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THE DUGONG (*DUGONG DUGON* (MÜLLER)) IN THE SEAGRASS SYSTEM

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ABSTRACT

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The distribution and ecological niche of the dugong are considered in relation to their effects on tropical seagrass ecosystems.

Features of the chemical and calorific nature of seagrasses are contrasted to those of most terrestrial plants.

Biomass levels of northern Australian tropical seagrass communities are discussed in relation to the estimated daily intake of dry matter. Implications for the species resulting from probable food limitation at any one site are considered. Effects of feeding and feeding behaviour are considered in relation to nutrient cycling in the seagrass ecosystem.

Interactions of dugongs with other users of the seagrass ecosystem particularly predators, including man, are discussed together with aspects of dugong conservation.

ECOSYSTEM RELATIONS AND INTERACTIONS WITH OTHER SPECIES

Introduction and position of the dugong in marine ecosystems

The dugong, *Dugong dugon* (Müller) (Fig. 1) is the only herbivorous mammal species that is strictly marine, and it is the only living representative of a highly specialized group of marine mammals (family Dugongidae; order Sirenia). The most closely related species, Steller's sea cow (*Hydrodamalis gigas* (Zimmermann)) became extinct in the late eighteenth century. The only other living members of the order Sirenia, the three species of manatees (genus *Trichechus* (Linn.)), differ from dugongs in structure, habits and geographical distribution. Ecologically, the dugong occupies an important position in the shallow water ecosystems along the subtropical and tropical coasts of the Indian and western Pacific Oceans.



Fig. 1. Dugong taken by aboriginal hunters near Forsyth Island, northern Queensland.

Dugongs require warm seas, as evidenced by their tropical and subtropical distribution. The results of aerial surveys being conducted in northern Queensland show that dugongs frequent shallow bays and channels which are protected against strong winds and heavy seas (Heinsohn, 1975; Heinsohn and Wake, 1976; Heinsohn et al., 1976 b and unpublished data). Extensive beds of seagrasses on which dugongs feed occur in these shallow coastal waters. The species of seagrass eaten by dugongs are generally intertidal and sub-tidal growing to a depth of 6–9.5 m below low water datum (Heinsohn and Birch, 1972).

Man is the most important predator of dugongs. In northern Australia Aboriginal dugong hunters consider that the estuarine crocodile (*Crocodylus porosus* (Schneider)), the killer whale (*Orcinus orca* (Linn.)) and large sharks prey on dugongs, particularly young ones (G.E. Heinsohn, H. Marsh and A.V. Spain, unpublished data). Due to extensive human exploitation for food and other products, the dugong is rare or in danger of extinction over most of its range (Fisher et al., 1969; Bertram and Bertram, 1973; Husar, 1975). However, recent publications (Heinsohn, 1972; Bertram and Bertram, 1973; Heinsohn and Spain, 1974) indicate that there are sizeable populations in northern Australia. Recent aerial surveys (Heinsohn et al., 1976 b; Ligon, 1976) confirm this for Queensland. The most up to date and thorough account of the present distribution and status of the dugong is given by Bertram and Bertram (1973).

Although the dugong is a unique and ecologically important marine mammal of economic value, very little definitive ecological and life history data have been collected on it in the past. Much of the published information has been hearsay and anecdotal.

Trophic relationships and food utilization

Dugongs are primary consumers, feeding almost exclusively on marine phanerogams of the families Potamogetonaceae and Hydrocharitaceae (Prater, 1928; Kingdon, 1971; Heinsohn and Birch, 1972). Marine algae are also occasionally eaten (Annandale, 1905; Hirasaka, 1932; Mani, 1960; Spain and Heinsohn, 1973), although this probably occurs when seagrasses are scarce (Spain and Heinsohn, 1973; Heinsohn and Spain, 1974). Invertebrate animals are sometimes taken. Hirasaka (1932) and Pfeffer (1963) report crabs; Spain and Heinsohn (1973), a few hydroids, holothurians and ascidians; and Wake (1975), hydroid thecae. These are probably eaten incidentally with seagrasses rather than being specifically sought after.

Heinsohn and Birch (1972) reported that dugongs feed selectively on at least six species, representing four genera, of seagrasses in North Queensland. These were identified from the stomach contents of 15 dugongs as follows: *Halodule* species (probably both *H. uninervis* (Forsk.) Aschers. and *H. pinifolia* (Miki) den Hartog, recorded as *Diplanthera*), *Cymodocea* species (probably *C. serrulata* (R.Br.) Aschers. & Magnus), *Zostera capricorni* Aschers., *Halophila decipiens* Ostenf., *H. ovalis* (R.Br.) Hook.f. and *H. spinulosa* (R.Br.) Aschers. In contrast, Wake (1975) demonstrated with limited data that dugongs did not show selectivity with regard to the species of seagrass eaten, but fed in accordance with the availability of species. Wake (1975) identified five species of seagrass from stomach content samples from three dugongs as follows: *Halodule uninervis*, *Halodule pinifolia*, *Cymodocea serrulata*, *Halophila ovalis* and *H. spinulosa*. However, Wake (1975) did observe that dugongs fed on sparsely distributed *Zostera capricorni* in preference to dense old stands of the same species in adjacent areas.

Wake (1975) carried out seagrass community studies and made dry weight biomass estimates for six study areas located on important dugong feeding grounds in tropical Queensland. The seagrass beds studied varied considerably in species composition and community structure. Standing crops of seagrasses, as shown by biomass of the entire plants, ranged from 1.37 to 277.97 g dry weight/m² for the areas studied. These values were generally lower than those obtained by H. Kirkman (personal communication, 1976) for dugong areas in subtropical Queensland. It appears that dugongs graze most heavily on seagrass beds of low density (biomass of 10–30 g dry weight/m²) in north Queensland and that their grazing activity would reduce seagrass biomass to even lower values.

The digging activities of feeding dugongs produce trails (Fig. 2) that are



Fig. 2. Dugong feeding trails in a seagrass community in Shoalwater Bay, central Queensland.

from 19 to 25 cm wide and from 1 to 5 m in length. These are usually dug to a depth of 3–5 cm (J. Wake and G.E. Heinsohn, unpublished data). Wake (1975) found that on the average 63% of the seagrasses were removed from feeding trails, although up to 86% removal occurred in some.

The quantity of food required by dugongs under natural conditions is not known, although two captive dugongs ate 50–55 kg of seagrass (wet weight)/day (Jones, 1967). This is equivalent to approximately 5.6 kg of oven dried seagrass per animal per day or slightly more than 2 tonnes/annum. Assuming a grazing efficiency of 63% and a seagrass community biomass of 94 g dry matter/m² (G.E. Heinsohn, unpublished data from Cleveland Bay, near Townsville, Qld.) an area of nearly 3.5 ha is required to support one dugong for 1 year. Higher biomass estimates of 772 g dry matter/m² were made by J. Wake (unpublished data) for seagrass communities near Thursday Island. The area required to support one dugong for 1 year is approximately 0.4 ha on this basis. However, the required area per animal would also depend on the extent of dugong movements, the amount of removed seagrass not ingested, the annual productivities of seagrasses (which are considered to be high) and on the rates of regeneration following grazing. Accurate estimates of dugong food requirements are planned.

As food for herbivores, tropical seagrasses represent, in chemical terms, a

considerable departure from terrestrial plants. Conflicting statements have been made about their nutritive value and further studies are required before they can be compared in detail with terrestrial plants. Low to moderate crude protein values (3.38–11.5%) have been recorded for seagrasses by Birch (1975) and Wake (1975). Birch (1975) also reported that seagrasses are low in phosphorus and calories. High ash levels have been recorded by Birch (1975) and Spain and Heinsohn (1973). As expected, sodium, potassium and chloride levels are substantially higher than in terrestrial plants (Birch, 1975). Murray et al. (1977) have recorded low (36%) neutral detergent fibre in seagrasses from the alimentary canal of a dugong. They report that the alimentary canal of the dugong is well adapted to digest seagrasses and obtained high apparent digestibilities of all fractions studied. Further investigations are under way on dugong digestive tract anatomy, histology and histochemistry (Marsh et al., 1977 and unpublished data).

Behavioural relations

Dugongs feed extensively on seagrasses both in the littoral and sub-littoral zones (Heinsohn and Birch, 1972; Heinsohn et al., 1976 b; P.K. Anderson, unpublished data). Their daily movements and activities are largely determined by tides and, to a lesser extent, by weather. Dugongs were only observed moving or feeding along exposed coastal areas in calm weather (Heinsohn et al., 1976 b and unpublished data).

Very little is known about seasonal movements, including possible migrations of dugongs. Evidence based on aerial surveys in Queensland (Heinsohn, 1975) indicates that dugongs undergo extensive movements. Large differences in numbers seen at different times of the year along a 230-km length of coast near Townsville, northern Queensland, and along one section of coast on northern Cape York indicate that dugongs are either nomadic or migratory (Heinsohn, 1975). It is possible that dugongs are both migratory and resident, with some animals remaining as residents in a given area and others migrating. Heinsohn (1972) suggested that there are resident populations when giving an account of the decimation by shark netting of what appears to be a local dugong population. Heinsohn and Wake (1976) suggested that, if dugongs do undergo extensive migrations along the Queensland coast, each shallow protected bay with seagrasses would be of importance to the survival of the species as a critical habitat because of the long stretches of coast that are not suitable as dugong habitats. The development of management strategies (e.g. establishment of national parks and other reserves) will depend on whether dugongs undergo long distance or local migrations. A dugong tagging program in conjunction with continued aerial surveys is being developed in north Queensland to determine the extent and nature of dugong movements.

Large herds of dugongs were reported in the past (Annandale, 1905; Prater, 1928; and Troughton, 1973). Heinsohn (1975) and Heinsohn et al.

(1976 b) reported large herds of dugongs, particularly along relatively undisturbed and uninhabited sections of the Queensland coast in 1974 and 1975.

The largest of these herds comprised more than 100 dugongs. In addition, a herd of 200 dugongs was observed (G.E. Heinsohn) in Moreton Bay off Brisbane in May, 1976. The effects of such large aggregations of dugongs would be to greatly reduce the carrying capacity of seagrass communities for other species. As shown above, single seagrass beds could not sustain the grazing pressure of such large herds for very long, and the herds would have to move constantly from one area to another. This has been substantiated for seagrass-covered sand flats near Lockhart River Aboriginal Community on Cape York by Aboriginal dugong hunters.

Effects on dugongs of natural environmental changes

Heinsohn and Spain (1974) reported on the effects of a tropical cyclone and the subsequent very heavy wet season on seagrass beds and on a population of dugongs. Severe wave action, shifting sand and low salinities caused extensive damage to seagrass communities. This resulted in a change in the diet of dugongs from seagrass alone to a mixture of seagrass and algae (Spain and Heinsohn, 1973). Further, it produced more extensive, or at least unusual, movement patterns that were reflected in a higher than usual mortality from shark netting (Heinsohn and Spain, 1974). Jones (1967) reported a great reduction in the number of dugongs along the south India coast of Palk Bay during the 10 years following a cyclone there.

Interaction of dugongs with other species of benefit to man

Dugongs interact with other species basically as a result of their effect on the species composition, structure and biomass of seagrass communities. Dugongs have both a direct effect on the seagrasses themselves and an indirect effect on other organisms, either by competing for seagrasses as food or by removing seagrasses which provide shelter and substrate.

Seagrass based food webs are largely detrital. Dead plant parts normally provide the nutrient and energy base for the detritus consumers of the ecosystem (Thayer et al., 1975). These latter, in turn, form the next layer of the energy pyramid leading to commercial fish and crustaceans. The impact of intensive grazing by large herbivores, such as dugongs and turtles, is to divert much of the secondary productivity to a grazing food chain. One consequence of this, which results from the relatively low assimilation rate of herbivores, is to stimulate, at least temporarily, nutrient cycling and energy flow. This is due to the rapid return and metabolism of a considerable proportion of the seagrass standing crop biomass as faecal and excretory products. Faecal return may, however, be lower than in many terrestrial herbivores because of relatively high digestibility of the younger, sparser seagrasses on which dugongs feed.

One further effect in areas where dugongs are present is that the standing crop biomass of seagrasses is undoubtedly maintained at a lower level than would otherwise be the case. Seagrass communities also provide shelter for small and juvenile fish and a variety of invertebrates. Young and Kirkman (1975) stated that inter-tidal vegetated areas such as seagrass beds are generally considered to be important habitats for juvenile fish and commercial prawn species (family Penaeidae). Heavy grazing by dugongs could reduce the value of seagrass communities as shelter and nursery areas for species important to commercial fisheries. In the long term, grazing would reduce the detritus that would otherwise be available for detrital chains leading to many commercially valuable food fishes. However, a given biomass of seagrass would support a higher biomass of a primary consumer such as a dugong than that of most commercial fish which are carnivores.

It is thought that marine turtles and dugongs compete for seagrass as food. Both turtles, particularly the green turtle (*Chelonia mydas* (Linn.)) and dugongs are of considerable economic value. The green turtle is known to feed extensively on seagrasses (Bustard, 1972; Hirth et al., 1973). Of the other five species of sea turtles occurring within the range of the dugong, one (the loggerhead, *Caretta caretta* (Linn.)) is known to be carnivorous and the others seem to be omnivorous (Bustard, 1972). Because the food habits of these other marine turtles do not seem to be well known, very little can be said about their competitive relationships. The green turtle is extremely abundant in Queensland waters (G.E. Heinsohn, unpublished data; C. Limpus, personal communication, 1976). Although dugongs and turtles are often seen in the same areas during aerial surveys, the largest concentrations of the two are very often separate (G.E. Heinsohn, unpublished data). Marine turtles utilize a much wider range of habitats than do dugongs. For example, turtles are commonly seen along rocky shores, along exposed sections of coasts, on coral reef flats, and around reefs and islands away from the coast, whereas dugongs mainly occur within sheltered inshore areas (Heinsohn, 1975; Heinsohn et al., 1976 b). While there are similarities in the foods taken by dugongs and green turtles, the overall feeding habits of the two species are quite different. Turtles crop and eat only the leaves of seagrasses (Hirth et al., 1973), whereas dugongs dig up and eat the entire plants (leaves, rhizomes and roots). Stomach contents of green turtles from Cape York and Torres Strait contained large amounts of algae, but no seagrasses (H. Marsh and G.E. Heinsohn, unpublished data). The less selective food preferences of turtles compared to dugongs, differences in feeding methods, and the wider range of habitats utilized by green turtles greatly restrict food competition between green turtles and dugongs.

EFFECTS OF HUMAN ACTIVITIES ON DUGONG POPULATIONS

Exploitation

Past exploitation, mainly through hunting and netting by indigenous people, has reduced dugong populations to their present low levels over most of the species' range (Bertram and Bertram, 1973). In Queensland, much of the past exploitation, which lasted into the 1960's, was commercial being primarily for dugong oil. Dugongs became legally protected in Queensland from commercial and most other forms of exploitation in 1969. With the gradual cessation of commercial exploitation over the last several decades followed by almost complete protection, southern Queensland dugong populations are said to be increasing (G. Price, personal communication, 1976). Dugongs are also legally protected in Western Australia and in the Northern Territory. However, Aboriginal people in Queensland, Western Australia and the Northern Territory are allowed to take dugongs (Figs 3 and 4) under prescribed conditions. In Queensland, the rate of dugong exploitation by Aboriginal people could be declining as traditions and hunting methods (Roughsey, 1971) are gradually lost and as the need for natural food declines (G.E. Heinsohn and H. Marsh, unpublished data). However, this could be offset through the use of modern methods, for example, the use of power boats to get to dugong hunting grounds and for pursuing dugongs. Bertram and Bertram (1973) estimate that at least 433 dugongs were taken during the 6-year period 1963--1969 at Numbulwar Community on the Rose River in the Northern Territory, Australia.

Dugongs are taken illegally in northern Australia, particularly in isolated areas. The extent of illegal hunting is unknown as poachers are rarely apprehended.

Incidental direct exploitation

Large nets set off swimming beaches, ostensibly to catch sharks for the protection of swimmers, have been responsible for killing large number of dugongs off Townsville in northern Queensland (Heinsohn, 1972; Heinsohn and Spain, 1974). The effects of shark netting at other localities along the Queensland coast have not been studied, although netting data are held by the Queensland Department of Harbours and Marine.

The accidental netting and drowning of dugongs in commercial fishing nets, in particular gill nets, could be the cause of high mortality of dugongs. Heinsohn et al. (1976 a) report on the occurrence of five accidental captures and drownings of dugongs in gill nets set by two commercial fishermen in the Townsville area in an 11-month period. The total effects of commercial netting would be almost impossible to evaluate. Other workers recognize the threat of commercial net fishing to dugongs. Bertram and Bertram (1973) state that the main cause for the scarcity of dugongs in waters around Sri



Fig. 3. Aboriginal hunter with wap (harpoon with detachable head) near Mornington Island, northern Queensland.

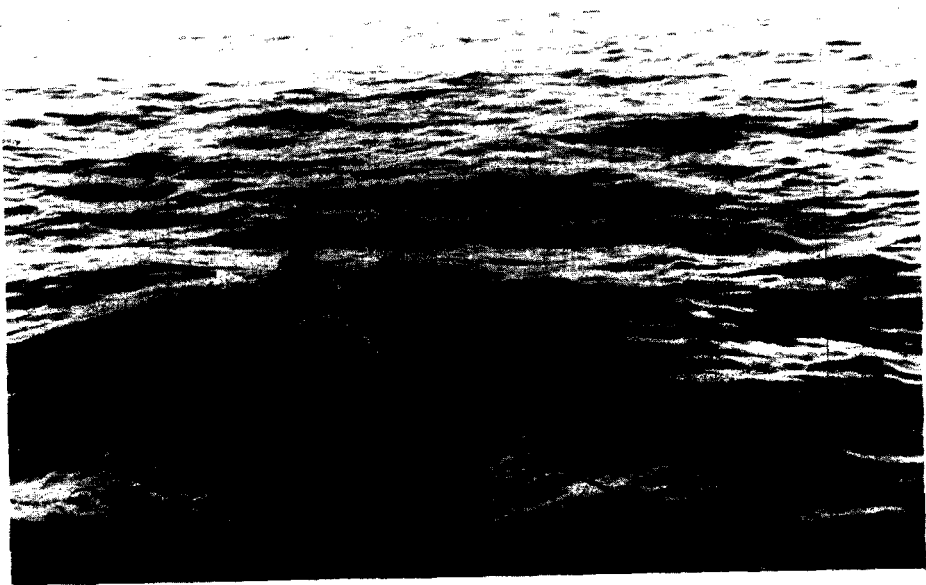


Fig. 4. Speared dugong held by detachable head and line to boat, near Forsyth Island, northern Queensland.

Lanka results from the big net fisheries in that region. P. Saw (personal communication, 1976) reports that the extensive use of shark tangle nets along the Kenya coast has greatly reduced the numbers of dugongs there.

Environmental modification

The inshore habitats, especially seagrass communities, required by dugongs are particularly vulnerable to human disturbances. Thayer et al. (1975) review human activities which are known to be or are considered to be harmful to seagrass communities in estuarine and coastal ecosystems. These are as follows: dredging and other disturbances of bottom sediments; additions of toxic and thermal wastes; certain types of commercial fishing on seagrass bottoms; commercial harvesting of seagrasses; clearing of lands for agriculture and channelling of streams which increase rates of erosion and inputs of sediments; stream diversion (e.g. dam construction and irrigation projects, which decrease freshwater runoff, thus limiting some seagrass species); spillage of oil, and sewage pollution. Dredging and other disturbances of bottom sediments increase the amount of material suspended in the water, which reduces light penetration and photosynthesis; accelerates sediment deposition, which smothers grass; changes the redox potential within sediments; and releases toxins from sediments. Sand mining for titanium and zirconium is very extensive along the east coast of Australia. Young (1975) discusses the possible consequences of sand mining on Fraser Island, southern Queensland, on seagrass communities in adjacent Great Sandy Strait, which is an important dugong habitat (Heinsohn and Wake, 1976). Young (1975) pointed out how areas of seagrass beds have been destroyed in Moreton Bay (the southernmost major habitat of dugongs in eastern Australia) through the deposition of sediments. In Cleveland Bay near Townsville, Queensland, seagrass beds have been reported to have been damaged by increased siltation resulting from harbour dredging (G.E. Heinsohn, unpublished data). Large-scale clearing of land for agriculture and overgrazing by stock has occurred in Queensland, resulting in the large-scale erosion and the deposition of sediments onto offshore areas. Large amounts of sediments resulting from mining are also carried into the sea. Seagrass beds in Hinchinbrook Channel, an important dugong habitat north of Townsville, may have been adversely affected by dredge spoil from tin mining being carried by the Herbert River during annual wet seasons.

The direct effects of toxic substances, such as pesticides and other chlorinated hydrocarbons, petroleum derivatives and heavy metals, on seagrasses are generally unknown (Thayer et al., 1975). The addition of such waste materials usually impinges more directly on animals than on primary producers. As part of a study of the long-term effects of heavy metals on marine organisms at James Cook University, the concentrations of ten heavy metals in organs from dugongs caught near Townsville have been obtained. G.

Denton (personal communication, 1976) has found iron concentrations to be very high in the dugong liver (19 620—34 600 ppm). This is comparable to liver iron values found for some other marine mammals, i.e. Antarctic seals (1 200—15 000 ppm) (Robertson et al., 1972). The high iron levels in dugong livers may be dietary as seagrasses collected near Townsville also have very high iron values of around 2 000 ppm (G. Denton, personal communication, 1976) compared with average values for terrestrial plants of around 140 ppm (Bowen, 1966). Accumulation of other heavy metals by seagrasses could have toxic effects if heavy metal pollution occurs in the sea. Effluent being dumped in the sea from a recently completed nickel refinery could result in heavy metal pollution near Townsville. Two additional threats to dugong habitats are oil spillage from tankers and drilling and thermal pollution from generating plants, both of which are known to have caused extensive damage to tropical seagrass beds (Thayer et al., 1975). Oil exploration using explosives for seismic work would also be expected to be harmful to dugongs.

Recreational boating is considered to have a disturbing effect on dugongs. Monthly aerial surveys indicate a possible decrease in the numbers of dugongs seen in Missionary Bay, a major dugong habitat north of Townsville since the opening of a resort in the area (G.E. Heinsohn, unpublished data). The resort has resulted in increased pleasure boat activity.

THE DUGONG AS A SPECIES TO BE CONSERVED AND AS A RESOURCE TO BE UTILIZED

The most important aim in dugong research and management should be to conserve the species over its entire range. In areas where dugongs are rare or close to extinction, management should be aimed at increasing population size. In northern Australia where large numbers still occur, dugongs and their habitats need to be protected from the various threats facing them, i.e. commercial net fishing, shark netting, illegal hunting, disturbance from power boats, pollution, and oil exploration and drilling. Limited traditional exploitation by Aboriginal peoples should be allowed with accompanying efforts being made to collect dugong data and specimen material. This is currently being done at Aboriginal settlements on Cape York, Mornington Island and the Torres Strait islands. Extensive marine national parks or other types of reserves should be established to fully conserve dugongs and other marine life and their habitats.

The dugong should also be studied as a source of high quality protein. Aboriginal people and Torres Strait Islanders in Australia, and indigenous people in many other coastal regions prefer dugong meat to many other kinds. In addition to palatability, the value of dugongs as a protein source depends upon several factors: (1) nutritional and trophic level production efficiencies of the dugong as compared to other edible animals that occur in subtropical and tropical seagrass ecosystems, (2) rates of reproduction and

recruitment, (3) growth rates and (4) production of meat and other useable products. The majority of animal species fished from seagrass ecosystems are carnivores dependent on detritus food chains. Therefore, in comparison with most edible fish, the dugong should be very efficient in terms of secondary productivity. The overall productivity of the dugong should be compared with other major herbivores, such as the green turtle. The reproductive and recruitment rate of the dugong is not known with certainty. Interpretation of limited aerial survey data (Heinsohn et al., 1976 b) suggests that one young per female may be produced every 2–3 years. Reproductive and ageing studies are presently being carried out at James Cook University.

Dugong growth rates also need to be accurately determined. Heinsohn (1972) constructed a growth curve and suggested that reproductive maturity is attained in 2–3 years, although Mitchell (1976) considered that it occurs somewhat later. Based on a growth curve (Heinsohn, 1972) and a weight for length curve (Spain and Heinsohn, 1975) dugongs would be expected to attain a weight of 200 kg in 2–3 years. About 20–25% of the total body weight of a dugong consists of useable meat (G.E. Heinsohn, H. Marsh and A.V. Spain, unpublished data). This compares with 30% muscle for British breeds of cattle and 35% for Brahman breeds (Springell et al., 1968).

The total biomass of dugongs in herds occurring in the Townsville area is huge. Using a mean weight of 200 kg for dugongs (Spain and Heinsohn, 1975), the total biomass of 41 dugongs caught in shark nets off Townsville in 1972 (Heinsohn and Spain, 1974) would have been about 9 000 kg, which would have consisted of 1 800–2 500 kg of useable meat.

A large amount of research is required on dugongs which should be studied as a species that could be utilized on a sustained yield basis, either through careful management of wild stocks or through aquaculture on artificially developed seagrass pastures. Research needs to be aimed at both species conservation and managed utilization. Studies in other locations, of a similar nature to those currently being conducted in northern Queensland, would be particularly valuable.

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