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Introduction

In 2008 a US federal court judge ruled that the Defense Department's plans to construct an offshore marine airbase on the island of Okinawa, Japan contravened the US National Historic Preservation Act of 1966 (Tanji 2008). The rationale for the court's decision, known as *Dugong* v. *Gates*, was that construction plans for the base failed to protect the dugong, one of the animals that are the subjects of this book. The dugong is listed as *critically endangered* by the Japanese Ministry of the Environment and as a National Monument on the Japanese Register of Cultural Properties because of its high cultural value to the people of Okinawa. In 2005 a companion court case (*Dugong* v. *Rumsfeld*) had established the legitimacy of declaring an animal to be a historically significant 'property' under US legislation, ensuring that the US National Historic Preservation Act of 1966 applied.

The outcome of these court cases does not guarantee the future of the dugong in Japan, where it is subject to multiple threats in addition to the airbase (Marsh *et al.* 2002; Ikeda and Mukai 2012; Chapter 8). Indeed, the court decision seems unlikely to prevent the construction of the airbase.

However, this controversy and the associated landmark court cases highlight the cultural importance of animals such as dugongs and manatees (species known collectively as sirenians) and the value of addressing their cultural significance at national and international levels (King 2006). Although these court cases were ostensibly about the conservation of the dugong and its associated cultural values, the underlying conflict results from the polarised attitudes of Japanese people to US military bases in Okinawa. Fourteen bases occupy 18% of the area of the main island, and two large bases are close to residential areas. People who support the bases give preservation of dugongs low priority (Tanji 2008).

The conflict over the Okinawan dugong is extraordinary, because it involves the environmental organisations, courts and governments of two powerful nations in a localised conservation issue. Nonetheless, high-profile national conflicts over the conservation of sirenians are manifestations of similar clashes of culture. The most obvious parallels occur in other

developed countries in the ranges of manatees and dugongs: the United States and Australia. The conflict between the conservation lobby and marine industry and coastal development interests over the management of human impacts on the Florida manatee has festered for decades (Reynolds 1999; Tripp 2006) and is an ongoing source of controversy. In Australia, there have been analogous conflicts over dugong conservation and fisheries management, particularly in the Great Barrier Reef region (Marsh 2000), where the dugong is explicitly listed as one of the World Heritage values (GBRMPA 1981). In addition, cultural conflict simmers between Australia's indigenous peoples and the wider community over traditional hunting of dugongs (Marsh *et al.* 2004).

Conflicts in the developing countries[1] that constitute most of the ranges of sirenians receive far less publicity but are much more intractable than the examples from the developed world. The ranges of the dugong and the three species of manatee collectively span more than 80 subtropical and tropical countries on five continents. In many such countries, conservation is seen as clashing with food security and the development associated with rapid human population increase. Here the challenge of sirenian conservation is a consequence of some of the world's major environmental problems: human population increase, the movement of people to coastal areas and the destruction of tropical and subtropical habitats, especially aquatic systems.

Globally, all four extant species of sirenians are considered to be in danger of extinction (IUCN 2009; Table 1.1). Nonetheless, in contrast to many other species, enough knowledge has accumulated about sirenian biology and the threats to their populations for governments to take

Table 1.1 *Scientific and common names and the IUCN global conservation status of the Recent members of the Order Sirenia as of October 2010: dugongs and manatees*

Species	Subspecies	Common name	IUCN global conservation status
Family Dugongidae			
Dugong dugon		Dugong	Vulnerable
Hydrodamalis gigas		Steller's sea cow	Extinct
Family Trichechidae			
Trichechus inunguis		Amazonian manatee	Vulnerable
Trichechus manatus		West Indian manatee	Vulnerable
	latirostris	Florida manatee	Endangered
	manatus	Antillean manatee	Endangered
Trichechus senegalensis		West African manatee	Vulnerable

effective steps towards their conservation, if the political will exists to do so. However, much of the required information on sirenian ecology and conservation is difficult to access and has not been synthesised. This book attempts to address this deficiency.

THE SIRENIA

The dugong and the Amazonian, West African and West Indian manatees are the only extant members of the mammalian Order Sirenia (or sea cows). Two subspecies of the West Indian manatee are recognised: the Florida manatee and the Antillean manatee.[2] The fifth Recent sirenian, Steller's sea cow, the largest mammal to exist in historic times other than the great whales, was exterminated by humans in the eighteenth century (Chapter 2).

The marine mammals include approximately 87 species in the Order Cetacea: the whales and dolphins; approximately 35 species in the Order Carnivora, Suborder Pinnipedia: the sea lions, walrus and seals; three species of fissipeds (members of the Order Carnivora that have separate digits): the sea otter, the marine otter and the polar bear; and the six Recent members of the Order Sirenia, if both subspecies of West Indian manatee are considered separately (Committee on Taxonomy 2009). The sirenians are exceptional as the only large herbivorous mammals that are strictly aquatic, justifying their common name: sea cows. Like whales and dolphins but unlike seals, sea lions, otters and polar bears, manatees and dugongs spend their entire lives in the water and do not return to land to give birth and suckle young.

The major groupings of marine mammals have evolved separately from the different groups of terrestrial mammals and are not closely related to each other (Reynolds *et al.* 1999). Nonetheless, they share many superficially similar morphological adaptations to their aquatic environments and the cetaceans, pinnipeds and sirenians were often grouped together in past centuries, even when it was recognised that the grouping was anomalous (Box 1.1).

The sirenians have a long evolutionary history extending back more than 50 million years (Chapter 3). Their closest contemporary relatives are the elephants and hyraxes, and the three groups have been linked together as the clade Paenungulata (see Chapter 3). At least 35 named species of sirenians have existed through time, ranging in mass from small sea cows weighing an estimated 150 kg to Steller's sea cow at a body mass estimated to be more than 10 000 kg. Some early sirenians walked on land with sturdy hind limbs, but fed on aquatic vegetation. Later forms evolved a variety of

Box 1.1. Herman Melville on the taxonomic position of sirenians

'I am aware that down to the present time, the fish styled Lamantins and Dugongs (Pig-fish and Sow-fish of the Coffins of Nantucket) are included by many naturalists among the whales. But these pig-fish are a nosy, contemptible set, mostly lurking in the mouths of rivers, and feeding on wet hay, and especially as they do not spout, I deny their credentials as whales; and have presented them with their passports to quit the Kingdom of Cetology.'

Melville (1851, p. 138)

foraging strategies, adapting to changing climatic, geologic, oceanographic and biological conditions within the bounds of aquatic megaherbivory (Chapter 3).

The Recent sirenians are classified into two families. The three species of manatees are grouped in the Family Trichechidae; the dugong and Steller's sea cow in the Family Dugongidae (Table 1.1). The ancestors of these families diverged some 25–40 million years ago (see Chapter 3). Despite this long separation, trichechids and dugongids look remarkably alike. Pictures labelled as dugongs often depict manatees, sometimes with dugong tails attached by photo editing. For example, in Torres Strait between Australia and Papua New Guinea, the dugong is one of the most significant cultural symbols (see Frontispiece). Nonetheless, some souvenir T-shirts from Torres Strait feature manatees mislabelled as dugongs.

The external form of all the extant sirenians (Figure 1.1) reflects their adaptations to a life of swimming, diving and eating aquatic flowering plants. Thus the sirenian body plan is radically different from that of large terrestrial herbivorous mammals, including the other paenungulates. However, because they live in relatively shallow waters, do not dive deeply for food, and apparently lack the complex social systems of some cetaceans, sirenians are considered to be less specialised for an aquatic life than whales or dolphins (Reynolds *et al.* 1999).

Nonetheless, sirenians are highly derived mammals. Their digestive tract is more similar to that of elephants and horses than to most other mammals (and has features in common with koalas, wombats and beavers; see Chapter 4). There are two mammary glands, each opening via a single teat situated in the axilla or 'armpit', a position that has some resemblance to that of the breasts of human females, which may explain links between (mythical) mermaids and sirenians – at least in the minds of sailors in days of old. (Indeed, the etymology for the name Sirenia dates from the sirens of

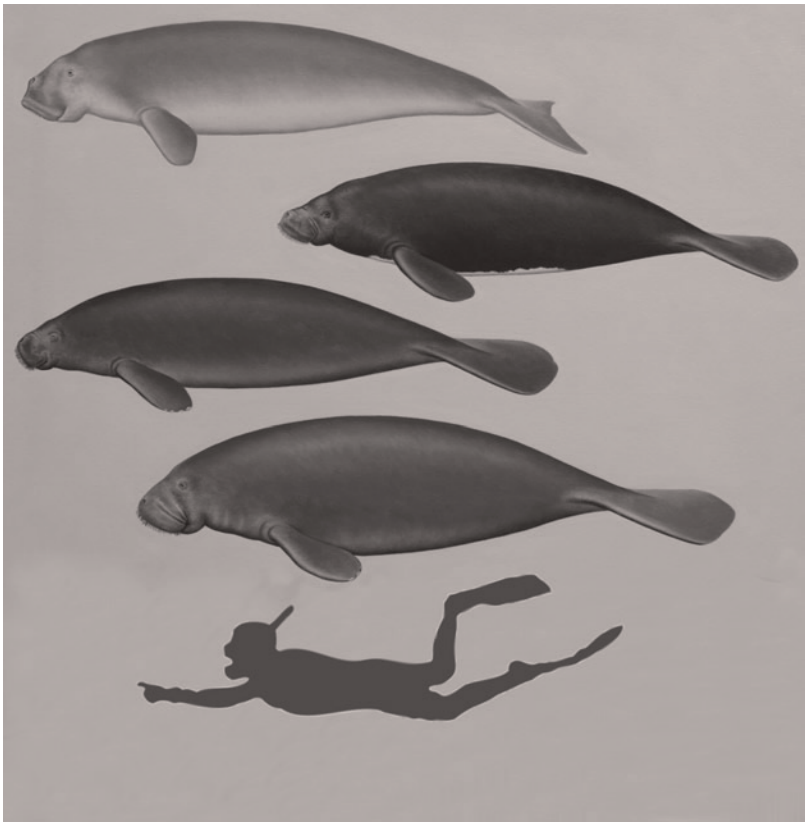

Figure 1.1. Illustrations of the four extant species of sirenians (from top: dugong, Amazonian manatee, West African manatee, West Indian manatee) drawn against the scale of a human diver. The sirenians were drawn by Brett Jarrett and are reproduced with permission. The human diver was drawn by Gareth Wild.

Greek mythology, who purportedly drew ships to wreck with their alluring songs.) Like most other marine mammals, the manatees and dugongs have pectoral flippers. Hind limbs are absent, with vestigial pelvic bones a reminder of their terrestrial forebears. Even though all extant sirenians have the same characteristic body plan, there are notable external differences (Table 1.2 and Figure 1.1).

The most obvious difference between dugongs and manatees is the shape of the fluke. Manatees have a spatulate fluke (Figure 1.1). Dugongs have whale-like flukes with a median notch and are more streamlined and cetacean-like than manatees, with a smooth fusiform body. Dugongs look like a cross between a walrus and a dolphin – or like a manatee that goes to

Table 1.2 *Differences in the external appearance of the three species of manatee and the dugong. Jefferson et al. (2008) provide a comprehensive guide to their identification*

Species	Adult body length	Body mass	Skin colour	Shape of tail fluke	Flipper nails	Other distinguishing features
Trichechus inunguis	2.8–3.0 m	Up to 450 kg[1]	Black; may have white belly patch	Rounded	No	Black or dark grey, often with white or pink belly or chest patches; more slender than other manatees
Trichechus manatus	Up to 3.5 m	Up to 1620 kg	Dark greyish-brown	Rounded	Yes, 3–4	
Trichechus senegalensis	Up to 3.5 m	Up to 460 kg[1]	Dark greyish-brown	Rounded	Yes[2], 3–4	Very similar to the West Indian manatee, but more slender and perhaps with slightly more bulging eyes
Dugong dugon	Up to 3.3 m	Up to 570 kg[3]	Grey-brown; old animals may have white 'scar backs'	Whale-like	No	Tusks erupt in mature males and some old females, but do not extend beyond end of premaxilla

[1] Few data on body mass are available.
[2] There are reports of animals without nails (Jefferson *et al.* 2008).
[3] There is an implausible report of one animal 4.1 m long and 1016 kg (Mani 1960).

Box 1.2. David Attenborough on the external appearance of a West Indian manatee

'On land she was not a pretty sight. Her head was little more than a blunt stump, garnished with an extensive but spare moustache on her huge blubbery upper lip. Her minute eyes were buried deep in the flesh of her cheek and would have been almost undetectable if they had not been suppurating slightly. Apart from her prominent nostrils, therefore, she possessed no feature which could give her any facial expression whatsoever. From her nose to the end of her great spatulate tail she was just over seven feet long. She had two paddle-shaped front flippers, but no rear hind limbs and where she kept her bones was a mystery for, robbed of the support of water, her great body slumped like wet sand.'

Attenborough (1956, p. 180)

the gym. Manatees are more rotund, and their bodies, especially that of the Florida manatee, often exhibit numerous folds and wrinkles. In addition, the flippers of manatees and dugongs differ. Manatees have long flexible flippers that are used to manipulate their food plants (Chapter 4). Like those of Steller's sea cow (Chapter 2), the flippers of dugongs are short and, unlike those of the West Indian and West African manatees, lack nails. Amazonian manatees also do not have nails.

Externally, the heads of the three species of manatees and the dugong are very similar: small with no discernible neck, reminiscent of the head of a walrus without the protruding tusks. The eyes are small and the external ears are tiny holes in the sides of the head. The two nostrils, located dorsally and at the cranial end of the snout, enable a sirenian to surface discreetly with only its nostrils out of the water, making the animals hard to see and census (see below and Chapter 8, especially Figure 8.1). The sirenian face is endearing but not beautiful from a human perspective, as attested by David Attenborough's description of a West Indian manatee (Box 1.2).

It is difficult to imagine how sailors mistook sirenians for seductive mermaids, especially when the sounds they make are bird-like chirps that are inaudible above water (Chapter 5). The link is likely to have been more about lust than likeness – stories abound about dugongs being used by sailors as surrogate human females. Kingdon (1971) claimed: 'To this day fishermen in Zanzibar who have caught a female dugong have to swear they have not interfered with it' (p. 198).

The most striking feature of the faces of dugongs and manatees is the fleshy oral disk, the greatly expanded region between the mouth and nose,

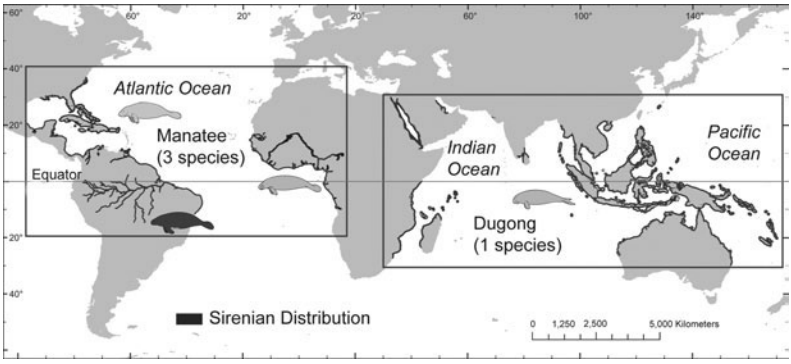

Figure 1.2. An outline of the distributions of the three species of manatees and the dugong, contrasting the Atlantic distribution of the manatees with the Indo-West Pacific distribution of the dugong. Drawn by Adella Edwards, with icons by Gareth Wild; reproduced with permission.

which is covered with vibrissae. The sirenian oral disk is an elaborate sensory–muscular complex that enables manatees and dugongs to find and manipulate food even in dark or murky environments (Chapters 4 and 5).

All sirenians have very sparse, short, fine, sensory body hairs. Roger Reep and his co-workers consider that sirenian body hairs constitute a tactile array equivalent to the lateral line systems of fish (Reep *et al.* 2002; Chapter 5), and have speculated that this may be an important aid to navigation at night and in shallow, turbid environments where visual acuity is of little value and acoustic communication limited to short distances.

Despite similarities in appearance, the three species of manatees and the dugong are unlikely to be confused in the wild, simply because their ranges have little or no overlap (Figure 1.2). All occur within the tropics, and the ranges of the Florida manatee and the dugong extend to the subtropics. The dugong occurs in the Indo-West Pacific Ocean, where its huge range spans the coastal and island waters from East Africa to the Solomon Islands and Vanuatu. Manatees occur on both sides of the Atlantic Ocean. The Amazonian manatee occurs in the freshwater systems of the vast Amazon River basin. The Florida manatee occupies coastal and riverine waters and inland lakes of the south-eastern United States. The Antillean subspecies has an extensive range from the wider Caribbean region, extending to south of the mouth of the Amazon River in Brazil, and may interbreed with the Amazonian manatee in areas where ranges abut or overlap (Chapter 3). West African manatees occur in most of the coastal marine waters, brackish

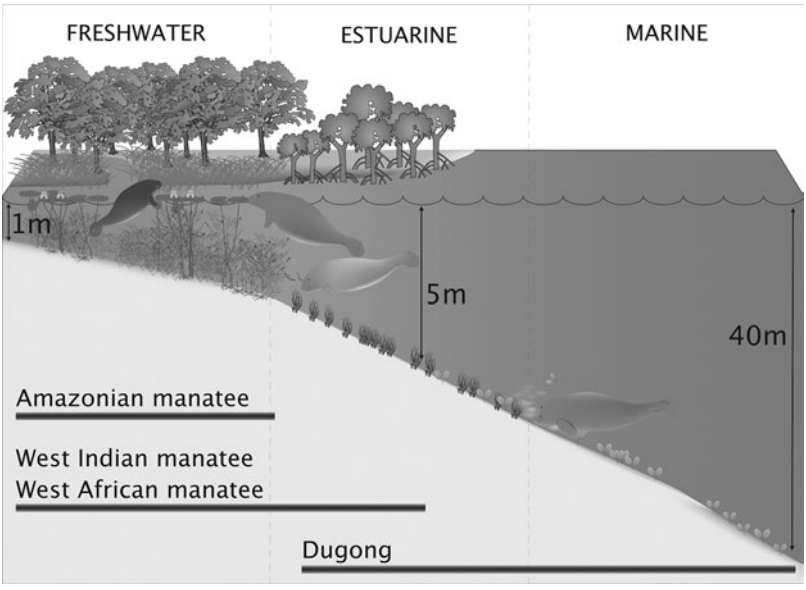

Figure 1.3. Schematic diagram illustrating the habitats and food plants of the four extant species of sirenians. Nowhere in the world do any of the four species occur together, except for the overlap in the ranges of the Amazonian manatee and the Antillean manatee near the mouth of the Amazon River. Drawn by Catherine Collier with assistance from Gareth Wild; reproduced with permission.

estuaries and adjacent rivers along the coast of West Africa from 16° N to 18° S, sometimes penetrating far inland. Chapter 8 gives further details of the ranges of each species.

The habitats of Amazonian manatees and dugongs are more specialised than those of the other two extant sirenians (Figure 1.3; Chapters 4 and 5). The dugong is marine, while Amazonian manatees occur only in fresh water, whereas West Indian and West African manatees are habitat generalists, occurring in lakes, rives, estuaries and shallow coastal waters. All four species show morphological adaptations that allow them to take advantage of the flowering plants available in their respective habitats (Chapter 4). The degree of snout deflection reflects where in the water column each species of sirenian feeds most efficiently (Domning 1982a; Domning and Hayek 1986; Chapters 3 and 4). Dugongs are benthic foragers that specialise in feeding on seagrass communities and have the most deflected snouts, whereas Amazonian and West African manatees have the least deflected snouts, a likely adaptation for feeding on natant and emergent vegetation.

The snout deflection of West Indian manatees is intermediate, reflecting their generalist foraging niche (Chapter 4). The horny plates in the mouths of manatees and dugongs help them masticate their food. Unlike almost all other mammals, manatees also have a system of constant tooth replacement, which enables them to eat plants with abrasive silica particles. In contrast, dugongs – which are considered to have the least abrasive diet of any extant sirenian – have simple peg-like molars that wear quickly. Fortunately, the dugong's last two molars are open-rooted and grow throughout life (Chapters 3 and 4).

POPULATION SIZES AND TRENDS

The first question people ask about any threatened species is: 'How many are there?' As will be explained in Chapter 8, this question has proved impossible to answer for any sirenian, even the Florida manatee, despite millions of dollars being spent over more than 30 years on research on its population biology. Scientifically defensible estimates of abundance greater than 1000 only exist for two species across five regions of the world; namely, dugongs in: (1) the Red Sea, (2) the Arabian Gulf, (3) New Caledonia, and (4) Australia; and (5) the Florida manatee. Australia is the only country where such estimates are in the tens of thousands (Chapter 8). In most developing countries, estimates of West Indian manatee and dugong populations either do not exist or are typically crude, but at best are in the low hundreds. There are no rigorously derived estimates of population sizes for Amazonian and West African manatees; only unverifiable expert opinions are available.

The second question people ask about threatened species is: 'How are they doing?' The International Union for Conservation of Nature (IUCN 2009) concluded that populations of the Amazonian and West Indian manatees are decreasing and that the population trends of the West African manatee and the dugong are unknown. Despite these uncertainties, the primary reason for categorising sirenians as at risk is not disputed. Their intrinsic rates of increase are low: less than 8% per annum (Chapter 6). Sirenians are several years old when they have their first calf; have a single offspring at intervals of several years; and experience low natural mortality rates (Chapter 6). Such species require very high and stable levels of adult survival to maintain their numbers and can sustain only very limited levels of mortality from human causes. Ways in which mortality rates might be reduced are discussed in Chapter 9.