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SYNOPSIS OF BIOLOGICAL DATA ON THE OLIVE RIDLEY SEA TURTLE *LEPIDOCHELYS OLIVACEA* (ESCHSCHOLTZ, 1829) IN THE WESTERN ATLANTIC

by

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PREPARATION OF THIS SYNOPSIS

This document provides information on the biology and exploitation of olive ridley turtles (Lepidochelys olivacea), and it is limited to their distribution in the western Atlantic Ocean. It was originally prepared for the second Western Atlantic Turtle Symposium (WATS II), held in Puerto Rico in 1987, but lack of funds prevented its publication at that time. In its present form, the document has been updated (as much as was feasible with the limited access to data resources available in Suriname, the author's current project location) with new information thought to be applicable to the western Atlantic olive ridley turtle populations.

In order to provide a systematic treatment of the various data categories, this document follows the FAO species synopsis format as prepared by Rosa (1965) and as applied by Witzell (1983). Topics include taxonomy, morphology, distribution, reproduction, life stages, food, growth, behavior, population characteristics, exploitation, protection, and management.

ABSTRACT

Worldwide, the olive ridley turtle is probably the most abundant one of the living sea turtle species. But it may also be the most exploited one, with the skins (for leather) being the major product; meat and eggs being only secondary products. Olive ridley turtle numbers are decreasing rapidly over most of the species' range, especially in the eastern Pacific region.

Adult olive ridley females weigh about 35 kg and they often form nesting aggregations at fairly predictable times near specific beaches, where hundreds of females come ashore simultaneously to nest. They are mostly carnivorous, with crustaceans being the preferred diet, which partially puts the species in competition with man for food resources.

The western Atlantic olive ridley turtle populations are relatively small. The well-studied olive ridley nesting population in Suriname, once abundant enough to have mass nesting aggregations characteristic of the Lepidochelys genus, has decreased in numbers to the point where it must now be considered to be in imminent danger of extinction. The once thriving population of the Guianas is currently at a very reduced level, although the downward trend in population size has only been clearly established for Suriname. Nowhere throughout its range in the western Atlantic are the sub-populations numerous.

Basic biological data, derived specifically from studies on the western Atlantic olive ridley populations, are very limited. Most of what is known has come from studies in the Guianas, especially in Suriname. To obtain other pertinent information on olive ridley turtles for this synopsis, literature from various other parts of the world, in particular from the eastern Pacific region, has been reviewed. Such data, when considered useful, have been included in this synopsis, but their applicability to western Atlantic populations is not necessarily implied. Caution must be exercised in extrapolating such information for use on western Atlantic olive ridleys.

Olive ridleys are incidentally caught in nets of shrimp trawlers. This type of mortality is not well documented in the western Atlantic, but circumstantial evidence suggest that it is high. The use of Turtle Excluder devices (TEDs) on shrimp trawlers operating in the western Atlantic Ocean must be made mandatory. Although fully protected in the western Atlantic, they are are easy to catch and transport, making this species more vulnerable to predation by man than any of the other marine turtle species.

Wildlife management decisions are usually made at the population level, and an understanding of population characteristics is essential for this. Our current knowledge of olive ridley population dynamics is only rudimentary. In order to design a successful conservation program, more data are needed, and greater research emphasis must be placed on increasing our knowledge of the olive ridley's population dynamics.

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1. IDENTITY

1.1 Nomenclature

1.1.1 Valid name

Lepidochelys olivacea (Eschscholtz, 1829).

1.1.2 Synonymy (modified from Deraniyagala, 1933, 1953; Mertens and Wermuth, 1955; Loveridge and Williams, 1957; Wermuth and Mertens, 1961).

Chelonia olivacea Eschscholtz, Zool. Atlas, 1829, p. 3, pl.iii: (type locality) Manila Bay, Philippine Islands, China Sea.

Chelonia Dussumierii Duméril and Bibron, Erpet. Gén., 2, 1835, p. 557, pl. xxiv, figs. 1-1a: China Sea and Malabar Coast.

Lepidochelys olivacea Fitzinger, 1843. Systema Reptilium p. 30.

Caouana Ruppellii Gray, Cat. Tort. Croc. Amphis. Brit. Mus., 1844, p. 53: ? India (nomen nudum).

Chelonia polyaspis Bleeker, Nat. Tijdschr. Ned. Indies, 14, 1857, p.239: Batavia, Java.

Thalassochelys corticata Hilgendorf, Sitz. Ber. Ges. Natürf. Fr.1880, p. 112: Japan.

Chelonia dubia Bleeker, in Boulenger, Cat. Chelon. Rhyncho. Crocod. Brit. Mus., 1889, p. 186: Borneo (nomen nudum).

Thalassochelys controversa Philippi, Anales Univ. Chile (Santiago), no. 104, 1899, p. 732: no locality.

Caretta remivaga Hay, Proc. U.S. Nat. Mus., 34, 1908, p. 194, pl.x, figs. 1-3, pl. xi, fig. 5: Ventosa Bay, Gulf of Tehuantepec, Mexico.

Caretta caretta olivacea Mertens and Müller in Rust, 10, 1934.

Lepidochelys olivacea olivacea Deraniyagala, 1943, p. 81, 91, figs. 1, 3a, 5a, 6a.

Pritchard and Trebbau (1984) gave the complete chronology on the synonymy of the olive ridley (Lepidochelys olivacea). Pritchard (1969a) provided a historical review of olive ridley nomenclature, and Frazier (1985) analyzed the taxonomic confusion that has existed for the species.

1.2 Taxonomy

1.2.1 Affinities

- Suprageneric

Kingdom Animalia
 Subkingdom Metazoa
  Phylum Chordata
   Subphylum Vertebrata
    Superclass Tetrapoda
     Class Reptilia
      Subclass Anapsida
       Order Testudinata
        Suborder Cryptodira
         Superfamily Chelonioidae
          Family Cheloniidae

- Generic Lepidochelys Fitzinger, 1843, Syst. Rept., p. 30.
  Type: Chelonia olivacea Eschscholtz (by original designation).

Colpochelys Garman, 1880, Bull.Mus.Comp.Zool. 6, p. 124.
Type : Colpochelys kempi Garman (by monotypy).

Diagnosis: The genus Lepidochelys includes two recognized species:

Lepidochelys kempi ----------Kemp's ridley

Lepidochelys olivacea ---------Olive ridley

Neither species includes recognized subspecies.

Generic description: head has two pairs of prefrontal scales and three or four postoculars; beak wide with smooth margins; upper mandible with two prominent, paired alveolar ridges; lower mandible with one alveolar ridge on each side; carapace with 5-9 central scutes and 5-9 pairs of costal scutes; nuchal scute in contact with the anterior-most of the costal scutes; plastron with four pairs of inframarginal scutes, each with a pore near its posterior edge (see section 1.3.1). Front flippers usually with 2-3 claws on leading edges (adults sometimes only one). Detailed generic descriptions to be found in Deraniyagala (1939), Carr (1952), Loveridge and Williams (1957), Pritchard (1969a, 1979), Márquez et al. (1976), Frazier (1983).

- Specific

Diagnosis: The olive ridley and the Kemp's ridley are very similar. There is a broad overlap of morphological characters in adult specimens. Separation of the species by morphometric criteria alone is difficult, but possible. In general, the olive ridley is more lightly built than the Kemp's ridley, and its shell is somewhat narrower and thinner (Pritchard, 1979). The olive ridley has a higher, flat-topped carapace which is green-olive in color, while the Kemp's ridley has a more greyish carapace. This difference, however, is not distinct enough to use as a single, selective criterion, because coloration can vary from grey-green to olive-green for both species (Pritchard, 1969a). To positively identify each species, a close evaluation of several characters is necessary. For instance, the bones of adult Kemp's ridley skulls are fused, but those of adult olive ridleys do not become fully fused until late in life (Pritchard, 1979). This is a useful feature to consider during post-mortem evaluation. A distinguishing characteristic between the two species is also the relative width of the skull of adult females. This relative width is obtained by measuring the skull at its widest point (at the back of the tympanum) and dividing it by the basicranial length (measured from the tip of the snout to the occipital condyle). Pritchard (1969a) thus compared eight Kemp's ridleys with fifteen olive ridleys from Guyana and another fifteen olive ridleys from Guerrero, Mexico. He found that all eight Kemp's ridleys had a relative width greater than 0.95, while all olive ridleys had a relative width less than 0.95. Furthermore, the orbits of olive ridleys are noticeable larger than those of Kemp's ridleys, probably because olive ridleys nest usually at night while Kemp's ridleys nest by day. Pritchard (1969a) provides an extensive analysis on the differences between Kemp's ridleys and olive ridleys.

Whereas the carapace of Lepidochelys kempi has five pairs (rarely six) of lateral scutes, and five (or sometimes six) central scutes, the Lepidochelys olivacea carapace shows considerable polymorphism in the carapace laminae by having anywhere from 5-9 pairs of costal scutes and 5-9 central scutes. Most often, though, the olive ridley has 6-7 pairs of costal scutes and only rarely five pairs. In addition, the two rows of costal scutes are quite often asymmetrical, whereas asymmetry is rare in Kemp's ridleys. Descriptions of external morphology can be found in Carr (1952), Pritchard (1969a, 1979), Schulz (1975), Pritchard et al. (1983), Frazier (1983), Pritchard and Trebbau (1984). A comprehensive analysis of carapace scutes polymorphism in the Surinam olive ridley nesting population was done by Hill (1971a). Deraniyagala (1939) described scutes polymorphism in olive ridleys from Sri Lanka waters. Comparable analyses were conducted by Hughes (1974) in east Africa; and Frazier (1983) in Mexico. Their findings provide a general comparison of scutes polymorphism between western Atlantic olive ridley populations and those in other parts of the world.

1.2.2 Taxonomic status

The taxonomic status of the olive ridley is based only on morphological differences from related species. Because Kemp's ridley occurs primarily along the Gulf and Atlantic coasts of Mexico and the United States, it is apparently geographically and reproductively isolated from olive ridley populations in the western Atlantic. Recent literature generally accords distinct species status to the Kemp's ridley and the olive ridley. Analysis of mitochondrial mtDNA have shown that Kemp's ridley is distinct from the olive ridley in matriarchal phylogeny, and that the mtDNA in the Pacific olive ridley is identical to that of the Atlantic olive ridley (Bowen et al., 1991).

1.2.3 Subspecies

The olive ridley has a near-circumtropical distribution within its temperature range, but there are no recognized subspecies. The Isthmus of Panama is a distinct, geographic barrier in this range, separating eastern Pacific olive ridley populations from those in the western Atlantic by some 25,000 km of ocean. These allopatric populations should genetically be the most distant, but Bowen et al. (1991) have shown that mtDNA digestion profiles between these two groups are identical, indicating that their divergence, if any, is only of very recent times.

Biochemical studies to resolve issues of sea turtle taxonomy are of recent times, and such research on olive ridley subspeciation has only just begun. Additional information on the biochemical evaluation of sea turtle taxonomy can be found in section 1.3.3.

1.2.4 Standard common names

In the Americas, the following common names are in use for Lepidochelys olivacea: Olive ridley turtle, Pacific ridley turtle (English); Tortuga amarilla, Tortuga cahuama, Tortuga frojolilla, Tortuga garapachi, tortuga golfina (Mexico); Tortuga bastarda (Cuba); Cul rond (Guadeloupe); Paslama (Nicaragua); Lora, Carpintera (Costa Rica); Tortuga mulato (Panama); Tortuga bestia, Manila, Mani (Venezuela); Teracai (Guyana); Warana (Suriname); Kalulashi (Carib Indian); Tortue olivâtre (French Guiana); Toti Yun (French Guiana creole); Pico de loro (Peru); Tortuga olivacea (Chile); Xibirro (Sergipe, Brazil); Tartaruga comum (Pirambu, Brazil).

The origin of the name "ridley" has been the subject of debate, but the etymological riddle of its origin has not yet been solved. Dundee (1992) gives an interesting review of the various suggestions.

Often, when the common name for Lepidochelys olivacea is used in the English literature, it is referred to as the "Pacific ridley". The species has a circumglobal distribution, and the vernacular reference to a limited geographic area should be discouraged. It is recommended that the common name for Lepidochelys olivacea in the English language be restricted to "olive ridley turtle".

1.2.5 Definition of size categories

Size categories for olive ridleys follow those established by Márquez et al. (1976) for eastern Pacific populations. Sources of additional data provided are as noted. Measurements given are straight-line carapace lengths:

(1) Hatchling - Newly hatched turtle: yolk sac, or umbilical cord remnant, still evident; dorsal keels on carapace scutes.

(2) Juvenile - Umbilical scar absent or almost so; scutes still show traces of dorsal keels; carapace length to 30 cm.

(3) Subadult - Carapace length less than 55 cm; turtle has the characteristics of an adult, but is not yet capable of reproduction.

(4) Adult - Carapace length 55 cm or longer; the turtle is capable of reproduction. Approximate weight: 35 kg.

Neonate Surinam hatchlings measure on average 4.2 cm in carapace length and 3.6 cm in width. The average straight-line carapace length for 500 nesting females measured was 68.5 cm (range 63-75 cm), the average straight-line width was 60.4 cm (range 53-66 cm). Average weight of 14 females was 35.7 kg (Schulz, 1975). These measurements fall within the range of those of con- specifics in the eastern Pacific, and therefore the same categories are here considered valid for the western Atlantic olive ridley populations as well. Frazier (1983) measured specimens from the eastern Pacific olive ridley population in Oaxaca, Mexico, and found that females have, on average, a shorter straight-line carapace length than males. Although females are thicker-bodied they are nevertheless heavier (about 62.98 cm/35.45 kg versus 64.35 cm/33.00 kg). Surinam olive ridleys seldom attain a weight of more than 50 kg, and Pritchard (1969b) gives 35.7 kg as the average weight for 14 females measured in Suriname. Morphometric data on other western Atlantic olive ridley populations, except Guyana (Pritchard, 1969a), are lacking.

1.3 Morphology

1.3.1 External/internal morphology and coloration

Pritchard (1969a), Schulz (1975), and Pritchard and Trebbau (1984) give descriptions of olive ridleys from western Atlantic populations. For comparison the following authors are cited to provide general descriptions of olive ridley morphology from other parts of the world: Deraniyagala (1939, 1953), Ceylon; Carr (1952), Honduras; Loveridge and Williams (1957), general; Bellairs (1969a, 1969b), general; Hughes (1974), east Africa; Márquez et al. (1976), Mexico.

Coloration is sometimes used to separate olive ridley and Kemp's ridley adults. However, Pritchard (1969a) found considerable overlap in coloration between the two species, thus invalidating this feature as a single, distinguishing criterion. Hatchling coloration is darker than that of adults. Pritchard (1969a) describes typical hatchling coloration as follows: "the hatchling ridleys were uniform grey-black in color with a small white mark at each side of the supralabial scale, another on the hind part of the umbilical protuberance, and more where the ridges of the plastron cross the abdominal and femoral laminae. The extreme border of the carapace and a very thin line along the trailing edge of both fore and hind flippers were also white."

Carapace scutes in hatchling olive ridleys are slightly imbricate, and the costal and central scutes are keeled. These conditions disappear as the turtle grows, and juveniles have very strong vertebral tuberculations. In adults the scutes are juxtaposed and smooth. With aging, the carapace changes in minor ways, as described by Deraniyagala (1939).The adult's carapace is ovate, tapering slightly posteriorly. In the Guiana population the maximum width of the carapace is equal to, or somewhat less than, its length, but Hughes (1974) found olive ridleys in southeast Africa where straightline carapace width was sometimes greater than its length. Figure 1 depicts an adult female olive ridley from the Indian Ocean. Figure 2 shows the general lepidosis (arrangement of scales or scutes) of carapace laminae in an adult female olive ridley, and figure 3 shows it for the plastron.

Head scales and shell scute nomenclature varies somewhat from author to author, but the most commonly used terms are described in Pritchard et al. (1983), and Pritchard and Trebbau (1984).

The olive ridley plastron has 4 pairs of inframarginal scutes, each perforated by a small pore located near the posterior margin of the scute (see figure 3). The pores lead to axillary and inguinal secretory glands (Pritchard, 1979). There is an additional pore at the posterior margin of the axillary scute, adjacent to the anterior-most marginal scute. This pore is common to all chelonids, but the other inframarginal pores occur only in the Lepidochelys genus (Rainey, 1981). The function of the glands is not well understood, but Carr (1952) postulates that they could function in species recognition. Pritchard (1969a) supports this by suggesting that the glands may serve to secrete a pheromone as an aid in the formation of "arribadas", the mass nesting aggregations which are typical for Lepidochelys species (see section 3.5.2). Ehrenfeld and Ehrenfeld (1973) believe that in freshwater turtles and sea turtles the glands' excretion may be intended to ward off predators or that they could serve in intra- or inter-specific communications. They further proposed the name "Rathke's glands", for the discoverer of the glands.

Head scalation varies somewhat for each sea turtle species, but the species cannot be identified on the basis of these characteristics alone. To present terminology, the lepidosis of a general sea turtle head is shown in figure 4. Figure 5 is the head scalation of an adult olive ridley.

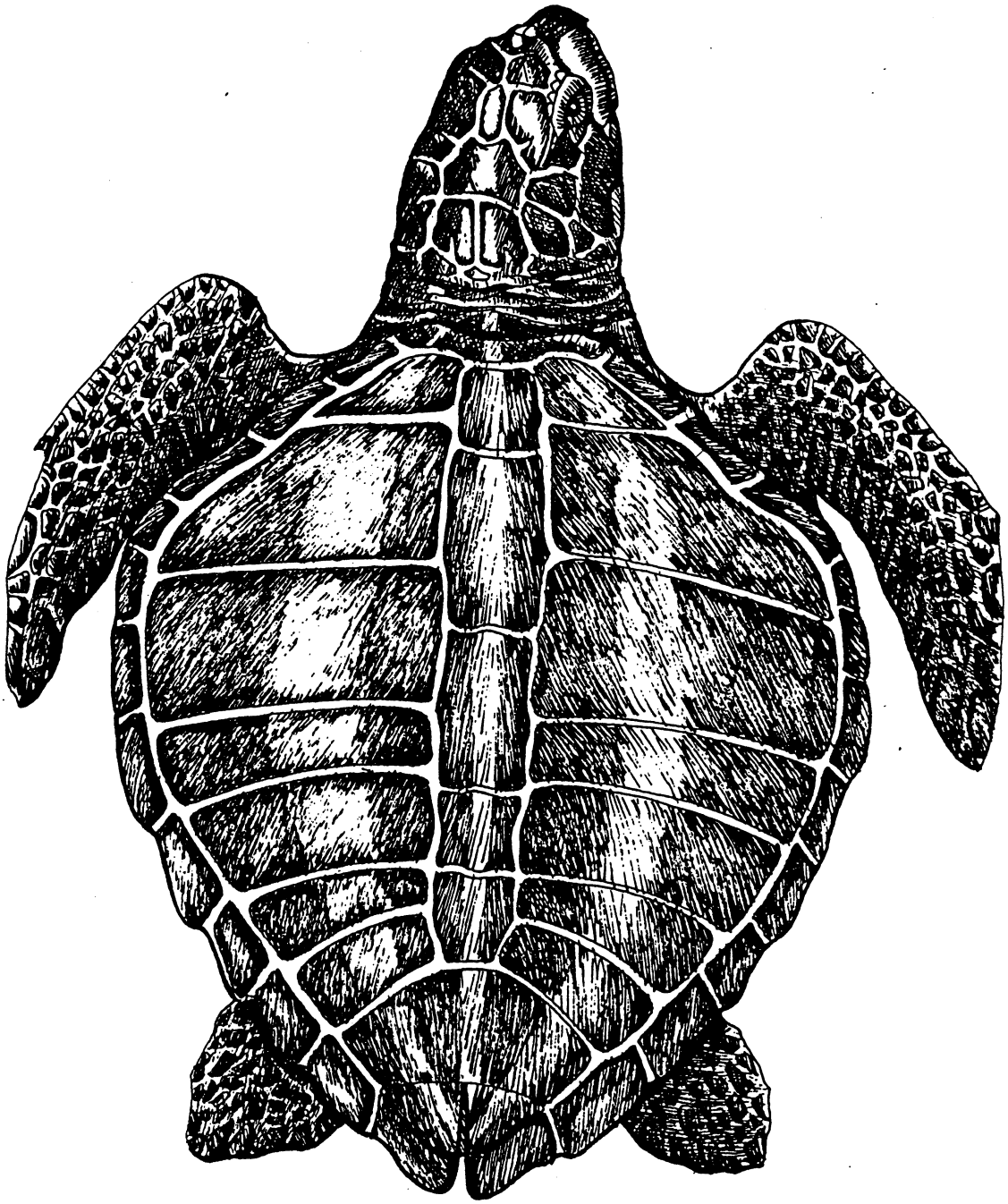


Figure 1 - Adult female olive ridley turtle (Lepidochelys olivacea) (after Deraniyagala, 1939)

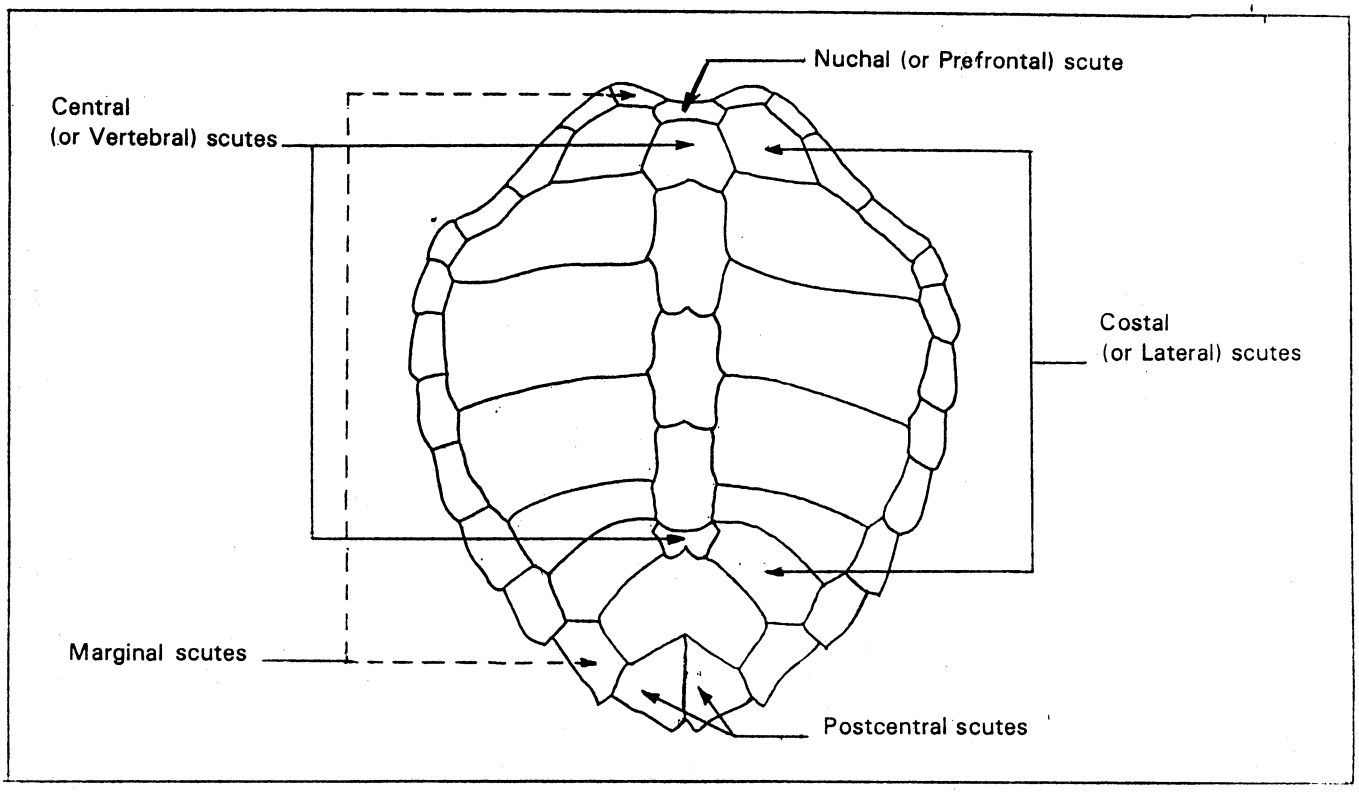


Figure 2 - Carapace of an olive ridley turtle (Lepidochelys olivacea)
(Surinam specimen, scaled drawing by S. Handigman)

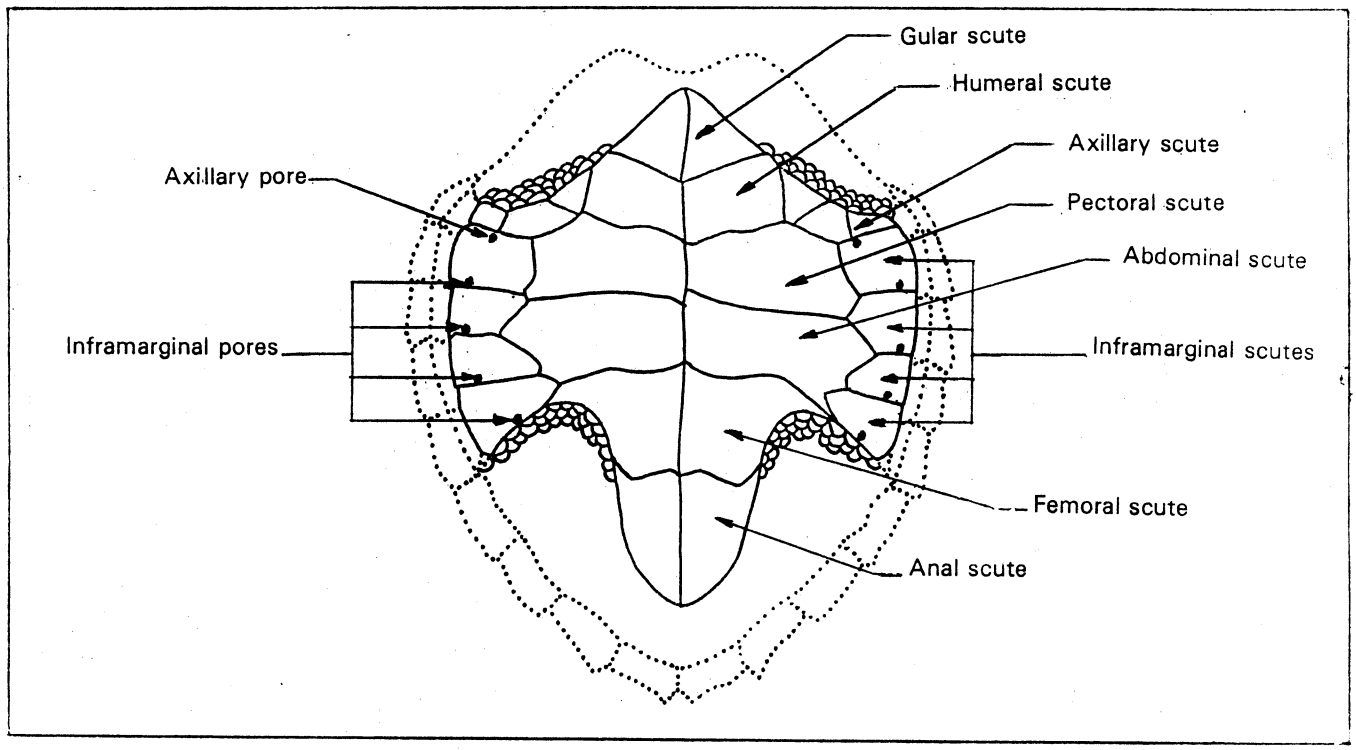


Figure 3 - Plastron of an olive ridley turtle (Lepidochelys olivacea)
(Surinam specimen, scaled drawing by S. Handigman)

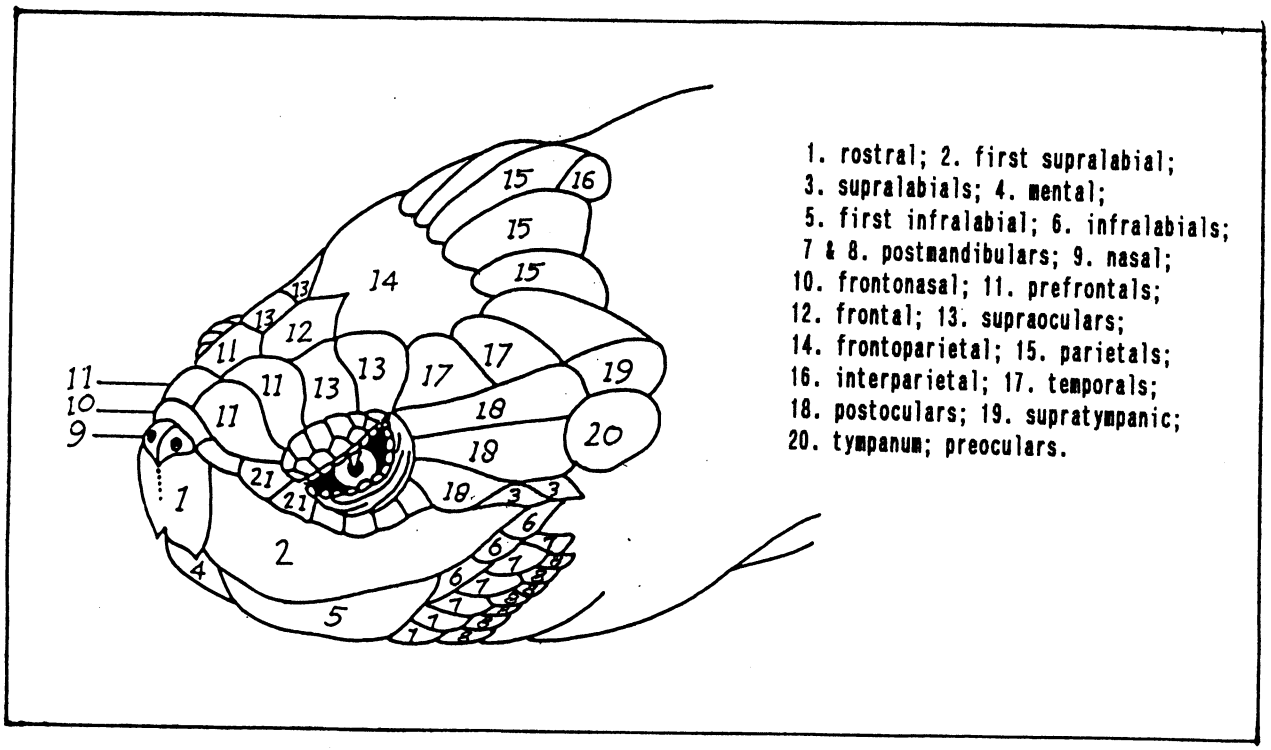


Figure 4 - Schema of general sea turtle head scalation (from Deraniyagala, 1939)

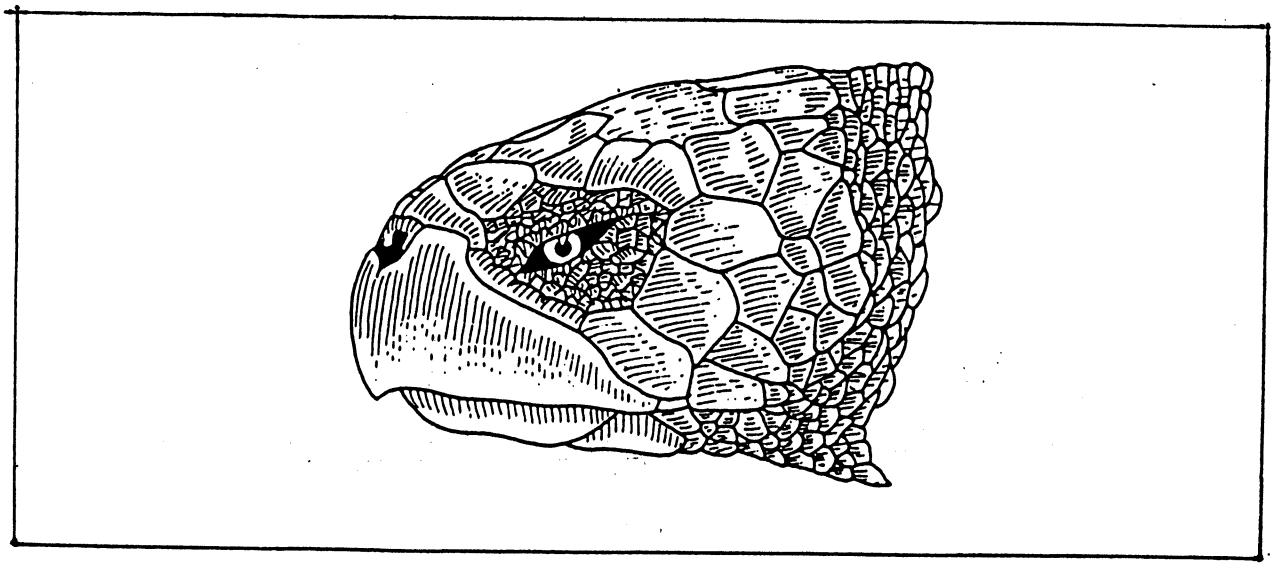


Figure 5 - Head scalation of an adult olive ridley turtle (Lepidochelys olivacea) (after Ferreira de Menezes, 1972)

A number of publications describe and illustrate aspects of sea turtle anatomy. Some do not refer specifically to olive ridleys, but are nevertheless useful for an understanding of general sea turtle anatomy. Descriptions of olive ridley skeletal anatomy are found in Deraniyagala (1939, 1953), Carr (1952), Pritchard (1969a), and Pritchard and Trebbau (1984). Hoffstetter and Gasc (1969) give a description of vertebrae and ribs in modern reptiles, with some reference to olive ridleys.

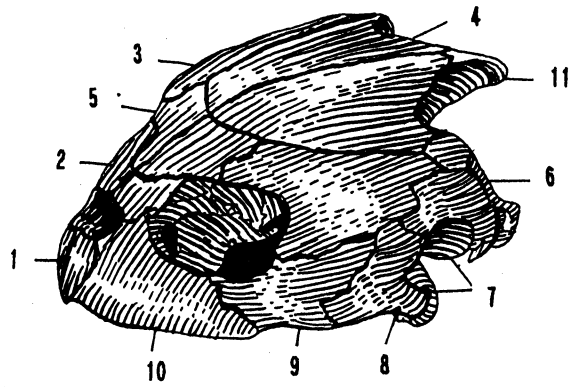
The carapace bones of the olive ridley display constancy only in the number of coastals; the neural bones are very variable, ranging twelve to fifteen, more than those in other chelonians; the marginals less so, varying from twelve to thirteen (Deraniyagala, 1939).

Pritchard (1969a) provides measurements comparing the skulls of olive ridleys and Kemp's ridleys. Bellairs (1969a) gives general information on reptilian biology, with some reference to olive ridleys. Figure 6 identifies the main features of olive ridley skull anatomy, and figure 7 shows the location of the carapace bones of an adult female.

Sea turtle populations occasionally exhibit an incidence of spinal deformities. These are: kyphosis ("humpback"), a dorsally convex deformity of the spine; lordosis ("swayback"), a dorsally concave deformity of the spine; scoliosis, a lateral curvature of the spine. Some of these deformities occur in combination. They are generally non-lethal. Rhodin et al. (1984) surveyed the literature and give an extensive analysis, with illustrations, of the phenomena. They found an incidence of less than 0.4% of spinal deformities in a western Atlantic olive ridley population. Such deformities are believed to be caused by nutritional deficiencies and/or genetic defects. Fuchs (1920a, 1920b, 1920c, 1920d) gives details on the ossification of the sea turtle cranium. Bellairs and Kamal (1981) describe the development of the skull in modern reptiles. Romer (1956) gives details on olive ridley limbs and vertebrae; Zangerl (1969, 1980) gives a comprehensive treatment of the evolution of the skeletal anatomy, from fossil chelonians to modern sea turtles, including descriptions of anatomical features of limbs, skull, carapace, and an analysis of the phylogenetic relationships between the living and extinct species.

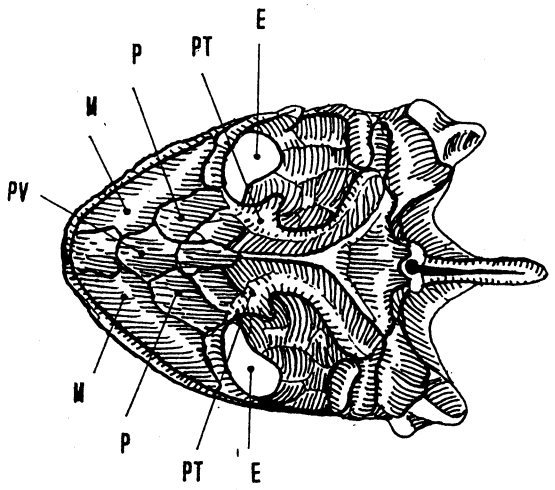
Vision has evolved to its greatest complexity in reptiles, and sea turtles show a great elaboration in structure because they must be able to see in an aquatic as well as a terrestrial environment Granda (1979), Granda and Dvorak (1977) give details on the anatomy and morphology of sea turtle eyes.

Little is known about the internal morphology of olive ridleys in particular, but available information for other sea turtle species may be of use. A simplified and diagrammatic representation of sea turtle internal morphology is given in a sea turtle necropsy manual by Wolke and George (1981). Detailed illustrations on musculature and nervous systems of the extremities of sea turtles can be found in Sieglbauer (1909). Kriegler (1960) gives details on the pelvis and the lower extremities; Shah (1962), on respiratory musculature; Deraniyagala (1953), on the olive ridley pectoral girdle. Shah and Patel (1964) on the myology of the pectoral appendage.



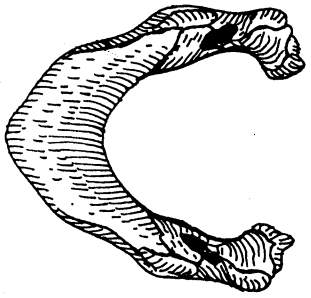
1. premaxillaries; 2. prefrontals; 3. postorbitals;
4. parietal; 5. frontal; 6. squamosal;
7. quadrate; 8. quadratojugal; 9. jugal;
10. maxillary; 11. supraoccipital process.

a) dorso-lateral view



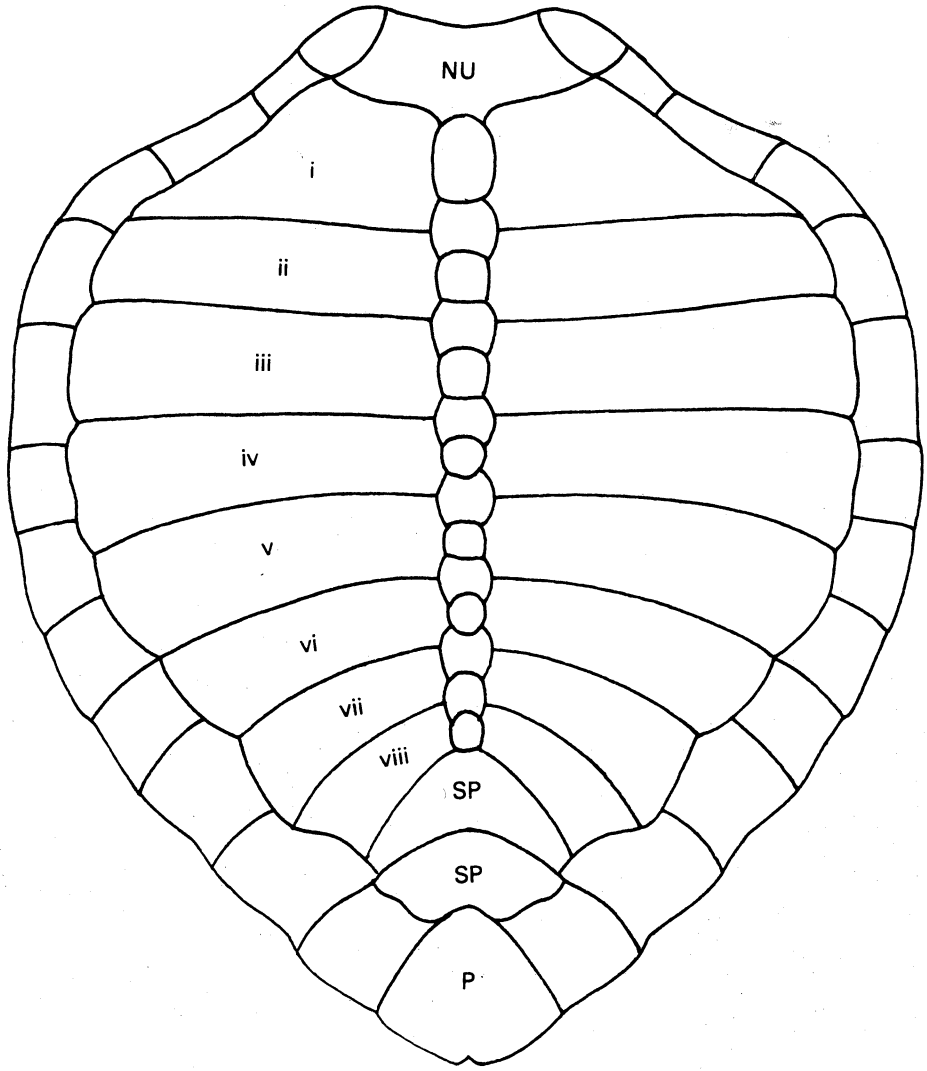
M, maxillary; PV, prevomer; P, palatines;
PT, pterygoids; F, frontal; E, orbit.

b) ventral view



c) dorsal view of mandible

Figure 6 - Skull of an adult female female olive ridley turtle (Lepidochelys olivacea) (from Deraniyagala, 1939)



NU, nuchal; i to viii, costal plates; SP, suprapygals; P, pygal.

Figure 7 - Carapace bones of an adult female olive ridley turtle (*Lepidochelys olivacea*) (from Deraniyagala, 1939)

Walker (1971) studied the movements of the pectoral flippers of olive ridleys by means of slow motion cinematography. Davenport et al. (1984) compared swimming in marine and freshwater turtles, and found that sea turtle forelimbs act like a bird's wing rather than like oars or paddles as previously thought. Musculature and innervation of the head are described by Poglayen-Neuwall (1953), Schumacher (1956), and Soliman (1964). Deraniyagala (1953) described and illustrated neck muscle attachments of olive ridley hatchlings. All the above-mentioned references pertain to studies done on various sea turtle species, and although they do not always specifically refer to olive ridleys, the information given is valid in descriptive terms of general sea turtle morphology.

The olive ridley esophagus has numerous spinelike protrusions which are covered with hard layers of keratin. These play a role in the downward guidance of the food, such as shrimps and crabs, before it enters the stomach (Skoczylas, 1978). Luppa (1977) describes the general sea turtle digestive system, with details on stomach musculature and intestines. Legler (1977) describes a stomach flushing technique to aid dietary studies. Rainey (1981) provides an excellent coverage of sea turtle visceral anatomy, with photographs of reproductive and other visceral organs of olive ridleys. Zug (1966) gives information on the penial morphology of sea turtles, which is quite different from that of other cryptodiran turtles, although he does not specifically mention olive ridleys.

Intracardiac blood shunting, which is considered to aid respiration and thermal regulation during deep dives, is discussed by Sapsford (1978). These studies were done on other sea turtle species, but the blood shunting mechanism in olive ridleys may be similar.

1.3.2 Cytomorphology

Sea turtle erythrocytes are nucleated and elliptical. Frair (1977a) reported a correlation between blood cell parameters (Table 1) and carapace length for olive ridleys, with larger specimens having:

a) Larger red cells size and volume.

b) Higher packed cell volume of red cells.

c) Lower red cell counts.

d) Probably more rounded cells.

TABLE 1

Red blood cell parameters of olive ridley turtles (*Lepidochelys olivacea*) modified from Frair, 1977b)

	Packed cell volume ($cm^3/100\ cm^3$)	Length/Width (µm)	Red cell count ($/mm^3 \times 10^3$)
Mean	31.0 ± 1.3	25.7 ± 1.1 14.4 ± 1.2	354 ± 65
Range	23 - 38	21.0 - 30.0 12.0 - 17.2	-----
Sample	19	1	1

Blood was taken from living turtles by cardiac puncture through the seam of the ventral midline over the heart (Frair, 1977b), or a needle was inserted into the ventricle after entering anteriorly to a hind limb. Blood was then easily collected in a vacuum tube, using adapters attached to large needles (7.5 to 30.0 cm long). Owens and Ruiz (1980) describe an alternate method of obtaining blood and cerebrospinal fluid from marine turtles.

Dessauer (1970) determined the plasma electrolytes in olive ridley blood (Table 2).

TABLE 2

olive ridley turtle (*Lepidochelys olivacea*) plasma electrolytes (mM/liter)

Na+	K+	Ca++	Mg++	Cl-	HCO-	Pi	SO=
163	6.6	5.2	1.4	108	29	3.5	0.3

Frair and Shah (1982) found a significant correlation between olive ridley turtle straightline carapace length and blood serum protein concentration. Specimen with longer carapaces had a higher concentration of serum protein.

Mohanty-Hejmadi et al. (1984) studied the biochemical constituents of serum in 8 and 13 day old olive ridley hatchlings from the Orissa, India, population and found that the serum constituents of hatchlings are within the range found for adults. It remains to be established, however, whether these data are applicable to the western Atlantic populations as well.

Morphometric chromosome analyses of spleen cells from 15-20 day old male olive ridley hatchlings revealed a karyotype of 56 chromosomes (Bhunya and Mohanty-Hejmadi 1986), and they were unable to detect the presence of morphologically distinctive male and female chromosomes. Sex chromosomes would not be expected in species with temperature modulated sex determination (see section 3.5.1). Karyotypes for Chelonia mydas, Caretta caretta, and Eretmochelys imbricata all include 56 chromosomes (Bickham, 1979; Bickham and Carr, 1983). Bickham and Carr (1983) stated that published findings of other diploid numbers for sea turtles have not been substantiated by their own work. Bickham (1979) considered previous reports of a heteromorphic pair of chromosomes as being inaccurate.

1.3.3 Protein composition and specificity

Phylogenetically, marine turtles are an ancient group with origins in the early or mid-Mesozoic Era. By the Cretaceous Period (which started about 135 million years ago), marine turtles were already distributed worldwide (Pritchard, 1979).

Turtles of the genus Lepidochelys are considered to be closely related to loggerhead turtles (Caretta caretta) (Pritchard, 1979; Zangerl, 1980), but most questions on sea turtle taxonomy have only recently been subjected to biochemical evaluation. Affinity between Chelonia mydas and the genus Lepidochelys genus is also widely recognized. Frair (1979) found that antigens of the Lepidochelys genus was the highest cross-reacting antigen, indicating that among the living sea turtles this genus is the closest to a possible ancestral turtle stem. This would support the suggestion that Lepidochelys was already fully differentiated from the other marine turtle genera during the Miocene Epoch (Carr in Pritchard, 1979). Frair (1979, 1982) expected Lepidochelys to test closest to Chelonia, but in reciprocal reactions of anti-serums against L. olivacea and L. kempi, E. imbricata was found to be closer than Chelonia. In all runs of anti-serums against Chelonia both L. olivacea and L. kempi were closest.

Serum albumins in mammals and reptiles have evolved at a relatively constant rate and, as such, can be used as an evolutionary clock to estimate phylogenetic distance and relative time of divergence between species (Chen et al., 1980). Using Anti-Clemmys serum, they calculated the immunological distance for Lepidochelys and estimated that the time of divergence for this genus has been during the Oligocene Epoch, some 29 million years ago, which they state is compatable with the geological records.

Chen and Mao (1981) studied the tryptic peptide patterns of olive ridley hemoglobins as an additional way of obtaining data useful for suggesting taxonomic affinities.

2. DISTRIBUTION

2.1 Total area

Olive ridleys occur nearly circumglobally in tropical oceans. Sternberg (1981) gives a worldwide distribution of olive ridley nesting beaches. The species may be the most abundant sea turtle (Pritchard, 1969a; Zwinenberg, 1976), and yet it may be the rarest sea turtle inhabiting the western Atlantic region.

Olive ridleys are widely distributed along the Pacific coast of South and Central America: from Ecuador to the Gulf of California in Mexico. At a few sites in this region, large synchronous nestings (arribadas) take place, comprising from 5,000 to 150,000 females (Cornelius, 1986). Most of these arribabas occur in Central America; for for details see Márquez et al. (1976), Cornelius (1981). Nesting of olive ridleys on the Pacific coast of Costa Rica was analyzed by Cornelius and Robinson (1984).

Extreme range reports of olive ridleys in the eastern Pacific have come from sightings in the south off the coast near Valparaiso in Chile (Frazier and Salas, 1982). North in the USA at La Jolla, California, where two olive ridleys were seen mating (Hubbs, 1977); in Monterey County, California, where Morejohn (1969) observed an olive ridley swimming in Monterey Bay; and in Humboldt County, California, where in 1957 a live specimen was found on the beach (Houck and James, 1958). These sightings are well outside the normal, tropical habitat of olive ridley turtles and should therefore not be considered as evidence of normal range limits for the eastern Pacific olive ridley population. General distribution data on olive ridleys can be found in Brongersma (1968a), Pritchard (1969a, 1969b), Schulz (1975), Ross et al. (1978), Pritchard and Trebbau (1984).

Olive ridleys have been reported in the western Atlantic region since 1963 (Schulz, 1975). Carr (1957), and Pritchard (1969a) have suggested that they may have come to the Caribbean as migrants from a west African, eastern Atlantic olive ridley population.

The species is only sparsely distributed in the western Atlantic, ranging from the coastal waters of Venezuela to Bahía and Sergipe, Brazil (Schulz, 1975; Schulz and Reichart, 1980; Guagni dei Marcovaldi, 1987). The only known olive ridley nesting beaches in the western Atlantic, north of the Equator, are in Guyana, Suriname and French Guiana, with Suriname having the largest known nesting population in the region. There have been sporadic sightings or captures of olive ridleys in the Greater Caribbean, in Puerto Rico (Caldwell, 1969); Trinidad, Tobago, Barbados (Bacon, 1975), (Schulz, 1975); Cuba (Varona, 1974). A report of nesting olive ridleys in Venezuela (Ross, 1981) should be considered as erroneous.

The olive ridley nests almost exclusively on beaches of the mainland and larger islands. Rumored reports of nesting on some of the smaller islands in the western Atlantic are in doubt (Schulz, 1975), but Bustard (1972) implies that they nest on some of the smaller islands around Australia. Until 1982, practically all known olive ridley nesting in the western Atlantic was reported from the Guianas, and was concentrated on the beaches in eastern Suriname, (Pritchard, 1969b; Schulz, 1971, 1975; Fretey, 1979). Frazier (1984) reports finding some juvenile olive ridley carapaces in Uruguay; the turtles had ostensibly been caught nearby by local fishermen. This extends the southern limit of the western Atlantic olive ridley distribution to at least 34° south latitude, but it is highly unlikely that there are any olive ridleys nesting further south than the state of Bahía. Table 3 summarizes all areas in the western Atlantic for which there have been reports of presence of olive ridleys. Figure 8 is a map showing recapture locations of olive ridley females tagged on Eilanti Beach in Suriname.

TABLE 3

Nesting and foraging areas, reported by sources cited, with nesting seasons of olive ridley turtles (Lepidochelys olivacea) for countries of the western Atlantic region [Parentheses states reported major nesting months]

LOCATION	NESTING	FORAGING	NESTING MONTHS	SOURCE
Antigua	---	---	---	Bacon (1975, 1981)
Aruba	N/A	N/A	N/A	" " "
Bahamas	---	---		" " "
Barbados	---	---	---	" " "
Barbuda	N/A	N/A	N/A	" " "
Belize	---	---	---	" " "
Bermuda	---	---	---	" " "
Bonaire	N/A	N/A	N/A	" " "
Brazil (states: Bahía, Sergipe)	yes	N/A	Oct-Mar	Dei Marcovaldi (pers. comm.)
Cayman Islands	---	---	---	Bacon (1975, 1981)
Colombia	unconfirmed	---	---	" " "
Costa Rica	---	---	---	" " "
Cuba	---	*	---	" " "
Curaçao	---	---	---	" " "
Dominica	---	---	---	" " "
Dominican Republic	unconfirmed	adults	N/A	" " " Carr et al. (1982)
French Guiana	yes	---	Apr-Sept	Fretey (1979)
Grenada	---	---	---	Bacon (1981)
The Genadines	---	---	---	" "
Guadeloupe	---	---	---	" "
Guatemala	---	---	---	" "
Guyana	yes	---	Apr-Aug [May-June]	Pritchard (1969a)

TABLE 3 (continued)

LOCATION	NESTING	FORAGING	NESTING MONTHS	SOURCE
Haiti	---	---	---	Bacon (1981)
Honduras	---	---	---	" "
Jamaica	---	---	---	" "
Martinique	---	juvenile (rare)	---	" " Carr et al. (1982)
Mexico	---	---	---	Bacon (1981)
Nicaragua	---	---	---	" "
Panama	---	adults (unconfirmed)	---	" " Carr et al. (1982)
Puerto Rico	---	adults	---	Caldwell (1969)
Saba	---	---	---	Bacon (1981)
St. Bartholome	---	---	---	" "
St. Eustatius	---	---	---	Bacon (1981)
St. Kitts, Nevis, Anguilla	---	---	---	" "
St. Maarten,	---	---	---	" "
St. Martin	---	---	---	" "
St. Lucia	---	---	---	Bacon (1981)
St. Vincent	---	---	---	" "
Suriname	yes	---	Apr-Sept [June-July]	Pritchard (1969a), Schulz (1975)
Trinidad and Tobago	**	adults	---	Bacon (1981), Carr et al. (1982)
Caicos Islands	---	---	---	Bacon (1981)
Uruguay	---	***	---	Frazier (1984)
USA	---	---	---	Bacon (1981)
Venezuela	---	adults	---	Schulz (1975). Pritchard and Trebbau (1984)
Virgin islands (UK)	---	---	---	Bacon (1981)
Virgin islands (USA)	---	adults	---	" "

Notes:

--- not present

N/A information not available.

* This was a single capture.

** Although Bacon (1975, 1981) indicates that a few olive ridleys are nesting on Trinidad; Carr et al. (1982, p. 27) state that "No olive ridley has been recorded nesting in Trinidad." Godley et al. (1993) claim that olive ridleys nest in Trinidad and Tobago, but give no data to back up this claim.

*** A single capture of a subadult, and does not necessarily indicate the presence of a foraging population.

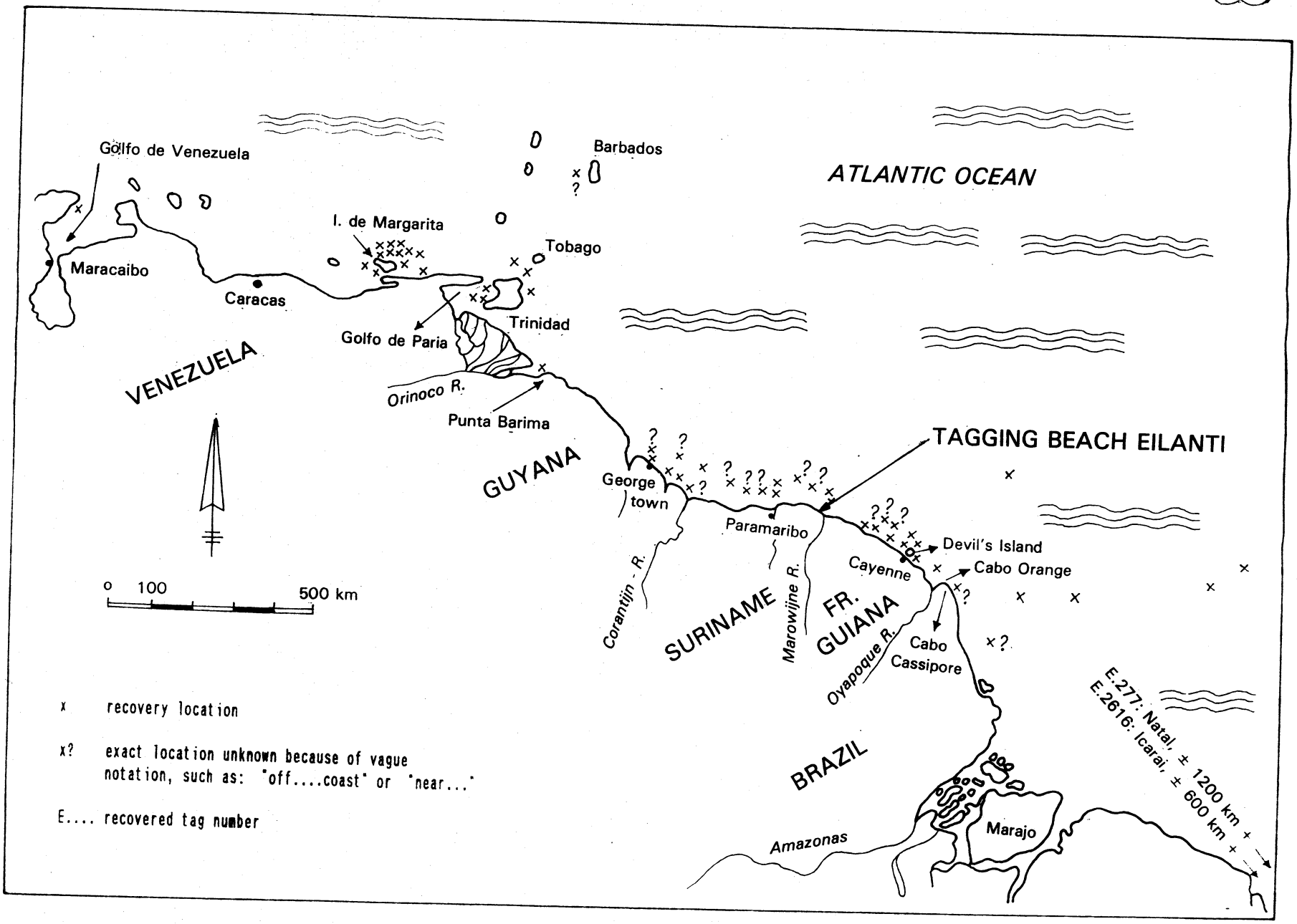


Figure 8 - Recaptures of adult olive ridley females (*Lepidochelys olivacea*) tagged on Eilanti Beach, Suriname (Schulz, 1975)

Pritchard (1969a) discusses causes of intra- and inter-specific distributions, and the interactions between L. olivacea and L. Kempi. He further suggests hypotheses with regard to the establishment of the Lepidochelys genus in the western Atlantic.

a. Lepidochelys olivacea originated in the eastern Pacific, along the west coast of Mexico, sometime during the Mesozoic. By way of the existing marine connection across the Isthmus of Tehuantepec (Mexico), the species became established in the Gulf of Mexico during the Cretaceous. After closure of the marine connection, the Gulf population evolved into kempi. Other groups of the eastern Pacific olive ridley populations radiated westward across (and settled in) the Pacific and Indian Oceans, moved around the Cape of Good Hope, and established themselves on the west coast of Africa. From there they crossed over to the western Atlantic.

b. The original population was Lepidochelys kempi in the Gulf of Mexico. The east Pacific was colonized by way of the Tehuantepec marine connection. After closure of this connection, the eastern Pacific populations evolved into olivacea, and radiated westward as described above.

c. An eastward, trans-Caribbean migration of Lepidochelys kempi reached the South Atlantic, where that population evolved into olivacea. Some groups of that population radiated eastward, and colonized the Indo-Pacific region.

d. After Lepidochelys olivacea was established throughout its worldwide range, the kempi population in the Gulf of Mexico evolved from a south Atlantic olive ridley group that had migrated across the Caribbean.

Pritchard is inclined to reject the last three hypotheses offhand, and he has some misgivings about the first one. The subject of radiation and speciation of the genus Lepidochelys merits further research.

2.2 Differential distribution

2.2.1 Hatchlings

Little is known about the distribution of olive ridley hatchlings, although some authors have made speculations based on what is known from hatchlings of other species, primarily Chelonia mydas (Schulz, 1975; Witham and Futch, 1977; Witham, 1980). It is quite probable that olive ridley hatchlings do show up in reasonable numbers in fishermen's nets but that, because of their small size and easy disposability, they are usually ignored and thrown overboard with the "trash fish". The lack of a suitable tagging method for hatchlings is a serious impediment in studies on their distribution (see section 4.5).

2.2.2 Juveniles, subadults, adults

Juvenile and subadult olive ridleys show up occasionally in commercial or incidental catches, but the frequency of these catches is such that no meaningful data can be extracted (Márquez et al., 1976). Tag return analysis of adult olive ridleys nesting in Suriname indicates a wide dispersal of the females after leaving the nesting beaches. Of the 3359 olive ridley females tagged on Surinam beaches between 1966 and 1973, 72 have been recaptured (Table 4).

TABLE 4

Location of captured of olive ridleys turtles (*Lepidochelys olivacea*) tagged in Suriname (Pritchard, 1976) (Also see Figure 8)

Isla Margarita (Venezuela)	4
Eastern Venezuela	13
Trinidad	8
Barbados	1
Guyana	12
Suriname	15
French Guiana	10
Devil's Island (French Guiana)	3
Northern Brazil	6

The migratory range of adult olive ridleys stretches some 4500 km, from Venezuela to the State of Rio Grande do Norte, Brazil (Schulz, 1975). Pritchard (1973) lists the individual tag returns with details on exact location of each recapture. In Venezuela, there are two distinct areas of concentration, namely around Isla Margarita and Golfo de París (including the Trinidad captures); Pritchard and Trebbau (1984) list more detailed locations of tag returns from those areas.

Most of the tagged olive ridleys were recaptured within a radius of 500 km from Eilanti Beach, in waters off the Guianas; quite a few of those were caught well before or after the nesting season, suggesting that a large number of individuals stay and forage not far from nesting beaches (Schulz, 1975). The sampling bias in Venezuelan waters could be due to the greater fishing activity in that area; or the presence of crustacean breeding grounds in the Orinoco River estuary may attract olive ridleys, since shrimps are a major constituent in the diet of olive ridleys (Pritchard, 1973).

2.3 Determinants of distributional change

Olive ridleys are typically diffusely distributed along the western Atlantic coastline, but concentrations of individuals are found near nesting beaches and high-density foraging areas, such as the Orinoco estuarine zone. Distributional changes occur as a result of seasonal reproductive activities when the olive ridleys converge on the nesting beaches in the Guianas, primarily Suriname, the only place in the western Atlantic where arribadas of olive ridleys are known to have taken place. For details see Pritchard (1969a, 1969b, 1969c) and Schulz (1975).

2.4 Hybridization

For decades, the genera Caretta and Lepidochelys were confused with each other (Schulz, 1975). The olive ridley was once also thought to be a hybrid of Chelonia mydas and Caretta caretta. This belief persisted, even after it had been established as a distinct species. Frazier (1985) provides an in-depth analysis of the past confusion on the taxonomy of olive ridleys. Sea turtle hybrids involving olive ridleys have not been reported in the western Atlantic region.

3. BIONOMICS AND LIFE HISTORY

3.1 Reproduction

Sea turtles are oviparous, i.e. females produce eggs that hatch outside the body of the female.

3.1.1 Sexuality

Sexual dimorphism is evident only in adults. The tail of the female barely extends beyond its carapace, but the adult male has a long, thick tail protruding well beyond the posterior end of its carapace, and often as far as the extended hind flippers. Adult males also have longer claws on their fore flippers than females. The male plastron is often more concave than that of the female, ostensibly to facilitate ventro-dorsal copulation, but this feature is not distinctive enough to separate the sexes. Sexual dimorphism in hatchlings and juveniles is not evident. Their gender can only be determined through captive rearing or by dissection and subsequent histological examination, and by radio immunology tests (Owens, 1981; Van der Heiden et al., 1985) (see also section 3.1.5.)

3.1.2 Maturity

There is no real evidence on the age when an olive ridley reaches sexual maturity. Márquez et al. (1976) suggest that olive ridleys from the eastern Pacific populations reach sexual maturity at the same age as Kemp's ridleys, which they state to be 7-9 years. The smallest, sexually mature individual they measured had a (straightline) carapace length of 52 cm. Size data for western Atlantic olive ridleys are available only for the Surinam nesting population. Table 5 gives carapace lengths for females of nesting populations from Suriname, and from some other regions for comparison.

TABLE 5

Straightline carapace lengths of adult olive ridley turtles (*Lepidochelys olivacea*) from nesting beaches in several regions

Location	Sex	Mean cm	Range cm	N	Source
Ceylon	mixed	73.3	68.0-79.0	4	Deraniyagala (1939)
Costa Rica:					
Nancite	female	63.7	57.2-71.4	404	Cornelius and Robinson (1984)
Naranjo	female	65.2	57.0-72.5	53	Cornelius (1976)
Honduras:					
Pacif.coast	female	66.6	64.8-68.7	4	Carr (1952)
Madagascar	mixed	60.58	52.8-66.5	21	Hughes (1974)
Mexico:					
Colima	mixed	64.3	60-68	19	Márquez et al. (1976)
Jalisco	mixed	63.2	54-70	115	
Oaxaca	mixed	62.9	52.5-73.0	1203	
Mexico:					
Oaxaca	female	62.98	54.0-67.0	81	Frazier (1983)
Oaxaca	male	64.35	60.5-68.5	17	
Mozambique (various)	mixed	65.36	58.1-69.5	5	Hughes (1974)
Suriname:					
Eilanti	female	---	64-72	14	Pritchard (1969a)

3.1.3 Mating

Mating usually occurs at the surface of the water and appears to be mostly polyandrous, with several males attending one female. Copulation takes place with the male mounting the female, hooking the recurved claws on his fore flippers around the the anterior edge of the female's carapace to maintain coitus. A full analysis of the mating process is lacking, but some descriptions are given by Schulz (1975), Márquez et al. (1976), Pritchard and Trebbau (1984), Cornelius (1986).

3.1.4 Fertilization

Fertilization is internal. Knowledge of ovulation and fertilization processes is limited. Owens and Morris (1985) describe the endocrine system of olive ridleys. Licht (1982) measured circulating gonadotropins and sex steroids during the annual cycle in eastern Pacific olive ridleys, and found that in males testosterone levels closely follow testicular growth and spermatogenesis, instead of showing a separate peak during the spring mating season. In the female the hormonal surge is completed by the time the shell membrane forms, and ovulation takes place again within 3 days after she has nested. He further found that each clutch represents a separate, ovulated set of follicles, which indicated to him that several sets of follicles must grow progressively throughout the nesting season.

Other researchers have suggested that sea turtles may demonstrate delayed fertilization, whereby the female is impregnated during a previous season and egg fertilization occurs during the next nesting season. But this view has been disputed as a non-adaptive trait (Ehrhart 1981). None of the reviews refers specifically to such studies on olive ridleys.

3.1.5 Gonads

The embryonic development of sea turtle gonads is the subject of intense research (Mrosovsky, 1980; Mrosovsky and Yntema, 1980; McCoy et al., 1983; Mrosovsky et al., 1984; Whitmore et al., 1985). In sea turtles, environmental conditions, possibly including nest temperature during the incubation of the eggs, influence the development of the gonads and thus the resulting gender of the turtle. The critical period for sexual differentiation in the gonads of sea turtles is unknown, but it may occur during the first half of the incubation process. Metabolic heat generated by the embryo during the development of the eggs contributes to the ambient nest temperature but, since this primarily occurs later in the incubation period when the effect of sexual differentiation have probably already been determined, it then is believed to have no effect on the eventual gender of the hatchlings. On the other hand, Merchant Larios et al. (1986), in studies including olive ridleys, found that sexual differentiation of the embryo's gonads takes place during the last days prior to hatching. In addition, they concluded that there is the possibility that this differentiation is not yet conclusive, and that sex reversal could take place in advanced stages, even after hatching.

The degree of metabolic heating is a function of clutch size, but clutch size does not necessarily affect the sex ratio in the hatchlings (Mrosovsky and Yntema, 1980). Nevertheless, for olive ridleys, higher temperatures will result in a preponderance of females, and lower temperatures will give mostly males (Table 6). Nest site selection by the female may therefore be a major factor in the sex determination of its offspring.

The temperature resulting in a 1:1 sex ratio is called the "pivotal temperature" (Mrosovsky and Yntema, 1980), the "threshhold temperature" (Bull, 1980), or the "critical temperature" (Pieau, 1976). The term "pivotal temperature" will be used throughout this paper.

Incubation temperature in a natural nest is known to fluctuate, but pivotal temperature is a constant temperature, maintained only under laboratory conditions in an artificial nest. Therefore, claims that the pivotal temperature is the incubation temperature that results in a 1:1 sex ratio in sea turtle hatchlings may be valid for laboratory studies, but is not necessarily applicable to eggs incubating in a natural nest.

TABLE 6

Percentage of female *Lepidochelys olivacea* hatchlings from different thermal conditions (from Standora and Spotila, 1985).

nest location	thermal condition	no. of nests	total no. of turtles	% females
open beach	warm	8	118	100
shaded beach	cool	7	100	15
tide beach	warm/cool	1	20	10
beach hatchery	cool	3	60	1.5
styrofoam box	cold	9	164*	0.5

Notes:

Nest temperatures during middle third of development were as follows:

Open beach - Average temperature: 33.1° C (range: 31.5 - 34.6° C).
Shaded beach - Average temperature: 28.3° C (range: 26.4 - 30.0° C).
Tide beach - nest subject to periodic cooling as a result of high tide inundations.
Beach hatchery - Average temperature: 27.4° C (range: 25.0 - 28.8° C).
Styrofoam boxes - Average temperature: 25.7° C (range: 24.6 - 26.7° C).

* three hatchlings were intersexes under this condition.

Pivotal temperatures may be different for populations of the same species, living in different regions. For olive ridleys eggs, taken from nests in Suriname, the pivotal temperature is about 28.7° C. In tests of eastern Pacific olive ridleys the following results were obtained: no olive ridley eggs hatched at a temperature of 23° C; eggs incubated at a constant temperature of 25° C, produced all male hatchlings; and eggs incubated at 32° C resulted in all females. When the eggs were incubated at 30° C a sex ratio of approximately 1:1 resulted (McCoy et al., 1983).

Pieau et al. (1984) provide a summary of the literature which deals with the effect of incubation temperature on sexual differentiation of turtle gonads. Mrosovsky (1980) gives an overview of the thermal biology of sea turtles, including the effect of temperature on sex ratio, and its possible adaptive value.

Recent research has shown that the hydric environment in a turtle nest also has a significant effect on sexual differentiation in the developing embryo. In the painted turtle (Chrysemys picta), Paukistan et al. (1983) found that, when the nest substrate was kept moist, and nest temperatures varied between 18° C and 30° C over the course of a day, a nearly equal number of male and female hatchlings resulted. When the substrate was kept dry, maintaining the same temperature regimen as above, the hatch resulted in predominantly males. Although these studies were done with a freshwater turtle, nest humidity may be be an important factor in sexual differentiation in developing sea turtle embryos as well.

Sex can be identified either through gross morphology of the gonads (McCoy et al., 1983; Van der Heiden et al., 1985) or by histological analysis of gonad sections, as described by Yntema and Mrosovsky (1980) and Mrosovsky et al. (1984). Jackson et al. (1987) analyzed these two methods to evaluate the ability of investigators to determine the sex of hatchling sea turtles. Using histological techniques their accuracy was 93-95%.; when using gross morphological characteristics of the gonads, the accuracy was only 33-53%. This indicates that sex determination by gross morphological characteristics was incorrect more than half of the time. A reliable in vivo test for sex identification in hatchlings is not yet available, therefore the animal must be sacrificed. Caillouet and Duronslet (1985) express concern about the possibility of a lower reproductive efficiency in so-called sex-reversed individuals, i.e. turtles in which the incubation temperature can override, or modify, the influence of the genotype in the development of the gender of the turtle. Standora and Spotila (1985) analyzed possible mechanisms of temperature dependent sex determination in sea turtles, including those for olive ridleys.

3.1.6 Nesting process

The larger sea turtle species nest primarily at night. When a large turtle, such as the green turtle (Chelonia mydas), is on land, the heat gain from solar radiation under full sun would soon become lethal. Even under overcast days these animals would become subjected to severe heat stress (Spotila and Standora, 1985). For the smaller olive ridleys this poses less of a danger, because they lose more heat through convection (Spotila and Standora, 1985), and therefore olive ridleys, at times, nest during the day as well. Nevertheless, olive ridleys in the Guianas nest mostly in the dark, usually before midnight (Pritchard, 1969a; Schulz, 1975).

Beach description: Like all sea turtles, olive ridleys usually nest on clean, sandy beaches that are easily accessible from the sea and that have a level beach platform above the springtide line. In Suriname there seems to be a correlation between beach type and the particular sea turtle species nesting there. Leatherbacks (Dermochelys coriacea) and green turtles (Chelonis mydas) are the predominant nesters on beaches with a relatively steep incline, usually combined with a near-vertical beach wall created by surf erosion during high tides.

The olive ridley, on the other hand, nests mostly on beaches with a gentle incline and no significant wall to keep them from reaching the dry beach platform. Because of its small size, the olive ridley is generally unable to negotiate a steep beach wall, whereas the more powerful leatherbacks and green turtles have little trouble crossing or flattening such a barrier. The prime olive ridley nesting beach in Suriname is Eilanti Beach, which is relatively free from driftwood, has a gentle incline, and has almost no beach wall. In addition, Eilanti Beach has shallow near-shore waters with a muddy substrate. At lower tides this is relatively easy to traverse for the olive ridleys, but extremely difficult for the larger species. Leatherbacks and green turtles are sometimes stranded in the mud before reaching open water, often resulting in death through exhaustion and exposure (Reichart, pers. obs.).

In Suriname the olive ridley nesting cycle usually takes about one hour (Schulz, 1975; Reichart, pers. obs.). Females arrive at, and depart from, the beach before the mudflats are exposed by the receding tide.On beaches without near-shore mudflats, green turtles and leatherbacks are the dominant nesters, with only dispersed olive ridley nesting there. In French Guiana, where newly created mudflats have drastically decreased known leatherback nesting on some beaches, an increase in olive ridley tracks has been observed. Further descriptions on olive ridley nesting beaches in the Guianas can be found in Pritchard (1969a, 1969b), Schulz (1975), Fretey (1979, 1981).

Nesting season: In addition to genetically determined factors, environmental factors influence the nesting season of olive ridleys, and there are temporal variations, depending on geographic location of the nesting beaches. Schulz (1975) found that olive ridley arribadas in Suriname depended on the presence of rough seas and offshore winds. Anticipated arribadas did not occur because the nights were still. But they did take place a few nights later when the sea was rough and there was a strong shoreward wind.

Table 3 (section 2.1) summarizes olive ridley nesting season information for the western Atlantic. Exact data on nesting seasons in this region are available only for the Guianas. The season ranges from April through August, with a nesting peak in Guyana during May-June (Pritchard, 1969b) and in Suriname during June-July (Schulz, 1975). These dates, incidentally, coincide with the time of the long rainy season in these areas. Recent reports indicate that olive ridleys nest in Bahía and Sergipe, Brazil, during the period of October through March (Dei Marcovaldi, Pers. comm.), but the period of most intensive nesting activity is not yet known.

Behavior: During the nesting season both Lepidochelys species exhibit a unique schooling behavior, which is described further for olivacea in section 3.5.2.

Nesting: Descriptions of olive ridley nesting from various parts of the world indicate that, in general, the process appears to be the same. For such detailed descriptions see Deraniyagala (1939), Carr (1952), Pritchard (1969a, 1969b), Schulz (1975), Pritchard and Trebbau (1984).

In summary, the nesting process can be divided into several stages:

(1) Landfall and emergence from the surf: the female approaches the beach warily, at times swimming parallel to the shoreline. When the female senses no danger she will emerge from the surf onto the beach, at times pressing her head against the sand, and then raising it again to look about.

(2) Travel from surf to nesting area: the female advances rapidly up the beach, alternately using diagonally opposed flippers for locomotion. Head is held low, but is occasionally raised to look around. Travel to the eventual nesting site is usually direct.

(3) Selection of nest site: when high beach (or dry sand area) has been reached, the female often immediately starts preparing a body pit. Little time is spent on nest site selection.

(4) Clearing the site and excavating the body pit: the female usually selects a clean site; no clearing of debris takes place. Extending the fore flippers far forward, close to the head, she then thrusts them back towards the body, throwing sand to the rear. After about a minute, the fore flippers stop and the hind flippers clear sand farther backward. The body pit is shallow, but deep enough to hide the animal's profile from the view of potential predators.

(5) Excavation of the egg cavity: the backward flailing movement of the hind flippers changes into a digging motion, with the female alternately using each hind flipper as a scoop to take sand out of the cavity and put it on the surface at the same side as the flipper in use. The resulting cavity is bell-shaped, with its widest part near the bottom. Its depth is as far as the hind flipper can reach into the hole.

(6) Oviposition: during the actual egg-laying process the fore flippers are extended backward at an angle to the body. Hind flippers cover the cavity. Eggs are usually expelled in groups, about 3-7 eggs at a time (Reichart, pers. obs). As each egg is laid, the turtle raises its head slightly, and the hind flippers show involuntary contractions.

(7) Filling the nest: immediately after oviposition is ended, the egg cavity is filled by scraping sand into it, alternately using the hind flippers only. The filling of the hole is periodically interrupted when the olive ridley compacts the sand using a rapid side-to-side rocking motion of the body, causing a clearly audible sound of the plastron thumping on the sand. This is a trait that is unique to the genus Lepidochelys.

(8) Filling the body pit and concealment of the nest: after the cavity has been filled, and the sand tamped down, the olive ridley sweeps sand over the body pit area by simultaneously using diagonally opposed flippers. As the body pit begins to blend in with the surrounding area, the turtle almost inconspicuously moves forward, effectively camouflaging the actual nest location.

(9) Return to the sea: the female abruptly moves away from the area and travels directly toward the sea. It enters the surf, and rapidly traverses open water. The entire process, from landfall to return to the sea, usually takes about one hour.

Multiple nesting: Data on the internesting period for olive ridleys is inconclusive, because nesting intervals for olive ridleys are affected by weather conditions. Nevertheless, data collected by Hill (in Schulz, 1975) in Suriname suggest intervals between nesting of 17 days and 30 days during a nesting season; Table 7 shows nesting frequencies obtained from mark-and-recapture studies in Suriname.

Olive ridleys nesting on the west coast of Mexico have a 28-day intra-seasonal nesting cycle (Márquez et al. 1981), but Minarek (1985) found a 17-day cycle for olive ridleys nesting in Honduras, which is similar to that for the Surinam population.

TABLE 7

Intra-seasonal nesting frequency of olive ridley (*Lepidochelys olivacea*) females on Eilanti Beach, Suriname (from Schulz, 1975)

	Numbers of nesting olive ridley females			
Year	Nesting once	Nesting twice	Nesting thrice	Nesting none *
1970	800	300	30	70
1971	500	450	30	20

* = false crawls (i.e. females that came ashore but did not lay eggs)

Virtually all olive ridley females nesting on Eilanti Beach in Suriname return here for nesting during subsequent seasons. Site fixity for this sub-population is strong but is apparently weaker for olive ridleys nesting on other Surinam beaches (Schulz, 1975). Of the Eilanti group, nearly two-thirds return the following year for renesting, one quarter have a two-year interval and about 8% have a three-year interval. From these data the average interbreeding period is calculated to be about 1.4 years. Renesting data for other western Atlantic olive ridley populations are not known.

3.1.7 Eggs

Like all reptilian eggs, sea turtle eggs are cleiodic, having heat, water, and respiratory gases exchange with the environment during incubation (Ackerman, 1980; Ackerman et al., 1985). Turtle eggs differ from those of birds by having a parchment-like shell, which consists of two layers. The outer layer is the calcareous component, and the inner layer separates the outer layer from the albumen. The outer layer has a large number of microscopic pores, which presumably serve in the exchange of respiratory gases for the embryo. Figure 9 gives major morphological features of a chelonian egg. Packard et al. (1982) give detailed descriptions of chelonian eggs.

Olive ridley eggs are white and almost spherical, and have a mucilaginous coating, when emerging from the female's cloaca. In the Guianas, the temperature of olive ridley eggs, as they emerge from the cloaca, is on the average 28.70° C, which is about 0.25° C cooler than the female's deep body temperature, but is usually warmer than the water in nearby shallows (average: 27.50° C) and the air, which ranged from 24.00° C to 27.75° C (Mrosovsky and Pritchard, 1971).

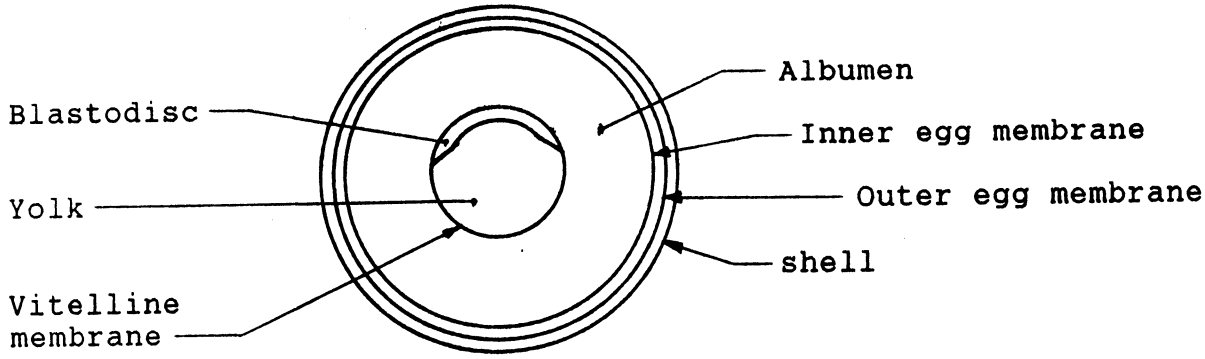


Figure 9 Diagram of a typical sea turtle egg (modified from Packard et al. (1977)

Eggs drop singly, or in groups of 3 to 7 in rapid succession. During at least part of the incubation period, sea turtle eggs absorb water and swell slightly. Newly laid eggs are fully rounded, but within 24 - 48 hours they appear to have loose space, giving an egg the appearance of a dented ping pong ball. During further incubation the egg seems to fill up again. The calcium and magnesium needed for bone ossification in the olive ridley embryo is recovered from the egg itself; calcium from the inner surface of the egg shell, and magnesium from the yolk (Packard et al., 1977).

Olive ridley eggs are the smallest of sea turtles. Eggs from the Surinam population are considered to be slightly larger than those from populations in other parts of the world, but Pritchard (1969a) suggests that this may only be a seasonal difference. Average diameter of Surinam olive ridley eggs is 4.0 cm, ranging 3.7 - 4.1 cm (Schulz, 1975). For olive ridleys in Guyana, Pritchard (1969b) gives a range 3.9 - 4.0 cm. Márquez et al. (1976) measured 757 eggs of the eastern Pacific olive ridley population of Oaxaca in Mexico and found averages of 3.80 cm (38.0 mm) - 4.81 cm (48.1 mm). Carr (1952) measured 50 olive ridley eggs from the Pacific coast of Honduras and found an average size of 3.75 cm (37.5 mm), ranging 3.21 - 4.54 cm (32.1 - 45.4 mm).

Bustard (1972) measured eggs from an Australian olive ridley population and found an average diameter of 3.88 cm (38.8 mm), ranging 3.85 - 4.10 cm (38.5 - 41.0 mm). Although these data may indicate that the western Atlantic olive ridley eggs are on the average larger than those elsewhere, this may not be so because of seasonal differences (Pritchard, 1969a), and possibly because different measuring techniques and accuracies were used. Measuring a relatively elastic object such as a turtle egg which, in addition, is known to change size somewhat during incubation (Ackerman et al., 1985), to sub-mm accuracy is unrealistic (Reichart, pers. obs.). Although there is considerable overlap at about 4.0 cm, the absolute accuracies in measurements implied above should be regarded as unreliable.

Table 8 summarizes olive ridley egg sizes from various parts of the world for easy comparison, and Table 9 give some weights for olive ridley eggs.

TABLE 8

Diameters of olive ridley turtle (*Lepidochelys olivacea*) eggs (in cm)

LOCATION	MEAN	RANGE	N	SOURCE
Australia	3.88	3.85-4.10	--	Bustard (1972)
Guyana	----	3.9- 4.0	--	Pritchard (1969b)
Honduras (Pac. coast)	3.75	3.21-4.54	50	Carr (1952)
Ceylon	----	3.8- 4.3	14	Deraniyagala (1939)
Mexico (Oaxaca)	3.88	3.22-4.81	757	Márquez et al. (1976) (averaged)
Suriname	4.0	3.7- 4.1	100	Schulz (1975)

TABLE 9

Weights of olive ridley turtle (*Lepidochelys olivacea*) eggs (in grams)

LOCATION	MEAN	RANGE	N	SOURCE
Ceylon	37.57	33.96-41.30	8	Deraniyagala (1939)
Mexico (Oaxaca)	32.60	----	757	Márquez et al. (1976) (averaged)

Clutch parameters for western Atlantic olive ridleys are known primarily from studies in Suriname (Pritchard, 1969a, 1969b; Schulz, 1975). Average clutch size is 116 eggs (range: 30 - 168), which makes the Surinam olive ridley clutches, on average, the largest recorded in the literature for the species, although recent findings indicate that the clutch size of olive ridleys nesting in Pirambu, Brazil, may be larger ((Guagni dei Marcovaldi, pers. comm.).

Pritchard (1969a) tentatively proposed a positive correlation between size of the nesting female and the size of her clutch. Even though studies of the relationship between average clutch size and mean carapace length have been made for several sea turtle species (Hirth, 1980), no such study is known for the western Atlantic olive ridleys. It is not implied that clutch size is the property of a specific geographic population. It may be the result of a population's breeding condition.

Incubation time is about 55 days (range: 51 - 61). In Australia, Bustard (1972) randomly selected 12 nests out of 50 olive ridley nests. Mean clutch size for 6 of the nests was 108 eggs (range: 50 - 147), and incubation time was about 50 days (range: 48 - 52). Table 10 is a summary of the number of eggs per nest from various parts of the world. The large clutch size shown for Brazil is based on a relative small sample and needs further analysis.

TABLE 10

Number of olive ridley turtle (*Lepidochelys olivacea*) eggs per nest

LOCATION	MEAN	RANGE	NO OF NESTS	INCUB. DAYS	INCUB. RANGE	SOURCE
Australia	108	50-147	6	50	48-52	Bustard (1972)
Brazil (Pirambu)	123	---	57	47	---	Guagni dei Marcovaldi (pers. Comm.)
Costa Rica (Pac.coast)	104	---	131	50	---	Camhi (1982)
Honduras (Pac.coast)	---	72-132	5	--	---	Carr (1952)
Ceylon	---	90-135	-	--	---	Deraniyagala (1939)
Suriname	116	30-168	1154	55	51-61	Schulz (1975)

Nest depth is essentially dictated by the length of the flipper of the digging female. In numerous nest excavating processes observed, the female's hind flippers are always practically fully extended when the nest nears completion, with the flexible, extreme end of the flipper bent into a scoop to lift out the sand (Reichart, pers. obs). A strong relationship exists between clutch depth and the female's hind flipper length. Therefore, average flipper length should be the parameter in establishing proper depth of burial when transplanting endangered natural nests to safer locations. Distance from beach surface (in the shallow body pit) to top of the nest is found by deducting height of egg mass from depth of nest cavity.

P. Dutton (pers. comm.) found that olive ridley nests in Suriname are relatively shallow, and varied from 30-40 cm in depth, which makes the nests more vulnerable to predation by crabs (see section 3.3.4), and to possible sex bias because of greater fluctuations in ambient temperatures.

3.2 Embryonic and hatchling phase

3.2.1 Embryonic phase

Embryological studies on Lepidochelys olivacea are limited and non-existent for western Atlantic populations. Deraniyagala (1939) gives detailed descriptions on late stages in the development of olive ridley embryos of the Indo-Pacific population. Crastz (1982) gives descriptions and illustrations for embryonic development of specimens from the Pacific coasts of Panama and Mexico (Figure 10). Vallen (1942) gives illustrations and descriptions of the ontogeny and comparative anatomy of the embryonic olive ridley carapace and plastron. For for the Cratz data, however, these stages of development were found in embryos which were incubated artificially at a temperature of 30° C, and therefore may not necessarily reflect the timing of developmental stages in natural nests, where temperatures are known to vary during the incubation process from 27.0° C to 34.5° C.

Olive ridley embryos produce significant amounts of urea throughout their development, and gaseous ammonia may be the primary excretory product during embryonic development (Packard et al., 1977).

Just prior to hatching, a somewhat pointed, horny thickening develops on the epidermis at the snout tip, and serves to tear the embryonic membranes at the time of hatching. This structure is properly called the egg-caruncle, but it is usually (although erroneously) referred to as the egg-tooth (Bellairs, 1969a). The egg-caruncle disappears shortly after hatching.

3.2.2 Hatching phase

Not all eggs hatch successfully. Some of the eggs were not fertilized. Others are destroyed through nest predation (see section 3.3.4). Entire nests are often destroyed by environmental factors, such as beach erosion. In Suriname the average hatching success of natural olive ridley nests is 60% (Schulz, 1975). When nests are clearly endangered, transplanting the eggs to safer locations on the beach will give a marked improvement in overall hatching success. The success rate of such transplanted olive ridley nests in Brazil is 85-87% (Guagni dei Marcovaldi, pers. comm.).

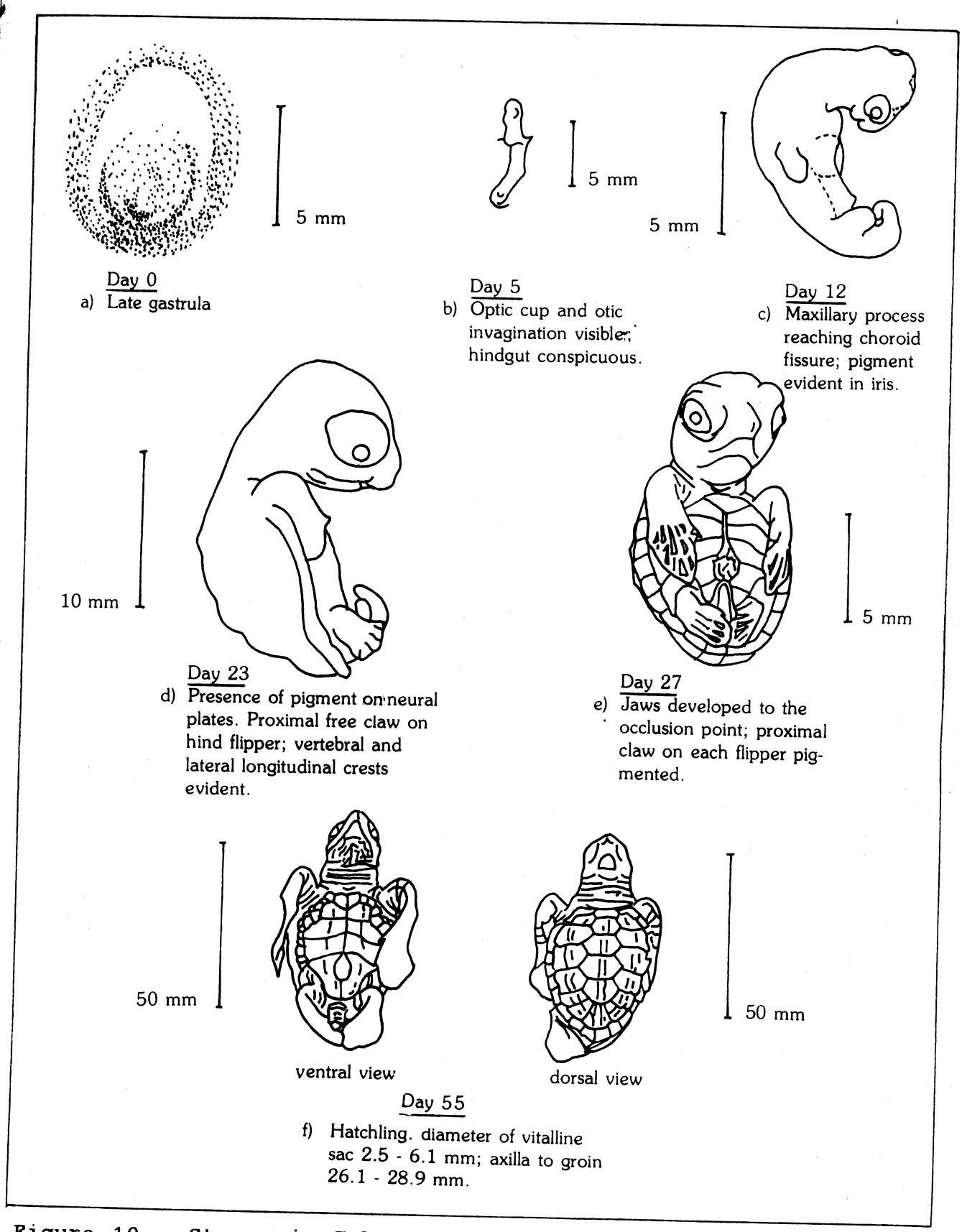


Figure 10 - Stages in Embryonic Development of the Olive Ridley Turtle (*Lepidochelys olivacea*) (extracted from Crastz, 1982)

Neonate sea turtle hatchlings remain quiet in the egg chamber until practically all eggs have hatched. At that time, the sides and top of the chamber are eroded by collective thrashing of the flippers of the hatchlings and the sand is transported through the clutch to the eggs chamber floor -- in essence moving the chamber with its contents, en masse, upward to just below the surface of the beach (Hendrickson, 1958). Here they remain quiet again prior to emergence. Carr (1981) observed similar behavior in several species, but it has not yet been recorded for western Atlantic olive ridleys. Cornelius (1986) provides a detailed description of the process for turtles nesting on the Pacific coast of Costa Rica. Emergence occurs at night, which is considered to be in response to lower surface temperatures (Mrosovsky, 1980). Most hatchlings in a nest emerge at the same time, but emergence of stragglers from the same nest on subsequent nights is not unusual (Schulz, 1975). Mrosovsky (1968) found that olive ridley hatchling activity was inhibited at temperatures above 28.5° C. This would support the suggestion that night emergence may not only be an adaptation to minimize exposure to predation, but also an adaption to avoid higher daytime temperatures on the beach, which could be equally lethal to hatchlings. The nest emergence "frenzy" is carried over into a rapid crawling movement across the beach to the surf. During this phase the hatchlings are no longer a cohesive group, but all nevertheless scurry unerringly in a direct line towards the water. Olive ridley hatchling dispersal, after they reach the sea, is probably similar to that of other sea turtle species, i.e. a frantic flipper activity propelling the animal quickly away from the shore in a near perpendicular direction, towards the horizon.

There are various theories with regard to the "sea-finding" mechanism in hatchlings, most of them referring to phototropism, whereby the bright (or less dark area) over the sea would provide the major stimulus (Deraniyagala, 1939; Verheijen and Wildschut, 1973; Van Rhijn, 1979), but none of these by itself is a satisfactory explanation of the sea-finding ability of the hatchlings (Carr, 1981). Mrosovsky and Kingsmill (1985) did an analysis of several hypotheses on sea-finding mechanisms, but they consider sea-finding mechanisms other than phototropism as unlikely. Raymond (1984) reviews the scientific literature on hatchling orientation and discusses various causes of disorientation. Table 11 summarizes some olive ridley hatchling sizes from various parts of the world.

3.3 Juvenile, subadult, and adult phase

3.3.1 Longevity

The potential life span of sea turtles is still a mystery and there are no reliable data on maximal longevity. Márquez et al. (1976) estimate 7-9 years before an olive ridley reaches sexual maturity (see sec. 3.1.2), and they give 18-20 years as the longevity for individuals from the Mexican eastern Pacific population. No such data are available for the western Atlantic olive ridley populations.

TABLE 11

Dimensions and weights of olive ridley turtle (*Lepidochelys olivacea*) hatchlings

LOCATION	CARAPACE LENGTH (mm)	CARAPACE WIDTH (mm)	WEIGHT (grams)	N	SOURCE
Ceylon	40-46	31-36	16-19	17	Deraniyagala (1939)
Mexico	40.3	---	16.2	25	Márquez et al. (1976)
South Africa	42.9-47.4	34.1-37.7	16.8-22.3	5	Hughes (1974)
Suriname	42	36	---	--	Schulz (1975)

3.3.2 Hardiness

The olive ridley is a hardy species within its normal distribution, but extended exposure to temperature extremes can be lethal. An olive ridley stranded on the beach during daytime may die of heat exhaustion within a matter of hours (Reichart, pers. obs.).

When in the sea, the ridley's body temperature is generally within 1°- 2° C of the water temperature (Spotila and Standora, 1985). But an olive ridley carried by an ocean current or by other means reaches water with temperatures below its normal range will suffer from hypothermia and may succumb. Schwartz (1978) exposed several sea turtle species to cold water, and found, for instance, that Kemp's ridleys died after being exposed to water of 5.0°-6.5° C for 20-24 hours, with the larger turtles being more vulnerable than the smaller specimens. Olive ridleys were not tested but, because they are more tropical in distribution than Kemp's ridleys, they will probably have a similar reaction at a somewhat higher minimum temperature threshold.

Olive ridleys, when raised in captivity, are, as with most if not all sea turtle species, prone to bacterial and fungal infections under crowded conditions. These afflictions are usually easily remedied when recognized and treated in time. Treatments of such infections are the same for all sea turtle species and are described by Witham (1973) and Banerjee et al. (1986). Rebell et al. (1975) analyzed an epizootic of skin lesions called gray-patch disease. They found it to have the characteristics of the herpes virus group which, if not treated, resulted in the death of 5-20% of the turtles with extensive lesions.

3.3.3 Competitors

The olive ridley is primarily carnivorous, foraging over the continental shelf for crustaceans, tunicates and small invertebrates. Although little is actually known about its feeding ecology, there seems to be little competition from other vertebrates, except man, in this niche. Competition with other sea turtles for nesting sites is avoided by the fact that in Suriname olive ridley nesting is minor on beaches frequented by leatherbacks and green sea turtles. On these shared beaches, most olive ridleys nest late in the season. They also nest on beaches that are difficult for the larger species to reach because of offshore mudflats (see section 3.1.6, and Schulz, 1975).

3.3.4 Predators

Like all sea turtles, olive ridleys are exposed to a variety of predators during their life cycle, but the greatest mortality occurs during the egg and hatchling stages. Schulz (1975) found a 40% hatch failure for natural nests in Suriname. It is difficult to pinpoint a specific cause for this high hatching failure, but the eggs are subjected to predation by, among others, raccoons (Procyon cancrivorus), ghost crabs (Ocypode quadrata), several lizard species, and dogs (both domestic and feral) (Schulz, 1975; Reichart, pers. obs.). In Suriname the ghost crab is by far the most important predator of eggs and hatchlings of all sea turtle species. Hill and Green (1971) monitored 100 green sea turtle nests in Suriname and found that 60% of the nests were attacked by ghost crabs within 4 days after the eggs were laid. The average percentage of eggs destroyed by ghost crabs was 11.8%, but in some nests up to 93% were eaten. Shallow nests were attacked more often than deeper ones, which may make olive ridleys more vulnerable to ghost crab predation than other sea turtle species. The low incidence of ghost crabs on Eilanti Beach in Suriname may be one reason that this area is the best olive ridley nesting beach in the western Atlantic. After nests have been disturbed, through predation or natural erosion, some of the remaining eggs may still hatch successfully, but such nests are usually fully destroyed by subsequently invading insects, dogs and birds, of which the black vulture (Coragyps atratus) is the most destructive.

A conventional method used by fieldworkers to locate sea turtle nests is by probing the sand with a pointed rod. During this procedure up to 5 eggs may break. For green sea turtles and leatherbacks the rotting contents of these broken eggs adversely affect the clutch to the extent that hatching success is drastically decreased, but no such effect was found on olive ridley eggs (Hill, 1971b).

Hatchlings on the beach must run the gauntlet against ghost crabs, vultures, seagulls, dogs (feral as well as domestic), and raccoons; in the water they are vulnerable to attacks by catfish, sharks and oceanic birds. Little quantitative data are available on predator impacts on hatchling sea turtles, but it is widely assumed, that less than 1% of the eggs laid will become adult turtles (Mrosovsky, 1989) and that about 0.1% of the eggs may eventually become adult sea turtles (Frazer, 1989).

Sharks are probably the only natural predator (excluding man) of adult sea turtles, although nesting females are occasionally killed by jaguars on some Surinam beaches (Reichart, pers. obs.). Stancyk (1981) gives a worldwide review of non-human predators for all sea turtle species. For a more detailed account of olive ridley predation in the Guianas see Pritchard (1969a), Schulz (1975), Fretey and Lescure (1981). For predation by man see section 5.

3.3.5 Parasites and commensals

Sea turtles harbor a variety of parasites and commensals, but literature specifically on western Atlantic olive ridleys is scant. Most of what is known comes from other regions or other sea turtle species.

On eastern Pacific olive ridleys from Oaxaca, Mexico, Frazier (1983) found 4 classes of epizoons: leeches (Ozobranchus sp.), barnacles, "eggs" and algae. Males were infected with leeches more so than the females, but in both sexes the leeches were predominantly found on the anterior parts of the body. Frazier (1983) postulates that, since these leeches are aquatic animals, they may aggregate on that part of the host's body which is submerged the most. Hubbs (1977) reports remoras, a crab of the species Planes cyaneus, two species of barnacles (Cylindrolepis darwini and Conchoderma virgatum), parasitic copepods, and some algae on an adult male olive ridley captured at La Jolla, California. Frazier et al. (1985) examined specimens from Mexico and India, and found filamentous algae, anemones, barnacles and bivalves adhering to the carapace. Mohanty-Hejami et al. (1989) found a number of sedentary invertebrates on the carapace and neck of olive ridleys nesting on Gahirmatha beach in Orissa, India. Some other organisms they found were the sea anemones Adamsia, Metridium, and Balanus barnacles. Brooks and Frazier (1980) found large numbers of the nematode Kathlania leptura in the intestinal tract and stomach of a dead olive ridley found floating near Zanzibar, East Africa.

Information about parasites and commensals on olive ridleys from other regions, or when it is obtained from other sea turtle species, should not be extrapolated to include western Atlantic olive ridleys, since the organisms involved may be site- or species-specific in their host selection. It can nevertheless provide a guideline for the type of organisms that may be found associated with olive ridleys.

3.4 Nutrition and growth

3.4.1 Feeding

The olive ridley feeds primarily on crustaceans, tunicates, a variety of small invertebrates, and some algae (Mrosovsky, 1983). Olive ridleys have been incidentally captured in trawl nets trawling at depths of up to 110 m, which indicates that they are capable of foraging in deep waters (Hughes, 1974). Little else is known about the feeding behavior of adult olive ridleys. Juveniles and hatchlings in the open sea may feed on jellyfish, salpae, pteropods (Brongersma, 1968a), and fish eggs (Fritts, 1981), but accurate studies on their feeding ecology are lacking. Pritchard (1969a), Schulz (1975), and Pritchard and Trebbau (1984) give some additional data.

3.4.2 Food

Olive ridleys are opportunistic foragers which probably includes scavenging. Gut analysis of an injured olive ridley caught incidentally off the coast of Suriname showed catfish, snails, crabs and jellyfish as items consumed (Caldwell et al., 1969). The digestive tract also shows mud and sand, ingested as incidental items, indicating that the olive ridley is also a bottom feeder. Shrimp abound in the waters of the Guianas, and Pritchard (1969a) postulates that shrimp may be a substantial part of the diet, although this is still unconfirmed.

Legler (1977) describes a method to examine stomach contents of live sea turtles, where, by means of a simple water pumping device, food in the stomach is flushed out through the esophagus without any evident harm to the animal.

3.4.3 Growth rate

Márquez et al. (1976) developed growth rate curves for eastern Pacific olive ridley populations in Mexico. They report a range of straight-line carapace lengths of 117 to 200 mm at an age of 8 months, with corresponding weights of 260 to 1300 grams. At the age of 12 months these measurements were respectively 182 to 237 mm and 1000 to 2300 grams. Sexual maturity for eastern Pacific olive ridleys was estimated to occur between the ages of 7 and 9 years, when the turtle weighs approximately 35 kg and has a carapace length of 51 to 59 cm.

Based on captures at sea near Oaxaca, Mexico, they developed the following growth equations:

Females.....$W = 0.0304\ L^{1.727}$

Males.....$W = 0.0195\ L^{1.820}$

Where: W = body weight in Kg
L = straight-line carapace length in cm

Hirth (1982) developed weight-length relationship equations for sea turtles based on information from various published sources. For adult female olive ridleys nesting in Suriname, the equation, when transformed into a form useful for comparison with the equations developed by Márquez et al. (1976), is:

Females.....$W = 0.0184\ L^{1.791}$

Frazer and Ehrhart (1985) took capture-recapture measurements from green sea turtles and loggerheads to develop growth rate models for these species. They found that the Von Bertalanffy growth model gave a slightly better fit to the data than the logistics model. Their method provides basic mathematical techniques, which may be useful as a basis to develop similar models for olive ridley populations.

These equations are approximations at best and are not necessarily applicable to populations of the same species in other regions. They may nevertheless serve as a comparative index between such populations. Much variablity in growth is due to genetic differences, nutritional value of prevalent food sources, and competition for these resources. Evidence suggests also that sea turtle growth is irregular rather than smooth.

3.4.4 Metabolism

There is no literature specifically on olive ridley metabolic rates, but metabolic rate studies on other sea turtle species may be applicable to olive ridleys as well. Jackson and Prange (1979) noted that oxygen consumption of exercising green turtles is almost 10 times higher than when they are at rest. Ackerman (1980) found that in green turtle eggs and leatherback turtle eggs metabolic activity increases throughout the incubation period, and that growth rate and mortality of sea turtle embryos are related to respiratory gas exchange.

The throat movement of sea turtles may facilitate inhalation and exhalation, although other researchers contend that the movement of the limbs and neck serve that function (Jackson, 1985). There are also indications that the movement of certain abdominal muscles brings about respiration, and that the throat movement is primarily for olefaction (Shah, 1962).

3.5 Behavior

3.5.1 Migration and local movement

Migration of western Atlantic olive ridley populations is known only from tagging studies in Suriname (Pritchard, 1969a, 1969c, 1973; Schulz, 1975). After nesting, large numbers of the ridleys stay in the waters of the Guianas. Other groups go to the coast of Venezuela, where there are small concentrations near Isla Margarita and the Gulf of París. A few olive ridleys tagged in Suriname have been recaptured along the coast of Céara, Brazil, but these, and occasional tag returns of olive ridleys in the greater Caribbean area should not be considered as indicators of possible regular migration routes. It remains to be seen whether these dispersals are made up of distinct sub-populations or if the migratory movements of the Surinam olive ridley nesting population is more one of general dispersal.

Marcovaldi and Marcovaldi (pers comm.) report nesting of olive ridleys in Sergipe and Bahía, Brazil, but their report does not shed light on any migration patterns or local movements of those populations. Pritchard (1973) gives some minimum travel speeds of olive ridleys after they leave the nesting beach at Eilanti: one female traveled 800 km to Venezuela in 60 days, which amounts to an average speed of 13.3 km per day; one swam 910 km to Trinidad in 32 days for an average speed of 28.4 km per day; and one swam 440 km to Brazil for an average speed of 36.7 km per day.

Such speeds are absolute minimums, since it is not known how long the turtle was in the area before it was recaptured. Although the Guiana Current, which flows with a velocity of about 1-3 km per hour past the Guianas (Schulz, 1975), would aid the turtles traveling toward Venezuela and Trinidad, the olive ridley swimming to Brazil swam against the Guiana Current, yet this turtle had the fastest minimum speed.

3.5.2 Schooling

Both species of the genus Lepidochelys exhibit a unique schooling behavior at nesting time, which Pritchard (1969a) so succinctly called "perhaps the most spectacular manifestation of reptile life in the world". Two interchangeable terms, "arribazon" and "arribada" (taken from the Spanish word for arrival) are now firmly established in the literature to describe the formation of nesting aggregations of ridleys. Arribada is the term most often used.

The first mention of an olive ridley arribada in the western Atlantic was in an unpublished Surinam Forest Service report by the game warden Lichtveld, who observed one in 1963 at Eilanti Beach, Suriname. The first published description was by Pritchard (1967). Some concurrent environmental factors appear to be indicative for arribadas to take place in Suriname, the most significant being:

1. high tide early at night (usually before midnight)
2. moderate or strong winds blowing inland
3. rough seas

Several authors have speculated on the adaptive advantages of arribadas and their environmental prerequisites. These range from "saturation nesting" by females so that predators will be satiated quickly because of an overabundance of food, to strong onshore winds keeping mosquitoes away from the nesting individuals (Pritchard, 1969a; Cornelius, 1986). For more detailed discussions see Pritchard (1969a), Schulz (1975), Pritchard and Trebbau (1984).

3.5.3 Responses to stimuli

It is not known how sea turtles navigate over long distances, and how they are able to return to the beaches where they have nested previously. Owens et al. (1982) suggest olfactory or chemical imprinting mechanisms as found in salmonid fishes, whereby the turtle responds to cues in chemical gradients in the water to find its nesting beach or foraging area. The presence of organic magnetite, found in the heads of loggerheads, suggests that some sea turtles may respond to the Earth's magnetic field during migration, as homing pigeons and honey bees do (Kirschvink, 1980; anon. 1990a). Hendrickson (1958) proposes the "social facilitation model" as a possible migration stimulus, whereby first-time nesters follow experienced adults to the nesting beach, the route of which they then learn through olfaction or responses to other environmental stimuli.

Aggression is also a response to stimuli, and although there is little information on aggressive behavior in the olive ridley, there is ample information on this in its cogener Lepidochelys kempi. During captive rearing experiments with Kemp's ridleys, aggressive behavior among the turtles was a major problem. Klima and McVey (1981) suggest that this aggressiveness may be the result of a hierarchy within the group, although certain individuals appear to be more aggressive, regardless of their status in the group. Because of the close relationship between the Kemp's ridleys and olive ridleys, one might assume similar aggressive behavior in olive ridleys. Whitaker (1979) reports that in a captive rearing project in India there was some aggressiveness among juvenile olive ridleys, but Reichart (unpubl. data) did not find any aggression in hatchling olive ridleys being reared in Suriname. More research in this area is required.

4. POPULATION

4.1 Structure

4.1.1 Sex ratio

Márquez et al. (1976) have published data from commercial turtle fisheries on the Pacific coast of Mexico. Between 1967 and 1975 a total of 137,794 olive ridleys was caught and sexed. There was a significant difference in sex ratio among the animals harvested, depending on location and season, but when their data are summarized for the entire period it comes to 48.6% females to 51.4% males, approximating a 1:1 theoretical sex ratio for the adult population.

4.1.2 Age composition

There are no reliable data on age composition of wild populations, because there is no known method to age specimens randomly sampled from natural populations. Age criteria based on information from captive reared sea turtles cannot be extrapolated because the diet usually fed to captive turtles may give an accelerated growth rate when compared to that of turtles living under natural conditions. Estimated age of sexual maturity is 7-9 years for eastern Pacific olive ridleys, and longevity is estimated to be 18-20 years (see section 3.1.2 and 3.3.1)

4.1.3 Size composition

The only known size composition of olive ridleys in the western Atlantic is of the Surinam nesting population. Measurements taken from 500 adult females gave an average curved carapace length of 68.5 cm (range 63 - 75 cm), and the average curved carapace width was 60.4 cm (range 53 - 66 cm). Surinam hatchlings measured on the average 4.2 cm long and 3.6 cm wide (Table 11, Schulz, 1975). For juveniles and subadults no data are available. For classification of size categories see section 1.2.5.

4.2 Abundance and Density

4.2.1 Average abundance and density

It is difficult, if not impossible, to make an accurate assessment of olive ridley abundance and density at sea. Márquez et al. (1976) developed a population model for olive ridleys nesting along the Pacific coast of Mexico, and they estimated a population of 430,000 adult olive ridleys along the eastern Pacific coast of Mexico for 1973. In some other Central American countries along the Pacific coast (El Salvador, Honduras, Nicaragua, Costa Rica) olive ridleys are the most abundant species nesting there (Cornelius, 1981). The olive ridley is generally considered to be the most abundant sea turtle species in the world (Zwinenberg, 1976), but as far as population status is concerned, the western Atlantic olive ridley population may very well be the most endangered population of this species.

Fretey and Lescure (1979) report on olive ridley nesting, including beach locations, in French Guiana for 1977-1979. Fretey (pers. comm.) provided some additional nesting data for French Guiana for 1980, 1986, and 1987; no records were available for 1981-1985. Although only some of the beaches were surveyed, and then only during part of the season, his findings confirm olive ridley nesting in French Guiana (Table 12).

TABLE 12

Olive ridley turtle (Lepidochelys olivacea) nesting reported in French Guiana (Fretey, pers. comm.)

Year	1977	1978	1979	1980	1981 - 1985	1986	1987
No. of nests	31	101	33	6	?	52	479

Very few olive ridley turtles nest in Guyana (Pritchard, pers. comm.; Pritchard, 1988). There is no reliable information available for other western Atlantic olive ridley populations.

Schulz (1975) estimated that during the 1967 and 1968 seasons the Surinam olive ridley nesting population consisted of some 2100 - 3000 females. Since that time this population has been declining, and the estimate for 1989 is that there may be only some 500 adult females left (Table 13).

The numbers of nests listed in Table 13 were obtained from surveys conducted on all Surinam beaches for the particular year listed. The calculated values for population estimates, however, are based on arithmetical manipulations, using crude parameters, as given in Table 13. Therefore, the stated population estimate for each year should not be considered as an absolute value, but rather more as an index to illustrate population fluctuations and its general decline.

TABLE 13

Nesting records and population estimates for the Surinam olive ridley turtle (*Lepidochelys olivacea*) nesting population

year	number of nests*	number of nesting females**	female population estimate***	average female population
1967	2875	1440-2050	2020-2880	2450
1968	3290	1650-2350	2310-3290	2800
1969	1665	830-1190	1160-1670	1420
1970	1750	880-1250	1230-1750	1490
1971	1595	800-1140	1120-1600	1360
1972	1270	640- 910	900-1270	1090
1973	890	450- 640	630- 890	760
1974	1080	540- 770	760-1080	920
1975	1070	540- 760	760-1070	910
1976	1160	580- 830	810-1160	990
1977	1030	520- 740	730-1030	880
1978	870	440- 620	620- 870	750
1979	795	400- 570	560- 800	680
1980	1020	510- 730	710-1020	870
1981	1220	610- 870	850-1220	1040
1982	1045	520- 750	730-1050	890
1983	1212	610- 870	850-1210	1030
1984	940	470- 670	660- 940	800
1985	670	340- 480	480- 670	580
1986	540	270- 390	380- 550	470
1987	659	330- 470	460- 660	560
1988	563	280- 400	390- 560	480
1989	585	290- 420	410- 590	500

* From: Schulz (1975); Reichart, Pers. data; Mohadin, Pers. Comm.

** Number of nesting females was calculated from Schulz (1975) data, which indicate that olive ridleys lay 1.4-2.0 nests per season in Suriname. Numbers rounded to nearest multiple of 10.

*** Female population estimate was calculated from Schulz (1975) data, which indicate an average breeding interval for olive ridleys in Suriname of 1.4 years. Numbers rounded to nearest multiple of 10.

During the period 1990-1993, the Galibi Nature Reserve, where most olive ridley turtle nesting in Suriname takes place, was occupied by rebellious Amerindians from nearby villages. As a result, no nesting data are available for that period. The problems with the villagers have been resolved, the reserve is staffed again, and it is expected that data collection will resume with the 1994 nesting season.

4.2.2 Changes in abundance and density.

Significant changes in abundance and density take place due to the formation of arribadas at the nesting beaches. These changes are merely a shift in density within the population, and they do not constitute a reliable measure of changes in overall population size. Nevertheless, a year-by-year comparison of the number of olive ridleys participating in arribadas can be a valuable indicator of abundance and density trends in the population. For the well-studied Surinam olive ridley population it has been determined that it is declining (Table 13). Since 1972 olive ridley nesting has been diffused over Surinam nesting beaches, and no mass nesting has taken place on Eilanti Beach. Habitat destruction is not a factor, but the excessive harvest of eggs by local indians, until its cessation in 1967, may finally have begun to exact its toll on the natural population. Additional causal factors are poaching on beaches in Guyana (Pritchard, pers. comm.) and incidental catches in fishnets along the coast of the three Guianas (Reichart, pers. obs.; Tambiah, pers. comm.), but those have not yet been adequately quantified.

4.3 Natality and Recruitment

4.3.1 Reproductive rates

From parameters established by Schulz (1975), a crude estimate for the reproductive rate in Surinam olive ridleys can be calculated. Schulz (1975) estimates 1.4 to 2.0 nests per season per female. Average clutch size is 116 eggs, with a hatching success of 60%. Consequently, if one female olive ridley lays about 162-232 eggs per season, this results in about 97-139 hatchlings per year per female. Data on reproductive rates from other western Atlantic olive ridley populations are not available.

4.3.2 Factors affecting reproduction

The massing of olive ridleys in arribadas is considered to be an effective reproductive strategy. A general assumption is that through mass-nesting, egg predators will become saturated with food (Pritchard, 1969a), and that nests of later arriving females will have considerably less predator pressure, thus a better chance for successful hatching (see section 3.5.2). However, arribadas often result in the digging up, exposure, and subsequent destruction, of thousands of eggs laid by previously nesting females (Cornelius, 1986). Hughes and Richardson (1974) estimated that only 0.2% of 11.5 million eggs laid during one arribada in Costa Rica produced hatchlings. This may very well negate the advantage of predator food saturation. Quantitative data to assess this in the western Atlantic are lacking. Because of its location, Eilanti Beach is eminently suited for the development of an arribada: the beach is small, it is virtually free of terrestrial predators, and the near-shore mudflats force nesting by high tides (Pritchard, 1969a).

In times, when man was not a significant contributor to olive ridley mortality, the high percentage of hatch failure, together with other natural causes of mortality, was more or less balanced by the turtle's reproductive potential. With the increasing human presence in coastal areas, and the extra predator pressure from man, the strategic advantage of arribadas may no longer be valid. Large quantities of eggs can be harvested in a short time, and arribadas may now be an indirect, contributing factor for declining olive ridley populations

Other aspects influencing the reproductive effort of olive ridleys are similar to those for other sea turtle species. These include such environmental factors as: sea state, precipitation, and temperature (Pritchard 1969a; Schulz 1975). Although not a natural environmental factor, artificial lights on nesting beaches are also detrimental to reproduction (Witherington, 1990).

4.3.3 Recruitment

Recruitment is the addition of sexually mature individuals to a population. Information on olive ridley recruitment is lacking, but a rather imperfect model can be constructed for the Surinam population from available data. It is often assumed that less than 0.1% of sea turtle eggs laid in a particular year will yield one adult (Frazer, 1989; Mortimer, 1990). If this assumption of 0.1% is accepted as valid for olive ridleys also, and one female lays some 162-232 eggs per year (section 4.3.1), 4-6 females would be required each year for the addition of one recruit to the Surinam nesting population. Or one female will, over 4-6 nesting seasons, provide one recruit to the population.

The interbreeding period for olive ridleys in Suriname is 1.4 years (section 3.1.6), therefore one female will produce one adult for the Surinam population every 5.5-8.0 years. If an olive ridley becomes sexually mature at 8 years, and lives to be 20 years (section 3.3.1), the female replaces itself only two or three times during its lifetime. This would seem to be a precarious balance for a natural population. Some wildlife populations exhibit enhanced recruitment during periods of stress, but this has not yet been demonstrated in marine turtles.

Hirth and Schaffer (1974) have developed a highly theoretical, mathematical model for the survival rate of green turtles and found that at least 2.2, and maybe as many as 10, hatchlings per 1000 must survive to maturity to maintain a stable population. Their algorithm for the green turtle may be useful in order to develop a similar model for the olive ridley, if the pertinent, applicable population parameters are substituted. Hirth (1980) also stressed the need for more reproductive and ecological data before the reproductive strategy of olive ridleys can be comprehended.

4.4 Mortality

4.4.1 Mortality rates.

There are no quantitative data on mortality rates in sea turtles. Although mortality is known to be high during the egg stage and the early years of life, an adult turtle has few enemies, except for man. The high reproductive rate of sea turtles is an apparent evolutionary adaptation to compensate for high mortality at an early age. Too little is known to construct an accurate population model for any of the sea turtle species. For an analysis concerning the paucity of information about sea turtle mortality rates see Bustard (1979).

4.4.2 Factors causing or affecting mortality

Indirect, human-caused mortality factors for sea turtle eggs in general are: crushing of nests by vehicular traffic on the beach (Eckert et al., 1992), or nest destruction from construction activities. For hatchlings they are primarily artificial beach lighting from buildings or roads, which tends to create disorientation (Raymond, 1984, Witherington, 1990). The latter causes hatchlings to move away from the sea, resulting in death through exposure or accidents. Along the coast of the Guianas, sea turtles are incidentally caught in fishermen's nets (Reichart, pers. obs.). Shrimp trawlers also appear to be an important factor in olive ridley mortality in the Guianas (Reichart, pers. data; Tambiah, pers. comm.).

In 1967, during exploratory fishing trawls off the Guianas, ten olive ridleys were incidentally caught along the Surinam coast (Caldwell et al., 1969). From mid-August to early September 1968, five more specimen were taken during a similar operation (Caldwell et al., 1969). Thirty-nine olive ridleys, tagged during a study on Surinam beaches, were caught by shrimp trawlers within a 1-year period (Pritchard, 1973). Shrimp trawlers of several nations are active along the coast of the Guianas and, although their contribution to olive ridley mortality is unknown, it must be considerable. There may be up to 150 shrimp fishing boats operating in the area. Most of these are French, German, Korean, Japanese, and Venezuelan. Some fishermen report that each trawler catches about one turtle per week (Reichart, pers. data). Others report an incidental catch of 16-25 turtles per year per boat (Tambiah, pers. comm.). It is obvious that some fishermen are not telling the truth and caution must be exercised in evaluating data obtained from informants. In the Guianas, fishermen make no attempts to resuscitate comatose sea turtles; they are either tossed overboard or eaten by the crew.

The development and use of the Turtle Excluder Device (TED) is a means to reduce the incidental catch (Anon., 1981a; Seidel and McVea, 1981). However, fishermen in developing countries are reluctant to use it, because TEDs also reduce by-catch, which is often an important source of income for fishermen. Hillestad et al. (1981) give a review of worldwide incidental catches of sea turtles. Although mortality caused by fisheries in which olive ridleys are the target species, is considerable in some areas, especially in the Pacific Ocean (see section 5), but it is probably minor for the western Atlantic population.

A serious egg destruction factor in the three Guianas is beach erosion. Large stretches of nesting beach, especially in Guyana and Suriname, are continuously being eroded by wave action. In some areas hundreds of marine turtle nests, some of them of olive ridleys, are destroyed by erosion each year. Such eggs are called "doomed eggs". Details on causes of beach erosion in Suriname, and its effect on sea turtle nesting, are given by Schulz (1975).

4.5 Dynamics of Population

The seasonal migratory behavior and marine habitat of adult sea turtles make a study of their population dynamics difficult. Except for a few localized studies conducted in marine habitat, little is known about their activities at sea.

Most parameters used in sea turtle population estimates are based on studies of nesting females. This is only a miniscule part of the life of a marine turtle, and is hardly a basis for scientific deductions on population dynamics. Occasionally, additional information can be extracted from turtle fisheries catches. These data are then used to develop a population index, or they are extrapolated for a bolder guess at an estimate of population size.

Meylan (1981) discusses methods and pitfalls for attempts to estimate sea turtle population sizes. Márquez et al. (1976) developed a population model for the eastern Pacific olive ridley population in Mexico. Márquez and Van Dissel (1982) developed a means to assess the number of females coming ashore to nest during an arribada. Schulz (1975) gives an approximation of the Surinam olive ridley nesting population, but no model is yet available to estimate other western Atlantic olive ridley populations.

The most essential item in an effective management program for a wildlife population is a thorough understanding of its population dynamics. There are scant data on natality, mortality, age of sexual maturity, longevity or sex ratio, and what is reported in the literature is unreliable. These are essential criteria in an analysis of population dynamics; without them, management of a population becomes largely a matter of making educated guesses. The major problem has been the lack of an effective way to follow a cohort of sea turtles through its life cycle or to construct a life table from which population parameters can be calculated with reasonable accuracy. The conventional method used in studying sea turtle populations is to mark females nesting, and then analyze data from tag returns upon recapture. Many, if not most, adult sea turtles lose their tag(s) within weeks, months, or at best in a few years. The use of externally fastened metal or plastic tags has been notoriously inefficient, yet the practice of tagging turtles in this manner continues unabated, with often only marginal scientific benefits. Mrosovsky (1983), who so aptly named this practice the "Tagging reflex", gives an excellent analysis of the problems associated with this technique.

Tagging studies can be quite useful, though, for instance in determining migration routes of populations. But because of the high rate of tag loss, drawing conclusions from tag return data to be used for population dynamics purposes may not be justifiable. Bustard (1979) estimates that, because of high early mortality, about one million hatchlings should be marked to give a reasonable expectancy of tag returns as adults. This would not only make the cost prohibitive, but it is highly doubtful that a single beach could produce such a large number of hatchlings. Furthermore, it is practically impossible to give hatchlings an externally fastened marker that will remain attached for any reasonable lengh of time.

A technique that shows promise as a permanent marker to be used on hatchling sea turtles is the "living tag" (Hendrickson and Hendrickson, 1981). In this method a small piece of plastron tissue is grafted on the carapace, resulting in a recognizable tissue mark of contrasting color, which remains visible for several years. Test results with living tags on captive loggerheads (Caretta caretta) in the Miami Seaquarium show that the graft is spreading and diffusing (Reichart, pers. obs.), and it remains to be seen if a graft put on a hatchling will be recognizable throughout the sea turtle's life, or even until animal reaches maturity. The early results are promising (Hendrickson and Hendrickson, 1986) and justify further tests.

4.6 The Population in the Community and the Ecosystem

Olive ridleys are circumtropical marine reptiles, of which only the females periodically leave their aquatic habitat to lay eggs. The eggs need a terrestrial environment for successful development. The species exists in distinct populations in primarily neritic habitats, although captures far offshore indicate that a some olive ridleys may be pelagic. Olive ridleys appear to frequent distinct types of habitat: a foraging area near biologically rich bays and estuaries, and a breeding area near suitable sandy beaches. Olive ridleys nest almost exclusively on mainland or large-island beaches (Schulz, 1975), with only rare nesting reported on small-island beaches (Bustard, 1972; section 2.1).

Because of the occasional massive nesting concentrations, olive ridleys can have a considerable impact on beach structure, but no studies are known how this affects other members of the community for that particular ecosystem.

5. EXPLOITATION

5.1 Fishing equipment and methods

The olive ridley is prized for its skin (Cornelius, 1986) which, when processed, produces a high quality leather. In Suriname, olive ridley nests are poached for the eggs, which are considered to be the best tasting of all sea turtle eggs. In Indonesia, olive ridley meat is sometimes offered for sale on local markets (Reichart, pers. obs.). In Guatemala, shark fishermen kill olive ridleys to use the meat as bait (Higginson, 1989). Probably because the olive ridley is relatively rare in the western Atlantic, there is no direct fisheries effort on the species in this region.

Such is not the case in other parts of the world, where olive ridleys are more abundant. Olive ridleys may be the most over-exploited sea turtle species in the world, with fishing equipment and methods varying only somewhat per region. For the eastern Pacific olive ridley population in Mexico, the most commonly used method is to catch turtles by hand by jumping overboard from a small boat. In this manner, up to forty olive ridleys can be captured per day (Márquez et al., 1976). Another method uses set nets to ensnare ridleys. A disadvantage of this method is that many turtles drown, lowering their market value. These capturing methods are fairly consistent throughout the eastern Pacific range of the species. In May 1990, the Mexican Government announced a total and permanent ban on the capture and trade in all sea turtles or their products. Whether this will bring an end to the illegal trade remains to be seen (Aridjis, 1990). In Central America, the taking of olive ridley females on nesting beaches is only a minor occurrence (Cornelius, 1986).

In western Atlantic populations, when fishermen incidentally catch a sea turtle, they are inclined to keep the animal for personal use, or for sale in a local market. Especially in Guyana, olive ridleys found nesting on the beach are often either slaughtered locally or carried off alive, making an accurate assessment of human predation from evidence on the beach difficult (Pritchard, pers. comm,). During several low level aerial surveys over the beaches in Guyana in the late 1970s carapaces of butchered sea turtles were regularly seen (Reichart, pers. obs.). Ground surveys by Pritchard (pers. comm.) showed that some of these were olive ridleys.

In Suriname, olive ridleys and other sea turtles are not taken for meat. They are fully protected by law, but many people would eat turtle meat if it were legal. An occasional turtle, incidentally killed in a fishing net, may be consumed surreptitiously, though. The Carib indians living along the Marowijne River will not eat sea turtles, because they do not like the smell of the meat (Kloos, 1971; Reichart, 1992). Another, now possibly forgotten, reason that they do not eat turtle meat is because they may become as stupid as the turtle itself. In 1725, Chrétien wrote: " Les Galibis ne mangent point de tortue quoy qu'elle abonde chez eux et qui en ait pèsent avec l'écaille plus de 3 à 400 livres, ils craindroient s'ils en mangeoient de participer à la stupidité de cet animal" (in Schulz, 1975).

In French Guiana, the olive ridley, because of its small size and light weight, is probably the only sea turtle that occasionally is taken by the indians for local consumption (Fretey and Renault-Lescure, 1978). As in Suriname, there are no legal turtle fisheries in French Guiana. Incidentally caught green turtles and leatherbacks are too large for the artisanal fishermen to manipulate in their boats. If already dead, these animals are untangled and set adrift. If alive, the flippers are cut off, and the often still alive torso pushed away (Reichart,pers. data).

Olive ridleys are seen occasionally off the coast of northwest Brazil and, when caught, they are consumed locally, or the meat is sold on nearby markets (Reichart, pers. obs.). No data are available on olive ridley fisheries activities in southeast Brazil where known nesting and foraging areas exist.

5.2 Fishing areas

Fishing for olive ridleys, legally or illegally, takes mostly place on the feeding grounds, and in the shallow waters off their nesting beaches. There are no legal fishing areas known for olive ridley in the western Atlantic.

5.3 Fishing seasons

To the best information available at this time, olive ridleys are fully protected in the coastal waters of all countries in the western Atlantic Ocean that have viable nesting or foraging populations; there are no fishing seasons.

5.4 Fishing operations and results

The animal is small and relatively easy to handle, which is an important consideration in fisheries operations. The shell of the olive ridley is a secondary product, and is of low value. Mack et al. (1981) provide an extensive analysis of international trade in sea turtle products, including those of olive ridleys. Due to the small population of olive ridleys in the western Atlantic, international trade in the animal's products from this area is negligible or non-existent. The eastern Pacific olive ridley populations, however, were heavily exploited. Between 1970 and 1977, about one million of them were taken by Government-sanctioned turtle fisheries in Mexico and Ecuador combined. In 1978, the skins of 85,000 olive ridleys were exported from Ecuador, and 50,000 olive ridleys were taken in Oaxaca, Mexico alone (Mack et al., 1981). In 1989, the year prior to the Presidential ban on killing sea turtles in Mexico, more than 35,000 olive ridleys were killed at a government-sanctioned slaughterhouse in Oaxaca; with the skins exported to Japan to make exotic leather products (anon., 1990b). Since 1990, Ecuador also has now extended full protection to all sea turtle species occurring in its waters, and prohibiting the capture, processing, and domestic and international trade in these animals (anon., 1991).

Prior to 1950 the olive ridley population along the Pacific coast of Mexico was estimated to consist of 10 million adults (Cliffton et al., 1981). Through over-exploitation its number has decreased to such an extent that the 1983 population is estimated to consist of only 79,900 adults (Mager, 1985). In 1979 approximately 107,000 olive ridleys were slaughtered by turtle companies operating in Ecuador (Green and Furtando, 1980). Mager (1985) gives a summary of worldwide harvest and trade figures. Sternberg (1982) has compiled a list of worldwide hunts and markets of sea turtles, including references on olive ridley exploitation.

6. PROTECTION AND MANAGEMENT

6.1 Regulatory measures

Almost all countries of the western Atlantic have legislation protecting or regulating the exploitation of their sea turtle resources. National laws pertaining to sea turtle legislation are too numerous to cite here, but a summary on a country-by-country basis, including sources for additional information, is given by Navid (1981). These laws are often ambiguous, ineffective, and ignored (Gomez, 1981). Some countries that do not have natural olive ridley populations, nonetheless have national legislation protecting, or regulating the use of, the species. For example, the Endangered Species Act of 1973 of the U.S.A. lists the olive ridley as a threatened species, with the exception of the breeding population along the Pacific coast of Mexico, which is classified as endangered. In view of the precipitous decline of the olive ridley population in the Guianas, the United States National Marine Fisheries Service has recommended that this population be listed as endangered as well (Mager, 1985). This recommendation was implemented in .....

Because of the worldwide distribution of marine turtles, and the demand for marine turtle products on international markets, their conservation and management is coordinated by international regulatory agencies. The most significant treaty for international sea turtle protection is the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Signatory countries to CITES have agreed, among other things, to prohibit import and export of almost all marine turtles and their products. CITES provides a framework for international cooperation in the protection and management of many endangered species, including sea turtles. Loopholes in the regulations and the lack of legal restraints have enabled some countries to continue harvesting their sea turtle populations for use in international trade. For example, Ecuador, which, although a member of CITES since 1975, still allows exploitation of their eastern Pacific olive ridley population and, in violation of international law, exports thousands of olive ridley skins each year (Mack et al., 1981). Other countries, such as Japan, either have taken a reservation for certain sea turtle species at the time of ratification, or they choose to ignore the CITES rules on international trade altogether.

Commercial trade has had a disastrous effect on sea turtle stocks in the Caribbean. In some areas entire populations have been extirpated because of over-exploitation. National laws and international agreements are difficult to enforce (Gomez, 1981), and so far have had only a moderate impact on sea turtle conservation. Recent legislation enacted in Brazil now prohibits the capture of, and trade in, all sea turtle species in its waters (Guagni dei Marcovaldi, pers. comm.), but its effectiveness has yet to be proven.

Some authors advocate a strict control or elimination of markets to end trade and thus, harvesting pressure on sea turtle populations (Bavin, 1981), but others suggest that farming and ranching sea turtles for headstarting (section 6.3 and 7.) and market use could take the pressure off natural populations (Reichart, 1981). Braddon et al. (1982) have developed an iso-electric focusing procedure that can differentiate turtle meat samples by species. This technique can be an effective tool to identify suspect olive ridley turtle meat in illegal trade activities.

6.2 Management Strategies

The olive ridley is by some considered to be the most abundant sea turtle species in the world (Zwinenburg, 1976), but it could also be the most exploited one (see section 5.). Although its behavioral trait of forming nesting aggregations may be an ecologically advantageous strategy in the natural world, it has made the animal particularly vulnerable to exploitation by man. Olive ridleys are small compared to other sea turtles and are easy to manipulate; during an arribada hundreds of individuals can be collected in a relatively short time. Management strategies should consist of, among other things:

a) protection of nesting and foraging habitat, and Government commitment to enforce legislation;

b) modification of fishing gear (primarily for shrimp fishermen) to reduce incidental catches of turtles;

c) installation of hatcheries where natural beaches are threatened by environmental factors or man's activities;

d) use of the public media for conservation education;

e) continuous monitoring and study of sea turtle populations to obtain baseline data for management decisions.

In the western Atlantic area, Suriname has an effective management program to protect olive ridleys (Reichart, 1992). All important nesting beaches are either located in nature reserves or are protected by annual decrees; they are patrolled the entire nesting season. Nests endangered by beach erosion are either relocated to higher places on the beach or placed in hatcheries. The resulting hatchlings are eventually released on the beach to reach the sea under their own power.

Stringent legislation prohibits the taking of olive ridleys in any of its life stages, inside as well as outside the nature reserves (Schulz, 1975). A regular education program, using the public media (newspapers, radio, television), and school lectures with films, is essential for public understanding and cooperation. This ongoing education program in Suriname effectively explains the rationale for sea turtle conservation. No sea turtle protection program can succeed without the support of the public -- legislation notwithstanding.

In Guyana, local Arowak indians have been hired to work as guards and conduct beach patrols. The conservation activities also include field trips and an education program for teenagers (Pritchard, pers. comm.). Involvement of local communities is proving to be a boon for marine turtle conservation in Guyana.

Much marine turtle conservation effort in the western Atlantic is devoted to projects for the successful hatching of the eggs. Doomed eggs are routinely transplanted to safer locations on the beach, centrally located hatcheries on the beach, or they are incubated in artificial nests, such as styrofoam coolboxes placed above ground. Each of these methods is fraught with potential problems if improper procedures are used. When transplanting eggs, extreme care must be exercised to avoid any unnecessary movement or change in the orientation of the blastodisc (Figure 9).

Limpus et al. (1979) found that movement can cause a significant decrease in hatching success for loggerhead turtle eggs. They found that eggs can be reasonably manipulated with impunity either during the first 48 hours after laying or just prior to hatching, but that there is a critical period in between these times when the eggs are extremely vulnerable to movement-induced mortality. Eggs of olive ridleys may have a similar response. Egg relocations could occur at anytime, with good to excellent hatching success, if the eggs are be handled individually and gently; and they must not be inverted (Witham, pers. comm.).

Mrosovsky and Yntema (1980) found that olive ridley eggs incubated in styrofoam boxes take a few days longer to hatch than eggs in natural nests. This was caused by the temperature in the box being 1-2° C cooler than the ambient temperature in the natural nest. This would also result in a preponderance of male hatchlings (see section 3.1.5). The result is that an otherwise well-intended conservation attempt may bias the sex ratio of a natural population if such animals are released to the sea. When the lids are left off styrofoam boxes during incubation, there is no cooling effect, which may give less of a sex bias in marine turtle hatchlings (Witham, pers. comm.). For olive ridleys the ambient nest temperature is of special importance since the nests are shallow, and the clutches are fairly close to the surface. When transplanting such nests to other beach areas, the location of the new nest is important. If relocated in an unshaded area the nest may be warmer, resulting in more females; if relocated in a shaded area the opposite could occur (see Table 6).

The release of hatchlings resulting from transplanted nests is also controversial. Some conservationists believe that emerging hatchlings should be set out on the beach in order that they may imprint on their native beach for eventual return there as nesting females. Although tagging studies have shown that many adult females return to the same nesting beach each season, there is no evidence to verify that beach imprinting takes place among hatchlings. Pritchard (1988) suggests that, because of good reproductive success in Suriname and French Guiana, some leatherback hatchlings upon reaching maturity may nest hundreds of kilometers away from where it hatched. However, the hypothesis of adults sea turtles returning to their natal beaches is being perpetuated in the literature as a fact, as exemplified by Mager (1985).

Experiments in Suriname have shown that great numbers of headstart hatchlings released on the beach never get beyond the surf, because they are eaten by predatory fish. On the other hand, when these hatchlings are released well beyond the surf, many survive the initial, near-shore onslaught (Reichart, pers. data). Owens et al. (1980) suggest imprinting on chemical gradients in the water. If this hypothesis is correct, releasing hatchlings beyond the surf may be a powerful technique for population enhancement. The currently prescribed management strategy, however, is based on the as yet unproven hypothesis of beach imprinting, allowing the turtles to enter the sea on their own power. Consideration should be given to the alternative method which is known to put more turtles in the sea. Pritchard et al. (1983) give guidelines and methods to be used in sea turtle conservation and management techniques in an effort to promote standardized field procedures. Márquez et al. (1973) give suggestions for "grass-roots" techniques to be used by local communities in protecting marine turtles.

The incidental take of olive ridleys by shrimp trawlers may be considerable in view of the fact that both occupy the same habitat. The development of Turtle Excluder Devices (TED) by the U.S. National Marine Fisheries Service, with which to modify traditional shrimp nets, could be a major contribution in efforts to reduce the incidental catch of ridleys by shrimp trawlers (Anon., 1981a; Seidel and McVea, Jr., 1981).

U.S. regulations require all domestic shrimp vessels to have TEDs installed on their trawl nets. Since 1989, these regulations have been extended to apply also to shrimp vessels of foreign nations exporting shrimp to the U.S.A. (Mitchell, 1992). In order to comply with these regulations, the Surinam Government has embarked on a program whereby all Surinam-based shrimp vessels will have TEDs installed on their nets. Implementation has been slow, and certification of compliance, given in 1992, has been rescinded.

The Sea Turtle Conservation strategy (Anon., 1981b), developed by the World Conference on Sea Turtle Conservation outlines policy considerations for the conservation of sea turtles with the goal:

> "to develop conservation action based on the biology of the species that will return sea turtles to former abundance while allowing controlled exploitation for the benefit of generations of humans to come".

Not all parts of this strategy are universally accepted. Some believe that controlled exploitation can be a powerful conservation tool, but others feel that any exploitation will be harmful. More details and opinions on this subject, and on management strategies can be found in Dodd (1978, 1981), Ehrenfeld (1981a, 1981b), Pritchard (1981), Pritchard et al. (1983), Reichart (1981).

6.3 Artificial stocking

Artifical stocking implies any human interference with the natural process of egg and/or hatchling development, with the resultant animals released into the wild population for its enhancement. The most common application of artificial stocking is the practice of transplanting doomed nests to a nearby, but safer location on the same beach. Doomed nests are nests that will almost certainly be destroyed through natural phenomena, such as beach erosion or being laid below the high tide line. Or, if predation is a factor, the eggs are taken to a central hatchery or to artificial nest boxes for incubation. The emerging hatchlings are then allowed to scramble to the sea under their own power. Hatchlings emerging from an artificial nest box are usually retained for about two days to allow the amniotic membranes, still attached to the yolk sac, to heal before releasing them on the beach (Pritchard et al., 1983). In natural nests, during the crawling upward to the surface, the yolk sac is absorbed through the mid-plastral surface and the membranes slough off through drying and abrasion, which does not occur in shallow nest boxes (Schulz, 1975).

An additional step that is sometimes taken is to raise the hatchlings for up to a year in a captive environment prior to release to the sea. By that time, the turtle will have grown large enough to be no longer threatened by the major predators of hatchlings. This method is controversial because opponents claim that such headstart turtles:

a) may not imprint on their native beach for return there as adults to nest;

b) may be incapable of foraging for themselves;

c) may be habituated to man, making it easier to capture them.

Proponents argue that there is no evidence of beach imprinting and furthermore that, because early life mortality is so high, raising hatchlings to yearlings before releasing them will assure survival of a greater number of that year class. Tag returns have shown that headstart green turtles are known to survive and grow in the wild (Witham and Futch, 1977; Witham, 1980; Klima and McVey, 1981; Schulz and Reichart, 1980; Reichart, 1981).

In the western Atlantic, doomed olive ridley eggs are being transplanted in: French Guiana (Fretey, pers. comm.), Brazil (Guagni dei Marcovaldi, pers comm.), and Suriname (Reichart, pers. data). Some captive rearing projects with olive ridleys are being conducted in India (Whitaker, 1979; Banerjee, 1984). An experimental project in Suriname has shown that olive ridley hatchlings can be reared successfully in captivity using similar stocking densities as for raising green turtles (Reichart, unpubl. data). Although Kemp's ridleys show intra-specific aggressive behavior when raised in captivity (Klima and McVey, 1981), none was seen among the olive ridleys (Reichart, unpubl. data). There are currently no known captive rearing projects for olive ridleys in the western Atlantic.

7. MARICULTURE

Several sea turtle species have been, or are being, raised in captivity for commercial purposes, conservation, or a combination thereof. There is widespread disagreement about the merits of aquaculture of sea turtles, and Ehrenfeld (1981a) lists several reasons why the mariculture of sea turtles may be detrimental to the conservation of natural populations. In addition to these should be added the susceptibility of sea turtles to bacterial infections and viral diseases when they are captive-reared under crowded conditions (Reichart, unpubl. data). Other workers assert that the economic incentive of sea turtle mariculture could reduce or eliminate the hunting pressure on the natural populations (Reichart, 1981).

The sea turtle most predominantly used in mariculture is the green turtle because it has the greatest overall commercial value and it is the easiest to maintain in captivity. The hatchlings are raised in a controlled environment and given a high-protein diet to induce rapid growth. This results in 3-4 year old turtles of marketable size, which in a natural population may require 10 or more years to attain for equivalent size. The turtles are then slaughtered and processed to provide meat, soup stock, oil, and ornamental items made from scutes. Hawksbill juveniles are often preserved whole and sold in curio shops as has been seen in Indonesia and Bahia, Brazil (Reichart, pers. obs.). Some hawksbills are raised to adults, and their thick carapace scutes processed to make tortoise shell products, especially in Brazil and Indonesia (Reichart, pers. obs.). Kemp's ridleys are raised for conservation only (see section 6.3). There are no known commercial mariculture projects for olive ridleys.

Captive rearing projects for several sea turtle species, and the techniques being used, can be found in the following sources:

Witzell (1983).....hawksbills

Hirth (1971), Wood and Wood (1977, 1980)
Witham (1978), Reichart (1981,1985).....green turtles

Klima and McVey (1981).....Kemp's ridleys

Whitaker (1971), Banerjee (1984).....olive ridleys

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