CHAPTER 9.
SUMMARY AND RECOMMENDATIONS

9.1. Summary

This study investigated aspects of the ecology of a sub-tropical population of dugongs. In relation to the seagrass resource, I examined the dugongs' distribution, movements, home range, habitat selection, feeding, diet and food preferences. I also considered the ways in which dugongs affect the seagrasses and the significance of their role in the seagrass system.

The Moreton Bay study areas contained 133 km² of seagrass, mostly (83%) on the eastern banks, where the vast majority of the dugongs occurred. Seven species of seagrass formed 15 recognised communities, which collapsed into five community-groups: those dominated by (1) species of Halophila, (2) Z. capricorni, broad-leaf morph, (3) Z. capricorni, thin-leaf morph, and (4) mono-specific communities of S. isoetifolium and (5) C. serrulata. Communities dominated by Halophila were the most widespread, covering 51% of the total area, but they were characterised by low biomass, and accounted for only 9% of the total standing crop of seagrass (total = 12,808 tonnes dry weight). In comparison, communities dominated by Z. capricorni broad occupied 38% of the area of seagrass, but contained 75% of the seagrass standing crop. Z. capricorni thin communities covered 10% of the area and contained 14% of the seagrass. Communities composed solely of S. isoetifolium or C. serrulata were very restricted (0.4 and 0.5% of area, accounting for 1.4 and 0.8% of standing crop respectively).

The climate of Moreton Bay (28° S) has distinct seasonal patterns, which are highly correlated with pronounced seasonal changes in seagrass abundance. There is a distinct summer/autumn peak in the abundance of shoots, above-ground biomass and below-ground biomass in most species. Only Z. capricorni has a different growth pattern, with a winter/spring growth period. Averaged across all species, shoot density changed by a factor of 1.9 (variation between species: 1.2-

2.4) between seasons of maximum and minimum abundance. Above-ground biomass changed by a factor of 2.3 (range: 1.9-2.9), as did below-ground biomass (range: 1.5-3.1).

The annual, above-ground production of seagrass within the study areas was estimated to be 41,728 tonnes dry weight, the East study area accounting for 82.4% of this total. While Z. capricorni was the dominant species in terms of biomass (57.5% of total above-ground standing crop), it was less important in terms of production, accounting for 34% of the total. Species of Halophila, however, accounted for only 20.5% of above-ground standing crop, but accounted for 36.6% of above-ground production. When below-ground productivity is considered, the contribution of Halophila species, relative to Z. capricorni is further enhanced.

Based on 28 aerial surveys, I estimate a Moreton Bay population of 600 dugongs, of which approximately 95% live in the vicinity of the eastern banks (the East study area). During the periods of tracking, the dugongs were relatively sedentary, staying within the Moreton Bay area. In winter, however, the dugongs undertook regular migrations between the feeding areas on the banks and the oceanic waters east of the Bay (15-40 km round-trip). During this period, water temperatures on the banks were usually 16-19° C, but were recorded as low as 14.7° C. At the same time, the water east of the Bay can be up to 5° C warmer. The dugongs ride the flood and ebb tides in and out of the Bay and may sometimes spend as little as 1.5 hr in the Bay feeding, during the top of the tide. Some dugongs stay in the warm water outside the Bay for days at a time in winter. During this season, the dugongs spend more time grazing areas of seagrass close to South Passage (the entry/exit to the Bay), even though these were less preferred species.

During the tracking periods (mean = 50 days) dugongs occupied an average range of 64 km^2. Partly due to their movements outside the Bay, the dugongs occupied larger home ranges in winter than other seasons. The larger ranges may have also resulted from a need to feed over wider areas during this period of low seagrass abundance. Within their home range, some of the dugongs sequentially used distinct sub-ranges, in which they concentrated their activities for periods of up to 35 days, before moving to a new area. A similar pattern was noticed for large dugong herds observed during aerial surveys: they tended to feed in the same location for periods of up to at least 31 days, before moving to a new feeding area. One tracked dugong displayed wide-ranging exploratory behaviour after abandoning one sub-range, and before adopting a second. Such behaviour may allow the dugongs to sample the nutrient status of seagrasses over a wide area before selecting a new feeding area.

Some areas on the banks were rarely, if ever used by dugongs, while other areas were persistently used. Some of the avoided areas were relatively shallow (but accessible at high tide when the aerial surveys were conducted), and almost all were dominated by Z. capricorni. Of the 8,504 dugongs sighted on seagrass during the aerial surveys, 76% were in areas dominated by Halophila. Likewise, 75% of locations from the satellite tracked dugongs on seagrass ($n = 773$) were from Halophila dominated areas. Dugongs mostly occurred in areas with relatively low seagrass biomass: 81% of sighted dugongs and 81% of locations from tracked dugongs were in areas with <50 g seagrass/m². Excluding the contribution of Z. capricorni broad (this species was often selectively avoided; see below) the mean biomass where dugongs were sighted and where tracking fixes occurred was 21.2 g/m² and 15.3 g/m², respectively. Areas dominated by Z. capricorni, S. isoetifolium or C. serrulata usually had biomass values of 100-200 g/m², and accounted for only 23% of sighting and 25% of tracking locations. Dugongs feeding in an area dominated by Z. capricorni broad frequently grazed selectively, conspicuously avoiding patches of Z. capricorni, but feeding on patches of other species (H. uninervis, S. isoetifolium, H. spinulosa or H. ovalis). When the Z. capricorni was inter-mixed with other species, it was not avoided.

Investigation of specific feeding sites confirmed that dugongs fed mostly in areas with a relatively low biomass of seagrass: median of 86.2 g/m² at 13 feeding sites (although low-biomass sites were under-represented in the sample). Of 115 herds of dugongs (containing about 4,000 dugongs) encountered by boat on seagrass areas, and presumably feeding, 63% were in seagrass classified as 'sparse', while only 10% were in 'dense' seagrass. H. ovalis was present at 89% of these sites, compared with H. spinulosa at 63%, H. uninervis at 19% and Z. capricorni at 13%.

Feeding sites were in water 1.5-2.5 m deep at high tide. Neither compaction nor mean grain size of sediments at feeding sites differed from values from randomly selected sites. However, the dugongs may avoid areas that contain a high level of shell in surface sediments. The dugongs may also adjust their feeding technique in such areas. By cropping primarily the leaves, they minimise the amount of sediment processed. This so-called surface grazing was also employed when the rhizome mat (usually of Z. capricorni) was particularly dense. Usually, however, the dugongs furrow grazed, removing shoots, rhizomes and roots.

Averaged across all species at 12 sites, grazing dugongs removed 85.6% of shoots, 90.8% of above-ground biomass, 58.5% of rhizome biomass and 25.1% of root biomass from along feeding trails. Total biomass (above- plus below-ground) was reduced by 53.1% along feeding trails, or 65.2% if sites dominated by Z. capricorni (where some surface grazing occurred), were excluded. Some species of seagrass were harvested more efficiently than others. In particular, the shoots of species with strap-like leaves (H. uninervis and Z. capricorni) were the least efficiently cropped.

Analysis of faecal samples revealed little about the dugongs' seagrass diet, due to differential digestion of species. Z. capricorni, which is the most fibrous and least digestible species, was the most abundant identifiable seagrass in the faecal samples. However, other evidence suggests that Z. capricorni is not a preferred species.

The analysis of faecal samples confirmed the findings of previous studies, that algae are not normally a significant part of the dugong's diet. Other evidence suggested that dugongs may actively avoid some algae (Caulerpa species, and some epiphytic species).

The faecal analysis revealed that ascidians are a significant component of the diet of dugongs in Moreton Bay. The stalks of the small colonial ascidian S. pulchra occurred in 69% of samples and comprised 29% of their wet weight. Mantles of solitary ascidians were found in 27% of samples and made up 20% of their bulk. Overall, ascidians were in 73% of samples and comprised 26% of the bulk of all samples. Comparable values for samples analysed from dugongs from tropical Australasia were 6.2% occurrence and 0.04% abundance. At least one dugong from Moreton Bay also fed on a colonial polychaete. There is little doubt that the dugongs fed selectively on the ascidians and polychaetes. In areas carpeted by S. pulchra, the dugongs selected for patches with high ascidian abundance, despite low seagrass abundance. Most solitary ascidians occur below the depth limits of seagrasses in Moreton Bay. Circumstantial evidence suggests that the dugongs deliberately excavated one normally buried species of solitary ascidian.

On the basis of the distribution of dugongs and feeding sites, and the selective grazing observed in several areas, it was possible to establish a preference rank of some the seagrasses. From most, to least preferred, the species were:

H. ovalis ≥ H. uninervis thin > H. spinulosa ≥
S. isoetifolium > Z. capricorni broad

Based on the nutritional composition of these seagrasses (Lanyon, 1991), it is apparent that dugongs select seagrasses primarily on the basis of high nitrogen and low fibre content. Avoidance of algae may be due to high levels of secondary compounds. The dugongs may also select for high soluble carbohydrate content during spring, as they fed on fruiting Z. capricorni thin at this time. The abundant seeds of this species are rich in soluble carbohydrate (60% compared with 15-32% in the leaves) and low in fibre (22% compared to 42-63% in leaves).

Dugongs in Moreton Bay occur in large herds. Half the dugongs seen during aerial surveys were in herds of 140 or more, and 27 of the 28 surveys of the study areas recorded at least one herd of ≥100. These herds tend to concentrate their feeding in one location for periods of days to weeks. As a result, they can reduce the abundance of seagrass dramatically (shoot density: reduced by as much as 95%; above-ground biomass: 96%; below-ground biomass: 71%) over large areas (40-75 ha). However, small tufts of seagrass shoots remain ungrazed amongst the dense network (nearly 100% coverage) of feeding trails. These tufts are an ungrazable reserve (110-120 shoots/m² in a H. ovalis meadow), which allows rapid recovery once all grazing ceases. In this regard the disturbance caused by grazing, although dramatic, differs to that caused by sedimentation, water scour, disease or other die-offs. However, even a low level of continued grazing can prevent a seagrass meadow from recovering.

Exclosure experiments demonstrated that intensive grazing by a large herd of dugongs (referred to as 'cultivation' grazing) can have significant effects on seagrass meadows. 'Cultivation' grazing can alter the species composition, the age structure and the nutrient status of seagrass meadows. As a result, relatively high biomass, mid-seral stage communities can be converted to ones of low-biomass and early seral stage. H. ovalis is advantaged by these changes, at the expense of Z. capricorni broad. This change of species results in a meadow-wide increase in nitrogen levels and decrease in fibre levels. This effect is enhanced by the subsequent increase in the relative abundance of young growth, which is characterised by low fibre and high nitrogen.

The nutritional benefits of 'cultivation' grazing can only be achieved if dugongs feed in large herds, and effect these changes over large areas. Experiments showed that individual dugongs, which feed by grazing seagrass from long narrow strips, could not disturb an area sufficiently to change the species composition. Furthermore, grazing by individuals could not concentrate regrowth sufficiently for it to be harvested efficiently. Only by feeding in large herds could the dugongs achieve a sufficient density of feeding trails, over a large enough area to effect an advantageous change in species composition.

The tendency for Moreton Bay dugongs to graze in large herds may make them unique. In no other area are dugongs known regularly to occur in large herds. The difference in herding behaviour does not appear to be related to predation levels, for although sharks were more abundant on the eastern banks in Moreton Bay following the calving season, dugongs with calves did not seek large herds for protection.

It is probable that the dugongs of Moreton Bay suffer particular nutritional stresses, especially during winter, and 'cultivation' grazing is an important component of their feeding strategy to maximise the quality of their diet. In other areas, especially in the tropics, dugongs may not suffer the same nutritional stresses, and other sources of disturbance may substitute for 'cultivation' grazing to maintain optimum seagrass meadows. Nutritional stress in Moreton Bay could result from a combination of two processes: firstly, the limitation of nitrogen availability during winter/spring, when the abundance and productivity of seagrasses, as well as the abundance of nitrogen in seagrasses, is lowest, and secondly, the effect of cold water temperatures in winter. For one quarter of each year, the water on the eastern banks is below 19° C (which other evidence suggests may be close to the threshold temperature below which dugongs cannot maintain homeostasis indefinitely), and the dugongs may be physiologically stressed. The dugongs counter this double stress of cold water temperatures and nitrogen limitation by regularly migrating out of the Bay to warm water and by maximising the quality of their diet. The latter is achieved by selectively feeding in communities and patches of favoured, nutritionally superior seagrasses, by feeding on invertebrates, and by 'cultivation' grazing.

In tropical areas, the benefits of 'cultivation' grazing may not be necessary, or relevant, in which case there may be no pressure to feed in large herds. There are three reasons why tropical areas may differ. Firstly, the nutritional stresses may not be as severe. Dugongs in tropical areas would not suffer the physiological stresses of cold water, although the availability of nitrogen may still be limiting at times. Secondly, Z. capricorni is the dominant species in Moreton Bay, but is relatively uncommon in most tropical areas in Queensland. Due to high levels of fibre, Z. capricorni is the least digestible of seagrasses so far examined from Queensland. One of the results of 'cultivation' grazing in Moreton Bay is the spatial containment of this species. If the arrest of the expansion of Z. capricorni is one of the principal benefits of 'cultivation' grazing, then it simply may not be necessary in other areas, where this species is not dominant. Thirdly, seagrasses in tropical areas experience a number of disturbances and limitations that may effectively perform the same role as 'cultivation' grazing. The combined effects of cyclones, turtle grazing, exposure (in inter-tidal areas) and turbid water may interrupt the successional development of seagrass communities, thereby maintaining large areas at low seral stages. Such areas have a relatively high abundance of pioneer species such as H. ovalis and H. uninervis thin, which are preferred species of the dugongs, and the species that most benefit from 'cultivation' grazing.

If herd formation in dugongs is density dependant, then the habit of Moreton Bay dugongs to form large herds, while those in other areas do not, may simply be due to a higher density of dugongs in Moreton Bay. There are no comparative data by which to assess the estimated density of 7.4 dugongs/km^2 on the eastern banks. However, it may well be high: a result of the concentration of dugong activity around South Passage, where the dugongs have easy access to warm water in winter. Other areas may either lack the stresses of cold water (tropics), or lack such a topographic configuration (eg. other sub-tropical areas such as Shark Bay and the Arabian Gulf).

This study has shown that grazing by dugongs can have significant ecological impacts on the seagrass system. There is evidence to suggest that by concentrating their grazing in favoured regions, dugongs may alter the composition of seagrass communities over large areas. It is suggested that grazing by dugongs is responsible for some of the spatial heterogeneity of seagrass communities on the eastern banks in Moreton Bay. The biomass and species composition of major regions of those banks is in accord with predictions of the intermediate disturbance hypothesis, with dugong grazing as the source of disturbance.

In favoured areas, like the Turtle Bank, dugongs may consume in the order of 28% of the total seagrass production. This compares with consumption levels of <3-10% of above-ground production only by grazers (invertebrates, fish, waterbirds) in other studies (excluding atypical populations of urchins). In undisturbed systems, where hunting pressure is low, green turtles are predicted to consume in the order of 20-30% of above-ground production. Previously, little attention has been paid to the role of large herbivores, such as sirenians and green turtles, in the energy flow through seagrass systems. This has occurred because most work on tropical seagrass systems has been conducted in regions with greatly depleted populations of these large grazers. Consequently, our understanding of the functioning of these systems has been based on the assumption that large herbivores do not consume a significant proportion of production, and therefore, do not play a major role in the ecology of the systems. The results of this study question those assumptions.

9.2. Conservation implications

Although this study focused on a sub-tropical population of dugongs, which may exist under a different suite of environmental constraints to those experienced by tropical populations, some findings have application beyond Moreton Bay. Some of the implications for the conservation management of dugong populations are listed below.

1. Management of dugongs, turtles and seagrass

Throughout their range, dugongs are sympatric with green turtles. Dugongs influence, and are influenced by seagrass, and presumably similar interactions occur between green turtles and seagrasses. Dugongs are listed as vulnerable to extinction, green turtles are considered endangered. The shared distribution, high conservation status and dependence on seagrass of dugongs and green turtles suggests that dugongs, green turtles and seagrasses should be managed as an ecological unit wherever possible. Generally, benefits that accrue to one taxon are likely to flow to the others. It is important, though, that management decisions are not implemented for the benefit of one at the expense of another.

2. Relative value of seagrasses

From a dugong's perspective, all seagrasses are not equal, and more is not necessarily better. Dugongs are specialised grazers that feed selectively on preferred seagrasses. A 1 km^2 meadow of high biomass Z. capricorni or

Thalassia hemprichii may be luxuriant and productive, and appear to be 'good habitat', but is unlikely to be as important to dugongs as a similar area sparsely covered with comparatively small H. ovalis or H. uninervis thin. Conservation of dugong habitat must recognise the habitat and seagrass preferences of dugongs.

3. Importance of large herds

Large herds of dugongs may have significant impacts on the structure of seagrass communities. By enhancing the nutritional status of seagrass meadows, the 'cultivation' grazing that may result from grazing by large herds is likely to increase the carrying capacity of dugongs, and probably green turtles. Protection from disturbances that may disrupt large herds, where they form regularly, should be ensured.

4. Home range and size of protected areas

Dugongs have large home ranges over which they regularly move and forage. In the Moreton Bay study, where the dugongs were tracked for $<0.3\%$ of their expected life span, they had ranges of 28-123 km^2. It is clear that for designated protected areas to be effective, they must be very large.

5. Access to warm water

At the sub-tropical edges of the dugong's range, access to warm water refugia during winter, may be important for the maintenance of dugong populations. This access should not be impeded by human activities or developments.

6. Need for more information

This study has contributed to our understanding of the habitat requirements, dietary preferences, feeding ecology, movements and home range of one dugong population. The Moreton Bay dugongs are unusual, but the extent to which they are unique is unclear, due to the lack of comparative data from other areas. This deficiency is most conspicuous for tropical areas. As these areas may be substantially different from Moreton Bay, extrapolation from the results of this study must be cautiously interpreted. The capacity of managers to make the most effective decisions for the conservation of dugongs and their seagrass system will be enhanced when we have a better understanding of the ecology of dugongs in tropical areas.

Many areas that support large populations of dugongs (eg. Starke River area, Torres Strait, Hervey Bay) also contain very large areas of deep-water seagrass beds (to 30 m), which are usually composed of Halophila species. The extent to which dugongs use these areas, and their importance to the populations is not known at this stage. Exploration of the use of, and dependence on these deep-water seagrasses promised to provide a important insight into the biology of dugongs.

9.3. Management recommendations for Moreton Bay

South-east Queensland has one of the fastest-growing human populations in Australia. Already 61% of the state's population occurs within 160 km of Brisbane, the estimated area of influence on Moreton Bay (Department of Environment and Heritage, 1991). The population of this area is predicted to grow from its 1986 total of 1.6 million to 2.2 million by 2001 and 2.6 million by 2011 (Department of Environment and Conservation, 1989). The effluent from this population, the discharges from the associated industries and the run-off from gardens, roads and surrounding farms all ends up in Moreton Bay. Furthermore, Moreton Bay is the largest navigable area of sheltered water between Hervey Bay and central New South Wales (a distance of 800 km), and hence, is a focus for recreational activities in south-east Queensland. As the regional population grows so does the recreational use of Moreton Bay.

To date there has been little conservation management of wildlife and other natural resources in Moreton Bay. With such a rapidly growing, affluent population, active management is quickly becoming essential. Management requirements for the conservation of dugongs in Moreton Bay have been discussed by Preen et al. (1992) and Marsh et al., (1990). Two over-riding recommendations are:

1. The maintenance of water quality to protect the seagrasses from enhanced algal growth resulting from eutrophication, and to protect the dugongs from contamination by oil, heavy metals and toxic chemicals.

2. The establishment of a multiple-use protected area for the management of the principal dugong habitat in Moreton Bay. The protected area should include:
   (1) the seagrass beds of the eastern banks that are the major feeding areas of the Moreton Bay population
   (2) the channels through the banks and the areas of deep water adjacent to the banks, which are used as low tide refuges and corridors to warm water in winter
   (3) the South Passage and adjacent oceanic waters to a distance of about 10 km that is the warm water refuge for the dugongs in winter.

Within the recommended, multiple-use protected area, managers need to be able to enforce conservation measures. Specific points that may need attention are developments in the Rous Channel and South Passage, control of gill-netting, disturbance of the dugong herds and the control of boat traffic.

The Rous Channel and South Passage are critical to the year-round occupation of Moreton Bay by dugongs. These areas should be protected from developments incompatible with their role in providing the dugongs access to the warm water refuge east of the Bay and in channelling warm flood-tide water to the seagrass banks during winter.

The patterns of commercial gill-netting in the East study area, during this study, did not appear to conflict with the conservation status of the area for dugongs. Generally the netting appeared to be conducted in areas that were too shallow for dugongs. I know of only one dugong that I am certain was caught and killed in one of these nets. If fishing practices change, and net entanglements become a problem, appropriate zoning may be necessary. In south-western Hervey Bay, gill-net fishers have adopted minor modifications to nets and practices that have reduced the risk of dugongs accidentally drowning in nets.

Disturbances that may disrupt the formation or maintenance of large dugong herds should be controlled. Such disturbances include boat traffic, industrial activity, hunting by urban Aborigines and harassment by the public and tourist operators.

Boats were not shown to affect the dugong's use of habitats in the East study area (section 5.4.5). This was probably because the current level of boat traffic in that area is relatively low. In the West study area boat traffic is dense and there is historical and circumstantial evidence to suggest that dugongs have been displaced from this area (section 5.4.6).

Boat traffic can also cause direct mortality through collisions with dugongs. In Florida, most living manatees bear scars from propellers (Beck et al., 1982), and it has been necessary to establish sanctuaries in areas of high boat and manatee use (Buckingham, 1990). In south-east Queensland boat registrations (excluding commercial boats, sailing boats and boats powered by less than 2.98 kW) increased by 19% between 1976 and 1979 (Curgenven and Shanco, 1982), and by 27% between 1979 and 1988 (Department of Environment and Conservation, 1989). In the Bay-side suburbs of Brisbane boat registrations increased by 47% between 1979 and 1988 (Department of Environment and Conservation, 1989).

Given these rates of increase, and the projected rate of human population growth, it is probable that active management will be required to prevent an increase in dugong mortality caused by boat strikes. Managers may need to establish 'Go-Slow' areas as the need arises. The most appropriate areas for such restrictions would be the Turtle Bank, Claire's Complex, the south-western arm of the Rous Channel and possibly the Maroom Bank. Green and loggerhead turtles would be major beneficiaries of 'Go-Slow' areas as they are frequently struck and killed by boats in Moreton Bay (pers. obs.).