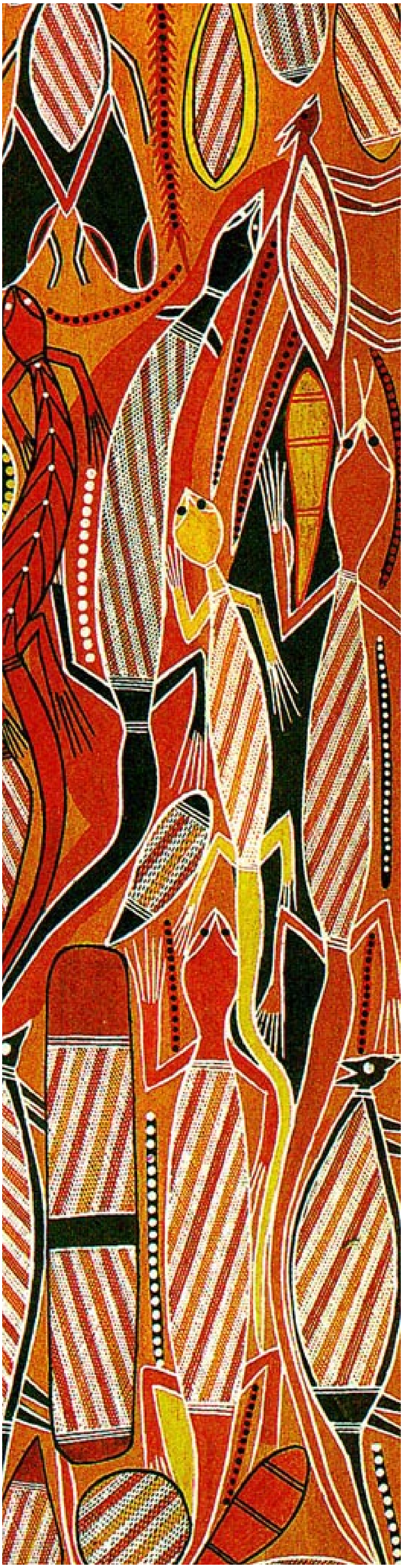

FAUNA *of* AUSTRALIA

57. DUGONGIDAE

HELENE MARSH

DEFINITION AND GENERAL DESCRIPTION

The order Sirenia, the only extant group of mammals adapted to feed exclusively on aquatic plants, contains five Recent species in two families. The three species of manatee are in the family Trichechidae, while the Dugongidae contains a single surviving species, the Dugong, *Dugong dugon* (Müller). The second Recent member of this family, the giant Steller's Sea Cow, *Hydrodamalis gigas* of the north Pacific, was exterminated by man in the eighteenth century (Domning 1978).

Externally, Dugongs are easily distinguished from the manatees by their whale-like tail – manatees have a paddle-shaped tail shaped rather like that of a platypus.

Dugongs and manatees also share a number of features with cetaceans, the only other aquatic mammals incapable of moving on land. Members of both groups have fusiform bodies, fin-like forelimbs, horizontally expanded tail flukes and lack hind limbs. Whereas cetaceans are carnivores, with cone-shaped teeth or baleen plates adapted for grasping or sieving prey, sirenians, as herbivores, have horny plates and/or teeth adapted for grasping and chewing plants.

HISTORY OF DISCOVERY

Dugongs were encountered by some of the earliest European visitors to both the western and eastern coasts of Australia. Identification was always a problem. Dampier reported that 'manatees' were common in a bay on the northern coast of western Australia (latitude 16°50'S) in 1688 (Dampier 1927). During another voyage in 1699, Dampier found the 'head and bones of a hippopotamus ... with teeth up to 8' long' in the stomach of a large shark caught in 'Shark's Bay' (see Dampier 1939). While exploring Pumicestone Passage in Moreton Bay in 1798, Flinders saw several large 'fish or animals that came up to the surface to breathe in the manner of a porpoise or rather seal, for they did not spout, nor had they any dorsal fin'. Flinders fired three musket balls into one and his Aboriginal companion, Bongree, threw a spear at another, but the animals sank without trace (Collins 1802).

While fishing commercially for Dugongs on the coast near Maryborough in southern Queensland in the 1870s, Lionel Ching collected specimens for European museums. In 1900-1901, Professor Dexler of the University of Prague visited Moreton Bay to obtain specimens for anatomical study (Dexler 1902, 1912a, 1912b; Dexler & Egar 1911; Dexler & Freund 1906a, 1906b, 1906c). In 1965, Colin and Kate Bertram travelled widely in northern Australia to obtain information on the status of Dugongs (Bertram & Bertram 1973). They also collected data and specimen materials from specimens killed either in shark nets or by indigenous hunters (Bertram & Bertram 1973; Mitchell 1973, 1976, 1978, 1981). Since 1969, scientists at James Cook University have extended this work into a program designed to provide a sound biological basis for management of the species.

Dugong research programs recently have been established by the Department of Conservation and Land Management in Western Australia and the Conservation Commission of the Northern Territory.

MORPHOLOGY AND PHYSIOLOGY

External Characteristics

From a distance, a Dugong looks rather like a rotund dolphin (Fig. 57.1a). Unlike most dolphin species, however, it lacks a dorsal fin. The head also is distinctive (Fig. 57.1b) with the mouth opening ventrally below the broad flat muzzle. The muzzle is covered sparsely with short stout hairs that are most developed around the mouth. Finer hairs are scattered lightly over the remainder of the body surface that is grey to bronze dorsally and lighter ventrally. Many older specimens have large areas of unpigmented skin and bear extensive longitudinal scars, particularly dorsally. The eyes are small and not prominent. The ears lack pinnae and externally consist of only small openings on the sides of the head. The nostrils are situated close together antero-dorsally, enabling Dugongs to breathe with most of the body submerged. During diving, the nostrils are closed with valve-like flaps which hinge anteriorly.

The flippers are short (about 15% of total body length, Spain & Heinsohn 1975) and, unlike those of the West Indian and West African manatees, lack nails. Two pectoral mammae are present, one on each side of a single teat located in the axilla behind the flipper.

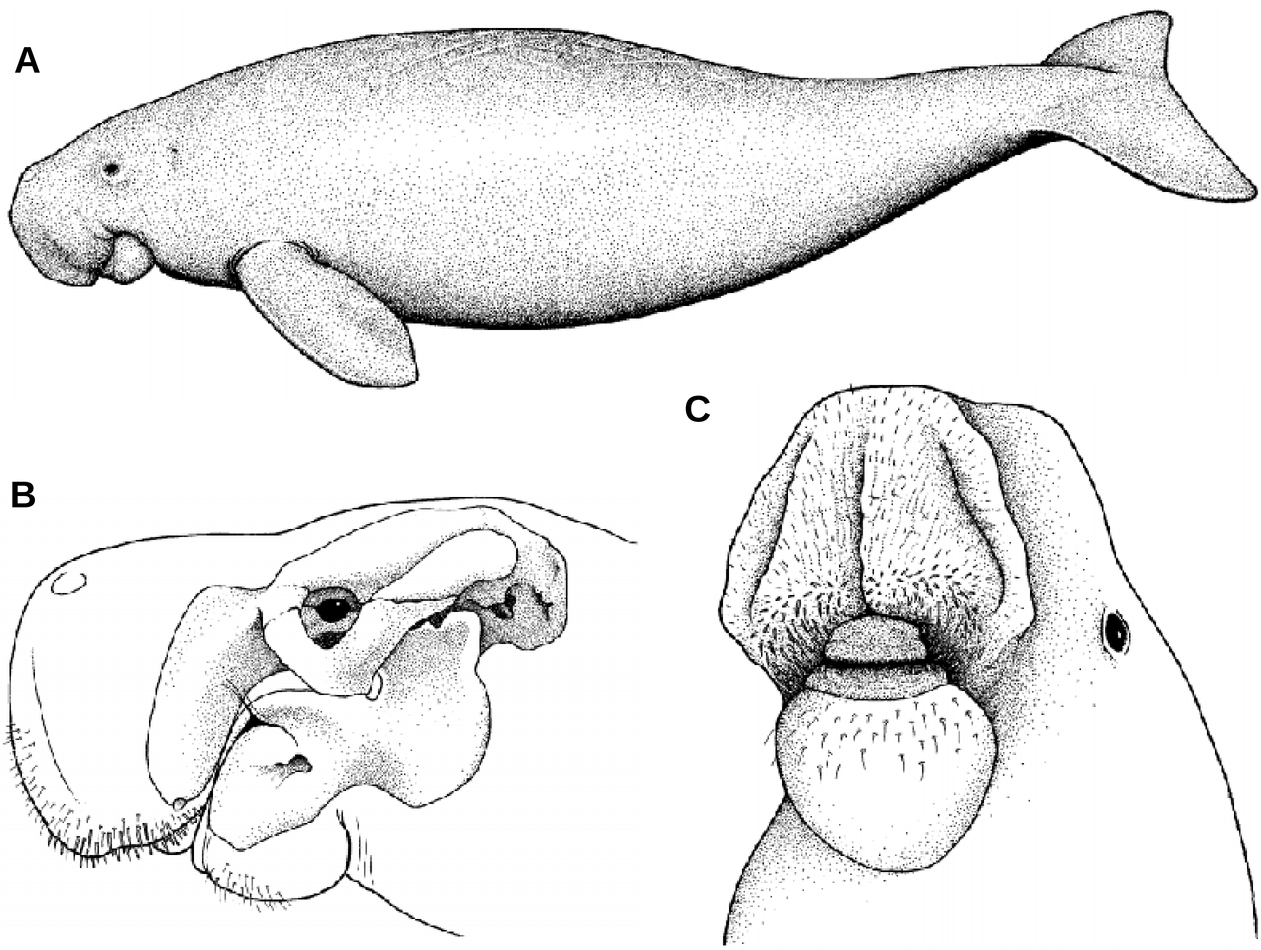

Figure 57.1 **A**, Sketch of a Dugong showing its streamlined shape and whale-like tail flukes x 1/20; **B**, diagrammatic representation of a dugong's head showing the relative positions of the skull, muzzle and nostrils x 1/6; **C**, sketch of the ventral surface of the muzzle x 1/6. (© ABRS) [G. Kelly]

The testes are abdominal and, unless the penis is extruded, dugongs are sexed on the basis of the relative positions of the umbilicus, genital aperture and anus. In females, the genital aperture and anus occur close together, whereas in males the genital aperture is much closer to the umbilicus.

Detailed descriptions of the external morphology are given by Dexler & Freund (1906a), Petit (1955) and Kingdon (1971).

The maximum weight reported for Dugong is 1016 kg for a specimen of 4.06 m body length (Mani 1960). This is substantially higher than the sizes recorded recently in the Australian region. Hudson (in Nishiwaki & Marsh 1985) found that less than 2% of the 310 adult-sized animals measured at Daru in Torres Strait were over 3 m long. The largest was a female 3.31 m long. There is some evidence (Marsh 1980) that the asymptotic length of females tends to be slightly greater than that of males. Neonates are 1.1–1.25 m long and weigh about 27-35 kg (Marsh, Heinsohn & Marsh 1984d). A growth curve has been developed by Marsh (1980) and an empirical weight for length curve by Spain & Heinsohn (1975). The estimated weight at an approximately pubertal length of 2.4 m is 248 kg. A 3 m animal is estimated to weigh nearly 420 kg.

Skeletal System

The skull has a remarkably enlarged and sharply downturned premaxilla and a correspondingly elongated symphysial region of the mandible. Although several features of the adult skull can be shown to be sexually dimorphic (Spain *et al*. 1976; Spain & Marsh 1981), the most obvious difference is in the thickness of the premaxillae, which are much more robust in males. This is associated with the different pattern of tusk growth in males and females.

The skeleton is of extremely dense bone which presumably helps the animal overcome buoyancy problems when bottom-feeding in salt-water. There are 57 to 60 vertebrae: seven cervicals, 17 to 19 thoracics, four lumbars, one sacral, 28 to 29 caudals (Husar 1975). The sternum is reduced. The scapula has a short acromion and a well-developed coracoid. The humerus has prominent tuberosities and the carpals show a tendency to fuse (Harrison & King 1980). The pelvic girdle is vestigial; pubic bones are absent and the ischium and ilium are both rodlike and fused in adults.

Locomotion

The flukes are the principal organ of locomotion, working vertically with slow powerful beats (see Anderson 1982b). When turning, a Dugong stops stroking and twists its flukes to effect the change in direction. During acceleration the flippers are raised and pressed against the body, whereas at normal swimming speeds they are sometimes raised, but often hang down loosely (Anderson 1982b). The flippers do, however, have a considerable range of movement and are used in guiding turns and to stop forward movement (Anderson 1981). The species is capable of swimming at about 10 – 12 knots for up to about 1 km (calculated from Marsh, Spain & Heinsohn 1978). Most movement is much more leisurely and Anderson (1981) estimated that the normal cruising speed matches that of a fin-equipped diver.

Calves often swim closely above their mothers, presumably to gain some locomotory assistance via the Bernoulli effect.

Feeding and Digestive System

The feeding apparatus of Dugongs reflects their role as herbivores specialising on benthic seagrasses. Domning (1976) claimed that the elongation and strong ventral deflection of the rostrum and mandibular symphysis from the palatine

plane (Fig. 57.1b) makes the animal virtually an obligate bottom feeder, although captive specimens can feed very efficiently on floating seagrass (Marsh personal observation). An expanded upper lip separates the nostrils from the mouth (Fig. 57.1c). This lip takes the form of a horseshoe-shaped disc or muzzle, a very complex and mobile structure described in detail by Gohar (1957). The way in which the muzzle functions when Dugong dig up seagrass has not been confirmed. The presence of numerous thick sinus (sensory) hairs described by Kamiya & Yamasaki (1981), who claimed they are the most well-developed of any mammal, suggest that the muzzle may be used to detect and select, as well as manipulate food. In captivity, Dugongs feed on fine floating seagrass leaves. These are picked up and manipulated into the mouth by the ventral edge of the upper lip, the region where the sinus hairs are most developed.

The end of the premaxilla is covered by a hairless bulb of connective tissue and skin which protrudes underneath the muzzle. The tusks erupt on the side of this bulb. Erupted tusks are extensively worn, suggesting that the bulb is used to dig up seagrasses.

A horny pad described by Gohar (1957), covers the downturned symphysial portion of the lower jaw and a pad is located on the corresponding ventral surface of the premaxilla. Four pairs of rudimentary sockets occur under the lower horny pad; sometimes one or more of these sockets contain vestigial incisor and/or canine teeth.

Dugong dentition is distinctly different from that of manatees which lack incisors and have a different pattern of cheek tooth replacement (Domning 1983). The description below is based on Marsh (1980). Other useful references include Heuvelmans (1941), Fernand (1953) and Mitchell (1973, 1976, 1978).

Two pairs of upper incisors are present in the juvenile. The deciduous incisors are small, do not erupt and are resorbed. The posterior growth of the permanent incisors (tusks) is similar in both sexes until about puberty, when the tusks are about 100 mm long. The female tusks continue to grow posteriorly throughout life and may reach a length of about 180 mm. In some old females the tusks do erupt, presumably because they have reached the base of the premaxilla and cannot grow any further posteriorly. Tusk eruption alone, therefore, cannot be considered diagnostic of male Dugongs. The tusks of males erupt after puberty. The lengths of the tusk alveoli remain relatively constant thereafter and never reach the base of the premaxilla. Adult male tusks may reach a length of 150 mm, but never protrude more than about 20 mm. The erupted end is worn into a chisel shape, the cutting edge of which is reinforced with enamel.

Apart from the tusks, the only functional teeth are the cheek teeth. In situ replacement of the dentition does not occur. During the life of the animal, there is a total of six cheek teeth in each jaw quadrant (premolars 2, 3 and 4 and molars 1, 2 and 3), but these are never all erupted and in occlusion at once. Three premolars are erupted at birth. The roots of the anterior teeth are progressively resorbed, causing them to fall out. Their sockets then become filled with bone. The molars progressively erupt during growth, the whole process continuing until usually only molars 2 and 3 (occasionally molar 1) are present in each quadrant in old animals. Molars 2 and 3 have persistent pulps and continue to grow axially and radially throughout life so that the total occlusal area of the cheek teeth is maintained and increased slightly even after the anterior teeth have been lost.

Dugongs have a simple stomach, remarkable only in that all the chief cells and most of the parietal cells occur in a discrete pouch which the digesta do not enter and which communicates with the main sac by a single aperture (Marsh, Heinsohn & Spain 1977). Two diverticula enter the duodenum just posterior to the pylorus. A small caecum occurs at the junction of the small and large

intestines. In an adult, the latter is up to 25 m long, more than twice as long as the small intestine. The caecum and the large intestine have been shown to be the principal areas of disappearance of the fibre fraction of the diet (Murray *et al*. 1977) indicating that the Dugong is a non-ruminant herbivore.

Circulatory System

The most remarkable feature of the circulatory system is the double ventricular apex of the heart (Fig. 57.2), a feature of sirenian hearts which has astonished scientists since the eighteenth century (see Steller 1751). Other unusual features of the heart include a double subvalvular conus and a dorsal left atrium (Rowlatt & Marsh 1985).

Retial structures such as the one associated with the brachial artery (see photograph in Elsner 1969) play an important role in thermoregulation (Elsner 1969).

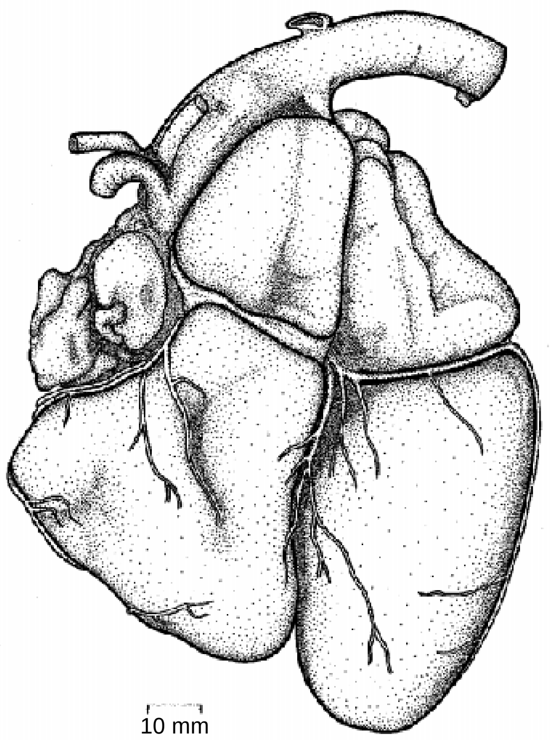

Figure 57.2 Dugong heart showing the double ventricular apex (arrow). (© ABRS) [S. Collin]

Respiration

The lungs are long and extend posteriorly almost as far as the kidneys (Hill 1945). They are separated from the abdominal viscera by a large obliquely sloped diaphragm. The lungs of Dugongs are considered unusual in terms of the nature of both the bronchial tree and the respiratory tissue itself (Engel 1959a, 1959b, 1962). The main bronchus runs almost the entire length of the lung with only a few side branches. The respiratory units (vesicles) arise laterally along the length of the bronchioli. Cartilage occurs throughout the air passages and cartilaginous platelets are present within the walls of even the most peripheral bronchioli . Engel considered the lungs to be extremely primitive. Whether they collapse on diving is unknown.

Excretion

Unrinsed seagrasses, as consumed by dugongs, contain about 15 times more chloride and 30 times more sodium than most terrestrial pasture plants (Birch 1975). Unlike manatees, dugongs appear to be physiologically independent of fresh water. Their salt metabolism is thus potentially very interesting. Dugong kidneys have an elongated external form quite unlike that of the lobulated kidneys of cetaceans. Batrawi (1953, 1957) considered Dugong kidneys to combine features similar to those found in camels and horses.

Sense Organs and Nervous System

The brain is relatively small (250 – 300 g, or about 0.1% of adult body weight, Dexler 1912b; Kamiya, Uchida & Kataoka 1979) and looks foetal-like because of the few and shallow sulci and the thin covering of leptomeninges (Hill 1945). The corpora quadrigemina, especially the inferior, are prominent, suggesting auditory sensitivity. The cerebellum is well developed and its large floccular lobes, composed mainly of the paraflocculus, are probably associated with pronounced swimming and equilibratory activities (Harrison & King 1980).

Aboriginal dugong hunters consider the animals to have acute hearing, but less well-developed visual powers (Roughsey 1971). Anderson (1982b) observed that Dugongs could detect, locate and make some preliminary and generalised identification of a stimulus at distances of up to 150 m when visibility (perceived by a human diver) was 5 m or less.

Endocrine System

The thyroid gland is exceptional in the relatively great abundance and density of its intervesicular stroma. Its histological appearance is consistent with other evidence favouring the occurrence of a functional hypothyroidism which may explain the osteosclerotic condition of the bones (Cave & Aumonier 1967). The same authors also describe the histological structure of the thymus and thyroid glands but did not find parathyroids. The histology of the pituitary and adrenal glands was described by Fernand (1951).

Reproductionv

Marsh, Heinsohn & Channels 1984b; Marsh, Heinsohn & Glover 1984c) describe the female and male reproductive systems. Females are polyovular and polyoestrus and may undergo a number of sterile cycles before becoming pregnant. Multiple corpora lutea (up to 90, Marsh unpublished data) are present during each pregnancy, persisting until term. The gestation period is estimated to be about 12 – 14 months (Marsh 1986a). Males breed asynchronously and discontinuously in the tropical populations studied (Marsh *et al*. 1984d). Although there are some reproductively active males present throughout the year, the proportion of reproductively active animals is significantly greater between June and January (Marsh, unpublished data).

NATURAL HISTORY

Life History

Almost all information is from specimens accidentally drowned in shark nets or killed by native hunters in northern Australia and Papua New Guinea (Marsh 1980, 1986a; Marsh *et al*. 1984b, 1984c, 1984d). Age has been estimated from tusk dentinal growth layer group counts, the deposition rate being deduced from the seasonal pattern of growth layer deposition. The maximum longevity

observed is 73 years, and the minimum pre-reproductive period 9 – 10 years for both sexes. The pre-reproductive period is variable and ranges up to 15 – 17 years for some females. Calving interval estimates based on apparent pregnancy rates, placental scar counts or calf counts range from 3 – 7 years for various Australian/Torres Strait populations (Marsh *et al*. 1984d; Marsh 1986a). There are no reliable data on age-specific fecundity or mortality, but there is evidence that some males may become post-reproductive (Marsh *et al*. 1984c).

Population simulations indicate that, even with the most optimistic combination of life history parameters, a low schedule of natural mortality and no man-induced mortality, a population is unlikely to increase at more than about 5% per year (Marsh 1986a).

Ecology

Our understanding of the habitat requirements of dugongs is incomplete and based largely on aerial survey observations. Dugongs are usually sighted in bays, shallows, and reef areas which are protected against strong wind and heavy seas and which contain extensive beds of seagrasses (Heinsohn *et al*. 1977). Preliminary results obtained from radio and satellite tracking two young male Dugongs confirm that they spend most of their time in the vicinity of inshore seagrass beds (Marsh & Rathbun 1990).

Dugongs have been seen up to 58 km offshore and in water estimated to be up to 37 m deep in the Great Barrier Reef lagoon (Marsh 1986b). It was estimated that about one third of the animals in the area between Cape Flattery and Cape Melville were more than 20 km offshore in November 1984. This pattern is unlikely to reflect diurnal feeding movements. Although it has often been stated that Dugongs remain offshore during the day, coming inshore during the night to feed, our aerial surveys have shown that inshore feeding in daylight hours is normal in this area.

The immature male tracked by satellite in late 1986 moved between inshore seagrass beds in two non-adjacent bays three times during the 9 week tracking period, taking as little as 2 days to cover 140 km or more. Another animal tracked by conventional radio telemetry remained in a seagrass bed near where he was tagged for more than 16 months (Marsh & Rathbun 1990).

Movements of tens of kilometres can be inferred from changes in the numbers of Dugong seen in various areas during shoreline surveys (see Marsh, Gardner & Heinsohn 1981; Anderson 1986), but there is no evidence of large scale migrations comparable to those of baleen whales. In Shark Bay, at the southern limit of the species’ range in Western Australia, movements between preferred habitats appear to correlate with seasonal changes in water temperature (Anderson 1986). On the east coast, lone animals are occasionally seen near Sydney and a young female was found shot near Tathra in southern New South Wales in December 1986 (Wombey unpublished data). The nearest known habitat area to this locality is Moreton Bay in southern Queensland, suggesting that individuals can travel many hundreds of kilometres.

Analysis of mouth and stomach contents indicates consumption of a wide variety of tropical and subtropical seagrasses (families Potamogetonaceae and Hydrocharitaceae). Those eaten include species of *Amphibolis*, *Enhalus*, *Cymodocea*, *Halophila*, *Halodule*, *Syringodium*, *Thalassia*, *Thalassodendron* and *Zostera* (Lipkin 1975; Johnstone & Hudson 1981; Anderson 1982b; Marsh *et al*. 1982; Nietschmann 1984). Halodule species are found in a high proportion of stomachs (see Marsh *et al*. 1982), but without better knowledge of the relative abundance of different seagrasses in various habitats, no estimate of discriminate food selection can be made (see Johnstone & Hudson 1981). Algae also are eaten in small amounts when seagrasses are abundant and there is

evidence from a few animals that algae can become a more important component of the diet when seagrasses are in short supply (Spain & Heinsohn 1973).

When feeding on smaller seagrasses such as species of *Halodule* and *Halophila*, the whole plant is dug up including the rhizomes, leaving a distinctive feeding trail (Heinsohn *et al*. 1977; Anderson & Birtles 1978). The rhizomes of taller growing species such as *Amphibolis antarctica* are not accessible and Dugongs graze only on the leaves and stems of this species (Anderson 1982b).

There is surprisingly little literature on non-human predation. Anderson & Prince (1985) presented evidence for predation by killer whales in Shark Bay. Specimens bearing scars which indicate that they have experienced and survived attacks by large sharks are occasionally sighted (Anderson 1979; personal observation). Bradley (in Marsh *et al*. 1984d) observed a fatal shark attack on a calf near the MacArthur River in the Northern Territory. Patterson (1939) wrote a popular account of the death of a female in sacrificial defence of her calf from a shark attack in Torres Strait.

Blair's (1981) checklist of parasites included one species of nematode and 19 species of digenetic trematodes. Campbell & Ladds (1981) described pathological changes in 14 wild and one captive specimen from north-eastern Australia. Diseases of the skin, gastro-intestinal tract and pancreas predominated. Fatal gastro-intestinal salmonellosis occurred in the single captive animal detailed in Elliott *et al*. (1981).

Behaviour

Because of the practical difficulties associated with observation, little is known of behaviour. The propensity to form herds of up to several hundred individuals in areas of high population density suggests that the Dugong is a social animal. The only long term social unit that has been identified, however, is the cow and calf.

The tendency to form groups suggests some degree of communication between individuals. Many disparate groups of Australian Aboriginals have described 'whistler' animals, whom they regard as dominant individuals in control of herds (see Roughsey 1971). Vocalisations have been recorded from captives (Nair & Mohan 1977; Mercer *et al*. reported by Marsh *et al*. 1978) and wild specimens (Nietschmann 1984). All sounds have been in the 1 – 8 KHz range.

Presumed courtship and mating behaviour have been described. The males may engage in simple displays (Anderson & Birtles 1978). The few accounts of Dugongs giving birth are summarised by Marsh *et al*. (1984d). On all occasions, the birth occurred in shallow water; in two instances the mother was effectively aground. The cow-calf bond is extremely close and calves apparently can suckle for at least 18 months (see Marsh *et al*. 1984d). Contrary to most popular accounts, suckling calves lie horizontally beside their attending cow with their muzzles pressed into the cow's axillary region (Anderson 1984).

Anderson & Birtles (1978) timed 370 dives in an area on the central coast of Queensland where individuals were digging up whole seagrass plants. The mean time for each dive was 73.3 sec. with a maximum of 400 sec. Submergence times whilst feeding on *Amphibolis antarctica* in Shark Bay were significantly shorter than these (Anderson 1982b). Anderson (unpublished data) concluded that the interval between appearances at the surface varied with locality, foraging mode, forage species, activity and reproductive status. His data from varying depths suggest a trend for Dugongs to remain submerged longer in deep water. Given its essentially coastal distribution and dependence on seagrass for food, it is doubtful that the Dugong dives to any considerable depth.

Economic Significance

Man has been hunting and netting Dugongs for thousands of years. Specialised cultures based on hunting developed in several countries including Australia (for example, Cape York; Thomson 1934). Today, the animal is still of great significance in the ceremony, religion, economy and culture of a number of Australian Aboriginal and Torres Strait Islander communities (Anon 1981; Nietschmann 1984; Marsh *et al*. 1984a; Hudson 1986; Marsh 1986a).

Dugong meat tastes rather like beef. An average adult yields about 100 – 150 kg of meat and 4 gallons of oil (Lack 1968). This oil, sought for its medicinal properties, was featured at the Paris exhibition in 1854 (Lack 1968) and, subsequently, formed the basis of an intermittent cottage industry at various places in Queensland until the Dugong was protected in the mid 1960s.

Like the three other extant sirenians, the Dugong is currently listed as vulnerable to extinction in the IUCN Red Data Book (Thornback & Jenkins 1982) and trade in products is regulated or banned (depending on the population involved) by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). As the only developed country whose waters harbour significant numbers, Australia has a special responsibility to ensure that the species does not become extinct.

In Australia, only indigenous people are allowed to hunt Dugongs; the relevant laws vary slightly in different areas. There are few or no restrictions on hunting technique, but the use of firearms, explosives and poisons is banned in Queensland. Reliable catch statistics for indigenous hunting are almost non-existent, but large numbers certainly have been caught in the Torres Strait area in the recent past (Nietschmann 1984; Hudson 1986). Marsh (1986a) estimated that an average total of 36 specimens per month were being taken by the residents of five Torres Strait communities in the late 1970s. There is evidence of a subsequent decline in the catch of some communities (Hudson 1986; Marsh 1986a).

As the only herbivorous mammal that is strictly marine, Dugongs are certainly of great scientific interest. Systematic aerial surveys are now being used to census dugong numbers in Northern Australia (Marsh *et al*. 1984a; Marsh 1986a, 1986b; Bayliss 1986). Even at high sampling intensities, the relatively low level of precision obtained (14% or less), coupled with the expected low rate of change of dugong populations, means that it will be a decade or more before it is possible to evaluate the status of populations using this technique.

BIOGEOGRAPHY AND PHYLOGENY

Distribution

The species occurs in the tropical and sub-tropical shallow coastal and island waters of the Indo-West-Pacific between latitudes 26 – 27° North and South as summarised in Fig. 57.3. Over much of this range, Dugongs are believed to be represented by separate, relict populations, many close to extinction or extinct. This assessment, however, is based almost entirely on anecdotal information and the precise extent to which the range has contracted is unknown.

Aerial surveys carried out since 1974 along much of the northern coastline of Australia including Great Barrier Reef and Torres Strait waters, have demonstrated that relatively large numbers still occur between Shark Bay in the west and Moreton Bay in the east (see Ligon 1976; Heinsohn, Spain & Anderson 1976b; Heinsohn *et al*. 1978; Elliott 1981; Marsh *et al*. 1981; Prince, Anderson & Blackman 1981; Anderson 1982a; Prince 1984; Bayliss 1986; Marsh 1986a, 1986b). Although Australian waters probably contain a sizeable

proportion of the world's total number, conversion from counts to absolute estimates is tentative due to the difficulties of compensating for animals missed in turbid water. Recent surveys in northern Queensland and the Northern Territory (Bayliss 1986; Marsh 1986a, 1986b), suggest that the total for Australian waters is in the tens of thousands.

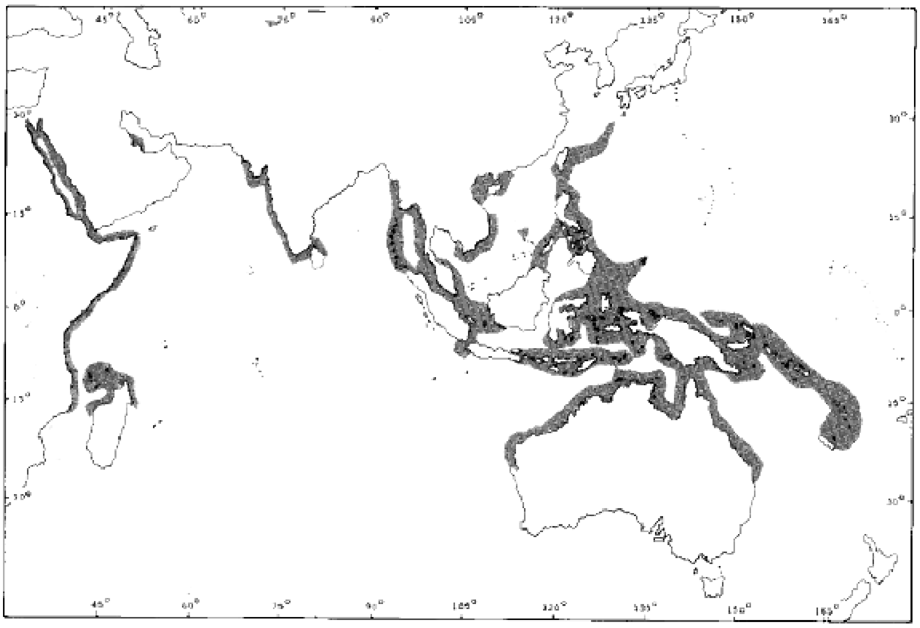

Figure 57.3 Worldwide distribution of the Dugong (shaded area).

Affinities with Other Groups

The closest non-sirenian relative of the Dugong may be the elephant. Albumin data indicate that sirenians, elephants, hyraxes and the Aardvark form a monophyletic group (Rainey *et al*. 1984). Eye-lens protein analyses also indicate a monophyletic origin for sirenians, hyraxes and elephants and place this group as the first offshoot of the main eutherian line after the edentates (de Jong, Zweers & Goodman 1981).

There are significant differences between the molecular and palaeontological estimates of sirenian divergence times. Recent palaeontological reconstructions suggest that dugong and manatee lineages diverged in the Middle Eocene (about 45 mybp), with the Steller's Sea Cow and dugong lineages diverging from an extinct common ancestor in the Miocene and Oligocene, respectively (Domning 1978). In contrast, the immunological data of Rainey *et al*. (1984) suggested that dugongs and manatees diverged about 17 – 20 mybp and dugongs and Steller's Sea Cows 4 – 8 mybp.

Fossil Record

Sirenians have an extensive fossil history (Savage 1976; Domning 1978) and first appear in Eocene deposits. Eocene sirenians have been found from the Caribbean to Java (Reinhart 1976; Savage 1976), which points to the shores of the Tethyan seaway (probably in the Old World) as the centre of origin (Domning 1978). At this time, Australia was widely separated from this region and only recently severed from Antarctica (Frakes & Rich 1982).

Sirenians reached their zenith in the Miocene (Domning 1978) when they numbered about a dozen (mostly monotypic) genera worldwide. Fordyce (1982b) reported that the only fossil sirenian described from Australia appeared to be a scrap of skull from the freshwater Pliocene Chinchilla Drift. Reinhart (1976) considered this specimen indeterminate. Re-examination is needed to confirm whether it is in fact sirenian.

The subfamily Dugonginae, in which *Dugong* is placed, lacks a fossil record (Domning 1978).

ACKNOWLEDGEMENTS

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LITERATURE CITED

Anderson, P.K. (1979). Dugong behaviour: on being a marine mammalian grazer. *Biologist* 61: 113-144

Anderson, P.K. (1981). Dugong behaviour: Observations, extrapolations, and speculations. Pp. 91-111 *in* Marsh, H. (ed.) *The Dugong: Proceedings of a Seminar/Workshop held at James Cook University, 8-13 May 1979*. James Cook University : Townsville

Anderson, P.K. (1982a). Studies of dugongs at Shark Bay, Western Australia. 1. Analysis of population size, composition, dispersion and habitat use on the basis of aerial survey. *Australian Wildlife Research* 9: 69-84

Anderson, P.K. (1982b). Studies of dugongs at Shark Bay, Western Australia. II. Surface and subsurface observations. *Australian Wildlife Research* 9: 85-99

Anderson, P.K. (1984). Suckling in *Dugong dugon*. *Journal of Mammalogy* 65: 510-511

Anderson, P.K. (1986). Dugongs of Shark Bay, Australia - Seasonal migration, water temperature, and forage. *National Geographic Research Reports* 2: 473-490

Anderson, P.K. & Birtles, A. (1978). Behaviour and ecology of the dugong, *Dugong dugon* (Sirenia): Observations in Shoalwater and Cleveland Bays, Queensland. *Australian Wildlife Research* 5: 1-23

Anderson, P.K. & Prince, R.I.T. (1985). Predation on dugongs: attacks by killer whales. *Journal of Mammalogy* 66: 554-556

Anon. (1981). Additional recommendations relating to the involvement of Aboriginal and Torres Strait Islander communities in information gathering and conservation programs. Pp. 215-216 *in* Marsh, H. (ed.) *The Dugong: Proceedings of a Seminar/Workshop held at James Cook University, 8-13 May 1979*. James Cook University : Townsville

Batrawi, A. (1953). The external features of the dugong kidney. *Bulletin of the Zoological Society of Egypt* 11: 12-13

Batrawi, A. (1957). The structure of the dugong kidney. *Publication of the Marine Biological Station, Ghardaqa, Red Sea* 9: 51-68

Bayliss, P. (1986). Factors affecting aerial counts of marine fauna and their relationship to a census of dugongs in the coastal waters of the Northern Territory. *Australian Wildlife Research* 13: 27-37

Bertram, G.C.L. & Bertram, C.K.R. (1973). The modern Sirenia : their distribution and status. *Biological Journal of the Linnean Society* 5: 297-338

Birch, W.R. (1975). Some chemical and calorific properties of tropical marine angiosperms compared with those of other plants. *Journal of Applied Ecology* 12: 201-212

Blair, D. (1981). Helminth parasites of the dugong, their collection and preservation. Pp. 275-285 *in* Marsh, H. (ed.) *The Dugong: Proceedings of a Seminar/Workshop held at James Cook University, 8-13 May 1979*. James Cook University : Townsville

Campbell, R.S.F. & Ladds, P.W. (1981). Diseases of the dugong in north-eastern Australia: a preliminary report. Pp. 176-181 *in* Marsh, H. (ed.) *The Dugong: Proceedings of a Seminar/Workshop held at James Cook University, 8-13 May 1979*. James Cook University : Townsville

Cave, A.J.E. & Aumonier, F.J. (1967). Observations on dugong histology. *Journal of Royal Microscopical Society* 87: 113-121

Collins, D. (1802). *An Account of the English Colony in New South Wales, from its First Settlement, in January 1788, to August 1801*. T. Caddell Jnr. & W. Davies : London 355 pp.

Dampier, W. (1927). *A New Voyage Round the World*. The Argonaut Press : London 376 pp. [facsimile edition]

Dampier, W. (1939). *A Voyage to New Holland*. The Argonaut Press : London 261 pp. [facsimile edition]

de Jong, W.W., Zweers, A. & Goodman, M. (1981). Relationship of aardvark to elephants, hyraxes and sea cows from α-crystallin sequences. *Nature* 292: 538-540

Dexler, H. (1902). Bericht über eine Reise nach Australien, zum Zweck der Erwerbung anatomischen und entwicklungsgeschichtlichen Materiales vom *Dugong*. *Deutsche Arbeit Prague* l: 552-562

Dexler, H. (1912a). Das Rückenmark von *Halicore dugong* Erxl. *Verhandlungen 8 International Congress Graz*: 527-534

Dexler, H. (1912b). Das Hirn von *Halicore dugong* Erxl. *Morphologisches Jahrbuch* 45: 97-190

Dexler, H. & Egar, O. (1911). Beiträge zur Anatomie des Säuger-rückenmarkes I. *Halicore dugong* Erxl. *Morphologisches Jahrbuch* 43: 107-207

Dexler, H. & Freund, L. (1906a). External morphology of the dugong. *American Naturalist* 40: 567-581

Dexler, H. & Freund, L. (1906b). Zur Biologie und Morphologie von *Halicore dugong*. *Archiv für Naturgeschichte* 72: 77-106 3 pls

Dexler, H. & Freund, L. (1906c). Contributions to the physiology and biology of the dugong. *American Naturalist* 40: 49-72

Domning, D.P. (1976). An ecological model for late Tertiary sirenian evolution in the North Pacific Ocean. *Systematic Zoology* 25: 352-362

Domning, D.P. (1978). Sirenia. Pp. 573-581 *in* Maglio, V.J. & Cooke, H.B.S. (eds) *Evolution of African Mammals*. Harvard University Press : Cambridge

Domning, D.P. (1983). Marching teeth of the manatee. *Natural History* 92: 8-11

Elliott, H., Thomas, A., Ladds, P.N. & Heinsohn, G.E. (1981). A fatal case of Salmonellosis in a dugong. *Journal of Wildlife Diseases* 17: 203-208

Elliott, M.A. (1981). Distribution and status of the dugong in Northern Territory waters. Pp. 57-66 *in* Marsh, H. (ed.) *The Dugong: Proceedings of a Seminar/ Workshop held at James Cook University, 8-13 May 1979*. James Cook University : Townsville

Elsner, R. (1969). Cardiovascular adjustments to diving. Pp. 117-145 *in* Andersen, H.T. (ed.) *The Biology of Marine Mammals*. Academic Press : New York 511 pp.

Engel, S. (1959a). The respiratory tissue of dugong (*Halicore dugon*g). *Anatomischer Anzeiger* 106: 90-100

Engel, S. (1959b). Rudimentary mammalian lungs. *Gegenbaur Morphologisches Jahrbuch* 106: 95-114

Engel, S. (1962). The air passages of the dugong lung. *Acta Anatomica* 48: 95-107

Fernand, V.S.V. (1951). The histology of the pituitary and adrenal glands of the dugong. *Ceylon Journal of Medical Science* (D) 8: 57-6

Fernand, V.S.V. (1953). The teeth of the dugong. *Ceylon Journal of Science* 25: 139-147

Fordyce, R.E. (1982b). The Australasian marine vertebrate record and its climatic and geographic implications. Pp. 596-627 *in* Rich, P.V. & Thompson, E.M. (eds) *The Fossil Vertebhrate Record of Australasia*. Monash University Offset Printing Unit : Clayton

Frakes, L.A. & Rich, P.V. (1982). Palaeoclimatic setting and palaeogeographic links of Australia in the Phanerozoic. Pp. 27-52 *in* Rich, P.V. & Thompson, E.M. (eds) *The Fossil Vertebrate Record of Australia*. Monash University : Clayton

Gohar, H. (1957). The Red Sea dugong. *Publications of the Marine Biological Station at Ghardaqa, Red Sea* 9: 49 pp.

Harrison, R.J. & King, J.E. (1980). *Marine Mammals*. Hutchinson : London 2nd edn 192 pp.

Heinsohn, G.E., Lear, R.J., Bryden, M.M., Marsh, H. & Gardner, B.R. (1978). Discovery of a large resident population of dugongs adjacent to the major port of Brisbane, Moreton Bay, Australia. *Environmental Conservation* 5: 910-92

Heinsohn, G.E., Spain, A.V. & Anderson, P.K. (1976b). Populations of dugongs (Mammalia : Sirenia) aerial surveys over the inshore waters of tropical Australia. *Biological Conservation* 9: 21-23

Heinsohn, G.E., Wake, J.A., Marsh, H. & Spain, A.V. (1977). The dugong in the seagrass ecosystem. *Aquaculture* 12: 235-248

Heuvelmans, B. (1941). Notes sur la dentition de Sireniens. 111. La dentition du dugong. *Bulletin du Musée Royal d'Histoire Naturelle de Belgique* 17: 1-14

Hill, W.C.O. (1945). Notes on the dissection of two dugongs. *Journal of Mammalogy* 26: 153-175

Hudson, B.E.T. (1986). The hunting of dugong (Mammalia : Sirenia) at Daru, Papua New Guinea during 1978-1982: community management and education initiatives. Pp. 73-94 *in* Haines, A.K., Williams, G.L. & Coates, D. (eds) *Torres Strait Fisheries Seminar, Port Moresby 11-14 February 198*5. Australian Government Publishing Service : Canberra

Husar, S. (1975). A review of the literature of the dugong (Dugong dugon). U.S. Department of the Interior Fish and Wildlife Service Wildlife Research Report 4 30 pp.

Johnstone, I.M. & Hudson, B.E.T. (1981). The dugong diet: mouth sample analysis. *Bulletin of Marine Science* 31: 681-690

Kamiya, T. & Yamasaki, F. (1981). A morphological note on the sinus hair of the dugong. Pp. 193-197 *in* Marsh, H. (ed.) *The Dugong: Proceedings of a Seminar/Workshop held at James Cook University, 8-13 May 1979*. James Cook University : Townsville

Kamiya, T., Uchida, S. & Kataoka, T. (1979). Organ weights of *Dugong dugon*. *Scientific Reports of the Whales Research Institute Tokyo* 31: 129-132

Kingdon, J. (1971). *East African Mammals. Vol. 1 An Atlas of Evolution in Africa*. Academic Press New York x 457 + 10 pp.

Lack, C. (1968). Dugong fishing in early Queensland. *Newsletter of the Royal Australian Historical Society, November 1968*: 4-6

Ligon, S. (1976). A survey of dugongs (*Dugong dugon*) in Queensland. *Journal of Mammalogy* 57: 580-582

Lipkin, Y. (1975). Food of the Red Sea Dugong (Mammalia : Sirenia) from Sinai. *Israel Journal of Science* 24: 81-98

Mani, S.B. (1960). Occurrence of the sea cow, *Halicore dugong* (Erxl.) off the Saurashtra coast. *Journal of the Bombay Natural History Society* 57: 216-217

Marsh, H. (1980). Age determination of the dugong *Dugong dugon* (Müller) in northern Australia and its biological implications. *Report of the International Whaling Commission* (Special Issue 3): 181-201

Marsh, H. (1986a). The status of the dugong in Torres Strait. Pp. 53-76 *in* Haines, A.K., Williams, G.C. & Coates, D. (eds) Torr*es Strait Fisheries Seminar, Port Moresby, 11-14 February 1985*. Australian Government Publishing Service : Canberra

Marsh, H. (1986b). Development of aerial survey methodology and results of aerial surveys for dugongs conducted in the northern and central sections of the Great Barrier Reef Marine Park. *Report to the Great Barrier Reef Marine Park Authority*, June 1986 142 pp.

Marsh, H. and Rathbun, G.B. (1990). Development and application of conventional and satellite radio tracking techniques for studying dugong movements and habitat use. *Australian Wildlife Research* **17**: 83–100

Marsh, H., Barker-Hudson, B.E.T., Heinsohn, G.E. & Kinbag, F. (1984a). Status of the dugong in the Torres Strait Area: Results of an aerial survey in the perspective of information of dugong life history and current catch levels. *Report to the Australian National Parks and Wildlife Service*, April 1984 72 Pp.

Marsh, H., Channells, P.W., Heinsohn, G.E. & Morrissey, J. (1982). Analysis of stomach contents of dugongs from Queensland, Australia. *Australian Wildlife Research* 9: 55-67

Marsh, H., Gardner, B.R. & Heinsohn, G.E. (1981). Present-day hunting and distribution of dugongs in the Wellesley Islands (Queensland): Implications for conservation. *Biological Conservation* 19: 255-267

Marsh, H., Heinsohn, G.E. & Channells, P.W. (1984b). Changes in the ovaries and uterus of the dugong, *Dugong dugon* (Sirenia, Dugongidae) with age and reproductive activity. *Australian Journal of Zoology* 32: 743-766

Marsh, H., Heinsohn, G.E. & Glover, T.D. (1984c). Changes in the male reproductive organs of the dugong, *Dugong dugon* (Sirenia, Dugongidae) with age and reproductive activity. *Australian Journal of Zoology* 32: 721-742

Marsh, H., Heinsohn, G.E. & Marsh, L.M. (1984d). Life history, breeding cycle and population dynamics of the dugong, *Dugong dugon* (Sirenia, Dugongidae). *Australian Journal of Zoology* 32: 767-788

Marsh, H., Heinsohn, G.E. & Spain, A.V. (1977). The stomach and duodenal diverticula of the dugong, Dugong dugon. Pp. 271-295 *in* Harrison, R.J. (ed.) *Functional Anatomy of Marine Mammals*. Academic Press : New York Vol. 3

Marsh, H., Spain, A.V. & Heinsohn, G.E. (1978). Minireview. Physiology of the Dugong. *Comparative Biochemistry and Physiology* 61: 159-168

Mitchell, J. (1973). Determination of relative age in the dugong *Dugong dugon* (Müller) from a study of skulls and teeth. *Zoological Journal of the Linnean Society* 53: 1-23

Mitchell, J. (1976). Age determination in the dugong, *Dugong dugon* (Müller). *Biological Conservation* 9: 25-28

Mitchell, J. (1978). Incremental growth layers in the dentine of dugong incisors (*Dugong dugon* (Müller)) and their application to age determination. *Zoological Journal of the Linnean Society* 62: 317-348

Mitchell, J. (1981). The coincidence between a distinct accessory groove in young dugong teeth and a tropical cyclone. *Biological Conservation* 20: 99-109

Murray, R.M., Marsh, H., Heinsohn, G.E. & Spain, A.V. (1977). The role of the midgut caecum and large intestine in the digestion of sea grasses by the dugong (Mammalia : Sirenia). *Comparative Biochemistry and Physiology* 56A: 7-10

Nair, R.V. & Mohan, R.S.L. (1977). Studies in the vocalisation of the sea cow *Dugong dugon* in captivity. *Indian Journal of Fisheries* 22: 277-278

Nietschmann, B. (1984). Hunting and ecology of dugongs and green turtles, Torres Strait, Australia. *National Geographic Society Research Reports* 17: 625-651

Nishiwaki, M. & Marsh, H. (1985). The dugong. Pp. 1-31 in Ridgway, S.H. & Harrison R.J. (eds) *Handbook of Marine Mammal*s. Academic Press : London Vol. 5

Patterson, E.K. (1939). The dugong hunters. *Walkabout* 5(12): 43-44

Petit, M.G. (1955). Ordre des Sireniens. Pp. 918-1001 *in* Grassé, P.-P. (ed.) *Traité de Zoologie*. Masson et Cie : Paris Vol. 17

Prince, R.I.T. (1984). Dugong in northern waters of Western Australia, 1984. Report to the Australian National Parks and Wildlife Service 38 pp.

Prince, R.I.T., Anderson, P.K. & Blackman, D. (1981). Status and distribution of dugongs in Western Australia. Pp. 67-87 *in* Marsh, H. (ed.) *The Dugong: Proceedings of a Seminar/Workshop held at James Cook University, 8-13 May 1979*. James Cook University : Townsville

Rainey, W.E., Lowenstein, J.M., Sarich, V.M. & Magor, D.M. (1984). Sirenian molecular systematics including the extinct Steller's Sea Cow (*Hydrodamalis gigas*). *Naturwissenschaften* 17: 586-588

Reinhart, R.H. (1976). Fossil sirenians and desmostylids new record from Florida USA and elsewhere. *Bulletin of the Florida State Museum of Biological Science* 20: 187-300

Roughsey, D. (1971). *Moon and Rainbow.* A.H. & A.W. Reed : Sydney168 pp.

Rowlatt, U. & Marsh, H. (1985). The heart of the dugong (*Dugong dugon*) and the West Indian Manatee (*Trichechus manatus*). (Sirenia). *Journal of Morphology* 186: 95-105

Savage, R.J.G. (1976). Review of early Sirenia. *Systematic Zoology* 25: 344-351

Spain, A.V. & Heinsohn, G.E. (1973). Cyclone associated feeding changes in the dugong (Mammalia : Sirenia). *Mammalia* 37: 678-680

Spain, A.V. & Heinsohn, G.E. (1975). Size and weight allometry in a north Queensland population of *Dugong dugon* (Müller) (Mammalia : Sirenia). *Australian Journal of Zoology* 23: 159-168

Spain, A.V. & Marsh, H. (1981). Geographic variation and sexual dimorphism in the skulls of two Australian populations of *Dugong dugon* (Müller) (Mammalia : Sirenia). Pp. 143-161 *in* Marsh, H. (ed.) *The Dugong: Proceedings of a Seminar/Workshop held at James Cook University, 8-13 May 1979*. James Cook University : Townsville

Spain, A.V., Heinsohn, G.E., Marsh, H. & Correll, R.L. (1976). Sexual dimorphism and other sources of variation in a sample of dugong skulls from North Queensland. *Australian Journal of Zoology* 24: 491-497

Steller, G. (1751) De Bestiis Marinis. *Novi Commentarii Academiae Scientiarum Imperialis Petropolitanae* 2: 289-398. English Translation: Jordan, D.S. (1889). The fur seals and fur-seal islands of the north Pacific Ocean. Part 3. Government Printing Office : Washington, D.C.

Thomson, D.F. (1934). The dugong hunters of Cape York. *Journal of the Royal Anthropological Institute* 64: 237-264

Thornback, J. & Jenkins, M. (eds) (1982). The IUCN Mammal Red Data Book. Part I: Threatened mammalian taxa of the Americas and the Australasian zoogeographic region (excluding Cetacea). Gland : IUCN xl 516 pp.