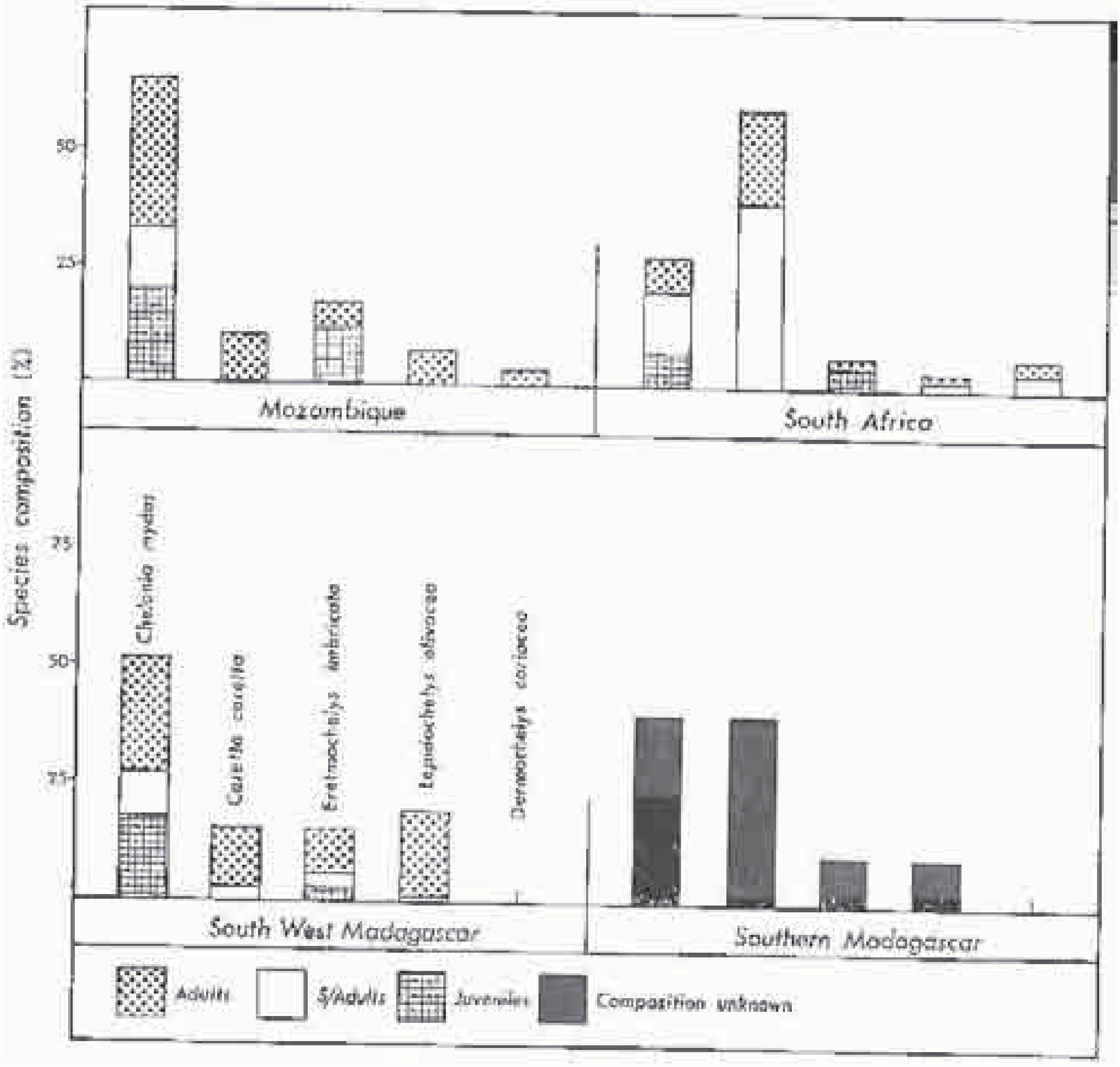

Fig. 7. The approximate species composition of the sea turtles found off (*a*) South Africa, (*b*) Mozambique and (*c*) Madagascar (southern and western regions).

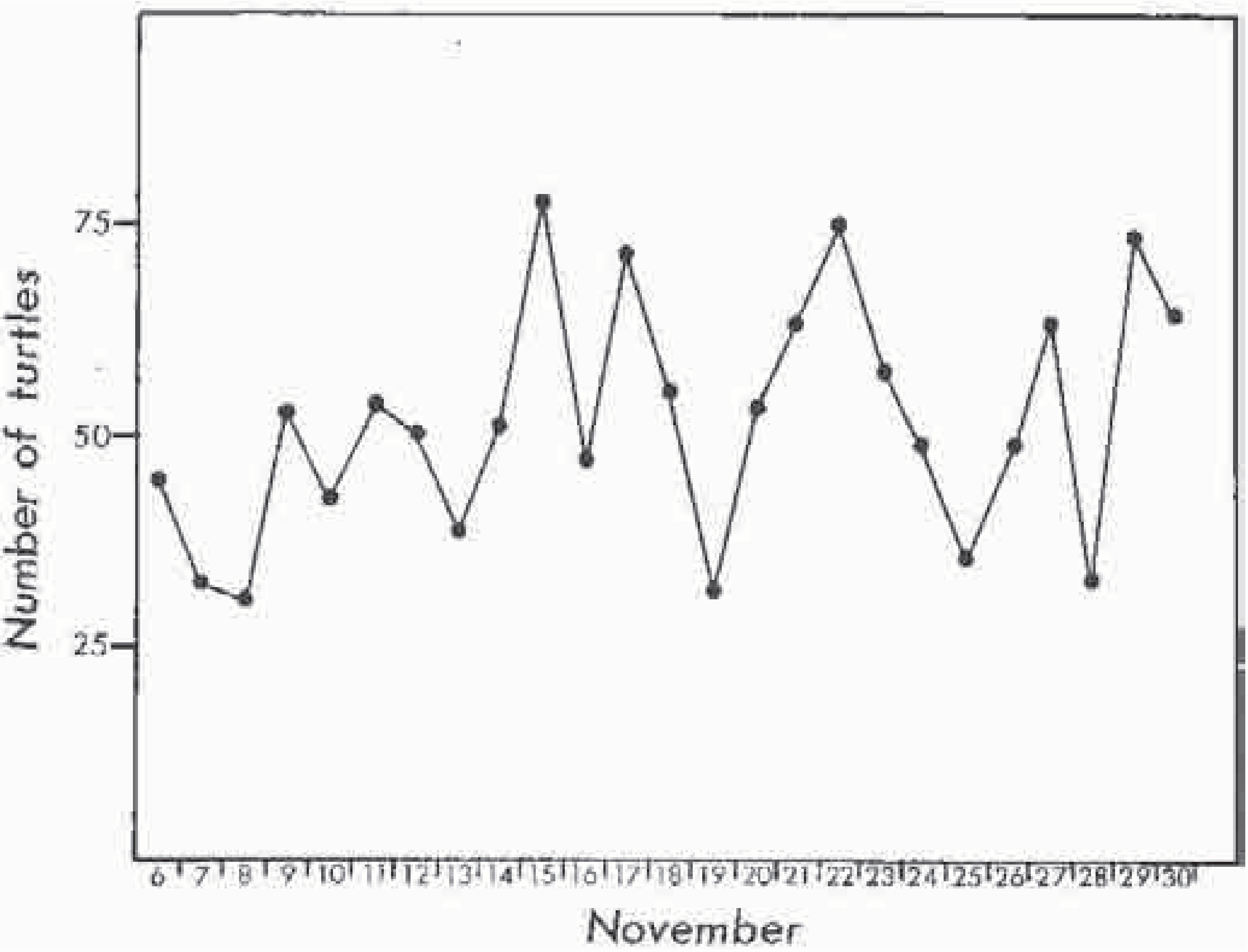

Fig 8. The number of nesting green turtle females encountered nightly on the 500m Station beach, Europa Island; 6-30 November, 1970.

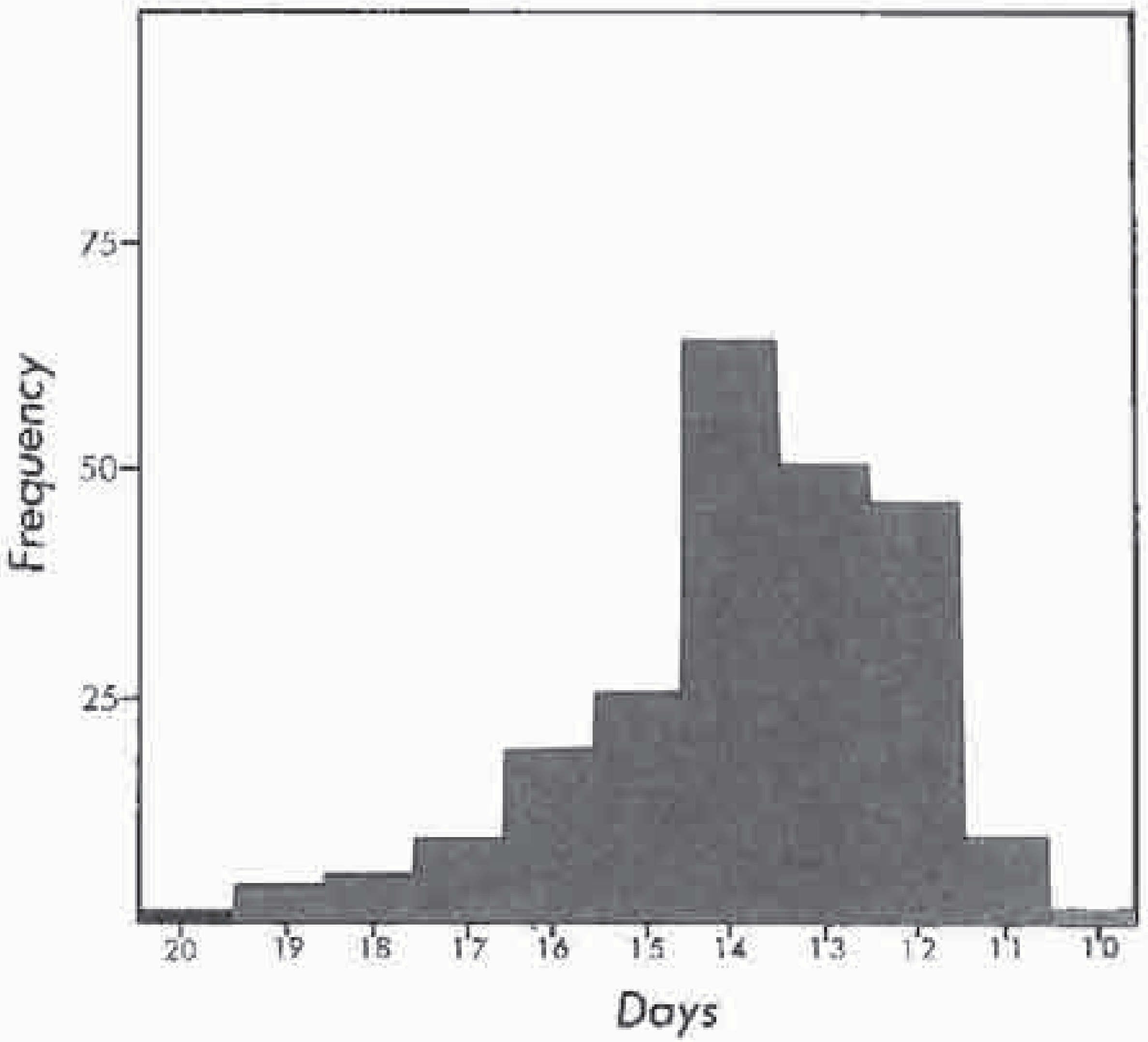

Fig. 9. Internesting intervals recorded from tagged female green turtle emergences on Station beach, Europa Island; November, 1970.

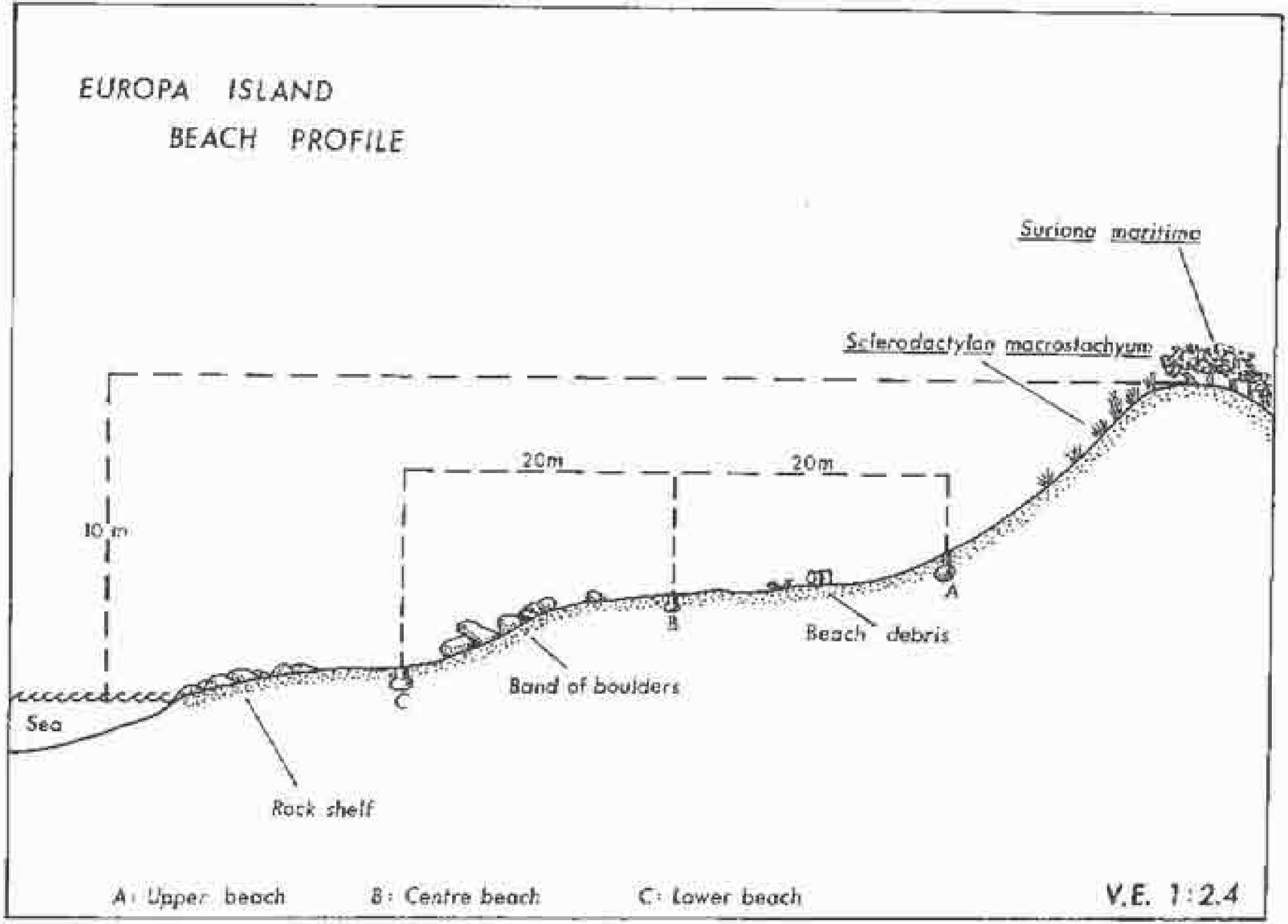

Fig. 10. Profile of Station beach, Europa Island showing sites from which sand samples were taken.

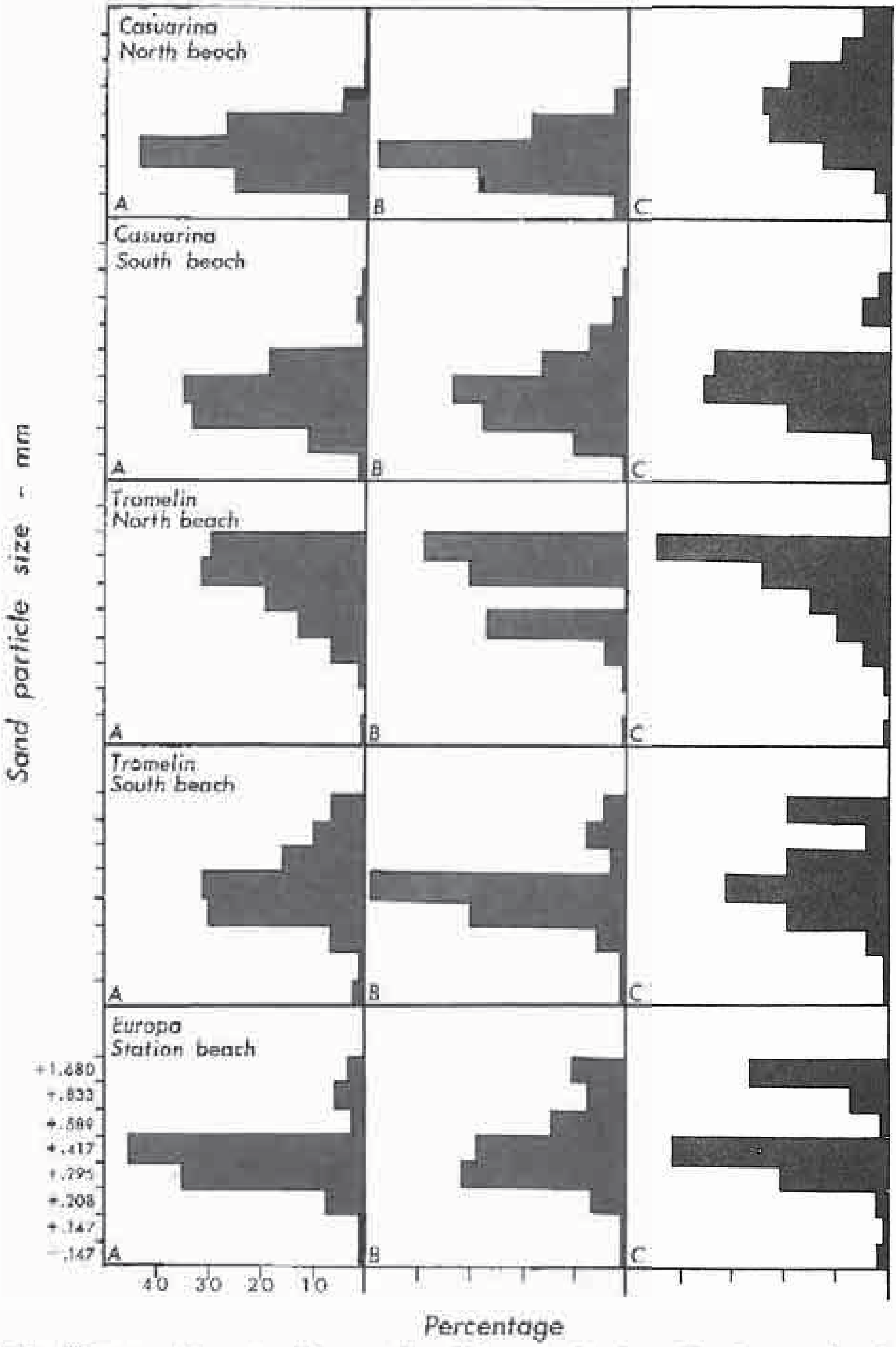

Fig. 11. Histograms of the sand particle composition of 15 samples of beach sand from 5 green turtle nesting beaches in the study area.

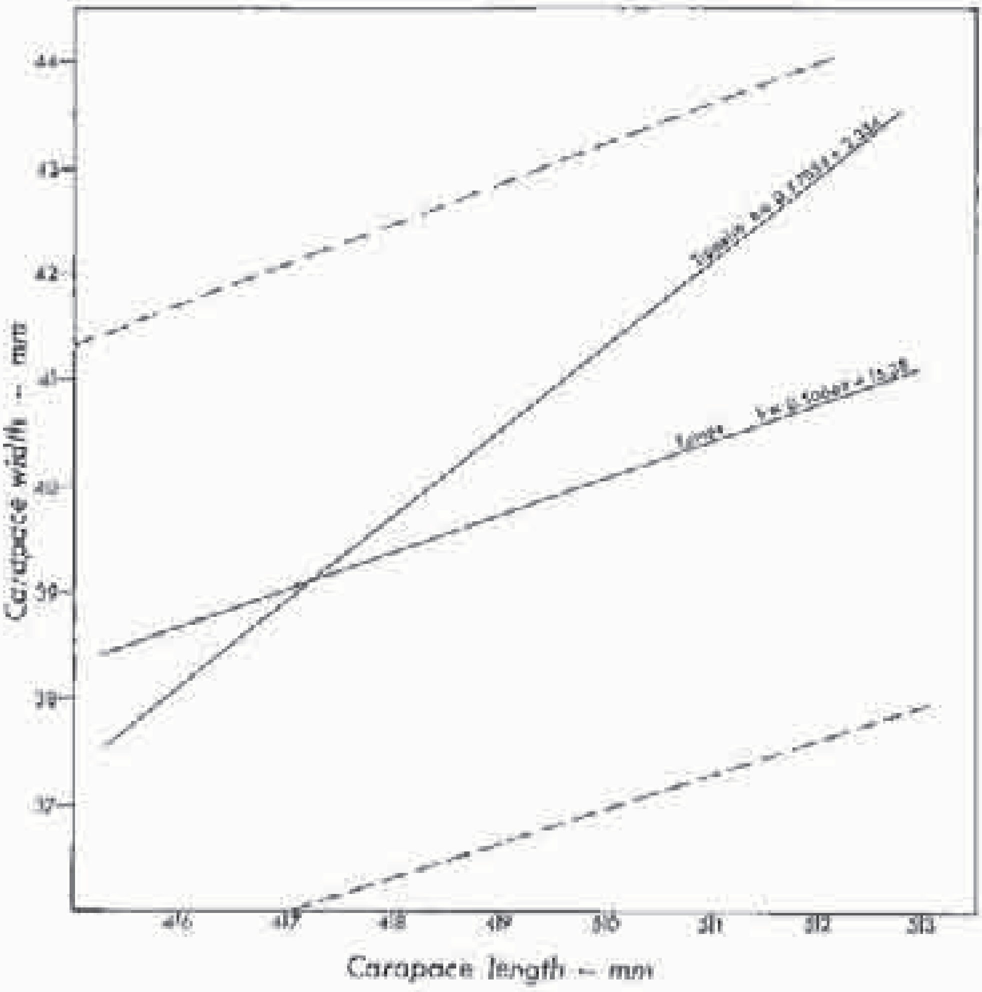

Fig. 12. The relationship between straight carapace length and straight carapace width in a sample of 50 green turtle hatchlings from Europa Island, November, 1970, with 95% confidence limits. The relationship between these parameters for a sample of 50 hatchlings from Tromelin Island (October, 1971) is also included.

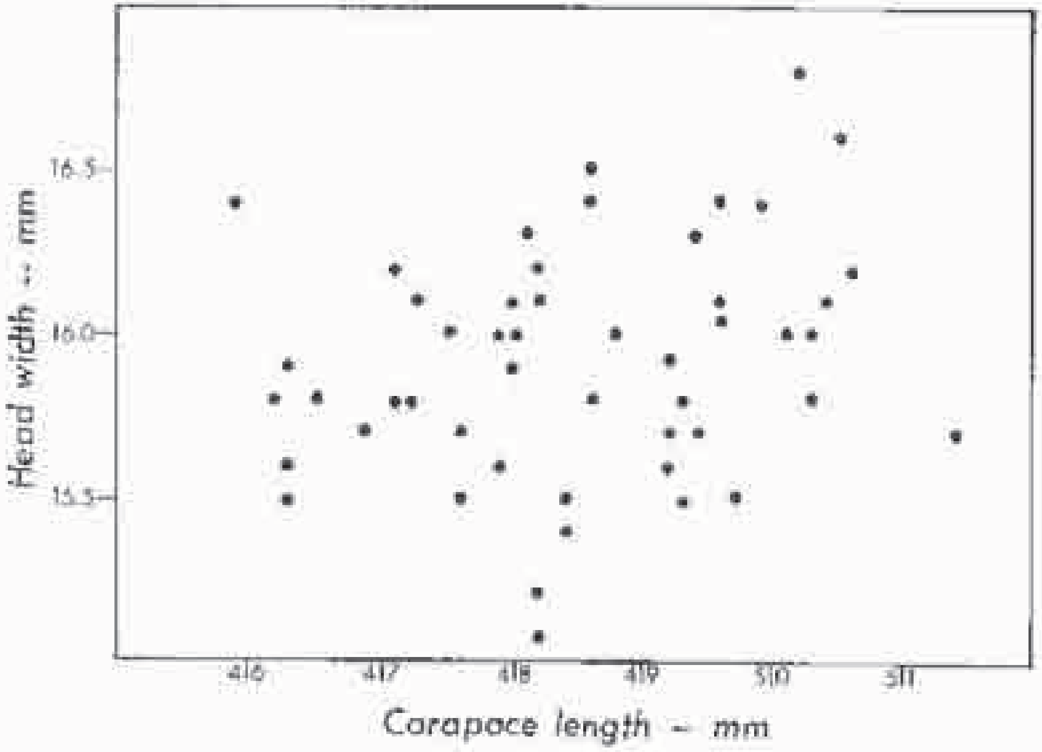

Fig. 13. The relationship between straight carapace length and straight head width in a sample of 50 green turtle hatchlings from Europa Island, November, 1970.

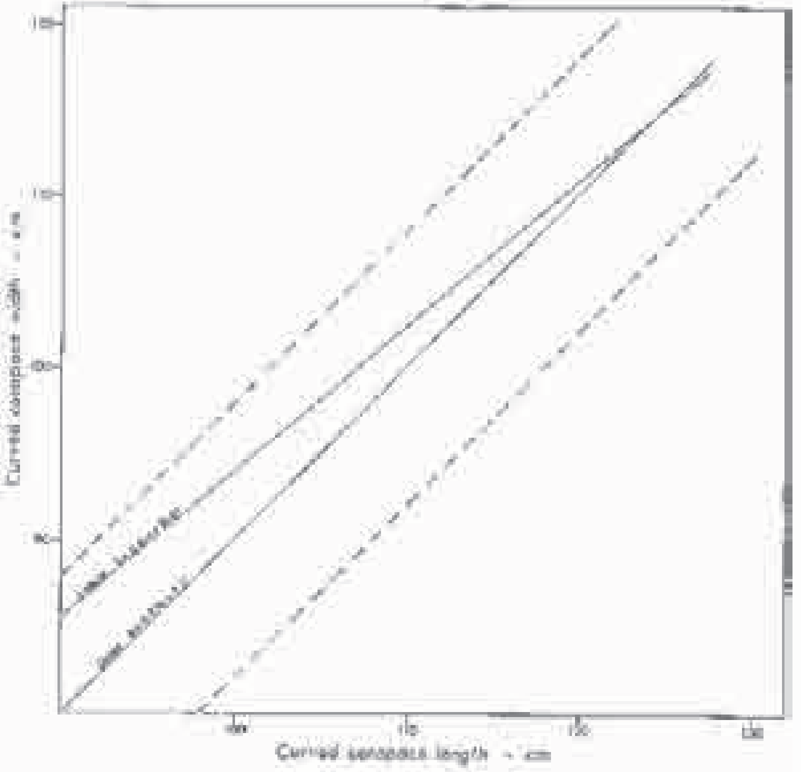

Fig. 14. The relationship between the curved carapace length and curved carapace width in a sample of 50 adult green turtle females from Europa Island, November, 1970, with 95% confidence limits. The same relationship in a sample of 44 females from Tromelin Island (October, 1971) is also included.

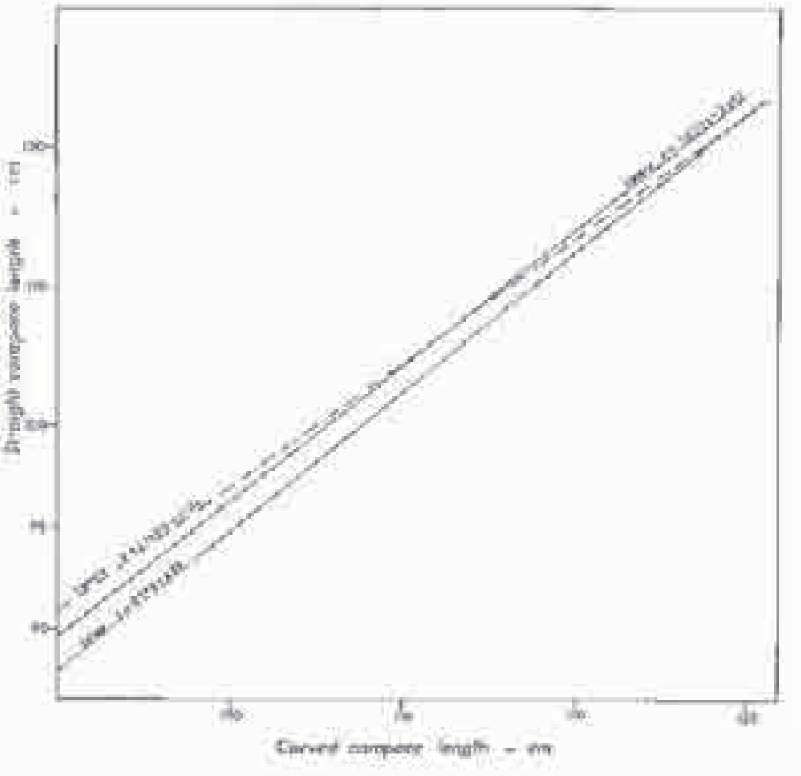

Fig. 15. The relationship between straight and curved carapace length in a sample of 29 adult green turtle females from Europa Island, November, 1970. Relationships between the same parameters in green turtle females from Tromelin (N = 28) and Aldabra (n = 7) are also included.

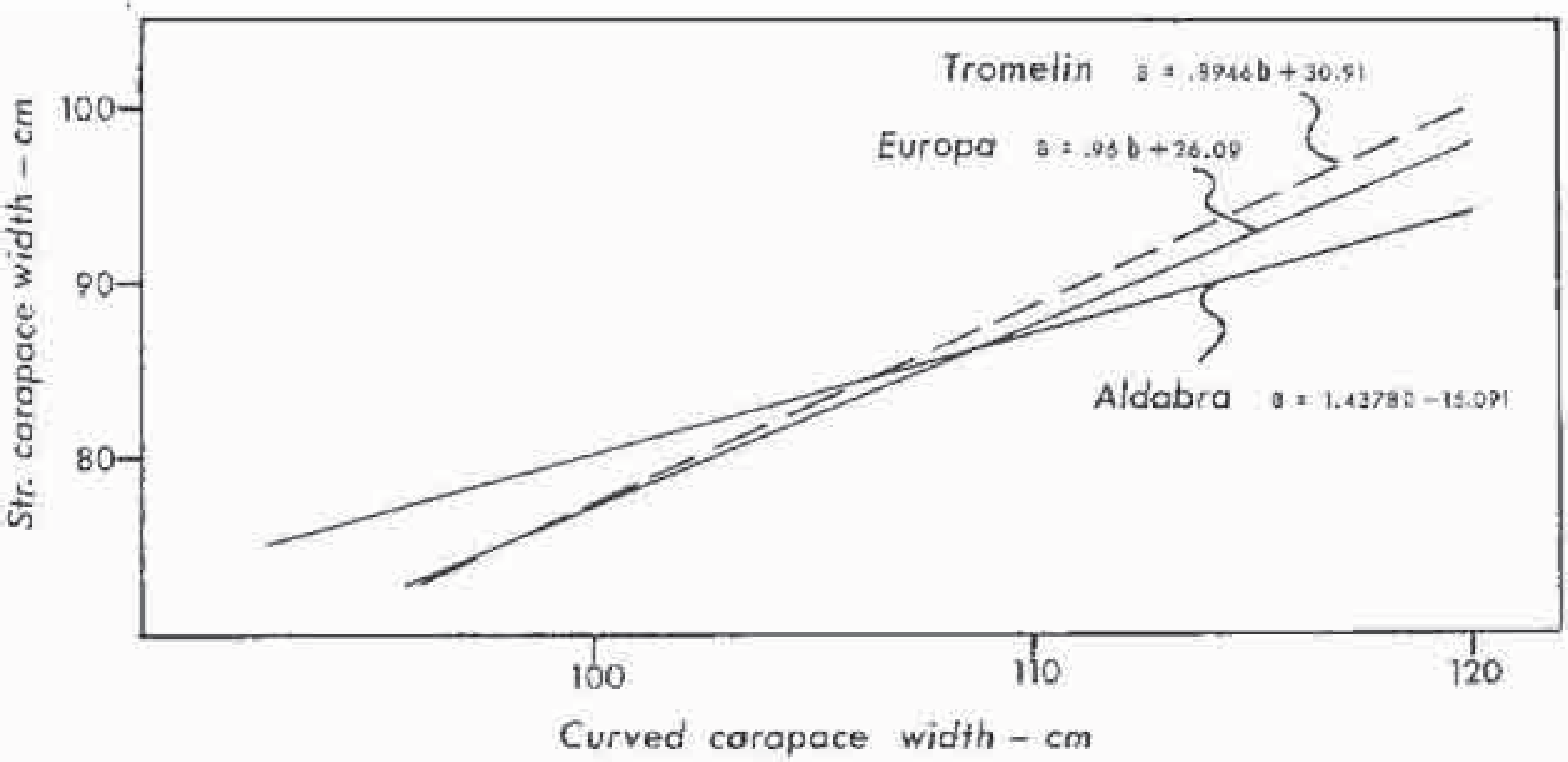

Fig. 16. The relationship between straight carapace width and curved carapace width in green turtle females from Europa Island ($n = 29$), Tromelin ($n = 28$), and Aldabra ($n = 7$).

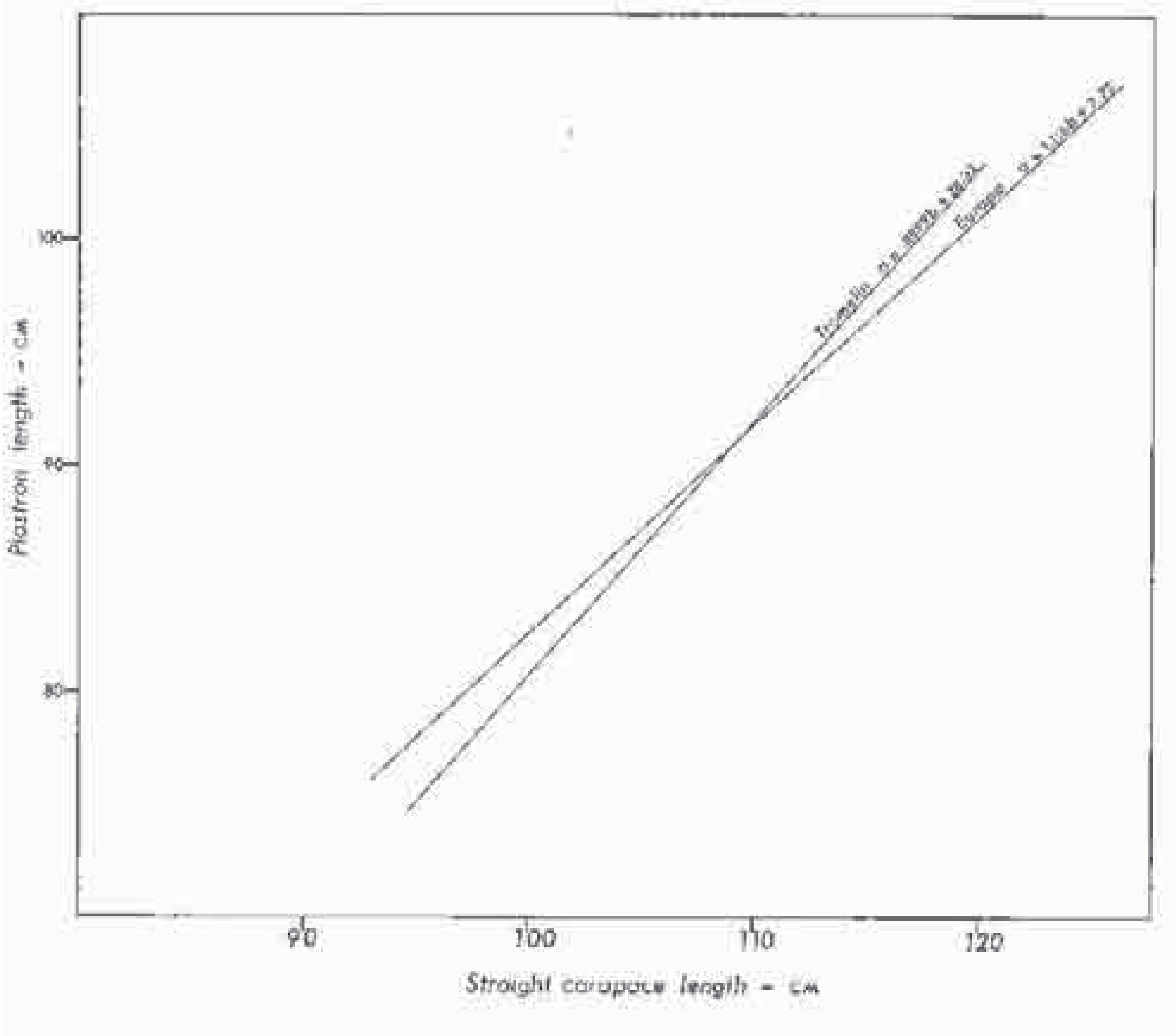

Fig. 17. The relationship between straight carapace length and straight plastron length in adult green turtle females from Europa Island ($n = 29$) and Tromelin Island ($n = 28$).

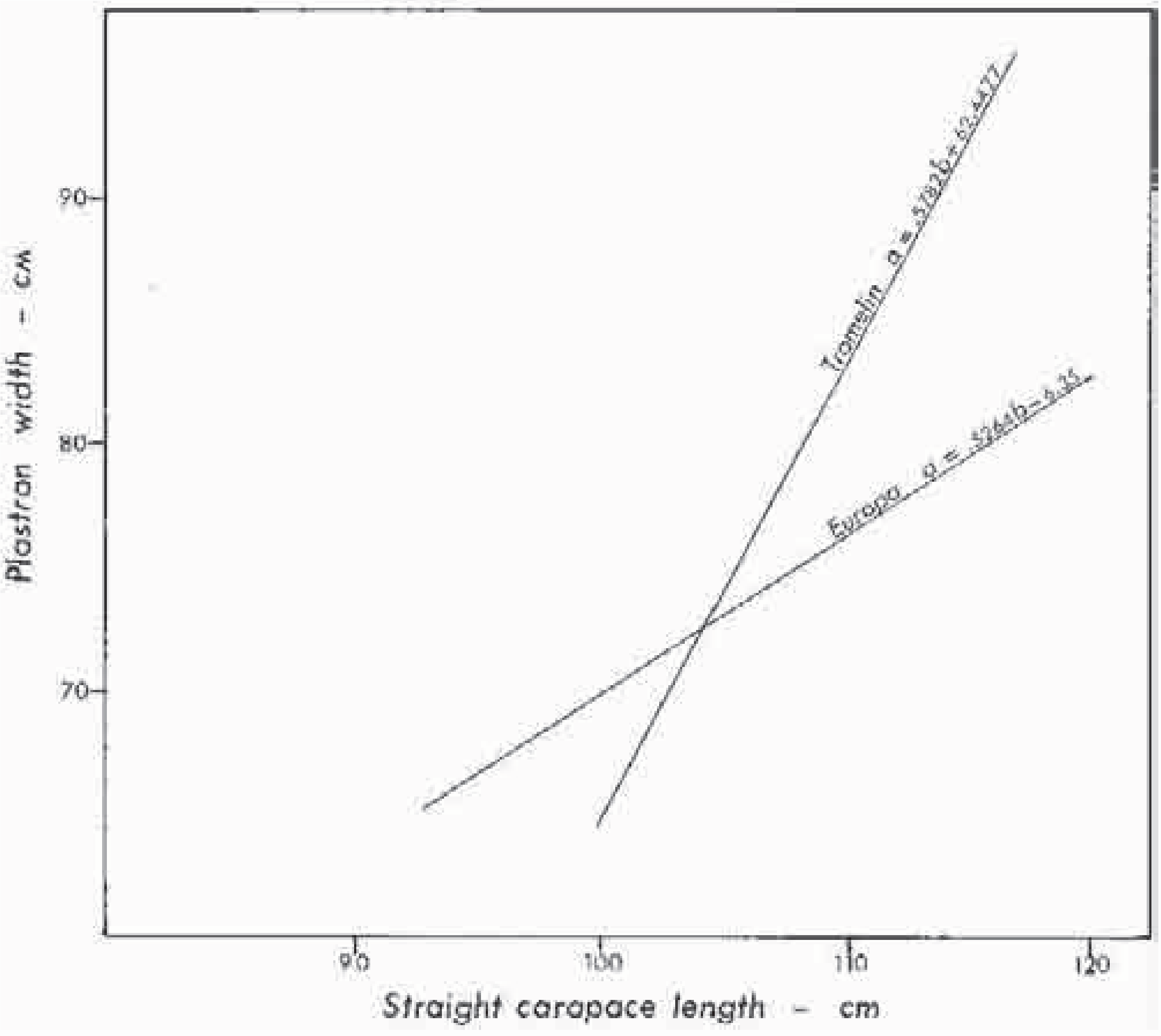

Fig. 18. The relationship between straight carapace length and straight plastron width in adult green turtle females from Europa Island (n = 29), and Tromelin Island (n = 28).

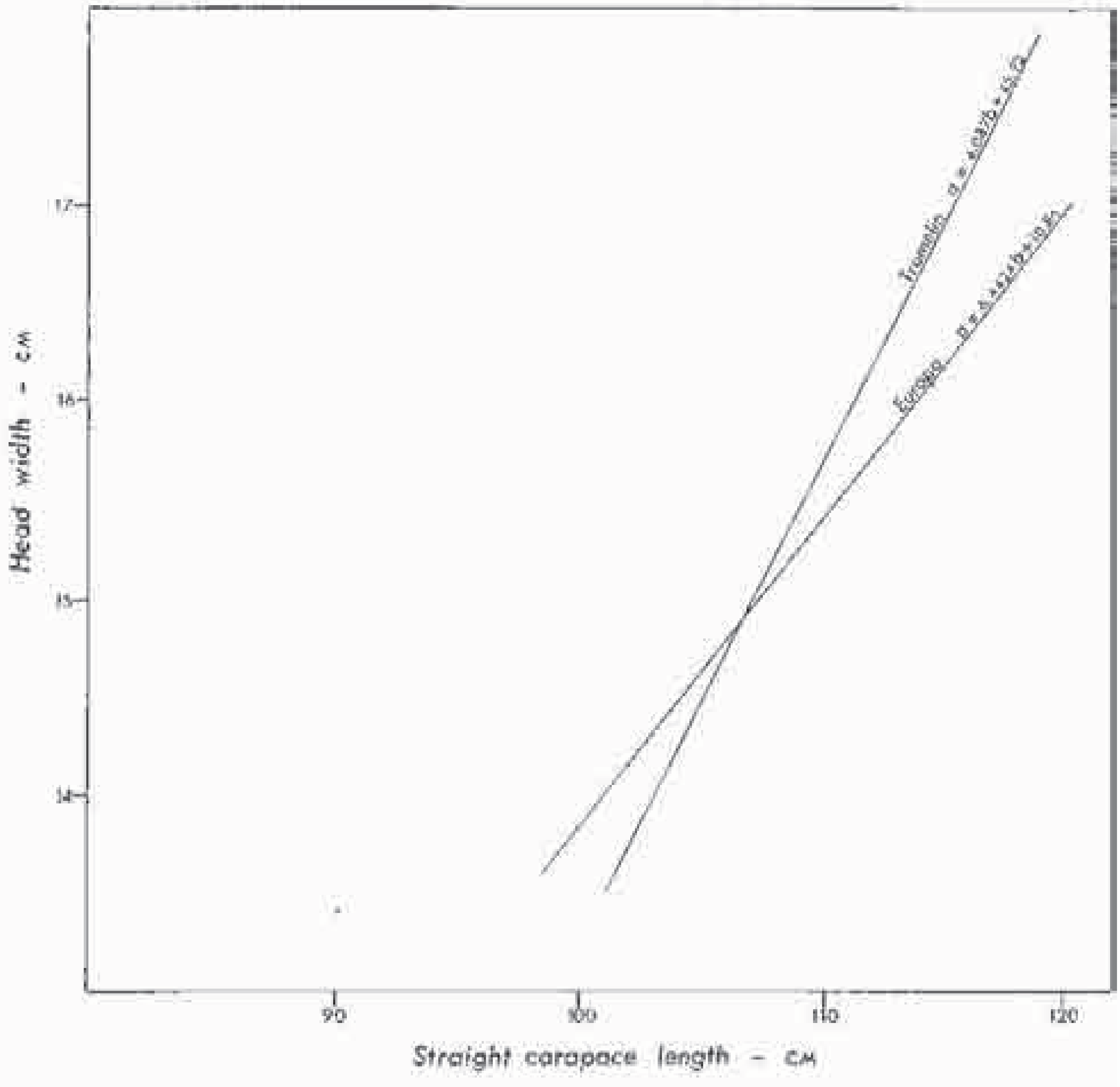

Fig. 19. The relationship between straight carapace length and straight head width in adult green turtle females from Europa Island (n = 29), and Tromelin Island (n = 28).

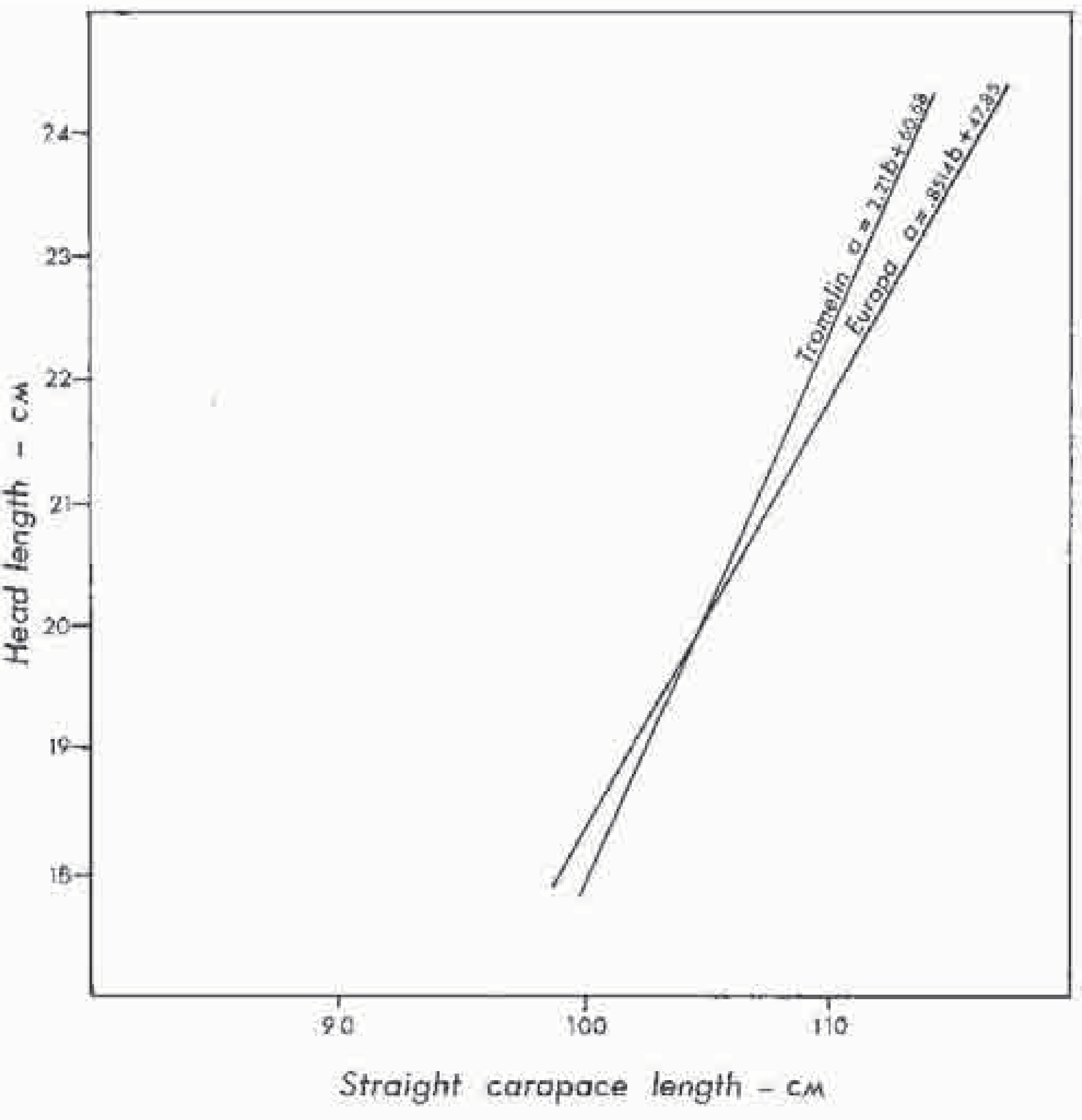

Fig. 20. The relationship between straight carapace length and curved head length in adult green turtle females from Europa Island (n = 29) and Tromelin Island (n = 28).

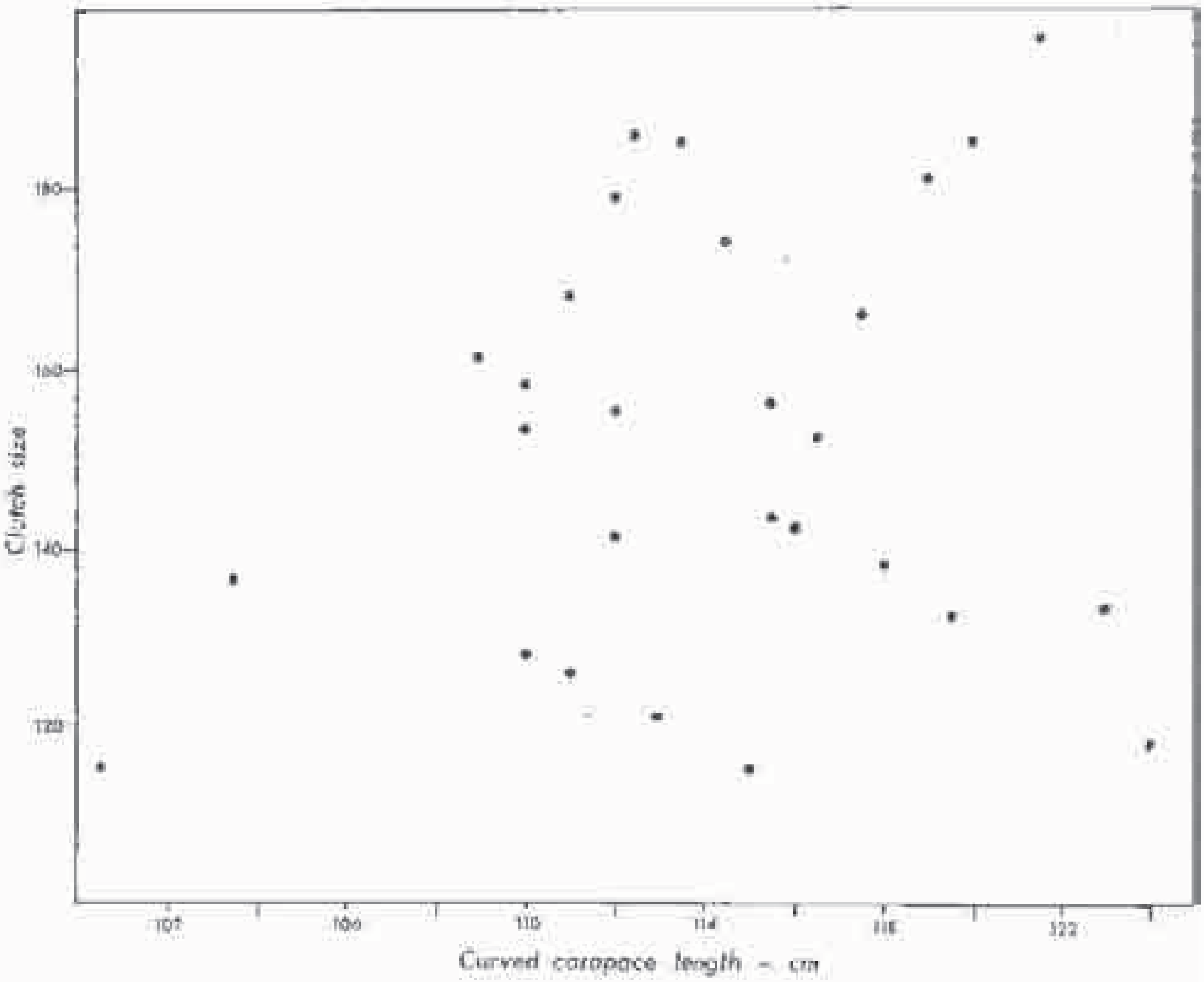

Fig. 21. The relationship between curved carapace length and egg clutch size in green turtles from Europa Island, November, 1970 (n = 28).

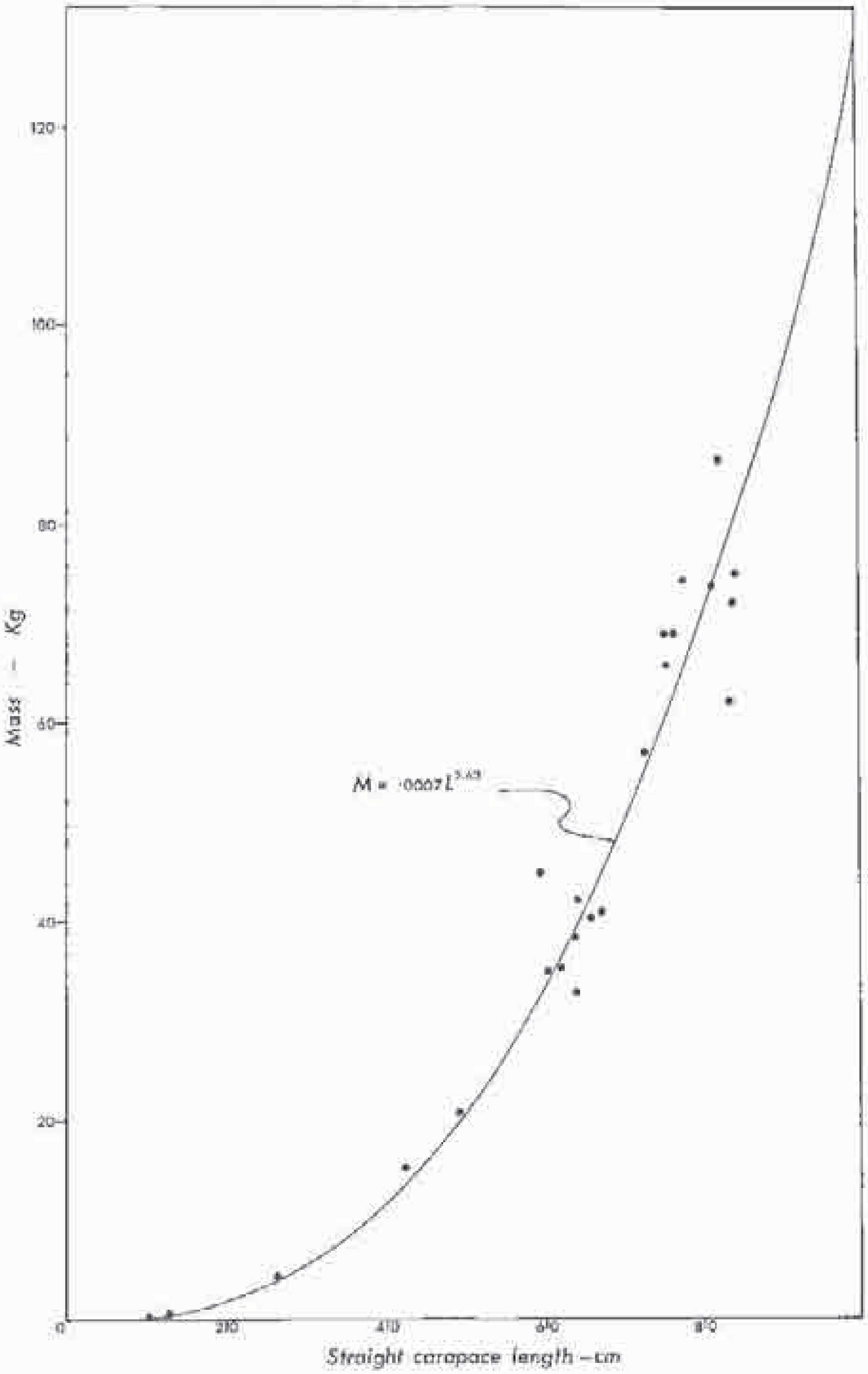

Fig. 22. The relationship between straight carapace length and mass in the hawksbill turtle in the study region.

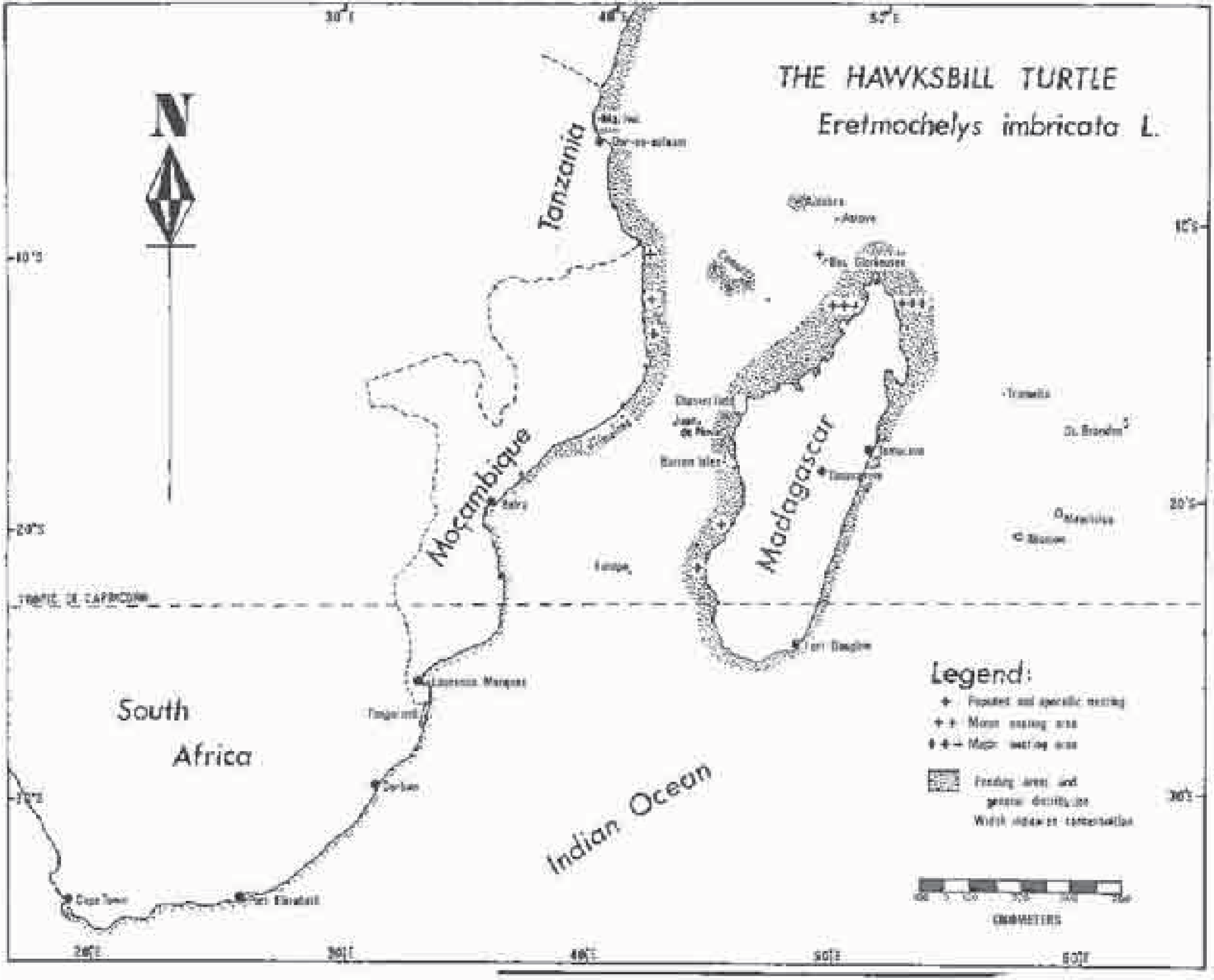

Fig. 23. **The** distribution and **nesting** areas of the hawksbill turtle *Eretmochelys imbricata* in the study region. Width of **stippling** indicates relative abundance.

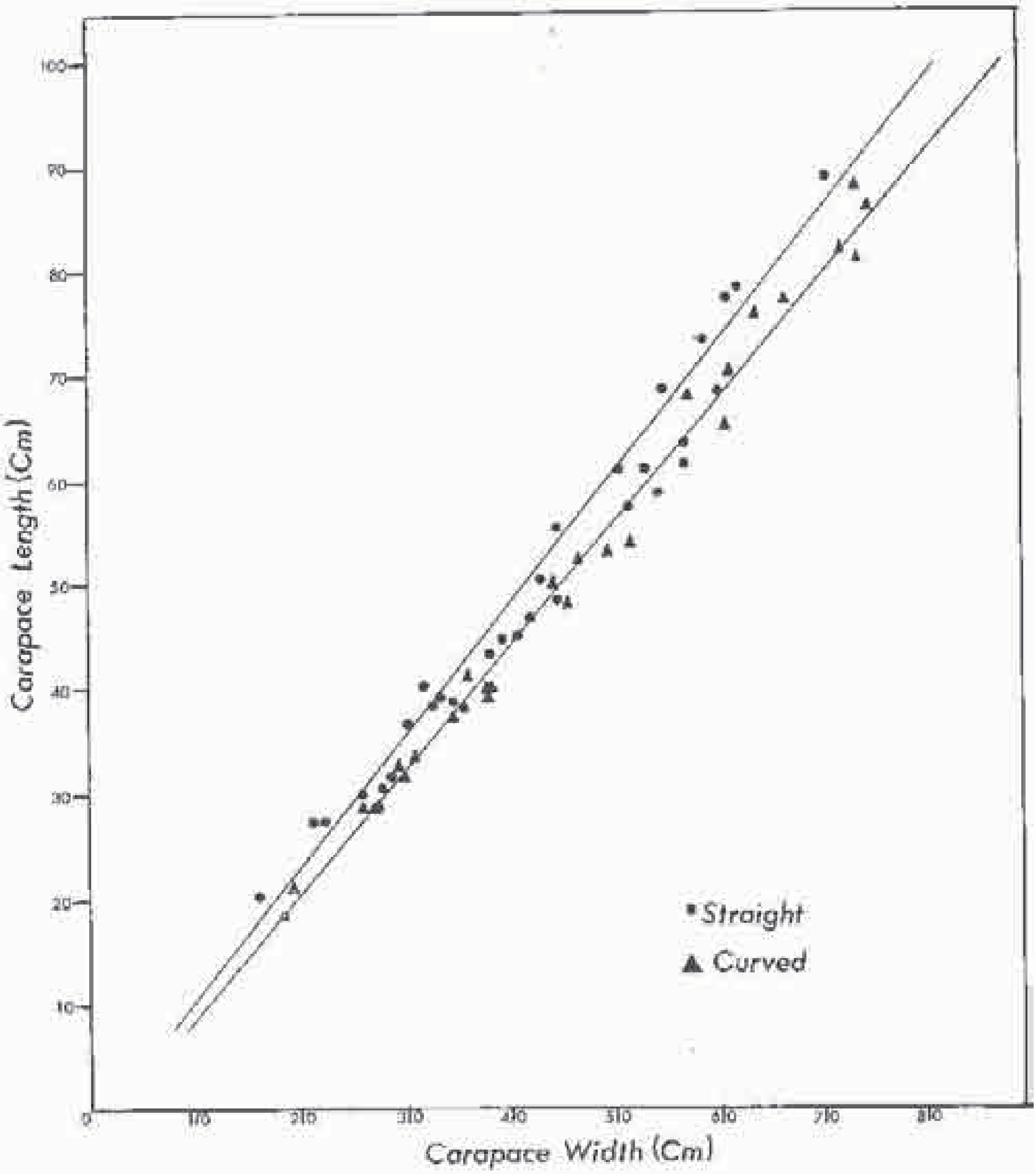

Fig. 24. The relationships between curved carapace length/curved carapace width, and straight carapace length/straight carapace width in hawksbill turtles from the study region.

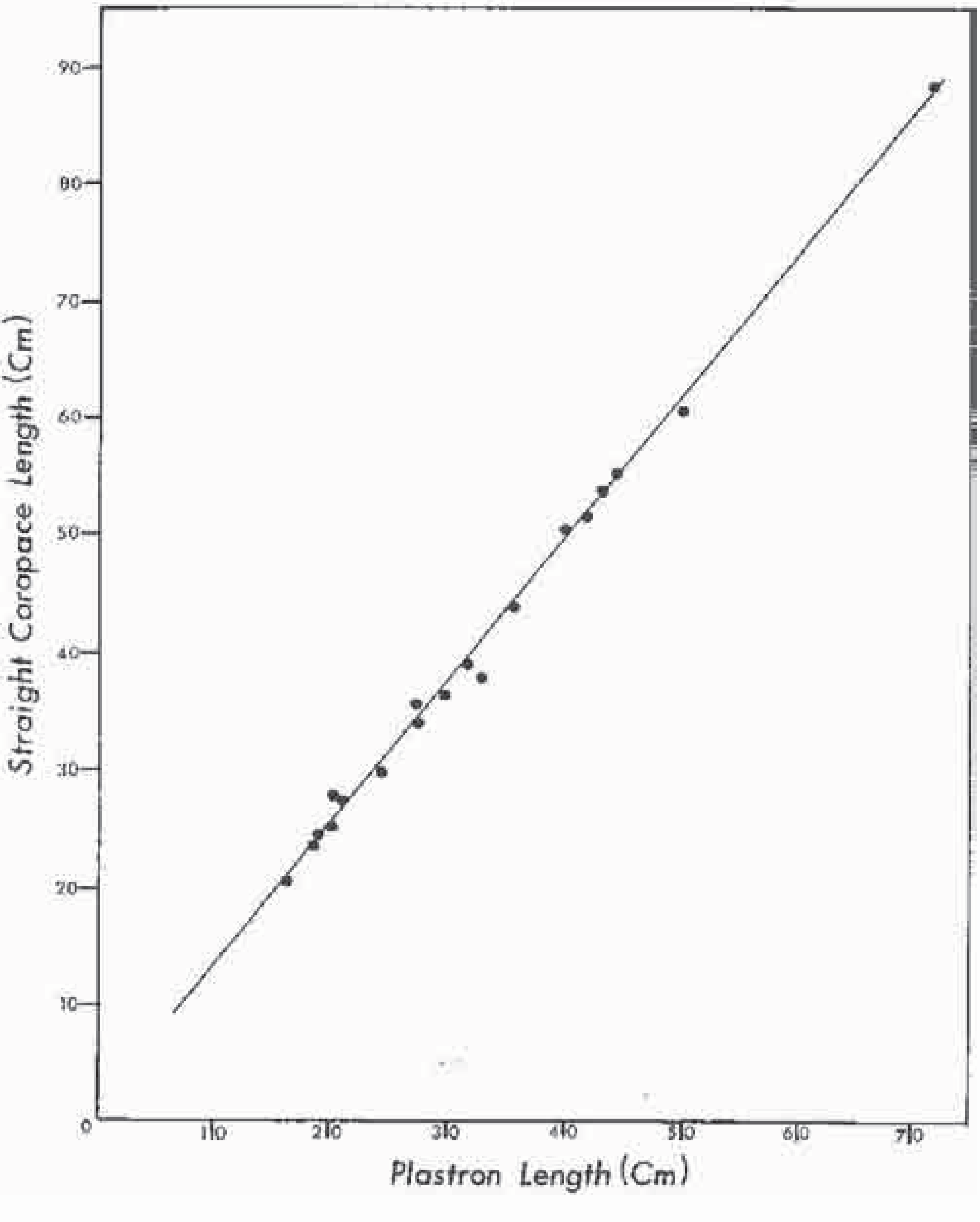

Fig. 25. The relationship between straight carapace length and plastron length in the hawksbill turtle.

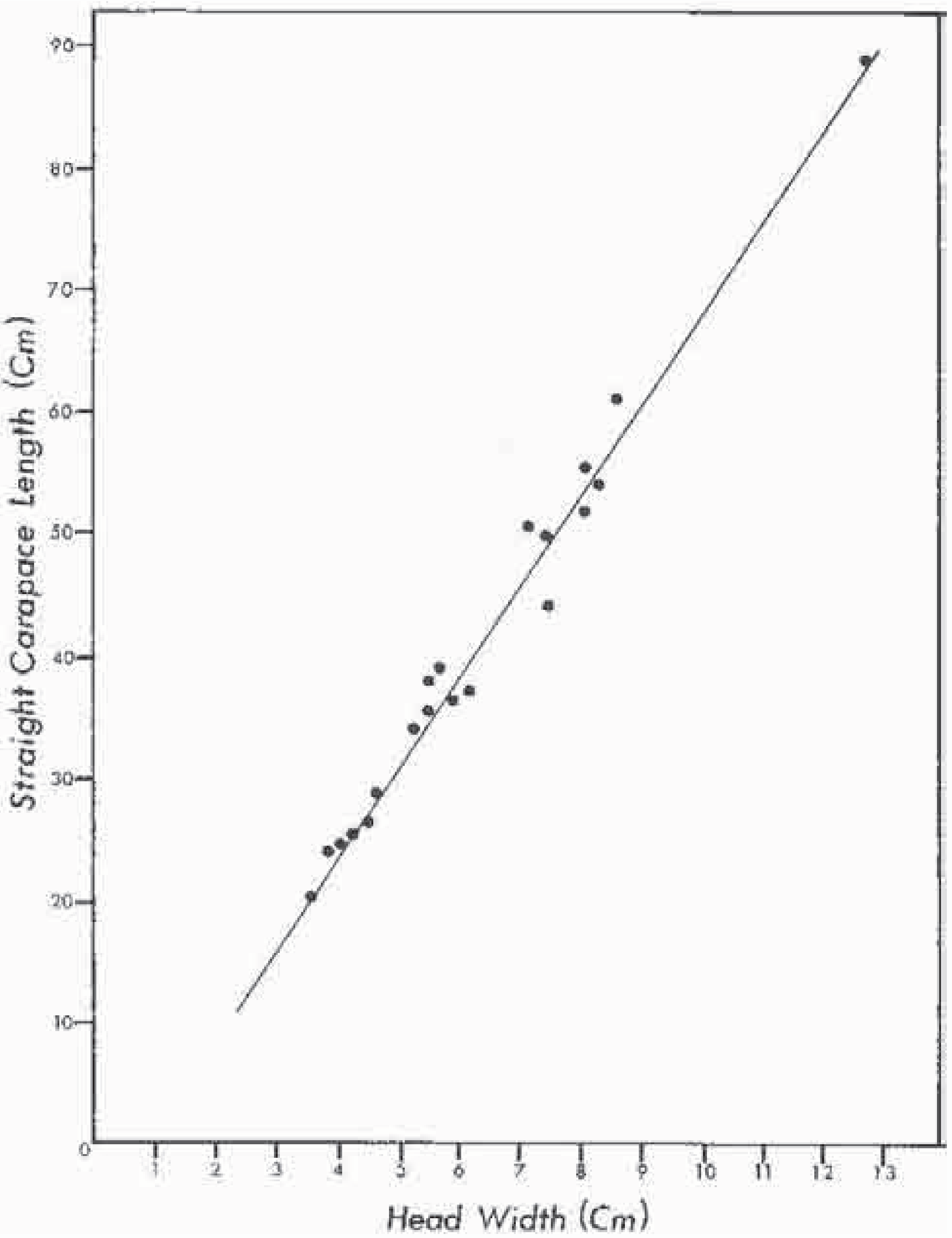

Fig. 26. The relationship between straight carapace length and head width in the hawksbill turtle.

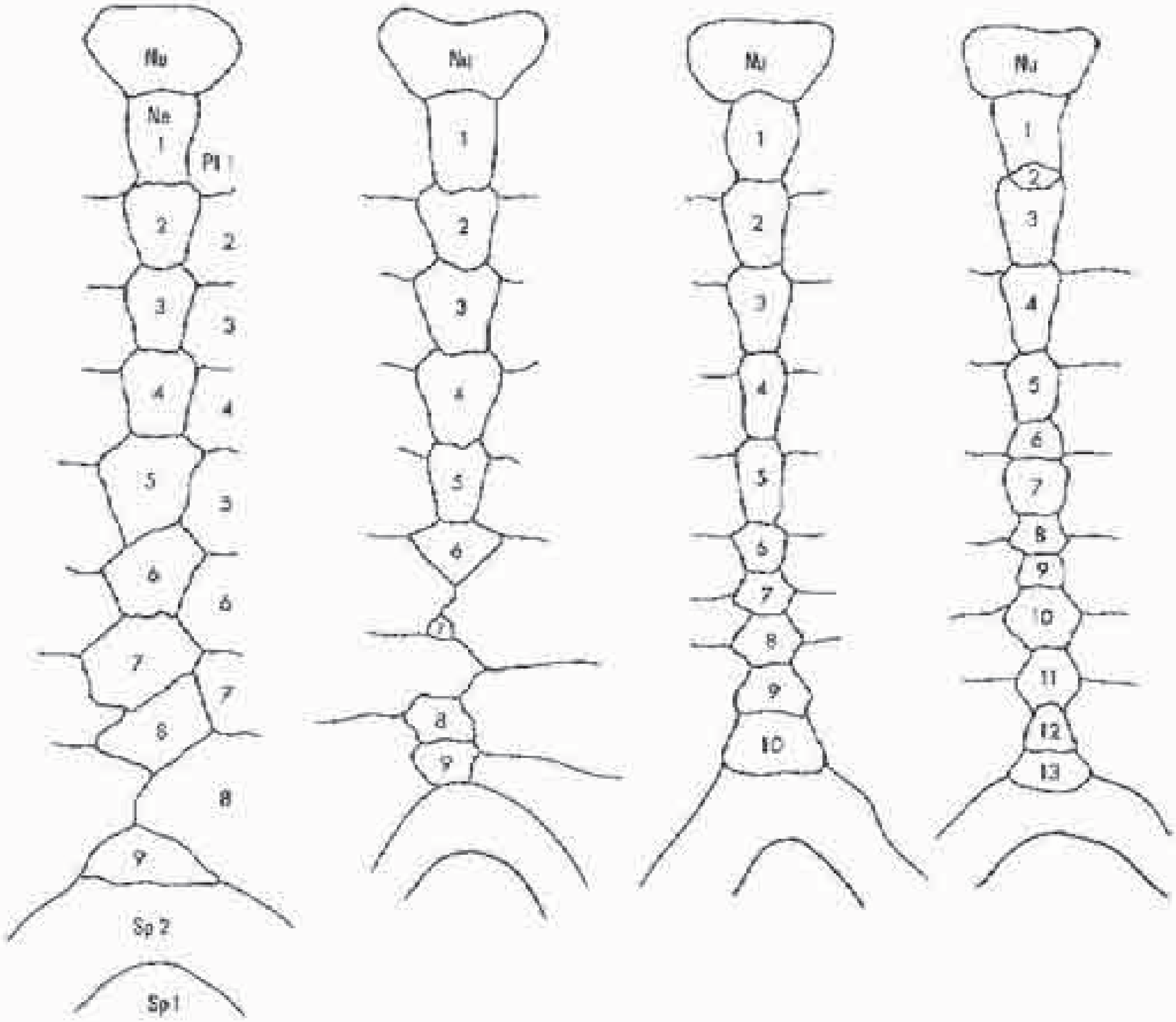

Fig. 27. Four examples of neural bone patterns in loggerhead carapaces from the Natal coast.

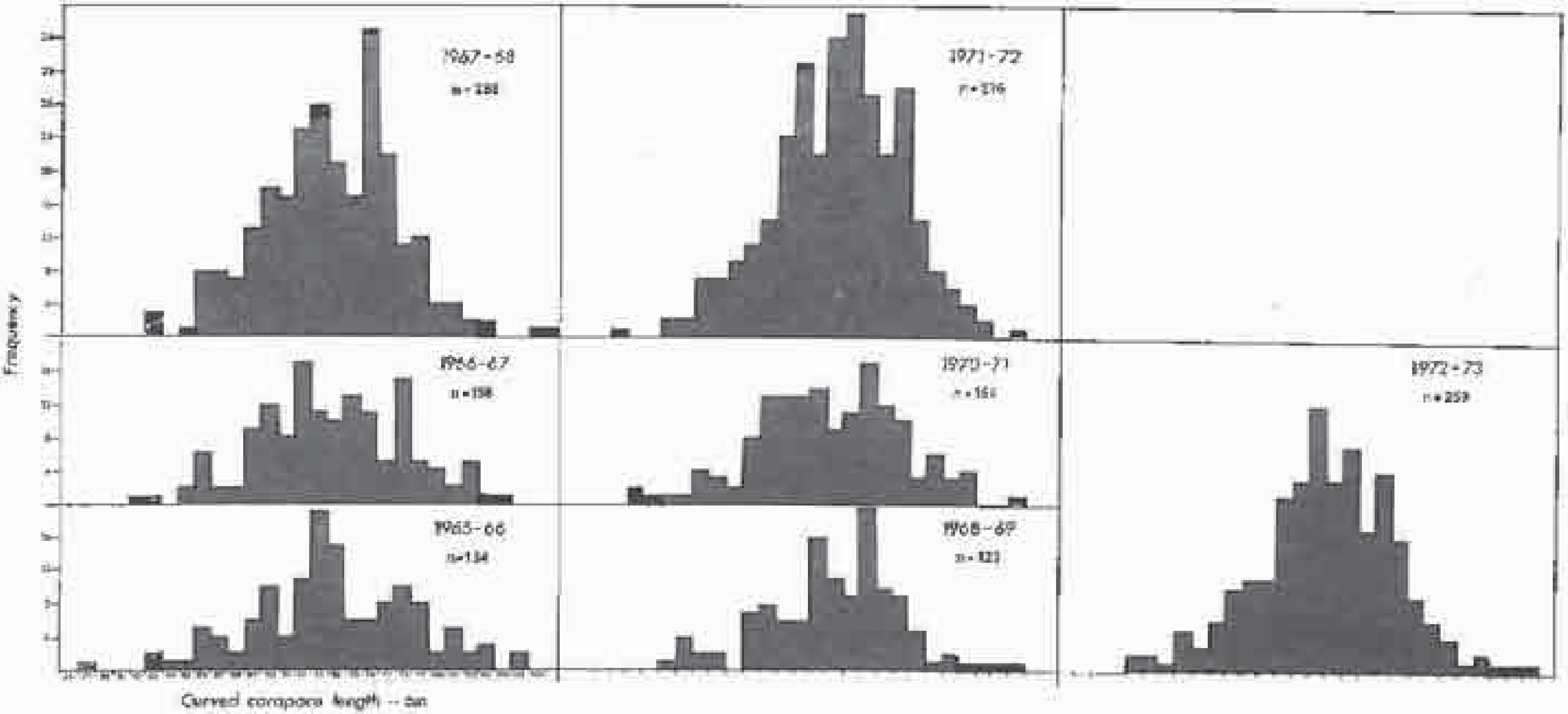

Fig. 28. The size distribution of nesting loggerhead females in seven seasons in Tongaland, Natal.

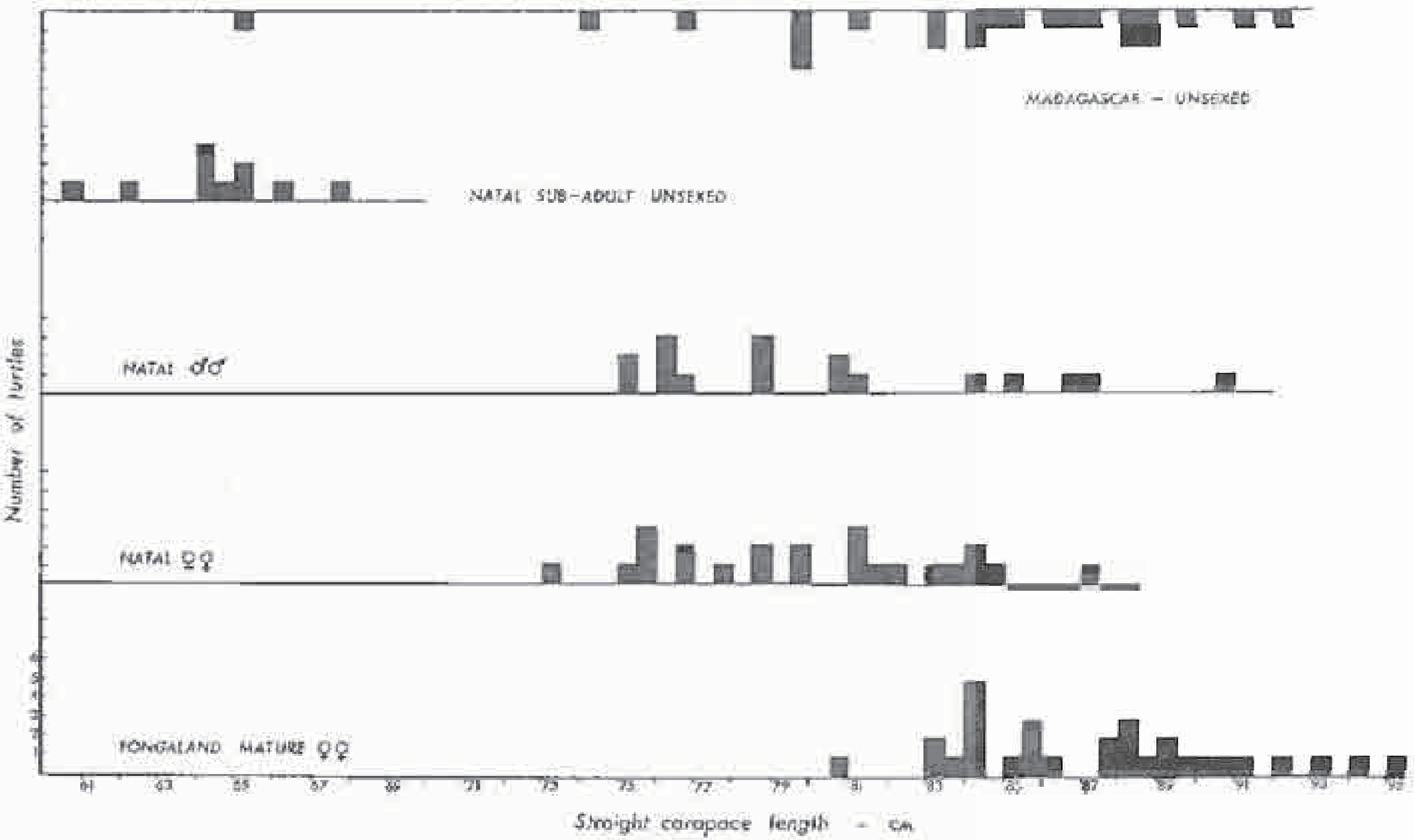

Fig. 29. The size distribution of loggerhead material examined in Natal (males, females and young sub-adults), a sample of mature females from Tongaland, and unsexed material from Madagascar.

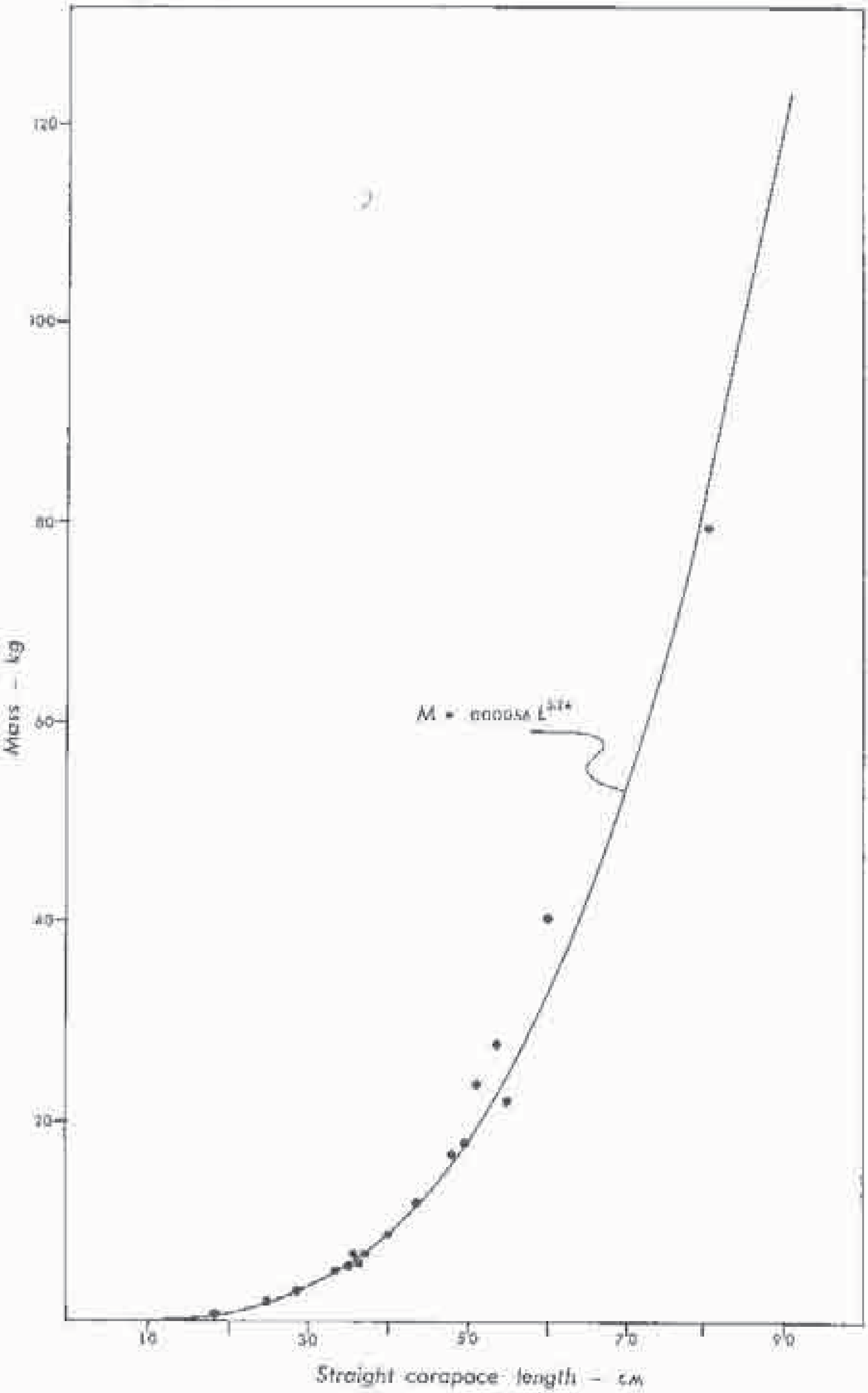

Fig. 30. The length-mass relationship in loggerhead turtles from the Natal coast.

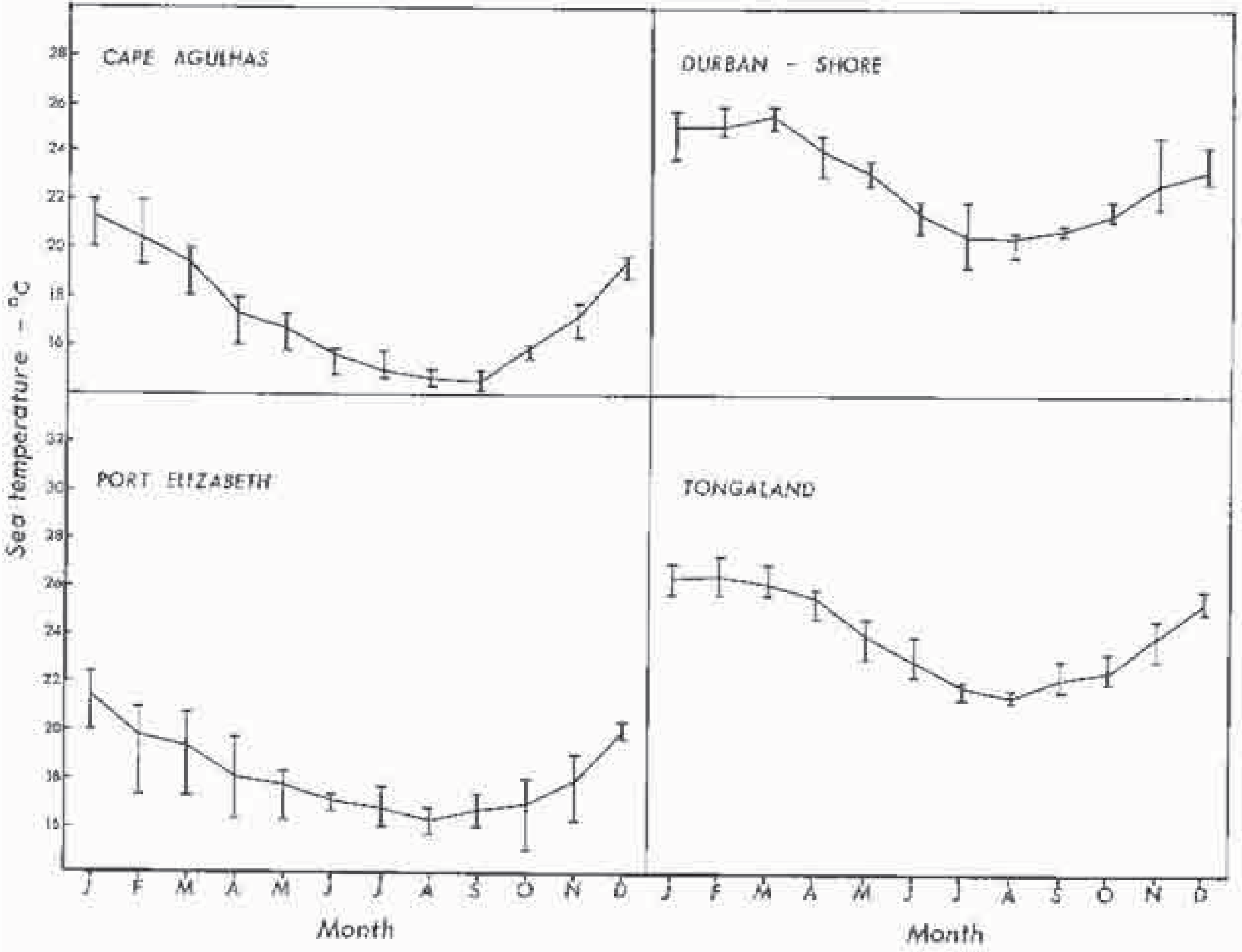

Fig. 31. Mean monthly sea shore temperatures at four localities on the east and south coasts of South Africa. Vertical bars indicate ranges from 1969-1972 inclusive.

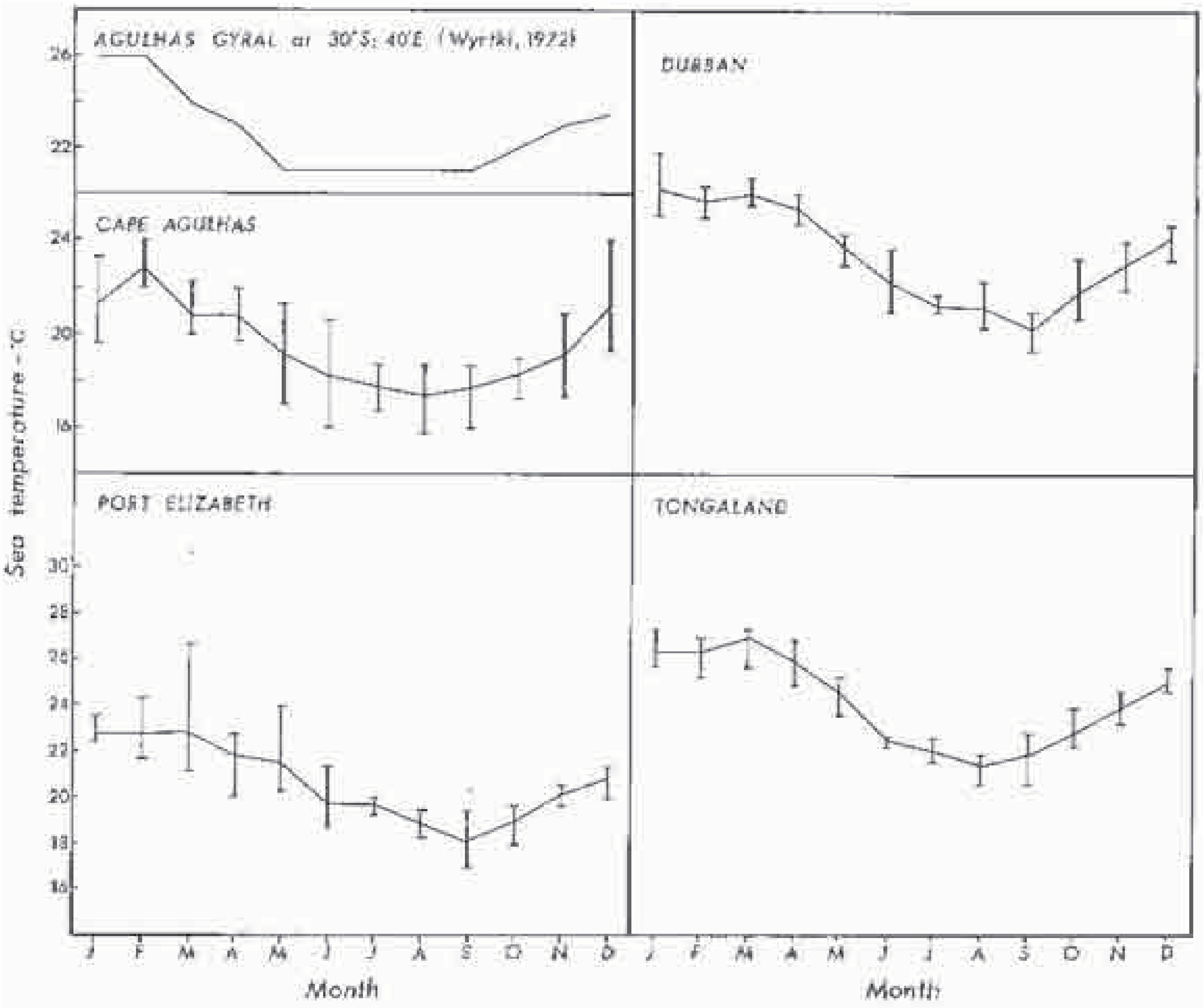

Fig. 32. Mean monthly sea temperatures 150 nautical miles offshore four localities on the east and south coasts of South Africa, and in the centre of the Agulhas Gyral. Vertical bars indicate ranges from 1969-1972 inclusive,

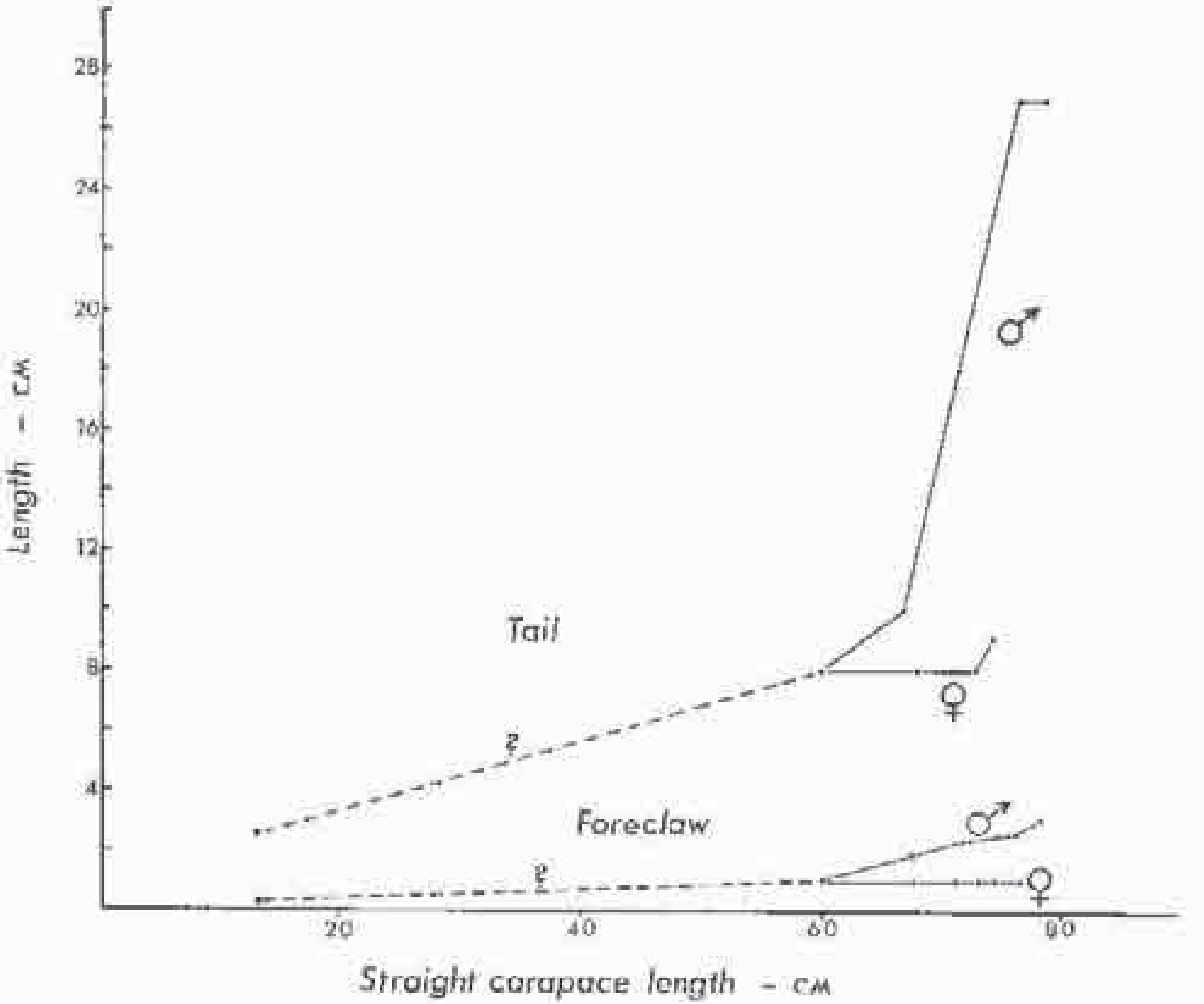

Fig. 33. Tail and claw growth differences in one male and one female loggerhead turtle from the Durban Aquarium.

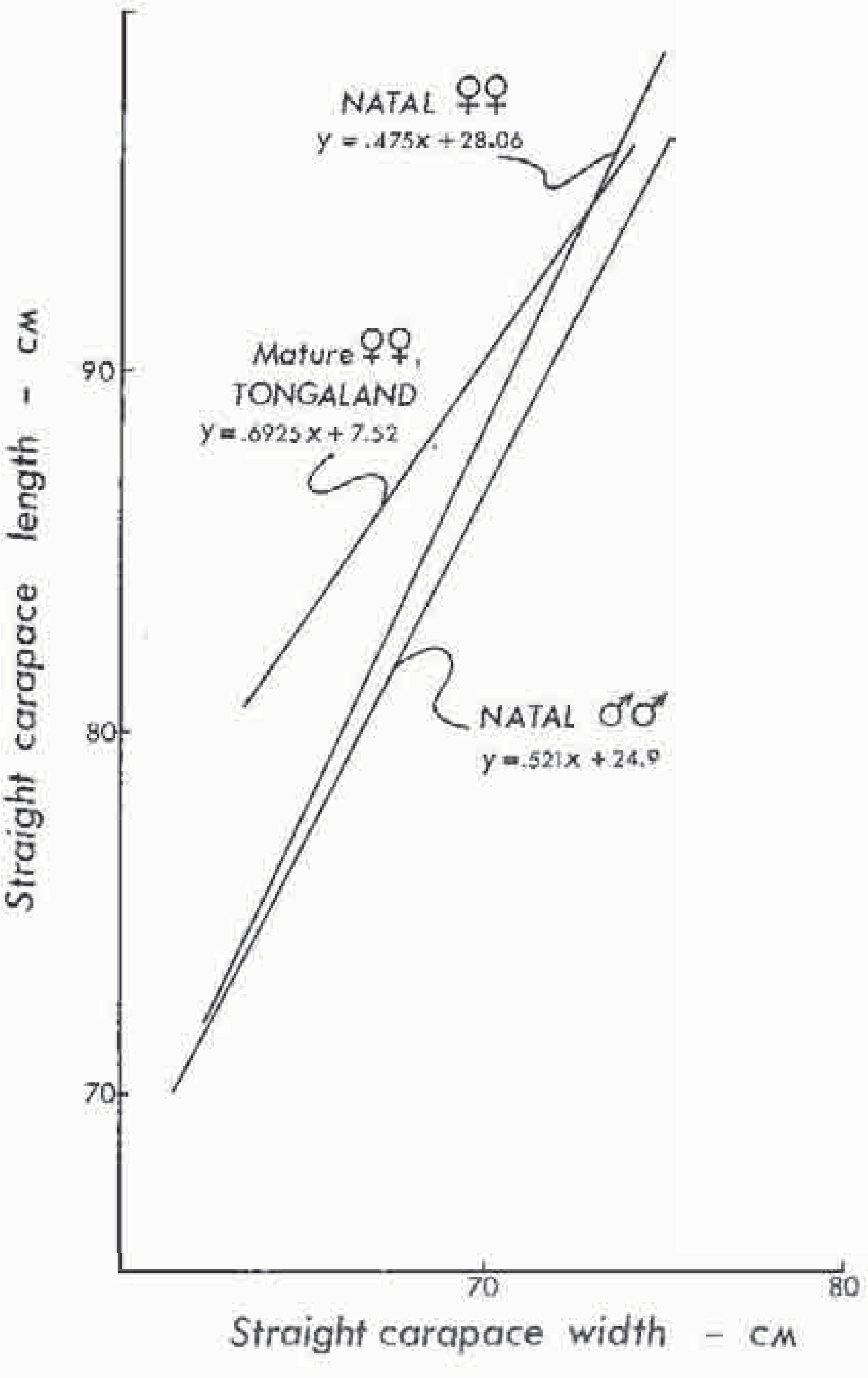

Fig. 34. The relationship between straight carapace length and straight carapace width in Natal coast males and females, and mature Tongaland females.

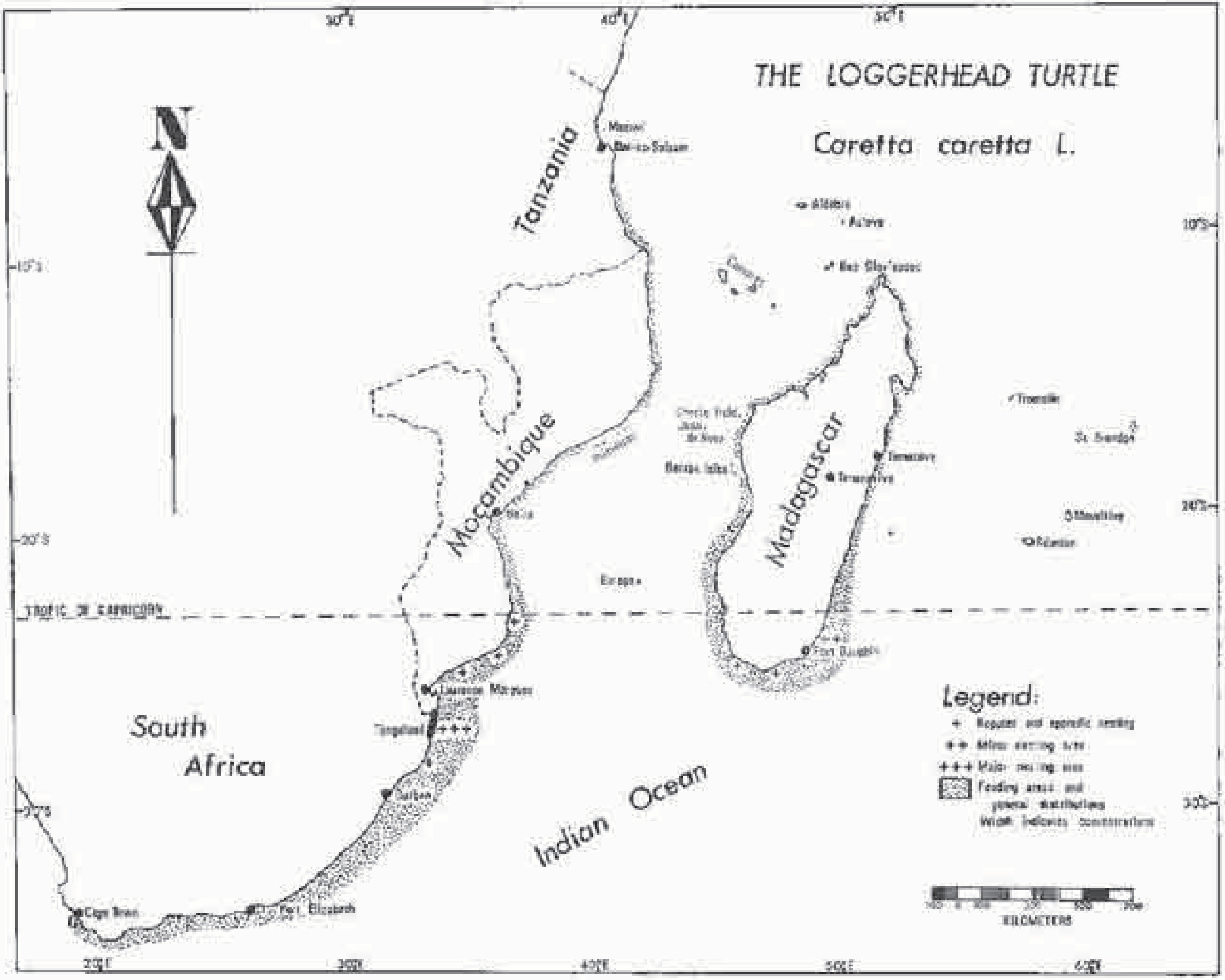

Fig. 35. The distribution and nesting areas of the loggerhead turtle *Caretta caretta* in the study region. Width

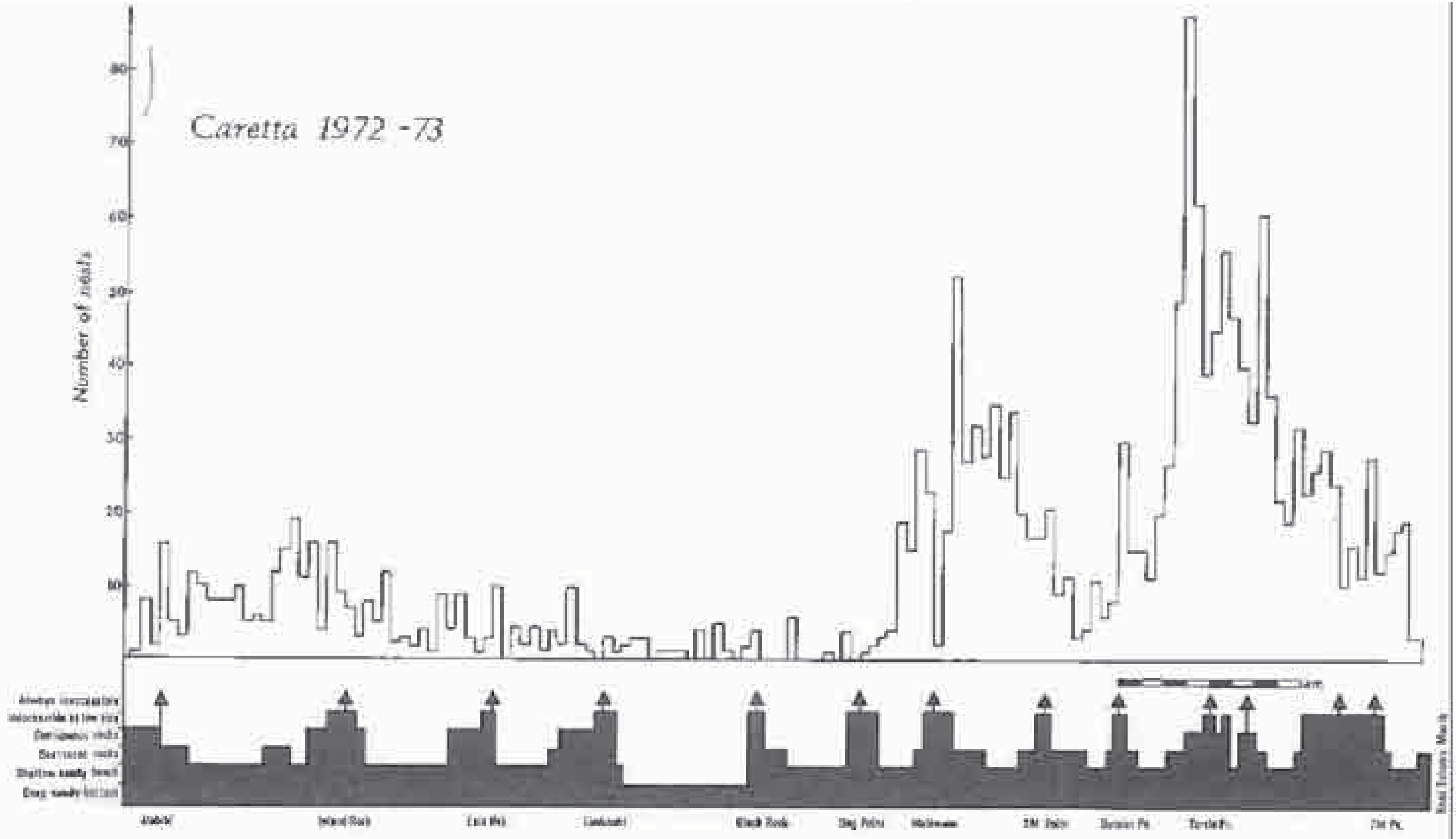

Fig. 36. Loggerhead nesting activity during the 1972-1973 season along the Tongaland study region showing the nature of the littoral zone.

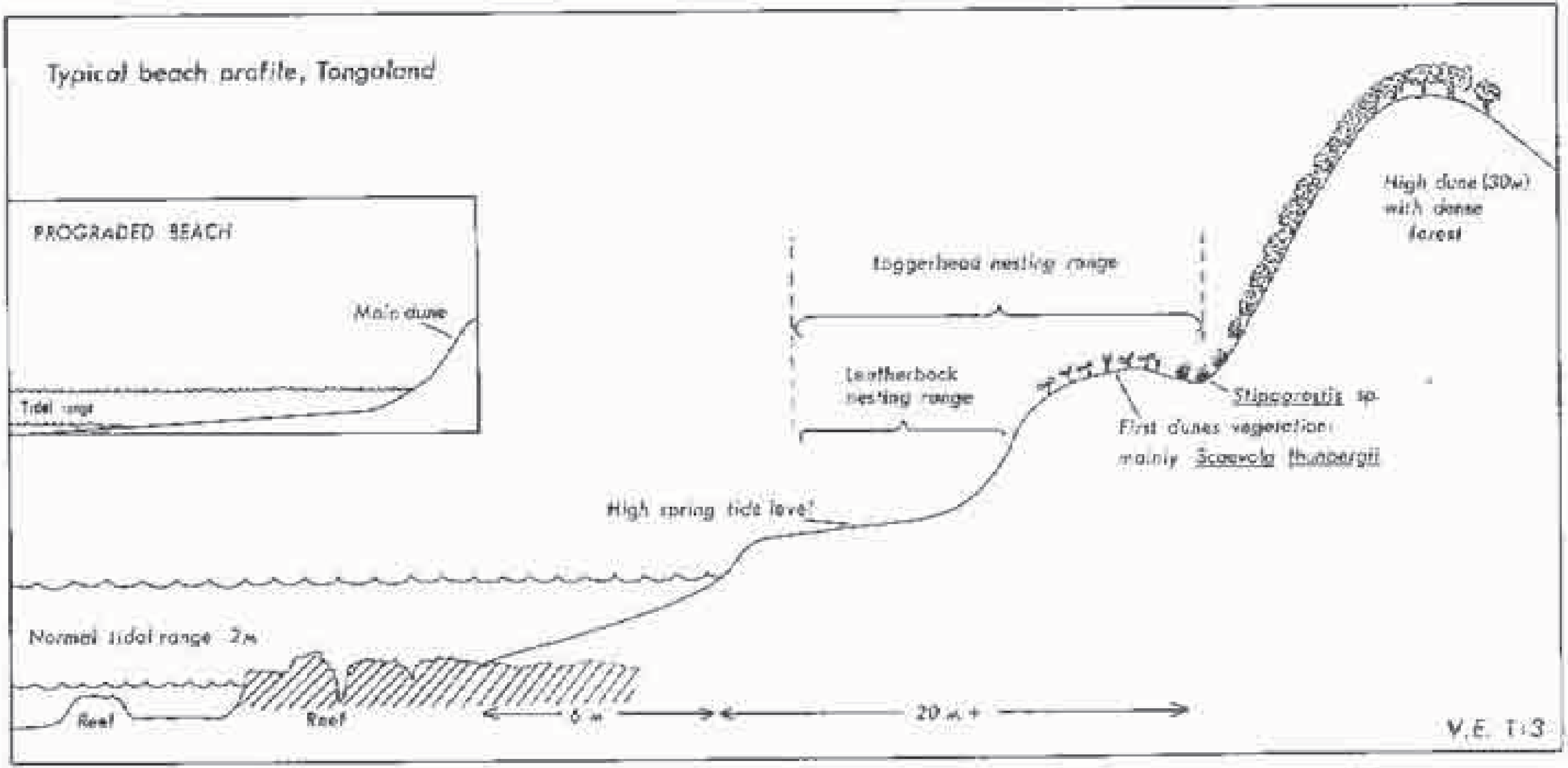

Fig. 37. An example of a typical retrograded beach in Tongaland, heavily utilized by nesting turtles. An example of the less common prograded beach type is inset.

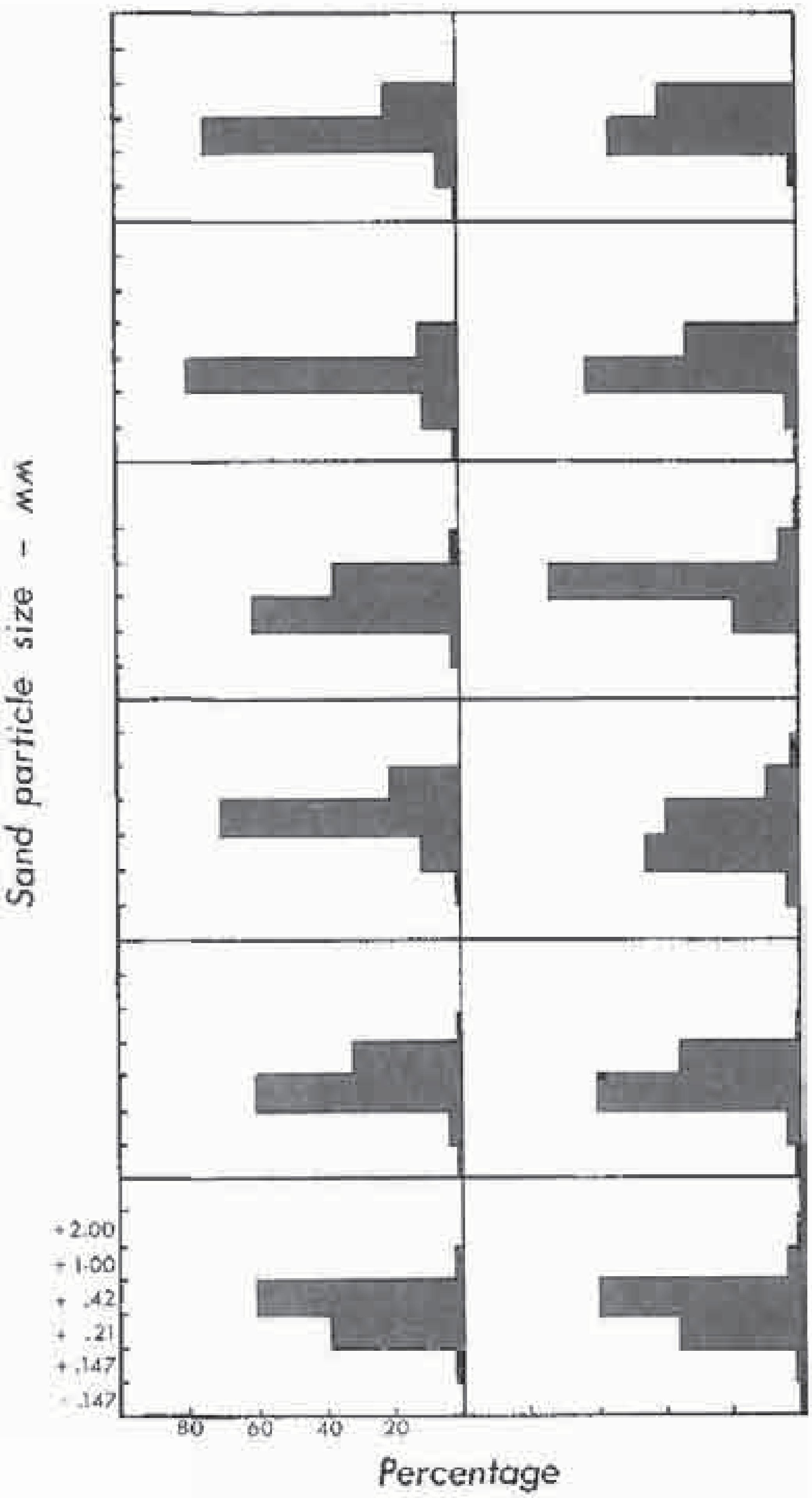

Fig. 38. Sand particle sizes from samples taken at 12 sites along the Tongaland protected zone.

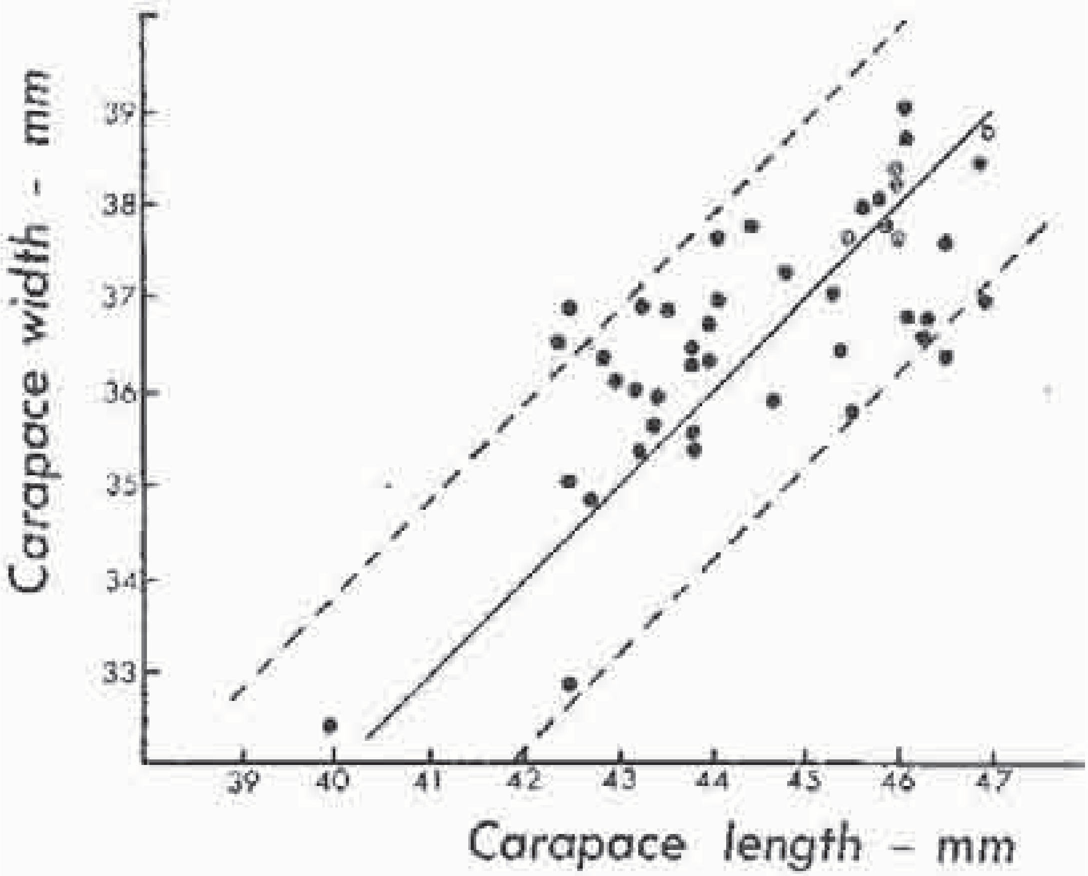

Fig. 39. The relationship between carapace length and width in a sample of 50 loggerhead hatchlings from Tongaland.

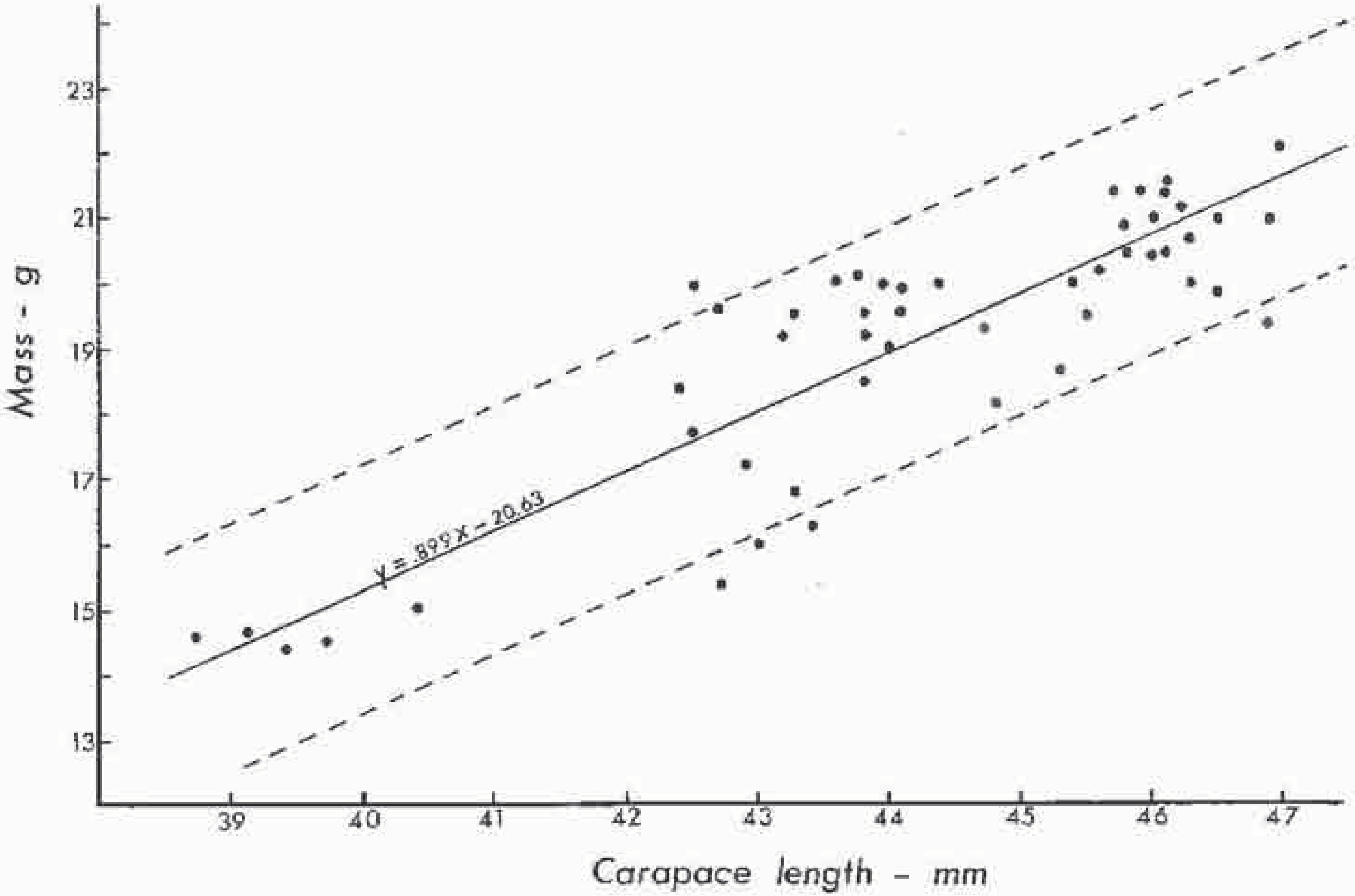

Fig. 40. The relationship between carapace length and mass in a sample of 50 loggerhead hatchlings from Tongaland.

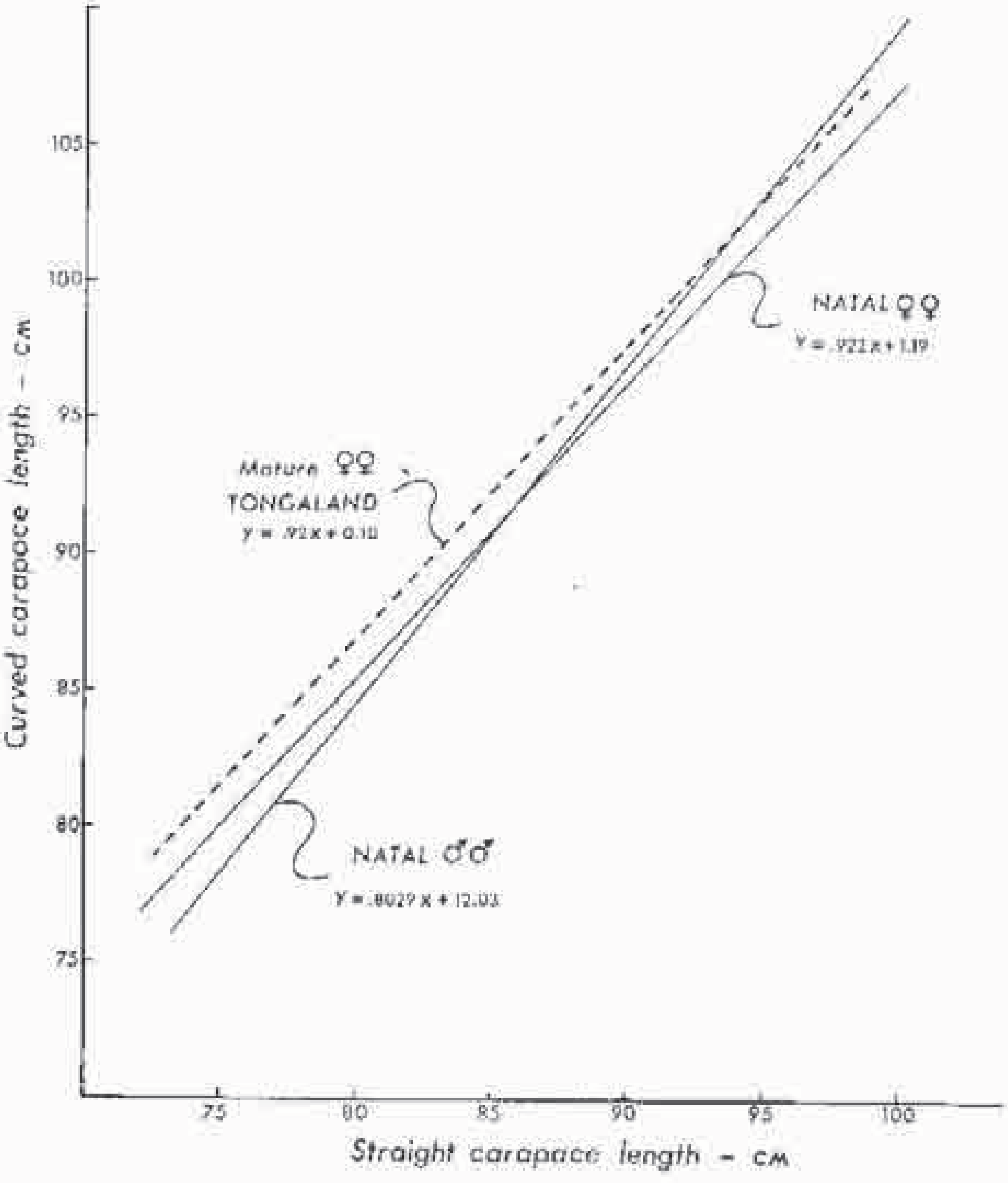

Fig. 41. The relationship between curved carapace length and straight carapace length in sub-adult male and female loggerheads from Natal, and mature loggerhead females from Tongaland.

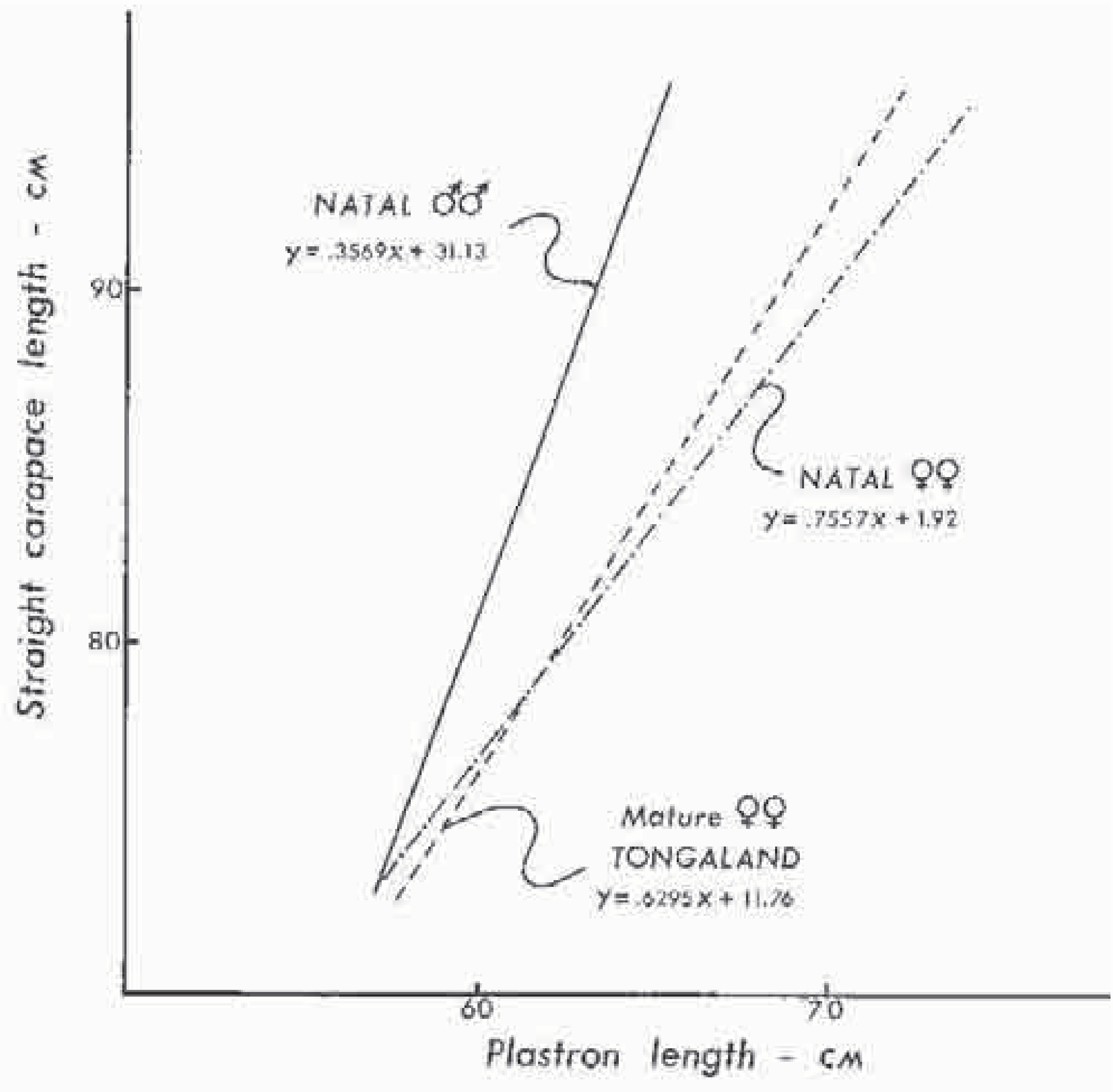

Fig. 42. The relationship between straight carapace length and plastron length in sub-adult male and female loggerheads from Natal, and mature female loggerheads from Tongaland.

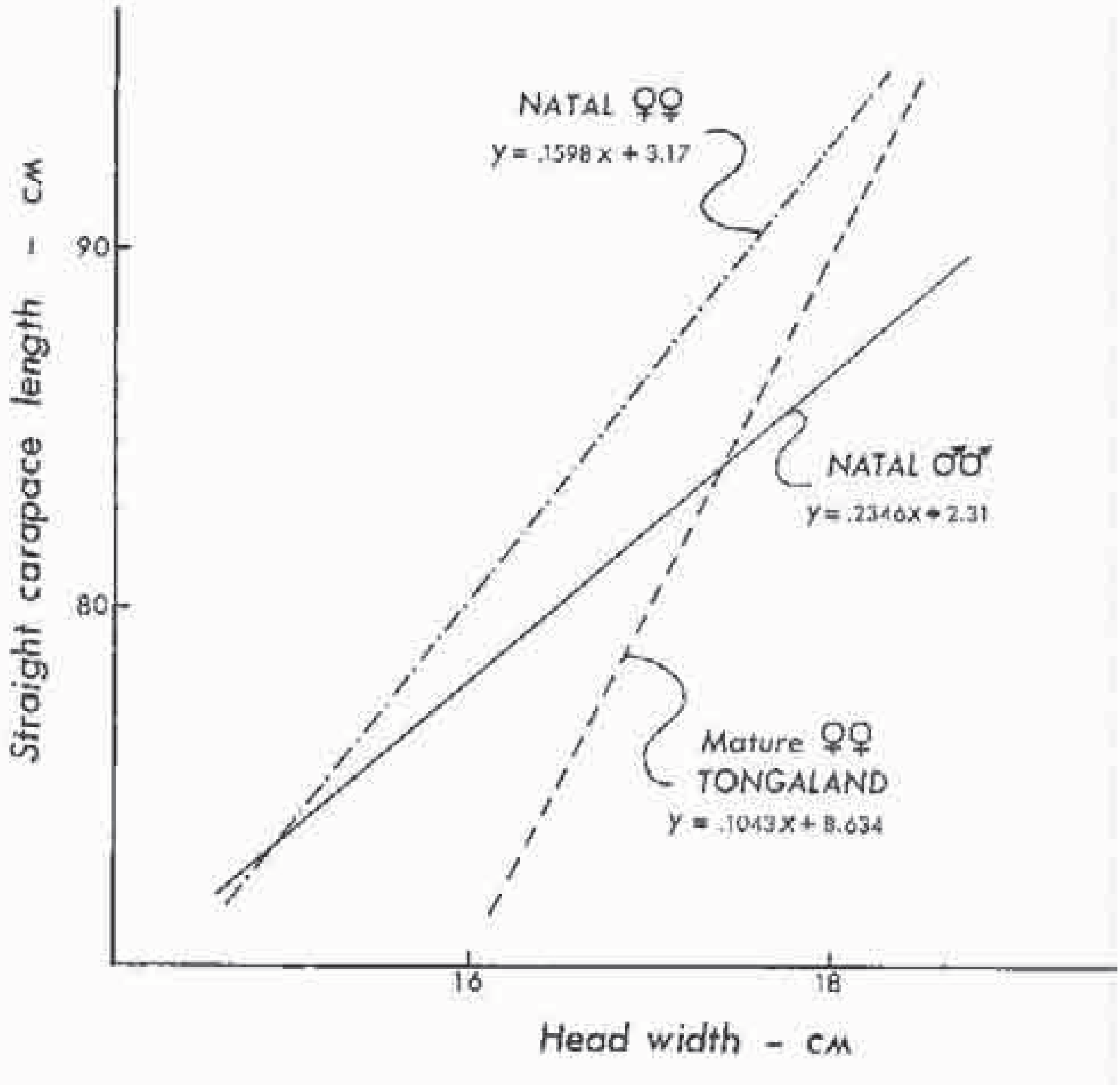

Fig. 43. The relationship between straight carapace length and head width in sub-adult male and female loggerheads from Natal, and mature female loggerheads from Tongaland.

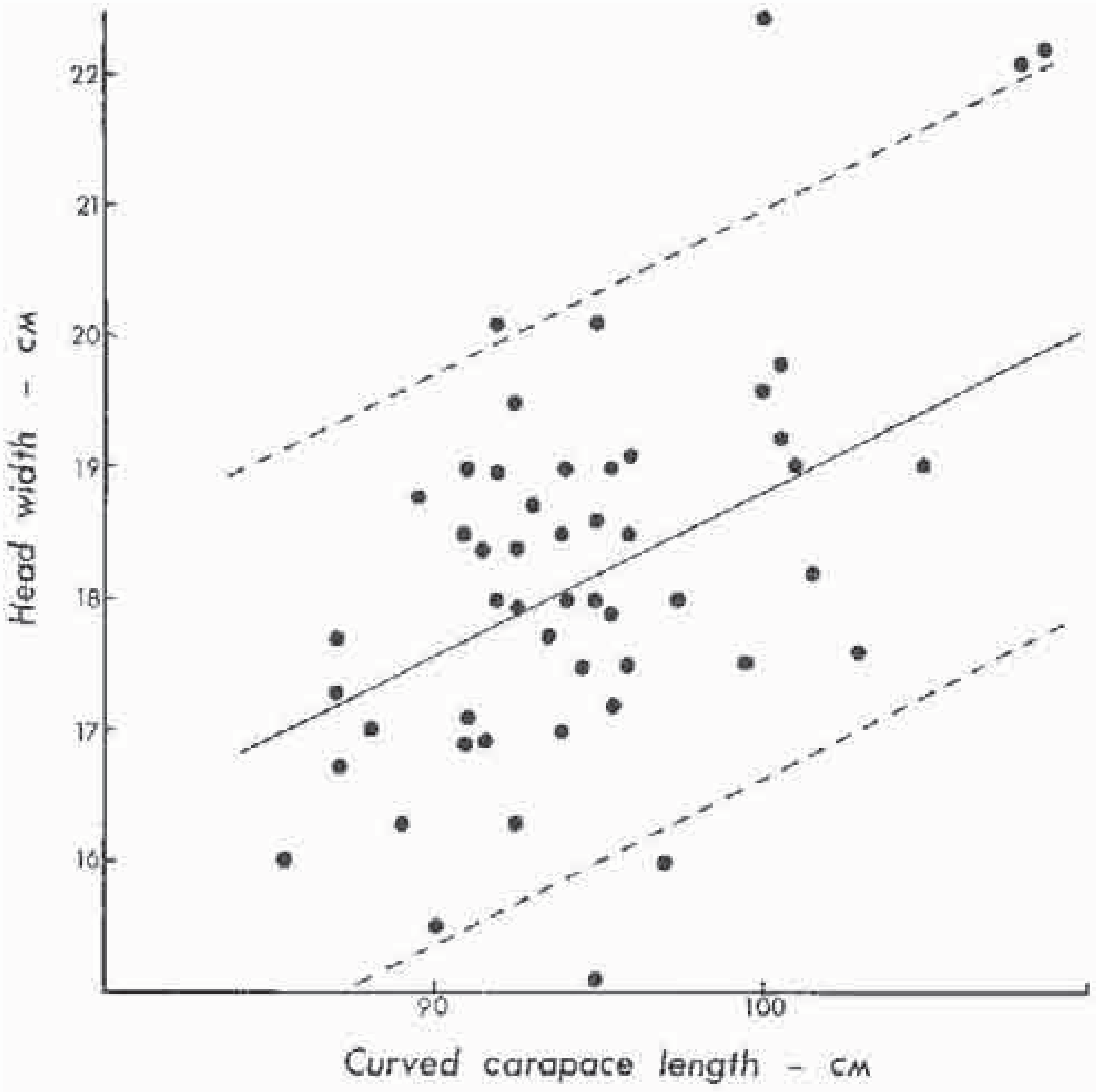

Fig. 44. The relationship between curved carapace length and head width in a sample of 50 mature loggerhead females from Tongaland.

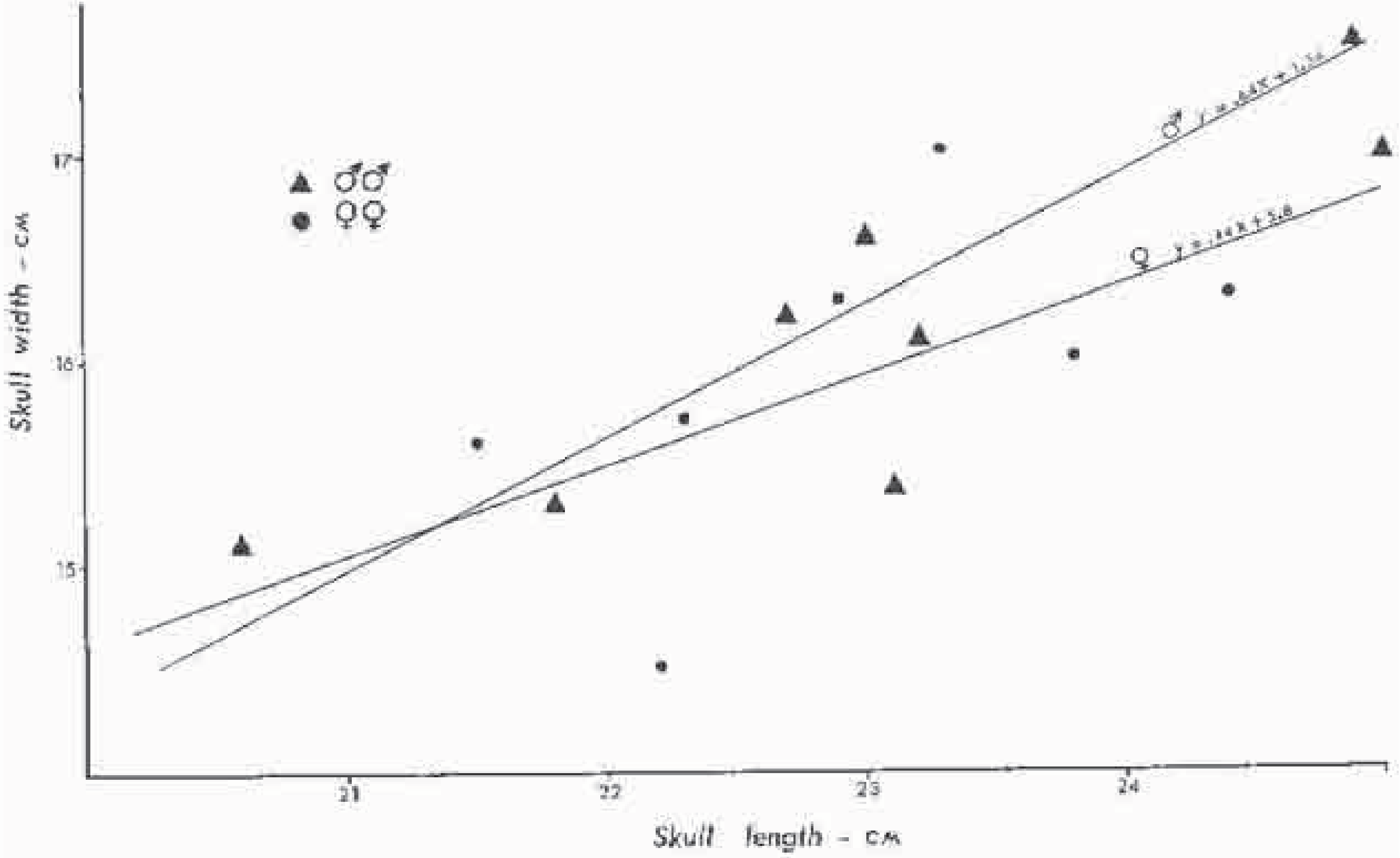

Fig. 45. The relationship between skull length and skull width in male and female loggerhead turtles.

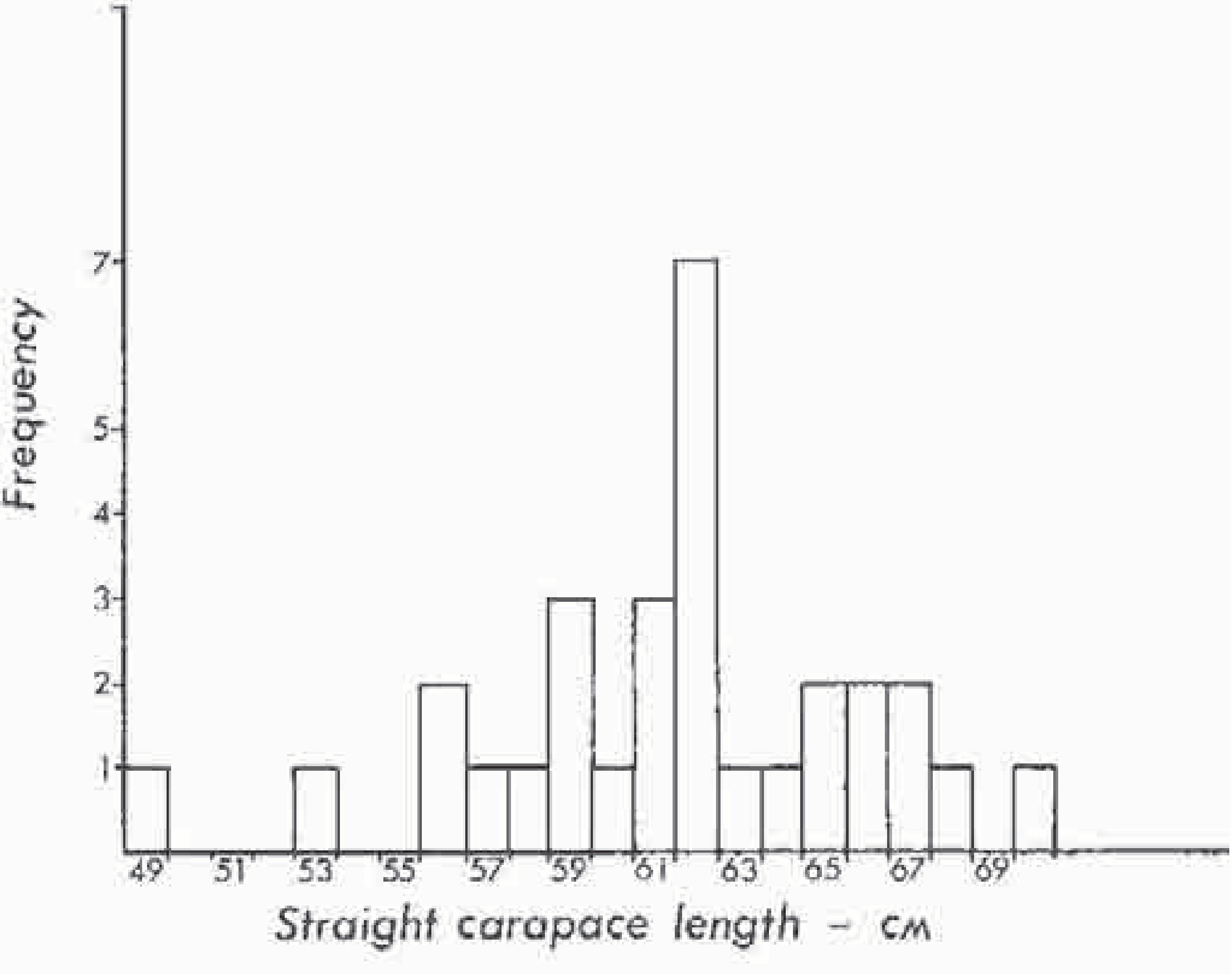

Fig. 46. The size distribution (straight carapace length) of olive ridley turtles from the study region.

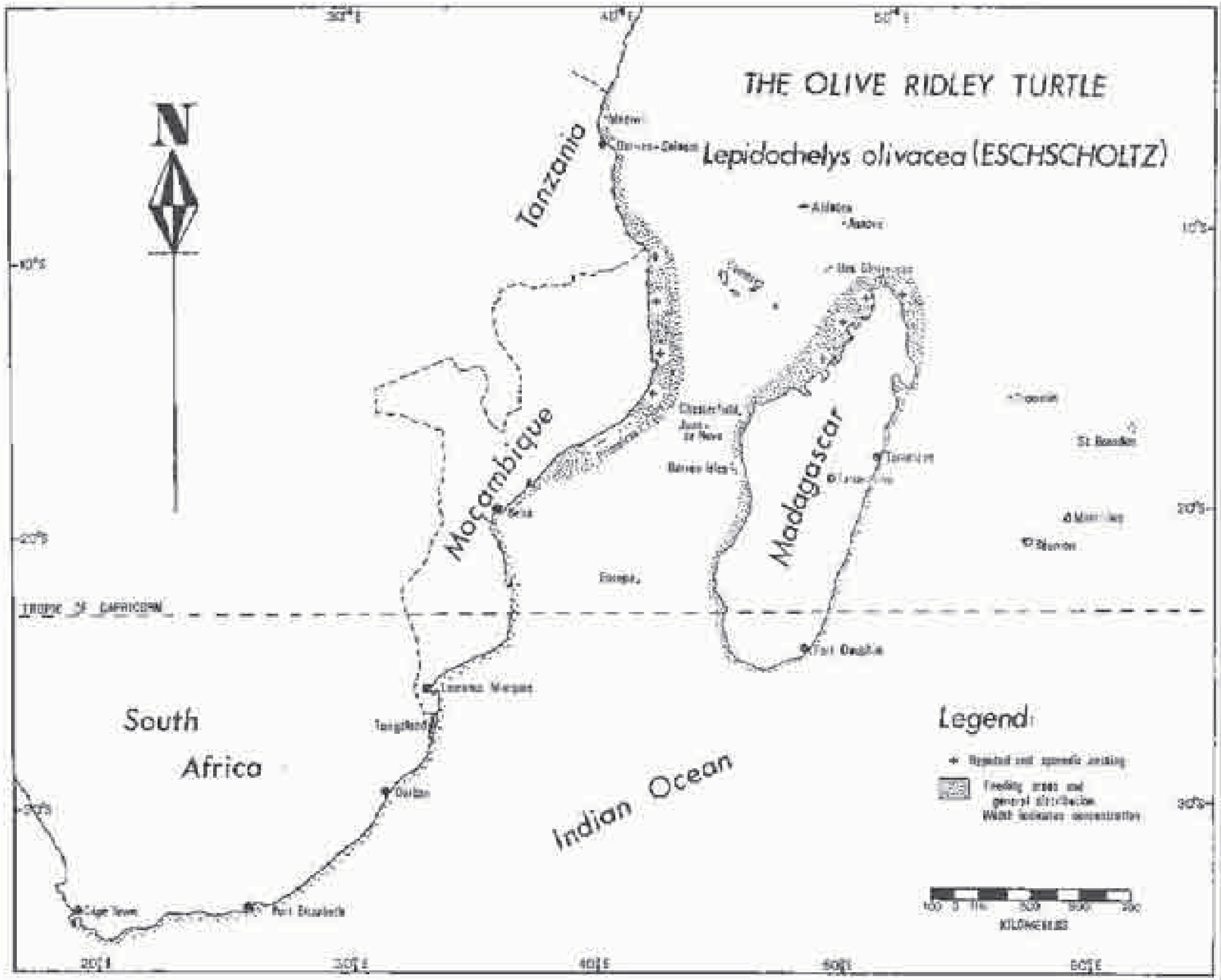

Fig. 47 The distribution and nesting areas of the olive ridley turtle *Lepidochelys olivacea* in the study region

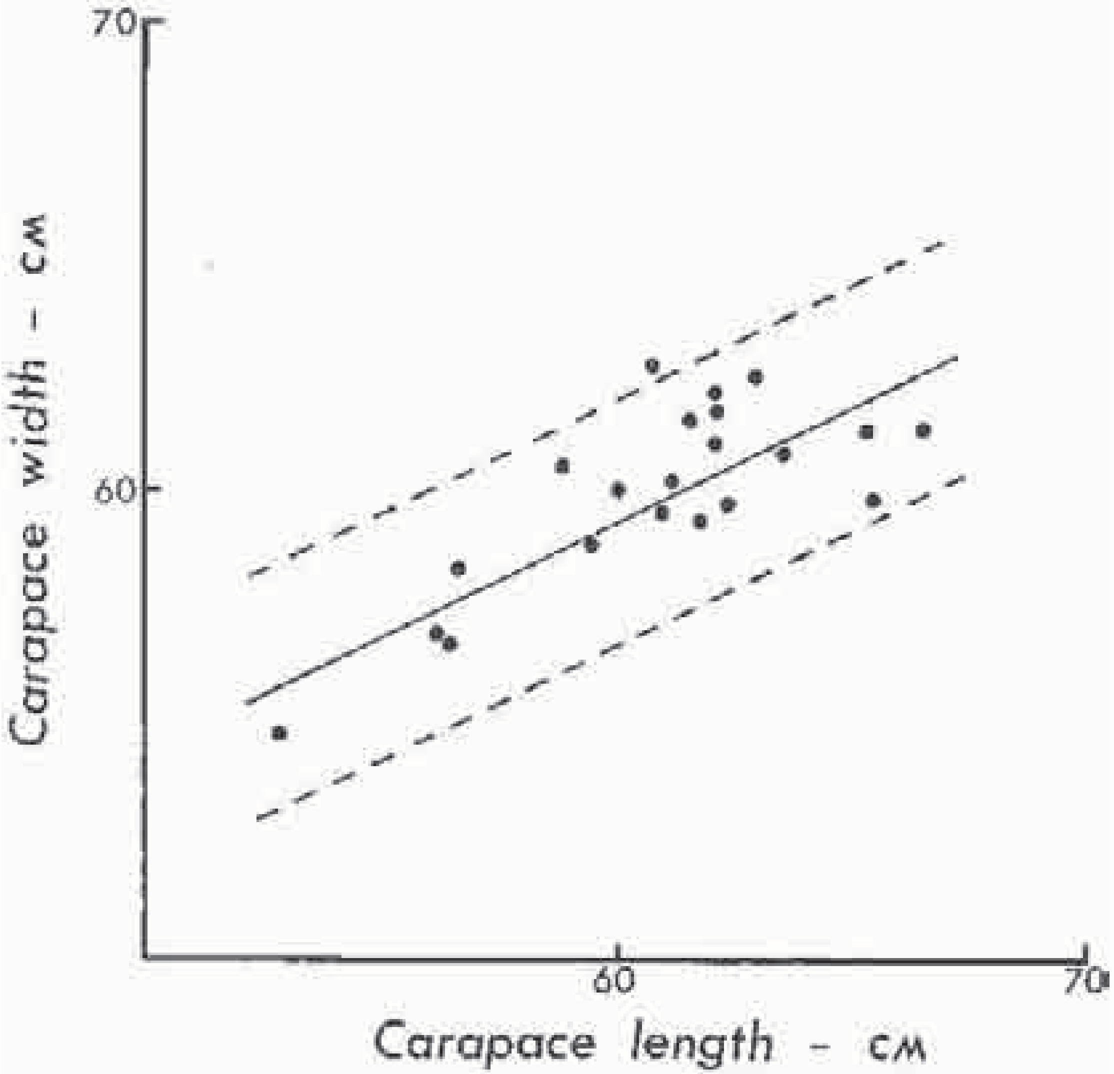

Fig. 48. The relationship between straight carapace length and width in olive ridley material from the study-region.

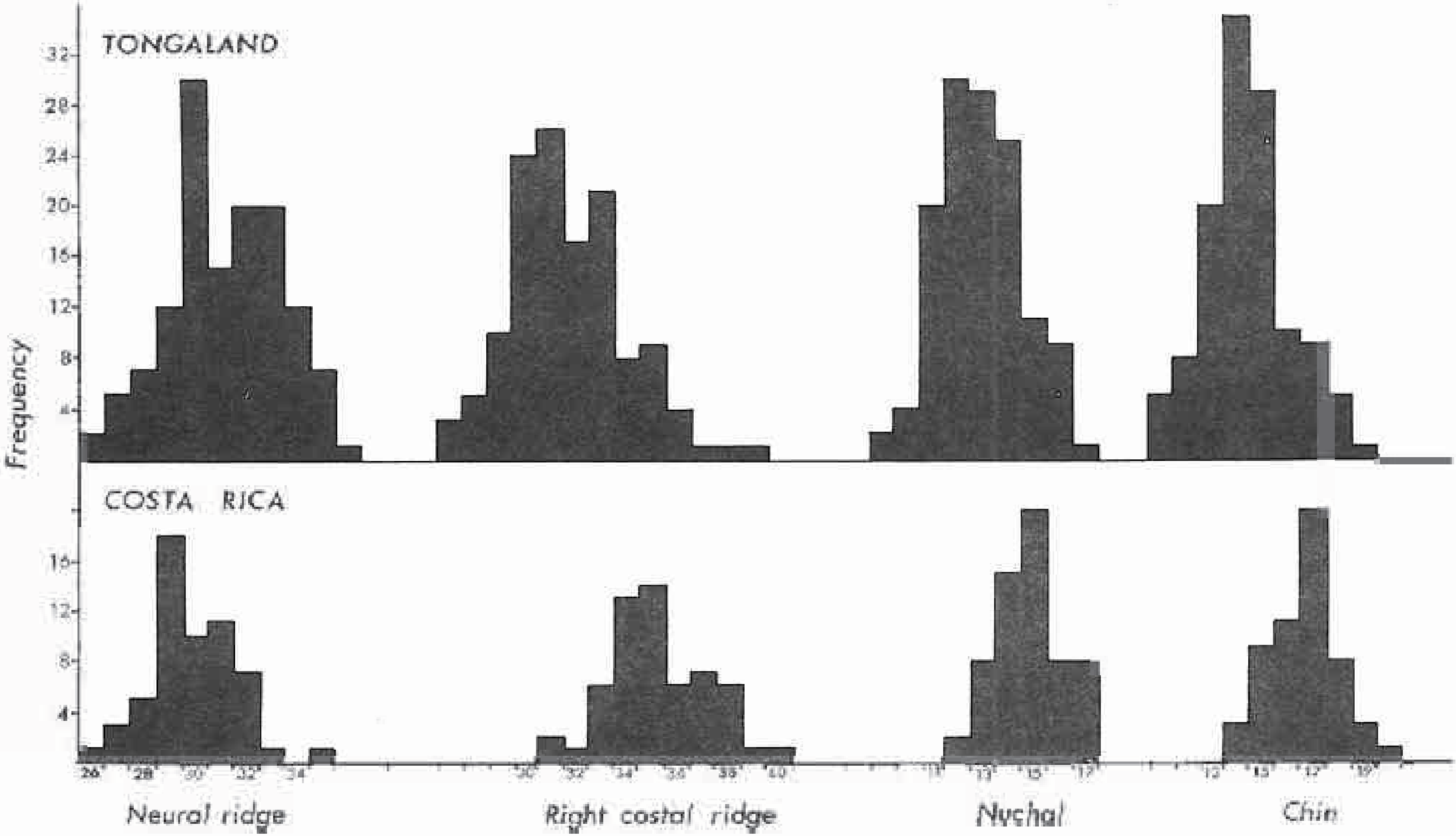

Fig. 49. The frequency of four different scale counts in a sample of leatherback hatchlings from 14 clutches in Tongaland, compared with counts from a sample of 84 hatchlings drawn from two clutches in Costa Rica.

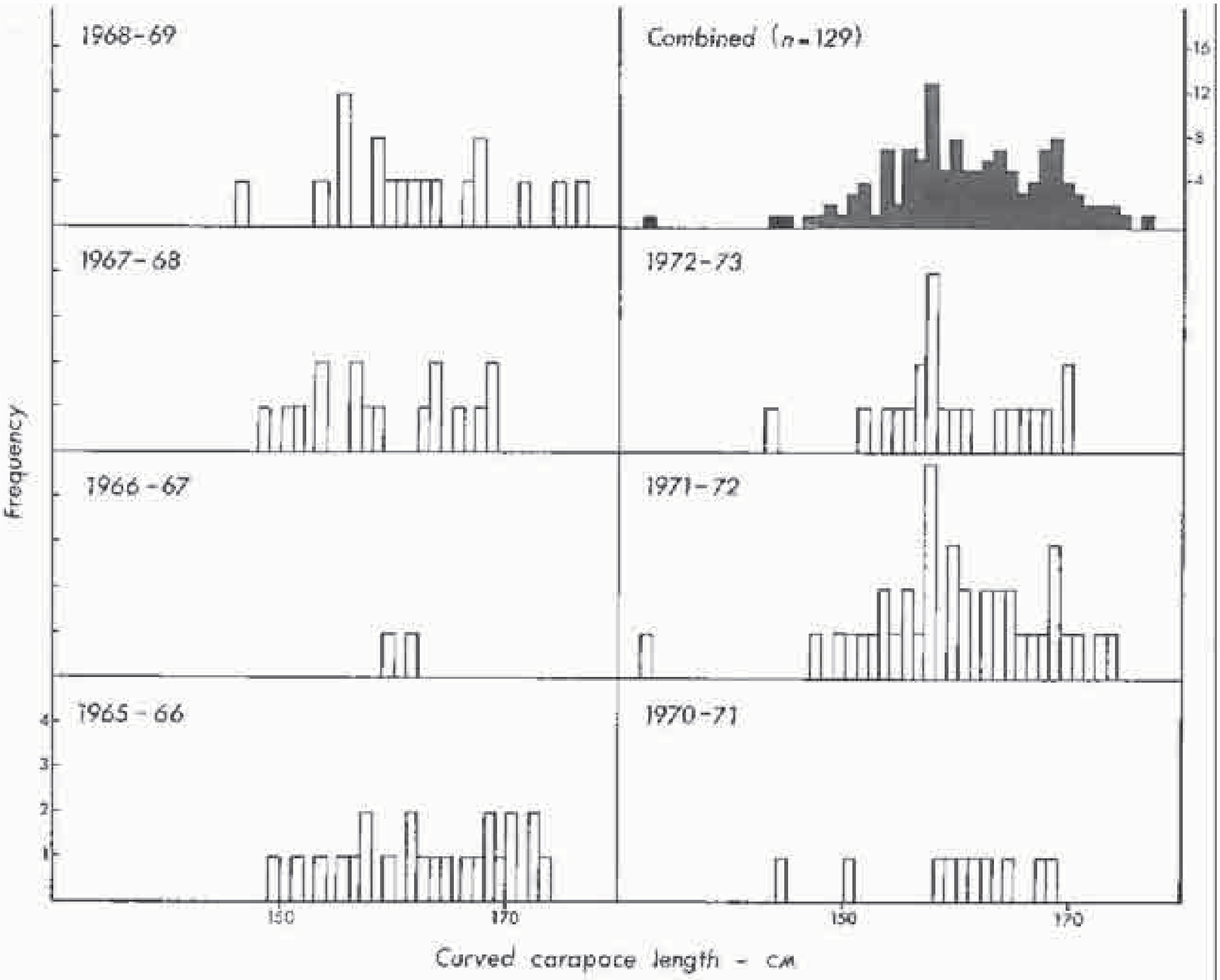

Fig. 50. The curved carapace length distribution of leatherback turtles in 7 seasons in Tongaland; and the combined size distribution.

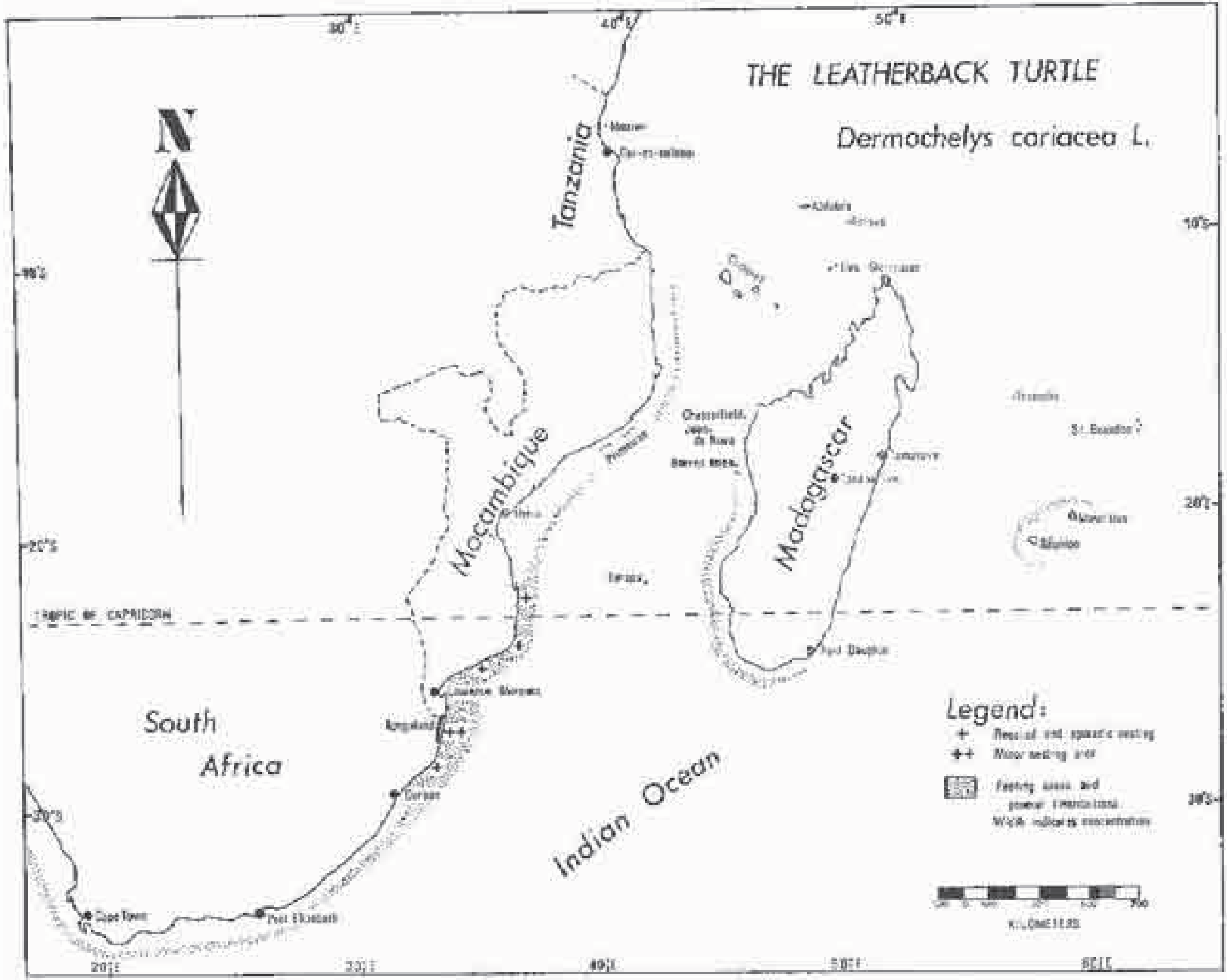

Fig. 51. The distribution and nesting areas of the leatherback turtle *Dermochelys coriacea* in the study region.

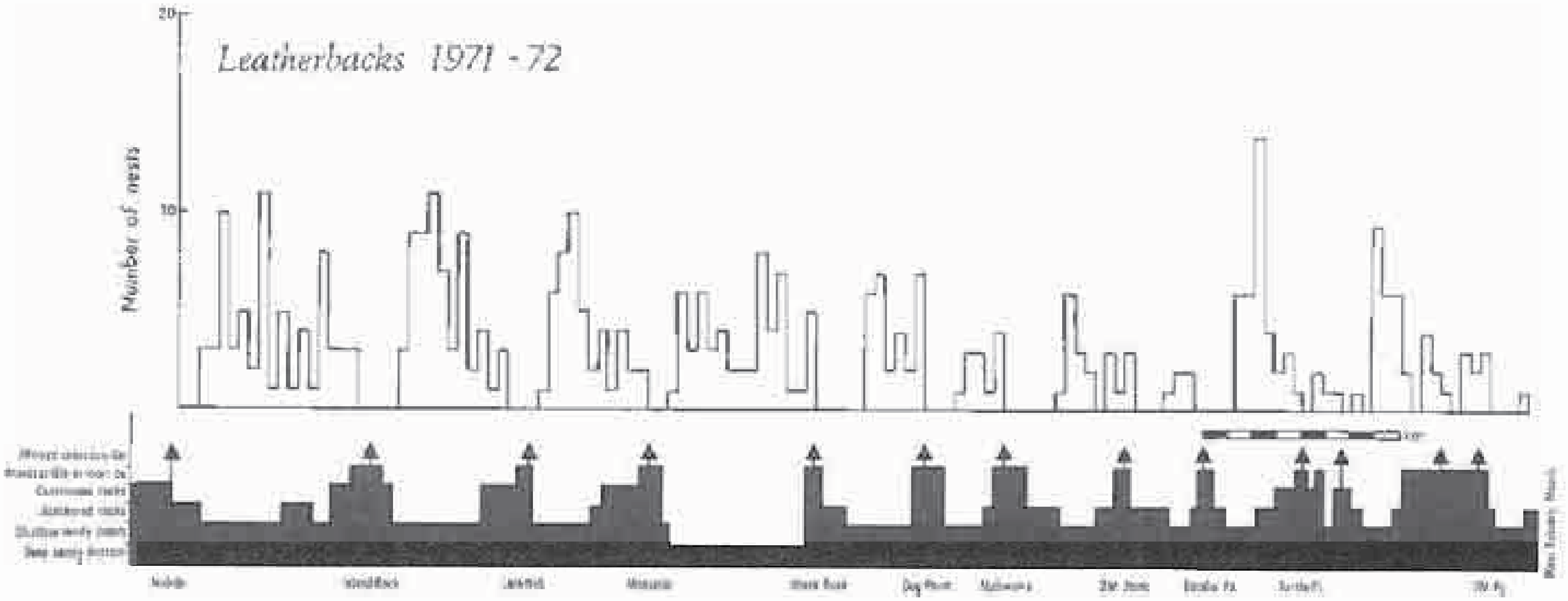

Fig. 52. **Leatherback nesting activity during the 1971-72 season in Tongaland showing the nature of the littoral zone.**

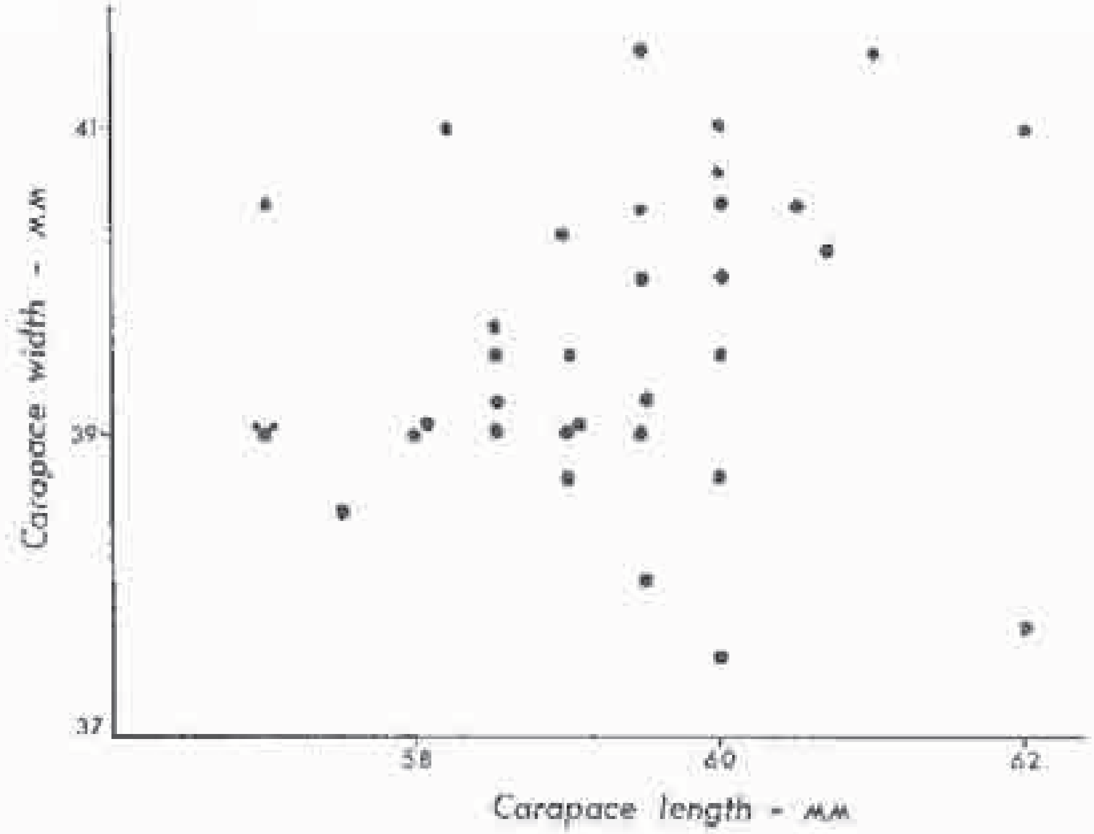

Fig. 53. The relationship between carapace length and width in a sample of 38 leatherback hatchlings from Tongaland.

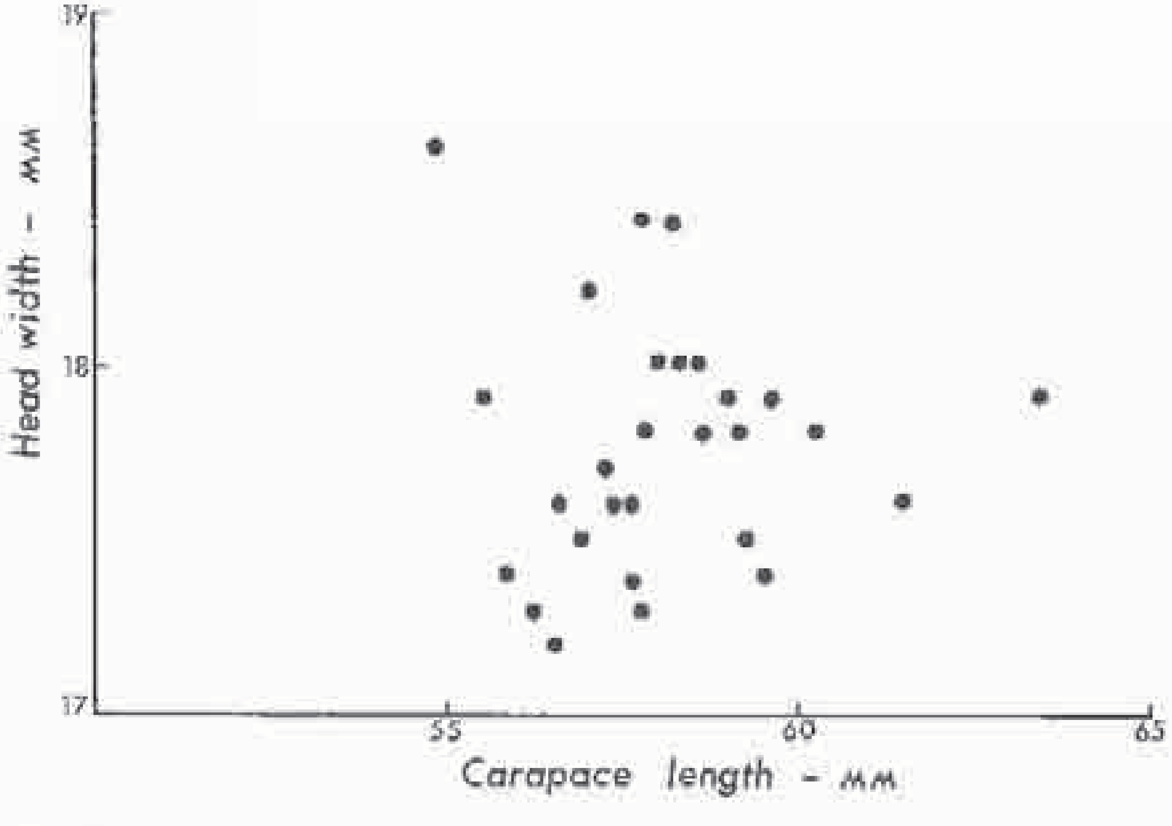

Fig. 54. The relationship between carapace length and head width in a sample of 28 leatherback hatchlings from Tongaland.

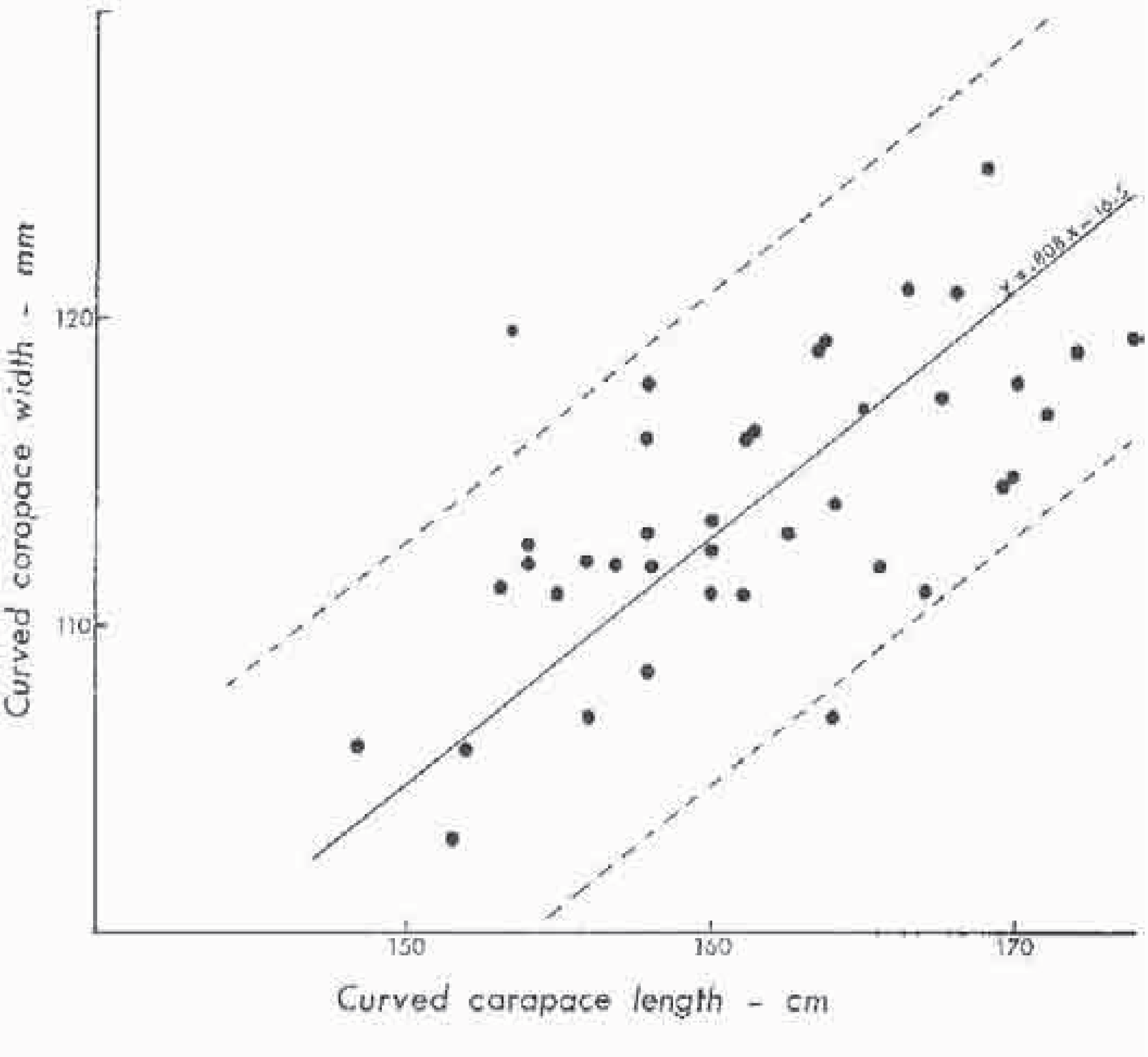

Fig. 55. The relationship between curved carapace length and curved carapace width in a sample of 40 leatherback females from Tongaland.

Plate 1. Carapace of juvenile green turtle showing semi-serrate margin.

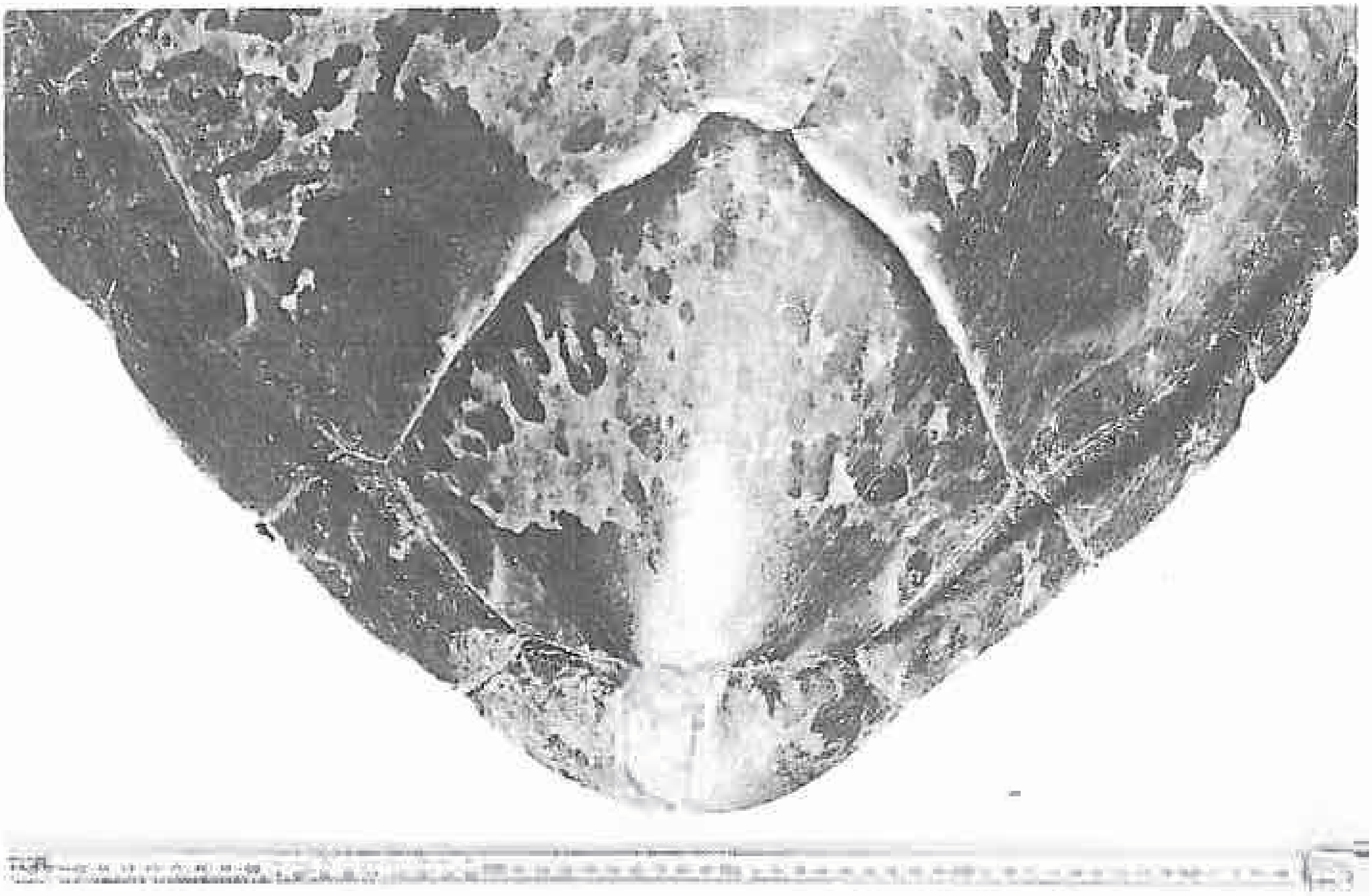

Plate 2   Posterior of adult green turtle carapace showing smooth margin.

Plate 3. Typical green turtle hatchling from the study region.

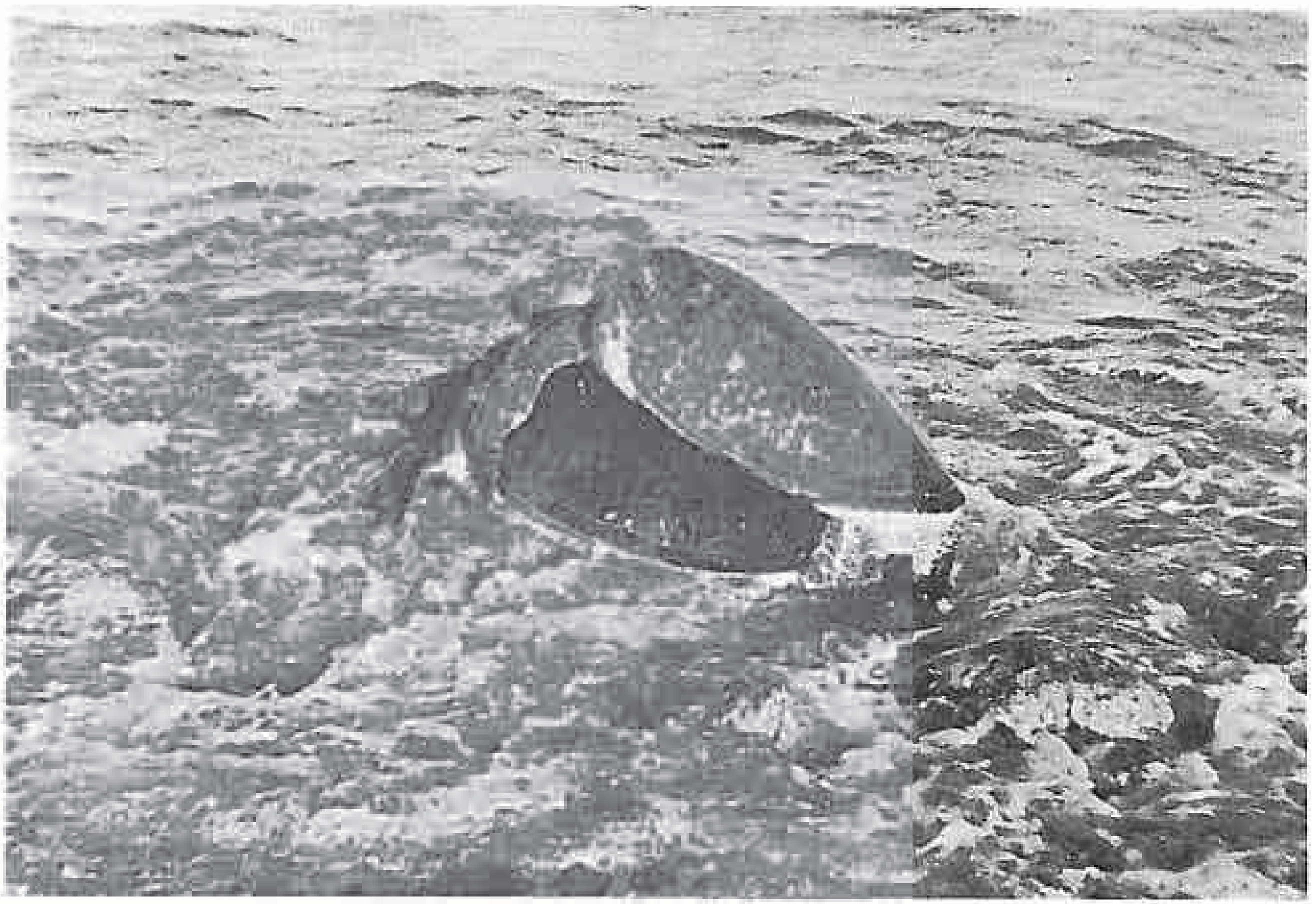

Plate 4. A pair of copulating green turtles on Tromelin Island showing the similarities in carapace colouring and pattern between male and female.

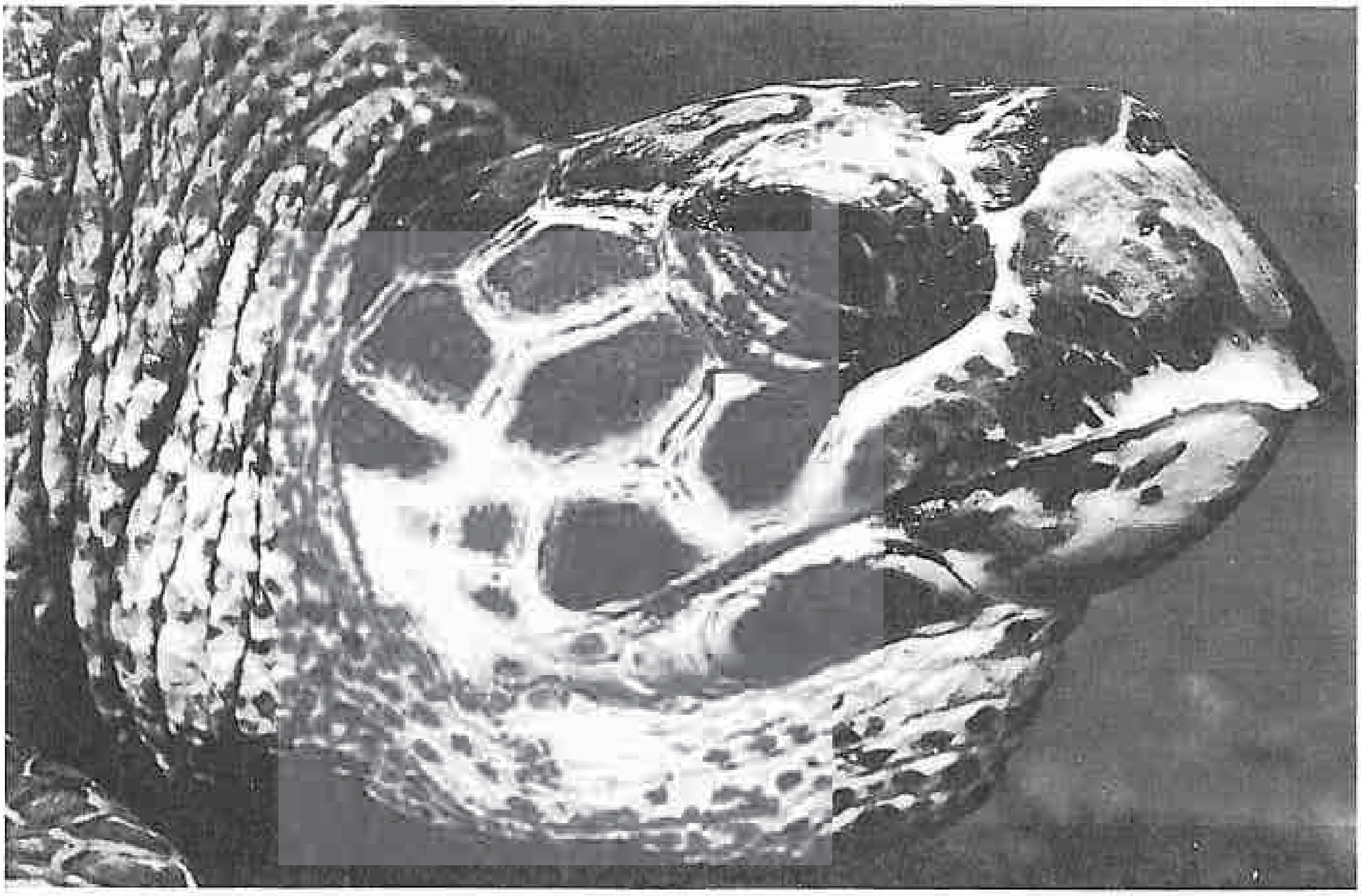

Plate 5. Head of hawksbill turtle showing head scales clearly outlined in yellow-white.

Plate 6. The carapace of a sub-adult hawksbill from the study region showing the dark phase.

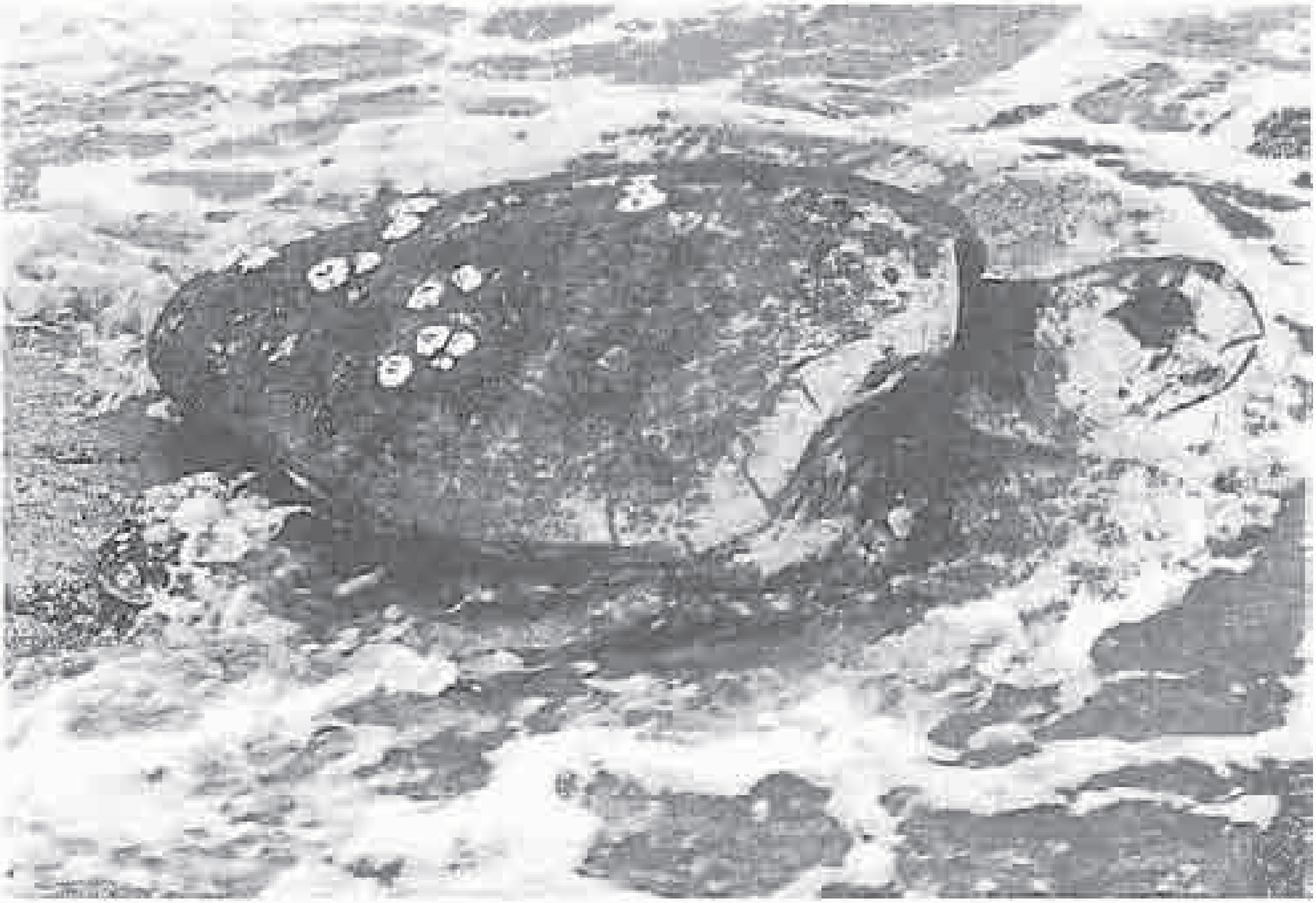

Plate 7. A typical loggerhead female from Tongaland, Natal.

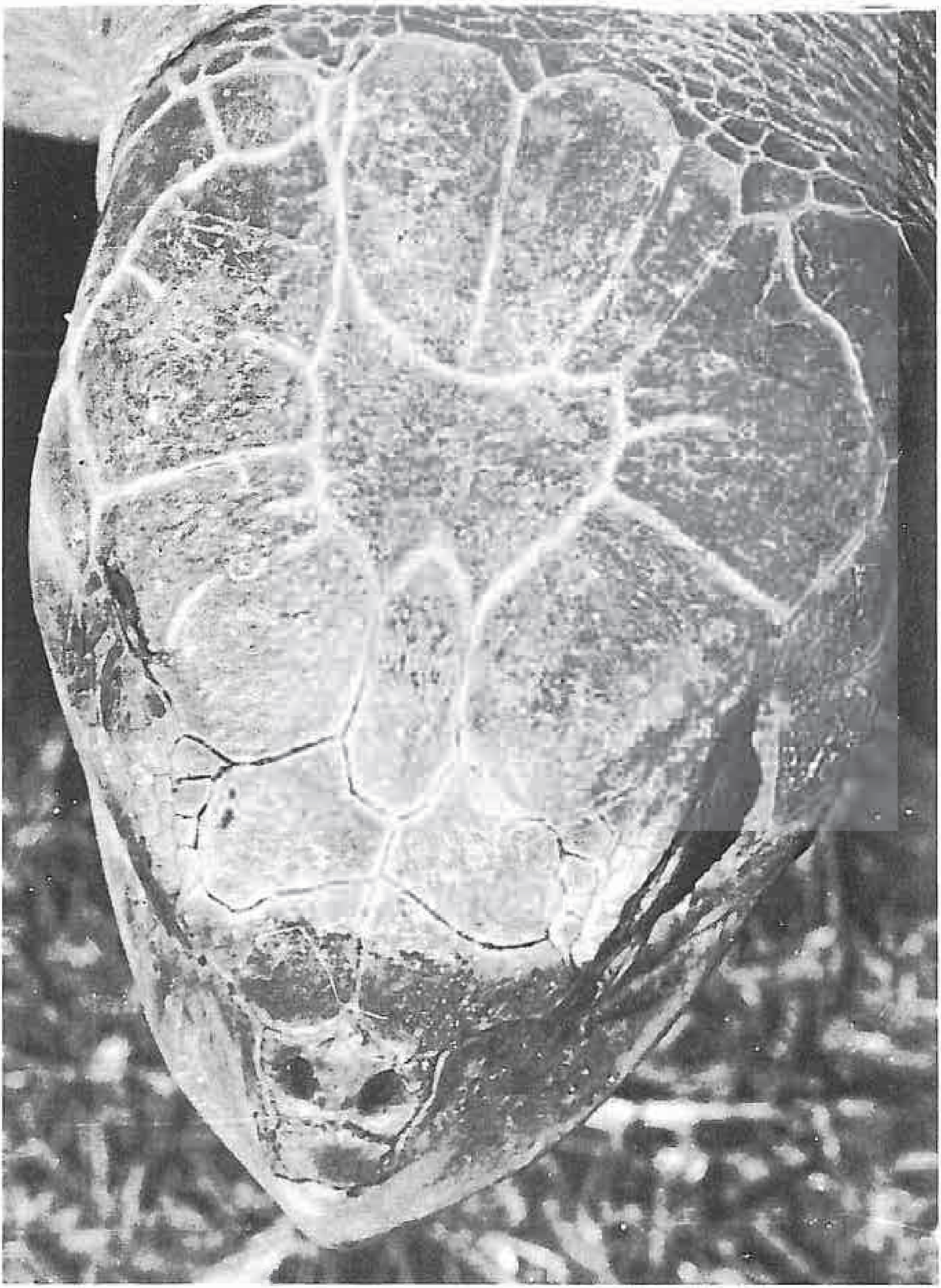

Plate 8. Head shield pattern of olive ridley from northern Mozambique.

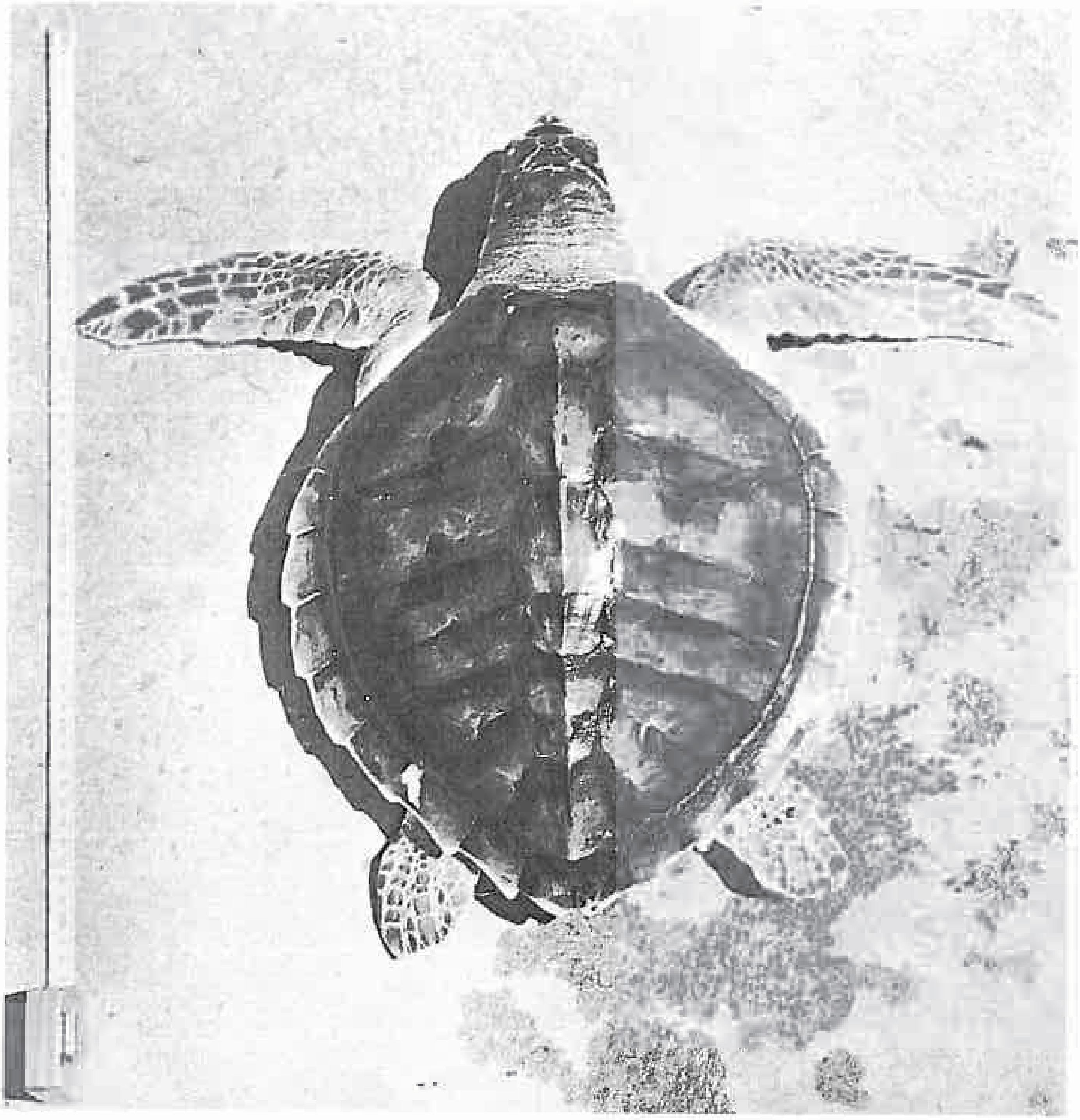

Plate 9. Juvenile olive ridley from the Durban Aquarium.

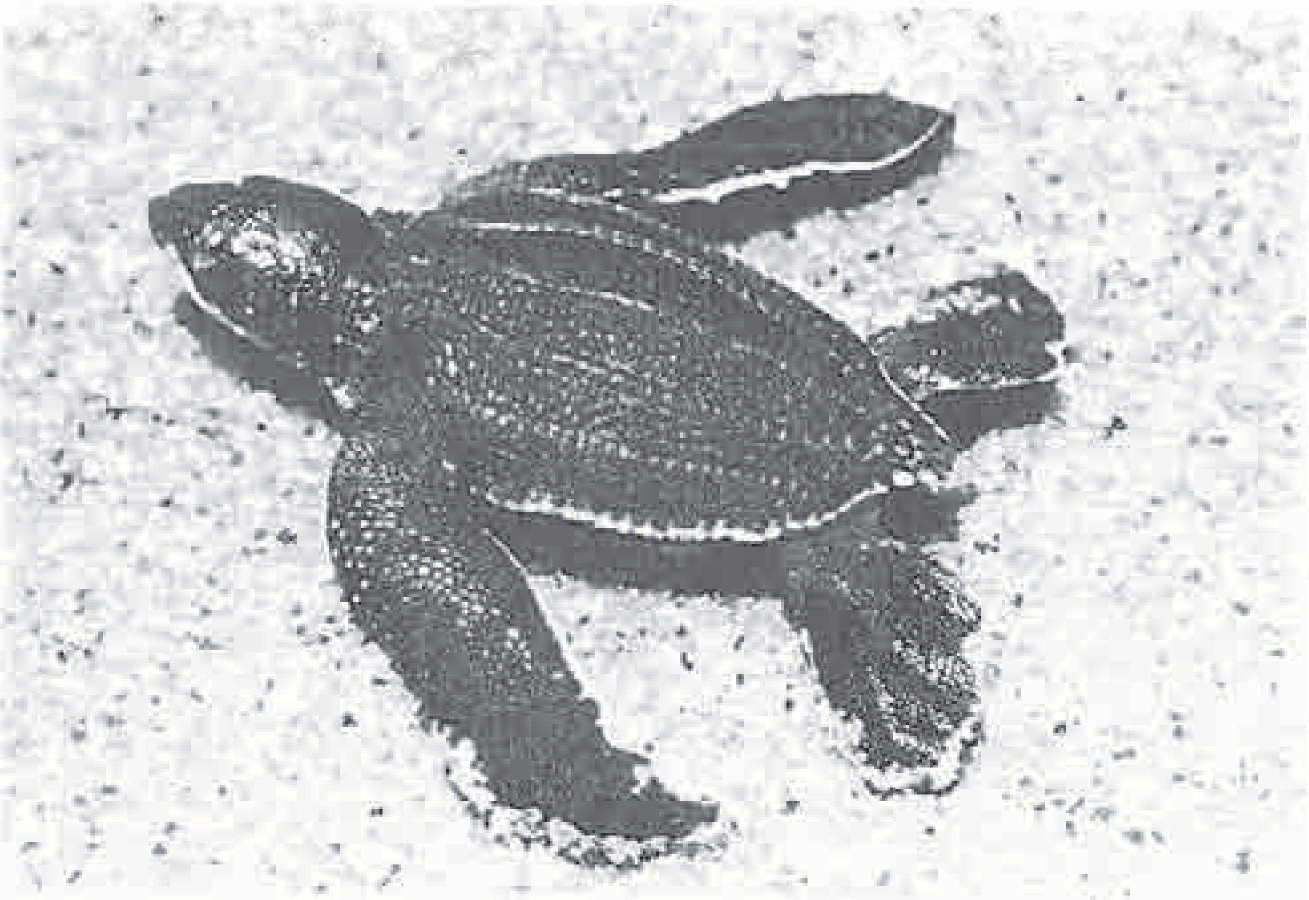

Plate 10. A typical leatherback hatchling from Tongaland.

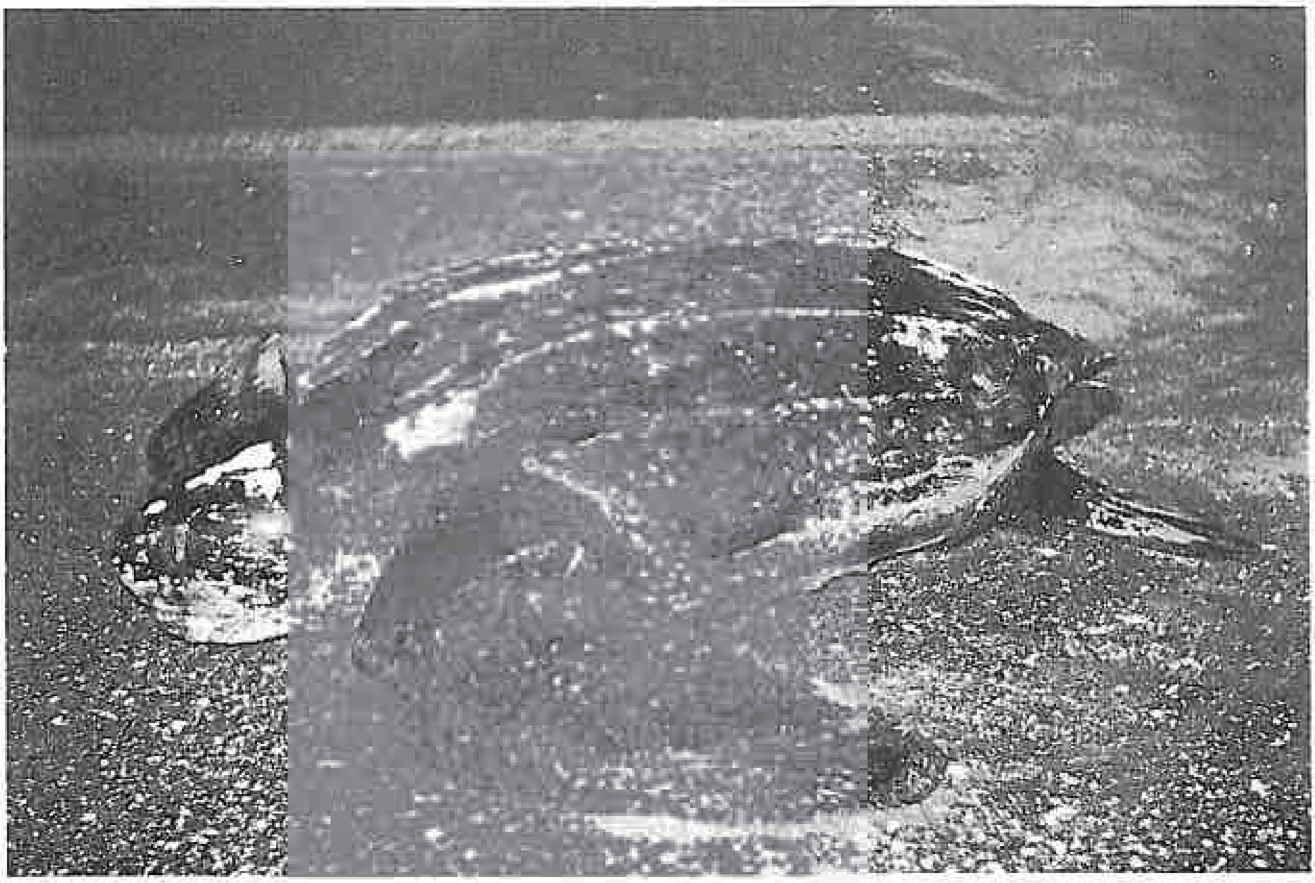

Plate 11. A typical adult female leatherback from Tongaland.