CHAPTER 1.

GENERAL INTRODUCTION

1.1. Introduction

Seagrasses are one of the most common and productive coastal ecosystems in the world (Hillman et al., 1989; Thayer et al., 1984; Zieman and Wetzel, 1980). Only four large herbivores exploit seagrasses as a food source: three species of sirenia (sea cows) and the green turtle (Chelonia mydas). Only one species, the dugong (Dugong dugon), feeds almost exclusively on seagrasses throughout its range (Gohar, 1957; Heinsohn and Birch, 1972; Johnstone and Hudson, 1981; Lipkin, 1975; Marsh et al., 1982). By contrast, West Indian manatees (Trichechus manatus) and West African manatees (T. senegalensis) feed predominantly on submerged and emergent aquatic vegetation in many areas (Best, 1981; Hartman, 1979), while green turtles feed almost exclusively on algae in some places (Bjorndal, 1980, 1985).

Dugongs are large mammals (adults weigh >400 kg; Spain and Heinsohn, 1975), and, therefore, presumably consume substantial quantities of seagrass (Heinsohn et al., 1977). Consequently, extensive areas of seagrass are necessary to support sustainable populations of dugongs. Despite this dependence, little is known of the habitat and seagrass requirements of dugongs, or of the effects of their grazing on seagrass systems. This is surprising. The dugong has high conservation status (IUCN, 1990) and seagrasses are important to the productivity of many inshore marine systems (Kemp, 1983) and as habitat for a suite of commercially and ecologically important species of fish and invertebrates (Bell and Pollard, 1989; Coles et al., 1987; Howard et al., 1989; Klumpp et al., 1989).

In algal-based systems and terrestrial grasslands, grazers can have profound impacts on vegetation. Grazers in these systems have been shown to alter the distribution, species composition, structure, productivity and nutrient status of plant communities (Bakker et al., 1983; Coppock et al., 1983a; Edroma, 1989;

Hinds and Ballantine, 1987; Hunter, 1980; Hunter and Russell-Hunter, 1983; Jaramillo and Detling, 1988; Lubchenco, 1978; McNaughton, 1976, 1979, 1984, 1985; McNaughton and Georgiadis, 1986). The interactions are not all unidirectional, as patterns in vegetation can determine grazing patterns (Turner, 1989). The abundance and species composition of seagrasses also can be influenced by grazing (by herbivorous fish and urchins; Ogden et al., 1973; Tribble, 1981), so it is probable that the types of dynamic interactions that occur between plants and herbivores in other systems also occur between dugongs and seagrasses.

An understanding of the interactions between dugongs and seagrasses is necessary for the effective conservation and management of both. Such an understanding, however, relies on a sound knowledge of the general ecology of dugongs, but this information is wanting. Most of the considerable literature on the biology of dugongs has been derived from carcasses, remote censusing, or interviews with fishers and traditional hunters (eg. distribution [see references in Chapter 5]; life history parameters [see references in section 1.2]; anatomy [Gohar, 1957; Hill, 1945; Lanyon, 1991; Spain and Heinsohn, 1974, 1975; Spain et al., 1976]; nutrition [Lanyon, 1991; Murray et al., 1977], diet [see references in section 6.6.2] and ethno-biology [Bradley, 1991; Jarman, 1966; Johannes and MacFarlane, 1991; Nietschmann, 1977, 1984; Olewale and Sedu, 1982; Smith, 1987]). There have been relatively few attempts to study live dugongs in the field (Aragones, 1990; Anderson and Birtles, 1978; Anderson, 1982b, 1986; Barnett and Johns, 1976; Marsh and Rathbun, 1990). The reason is clear: dugongs are very difficult animals to study in the wild. To quote Bertram and Bertram's seminal paper (1973, p. 302):

> "...indubitably now the Sirenia are among the most difficult to see
> of all large mammals for the purposes of actual observation. This
> applies equally to dugongs and to manatees: the animals today are
> extremely surreptitious in their movements, strongly allergic to
> noise and in practice almost always invisible."

Add to these characteristics the logistic difficulties of working on the spatial scale used by dugongs (tens of kilometres) in often turbid waters, and some of the challenges can be appreciated.

As a consequence of the low number of field studies, most aspects of the ecology and behaviour of dugongs, including their interactions with seagrasses, are poorly known. This dearth of information is evidenced by the frequent reference to old and often anecdotal publications in this thesis and in most papers on dugong biology.

The principal objective of this study was to investigate the interactions between dugongs and seagrass. However, because of the paucity of baseline ecological data, that objective had to be set within the framework of a broad ecological study. Hence, the main ancillary objectives of the study were:

1.   To document spatial patterns of seagrass species and abundance over the area used by the dugongs.

2.   To document temporal patterns in seagrass abundance.

3.   To determine the fine scale spatial distribution of dugongs over a range of time scales.

4.   To identify movement patterns at the individual and population levels.

5.   To determine the size and other characteristics of the home range of dugongs

6.   To identify the determinants of habitat selection by dugongs.

7.   To investigate the causes of gregariousness in dugongs.

8.   To determine the diet and food preferences of dugongs.

9.   To examine the methods and strategies of feeding.

10.   To investigate the effects of grazing by dugongs on seagrasses.

As well as contributing to the conservation and better management of dugongs and seagrass systems, it was hoped that an understanding of the ecological role of the dugong may provide insights into the functioning of seagrass systems in other areas that now lack such large herbivores. In some regions, hunting pressure has reduced the abundance of green turtles by orders of magnitude (Bjorndal, 1979, 1980), and there may have been similar declines in the abundance of sirenians in some areas (Bertram and Bertram, 1973; Caldwell and Caldwell, 1985; Lefebvre et al., 1989; Thornback and Jenkins, 1982). Consequently, the seagrass communities in these locations may now be quite different from when they were

subjected to the grazing pressure of these large herbivores (Bjorndal, 1980; Thayer et al., 1984).

Moreton Bay was chosen as my study area for several reasons: (1) the main seagrass banks in the east of the Bay are characterised by relatively clear water, (2) the area is well serviced with the necessary logistic support (particularly, readily available aircraft) and (3) the dugong population lives on the door-step of Brisbane and within the recreational waterway of south-east Queensland, one of fastest growing human population centres in Australia. Consequently, the need for information for management purposes was acute.

Moreton Bay is also at the southern edge of the dugong's range. In this regard, the Moreton Bay population may be considered an outlier, unrepresentative of the bulk of tropically-distributed dugong populations. Alternatively, by virtue of its relatively simple seagrass system and strong environmental gradients, Moreton Bay provides the opportunity to clarify issues that may be intractable in the tropics, where seasonal patterns are more complex (Jones, 1987) and seagrass communities more diverse (Poiner et al., 1989).

1.2. Background literature

1.2.1. The dugong

1.2.1.1. Taxonomy

The dugong (Dugong dugon) is the only surviving representative of a small, highly specialised group of marine mammals (family Dugongidae, order Sirenia), and the only herbivorous mammal that is strictly marine. The most closely related species, Steller's sea cow (Hydrodamalis gigas, family Dugongidae), was exterminated by sealers in the late eighteenth century (Domning, 1978). The other living members of the Sirenia, the manatees (family Trichechidae) are usually closely associated with, and may be dependent on, fresh water (Reynolds and Odell, 1991). The West Indian and West African manatees (respectively Trichechus manatus and T. senegalensis) often occur in estuarine and marine

areas (Lefebvre et al., 1989; Reynolds and Odell, 1991), but the Amazonian manatee (T. inunguis) occurs in fresh water only (Domning, 1980).

1.2.1.2. Morphology and physiology

Dugongs have been reliably measured to a maximum length of 3.31 m (Nishiwaki and Marsh, 1985). An empirical weight for length curve, based on 44 animals from north Queensland, indicates that a 3 m-long adult dugong would weigh nearly 420 kg (Spain and Heinsohn, 1975). The asymptotic length of females tends to be slightly greater than that of males (Marsh, 1980). There is minimal sexual dimorphism, although tusk-like incisors erupt in mature males and some very old females (Marsh, 1980).

The dugong is a hindgut fermenter (Murray et al., 1977). The three species of manatee, which are also hindgut fermenters, have a large number of enamelled bilophodont teeth with enamelled edges (Domning, 1982; Domning and Hayek, 1984), consistent with the need for hindgut fermenters to maximise the release of the cell contents of plant tissues (Lanyon, 1991). The dugong, by contrast, has little dental specialisation, and thus, appears to be atypical of most hindgut fermenters. Dugongs have simple peg-like cheekteeth, composed of layers of soft degenerative dentine, which, as a function of body size, are extremely small compared to other hindgut fermenters (Lanyon, 1991). However, the soft mouthparts of the dugong are highly modified, displaying great development of the horny palatal pad, tongue and associated skull parameters, such that the entire oral cavity may function to crush seagrass (Lanyon, 1991).

The physiology of the dugong has not been studied, but is expected to be generally similar to that of the manatees. Manatees have exceptionally low metabolic rates: 17-36% of the values predicted from body weight (Irvine, 1983; Gallivan and Best, 1980). Perhaps as a consequence, manatees have limited thermoregulatory abilities and are restricted to waters warmer than 20-22° C for all but short periods (Gallivan and Best, 1980; Gallivan et al. 1983; Irvine, 1983). The distribution of dugongs, relative to water temperature, suggests a similar sensitivity to water temperature (Anderson, 1986; Marsh et al., 1991;

Preen, 1989a).

1.2.1.3. Life history

Dugongs have a maximum longevity of about 70 years (Marsh, 1980, 1986; Marsh et al., 1984a), a minimum pre-reproductive period of 9-10 years and a calving interval of 3-7 years (Marsh 1986; Marsh et al., 1984a, 1984b, 1984c). Single calves are born after a 13-14 month gestation (Nishiwaki and Marsh, 1985). In north Queensland, calving is diffusely seasonal, most calves being born from September through December (Marsh et al., 1984a).

1.2.1.4. Distribution, abundance and status

Dugongs occur unevenly throughout the shallow near-shore waters of the Indian and west Pacific Oceans. Their distribution spans some 40 countries between latitude 27° north and south, and ranges from Mozambique in the west to Vanuatu in the east (Husar, 1975; Nishiwaki and Marsh, 1985; Thornback and Jenkins, 1982). The essentially tropical nature of this distribution is probably dictated by the dugong's presumed low metabolic rate and limited thermoregulatory capacity. Dugong distribution within this region is probably determined by the availability of suitable seagrass and other habitats, as well as hunting pressure.

Dugongs were long thought to be rare or endangered throughout most of their range (Bertram and Bertram, 1973; Heinsohn et al., 1977; Husar, 1975), however, recent improvements in aerial survey methodology (Marsh and Sinclair, 1989) are resulting in a reassessment of their abundance. Populations of over 5,000 dugongs have been estimated for the Arabian Gulf (Preen, 1989a) and several areas in Australia: the northern Great Barrier Reef (Marsh and Saalfeld, 1989), Torres Strait (Marsh and Saalfeld, 1991), the southern Gulf of Carpentaria (H. Marsh, pers. comm.), the western Gulf of Carpentaria (Bayliss and Freeland, 1989), the northern Northern Territory (Bayliss, 1986) and Shark Bay (Marsh et al., 1991).

Despite the abundance of dugongs in these areas, the future of the species is not assured. It is not known whether censused populations are stable, increasing or decreasing, and due to the low reproductive potential of dugongs, they remain vulnerable to hunting pressure or habitat disturbances. With the most optimistic schedule of reproduction and juvenile mortality, an adult survivorship of about 90% per year is required for population maintenance (Marsh, 1986). Dugongs have been exterminated from some areas (Husar, 1975), and populations are believed to have been reduced, primarily by hunting, in others (Nishiwaki and Marsh, 1985). Due to the inherent difficulties in censusing dugongs, it may be impossible to detect a significant decline in smaller populations until they are all but extinct (H. Marsh, pers. comm.; see also Taylor and Gerrodette, in press). As a consequence, the dugong is listed as vulnerable (likely to become endangered if circumstances do not change) by the World Conservation Union (formerly the International Union for the Conservation of Nature and Natural Resources; IUCN, 1990).

1.2.1.5. Movements and home range

Despite a suggestion by Ligon (1976) that herds of dugongs may migrate from the east to the west coast of Cape York, Queensland, there is no evidence that dugong populations undertake such large scale migrations (hundreds of kilometres; Marsh, 1989a). In Shark Bay, at the southern limit of the dugong's range in Western Australia, population movements between preferred habitats (tens of kilometres) correlate with seasonal changes in water temperature (Anderson, 1986; Marsh et al., 1991). In northern Queensland, a pubertal male dugong travelled between two bays about 140 km apart on three occasions during 63 days of tracking (Marsh and Rathbun, 1990). However, five other male dugongs stayed within 22 km of their capture site during the 32-483 days of tracking. Home ranges (MAP 0.95; D.J Anderson, 1982) ranged from 5.2-23.1 km² (Marsh and Rathbun, 1990).

1.2.1.6. Habitat requirements

Our understanding of the habitat requirements of dugongs is based largely on the distribution of dugongs observed during aerial surveys. Hence, it is necessarily coarse grained. Dugongs are most commonly sighted in bays, shallows and reef areas that are protected from wave action and where seagrasses are abundant (Heinsohn et al., 1977), but they have also been sighted in 37 m of water, up to 58 km from shore (Marsh and Saalfeld, 1989). Dugongs may have limited diving capacity (Marsh et al., 1978), thus confining their feeding to relatively shallow areas. This is unlikely to be restrictive, however, as light attenuation limits most seagrasses to relatively shallow waters (<30 m; Duarte, 1990) and the biomass of seagrass is usually greatest in water <10 m deep (eg. Coles et al., 1987).

There is limited evidence that dugongs may have specific habitat requirements for courtship (Anderson, manuscript) and for giving birth (Marsh et al., 1984a).

1.2.1.7. Food

Dugongs feed on a wide variety of tropical and sub-tropical seagrasses (Gohar, 1957; Heinsohn and Birch, 1972; Johnstone and Hudson, 1981; Lipkin, 1975; Marsh et al., 1982). Algae may also be consumed (Annandale, 1905; Hirasaka, 1932; Johnstone and Hudson, 1981; Lipkin, 1975; Mani, 1960; Marsh et al., 1982), especially when the abundance of seagrass is low (Spain and Heinsohn, 1973). Macro-invertebrates have been recorded in samples of stomach contents from dugongs (Hirasaka, 1932; Lipkin, 1975; Spain and Heinsohn, 1973; Wake, 1975). Macro-invertebrates have usually been considered to have been ingested incidentally, although observations by Anderson (1989) raise the possibility of deliberate consumption.

1.2.1.8. Food preferences

All the studies of the dugong's diet have been based on stomach or mouth samples collected from carcasses. In the absence of information on seagrass availability, these studies have provided measures of usage, but not preference

(Johnson, 1980). Many authors have noted, however, that dugongs appear to select smaller, relatively delicate seagrasses (Heinsohn and Birch, 1972; Lipkin, 1975; Marsh et al., 1982; Wake, 1975). Dugongs appear to prefer to feed on low-biomass rather than high-biomass beds of Z. capricorni (Anderson and Birtles, 1978; Wake, 1975).

1.2.1.9. Feeding behaviour

When feeding on smaller seagrasses, dugongs excavate both the leaves and rhizomes. Their foraging produces feeding trails that are 19-25 cm wide, 3-5 cm deep and up to 8 m (usually 1-5 m) long (Anderson and Birtles, 1978; Heinsohn et al., 1977). On average, 63% (but up to 86%) of seagrass biomass is removed along feeding trails (Heinsohn et al., 1977). When feeding on a large, temperate seagrass (Amphibolis antarctica), only the leaf clusters at the ends of the long wiry stems are eaten (P. K. Anderson, 1982b).

1.2.1.10. Effects of grazing

Based on the daily consumption of two captive dugongs (which may have been incorrectly interpreted, see Appendix 7.1.1) and rough estimates of wet weight:dry weight conversion, Heinsohn et al. (1977) estimated that a single dugong may consume >2 tonnes dry weight seagrass/year. Assuming a grazing efficiency of 63%, this was translated to areal requirements of 0.4-3.5 ha/dugong/yr, depending on seagrass biomass (Heinsohn et al., 1977). Heinsohn (1981) suggested that the dugongs' destructive grazing may increase the diversity of seagrass communities by maintaining a number of seral stages, however, this hypothesis has not been tested (Lanyon et al., 1989).

1.2.2. Seagrasses

1.2.2.1. Taxonomy

Seagrasses are the only vascular plants that can complete their life-cycle fully submerged in a saline environment (Kenworthy et al., 1988). There are 48-55

species of these grass-like flowering plants found in the shallow-water coastal areas of the world (excluding Antarctica; Larkum and den Hartog, 1989; Phillips and Menez, 1988). All seagrasses are monocotyledons and are placed in one of two families: Potamogetonaceae (nine genera) and Hydrocharitaceae (three genera). Except for Zostera (10 species), Halophila (11 species) and Posidonia (5 species), most genera have relatively few species (Phillips and Menez, 1988).

1.2.2.2. Distribution

The distribution of seagrasses is uneven. The greatest concentration of species occurs in the Malesia region (Indonesia, Borneo and New Guinea), where up to 12 species can be present at any one location. By contrast, there is a paucity of seagrasses on the South American continent and along the west coast of Africa (Larkum and den Hartog, 1989). Along the east coast of Australia, species diversity follows a latitudinal gradient, ranging from 14 species in the Torres Strait (10° S; Coles et al., 1989) to 6 species in the south-east (38° S; Larkum and den Hartog, 1989). There are seven species of seagrass in Moreton Bay.

1.2.2.3. Ecological role

Seagrasses tend to develop extensive underwater meadows on muddy or sandy substrates. These meadows can have productivities that rival cultivated crops (Thayer et al., 1975). Organic matter derived from seagrass production is transfered to secondary consumers by (1) direct consumption by herbivores, (2) consumption of dead particulate matter by detritivores and (3) uptake of dissolved organic matter by micro-organisms (Thayer et al., 1984).

Under most circumstances, the role of grazing has been considered to be relatively unimportant (Thayer et al., 1984), largely due to the relatively small number of herbivores that feed directly on seagrass. McRoy and Helfferich (1980) compiled a list of 154 species, mostly fish and invertebrates, that consumed living seagrass, although the diets of nearly half of these species consisted of <10% seagrass.

Grazing intensity may vary substantially between regions. Seagrass grazers are more important in the tropics than in temperate areas (Bell and Pollard, 1989; Thayer et al., 1984). The Caribbean is acclaimed for its abundance of seagrass-grazing reef fish and sea urchins (Bjorndal, 1980; Ogden, 1976; McRoy and Helfferich, 1980), although there are few comparative data from other tropical seagrass systems (Klumpp et al., 1989). In some areas, such as Torres Strait, green turtles and dugongs are abundant (Limpus and Parmenter, 1986; Marsh and Saalfeld, 1988, 1991), while in other areas the abundance of large seagrass grazers (green turtles and sirenians) has been greatly reduced in historical times (Bertram and Bertram, 1973; Bjorndal, 1980; Caldwell and Caldwell, 1985; Lefebvre et al., 1989; Thayer et al., 1984; Thornback and Jenkins, 1982).

In most macrophyte systems (kelp beds, salt marshes, mangroves, terrestrial forests), <10% of the carbon fixed by large plants is consumed directly (Klumpp et al., 1989 and references therein). Few detailed studies of the partitioning of primary production and consumption in seagrass systems have been attempted. In the Caribbean, where seagrass herbivory is prevalent, no more than 10% of primary production is usually cropped (Ogden, 1980; Bjorndal, 1980). In the Zostera beds of northern Europe, only 4-8% of production is grazed (Nienhuis and Groenendijk, 1986), while just 3% of the annual production of Posidonia beds in south-eastern Australia is consumed by grazers (Kirkman and Reid, 1979).

In temperate seagrass systems, energy transfer occurs mainly by detrital pathways (dissolved organic carbon is classified as detritus; Kirkman and Reid, 1979; Klumpp et al., 1989; Poiner et al., 1992). Most detritus is consumed by bacteria, which are the basis of primary and secondary chains of consumers including protozoans, meiofauna, invertebrates (crustaceans and molluscs) and fish (Klumpp et al., 1989 and references therein; Poiner et al., 1992).

Seagrass beds contain other sources of primary production, and these can make significant contributions to the trophic base of the system. Surfaces of seagrass leaves typically carry a diverse assemblage of periphyton comprising diatoms, bacteria, fungi, macro-algae, encrusting algae and debris. The periphyton

effectively use the dissolved organic matter that is exported by the seagrasses (Moriarty and Pollard, 1982). Periphyton production is thought to average 20% of the total seagrass-epiphyte complex, and supports heavy grazing, perhaps 80% of total algal production. The periphyton may supply more carbon into the food web than living seagrasses (Klumpp et al., 1989). Unattached macro-algae and benthic algae may also contribute significantly to the net productivity of the seagrass system (Klumpp et al., 1989).

1.2.2.4. Seagrass as a food source

The value of seagrasses as a food source is a function of their abundance, the digestive strategy of the grazer and the chemical composition of the plant components (Lanyon, 1991; Thayer et al., 1984). Dugongs are hindgut fermenters (Murray et al., 1977), and hence, are adapted to utilise the cell contents, rather than the cell wall components of plants (Lanyon, 1991). Due to their unspecialised dentition, Lanyon (1991) believes that dugongs have specialised on a low fibre diet.

Critical comparisons of the chemical composition of different seagrasses is not possible between studies due to the wide variety of non-comparable analytical techniques used (Thayer et al., 1984). Lanyon (1991) found that seagrasses are generally low in total nitrogen, fibre (NDF) and lignin, compared with most terrestrial grasses, and that there are significant differences between species and between seasons within species. In the context of the dugong's digestive structure, some seagrasses are nutritionally superior to others (higher nitrogen content, lower fibre content). Of the seagrasses occurring in Moreton Bay, H. ovalis and H. uninervis (thin-leaf morph) have low levels of fibre and high levels of total nitrogen, while Z. capricorni contains high levels of fibre. Seagrass leaves generally have higher fibre and nitrogen levels, and lower levels of tannins and carbohydrates than the rhizomes and roots.

The nutrient content of seagrass leaves is a function of their age and degree of epiphyte cover. The nitrogen content is highest in fresh, green leaves. As the leaves grow, they become covered in epiphytes and the C/N ratio rises (Harrison

and Mann, 1975; Zieman et al., 1984). Lignin increases with age in the leaves of some seagrasses, with a corresponding drop in the digestible cell contents (Bjorndal, 1980).

1.2.2.5. Responses of seagrasses to grazing

Seagrasses increase the level of nitrogen and decrease the level of lignin or ash in new leaves in response to cropping or clipping experiments (Bjorndal, 1980; Dawes and Lawrence, 1979; Thayer et al., 1984; Zieman et al., 1984). Green turtles exploit this response by recropping particular feeding areas. Thus they maintain the seagrass leaves at a young stage, with high nitrogen and low fibre levels (Bjorndal, 1980; Ogden et al., 1980; Thayer et al., 1984).

Grazing by fish and sea urchins can change the abundance and species composition of seagrass meadows. Halos of low seagrass biomass surrounding patch reefs result from 'over-grazing' by fish and urchins (Ogden et al., 1973). Where this grazing is selective, concentric zones of different seagrass species can develop (Tribble, 1981).

Zieman (1976) documented the effects of boat propeller trails, that resembled long feeding trails of dugongs, in a climax seagrass community (Thalassia testudinum). Due to changes in the rhizosphere, the seagrass recolonised the trails very slowly (2-5 years). Because grazing dugongs and manatees feed on the leaves and rhizomes of seagrasses, thus disturbing their rhizosphere, Thayer et al. (1984) speculated that grazing by sirenians would have a more acute and long-term affect on seagrasses than grazing by green turtles, which crop the leaves only. Grazing by manatees has not been found to have any significant short-term impact on the regrowth of seagrass shoots. Most of the 1 m² grazed plots monitored by Lefebvre and Powell (1990) recovered substantially within one growing season.

1.3. Thesis outline

In Part 1, I describe and quantify the physical and biological environment of

Moreton Bay, particularly those aspects expected to be most important to the dugongs. Chapter 2 details the climate, sediments and bathymetry of the study areas. In Chapter 3, seagrass communities are identified and the spatial distribution of seagrasses is mapped in terms of communities and biomass. The seasonal patterns in seagrass abundance are documented in Chapter 4.

The biology of the Moreton Bay dugong population, in relation to the described environmental parameters, is examined in Part 2 of this thesis. The results of satellite tracking and aerial surveys are addressed in Chapter 5. These data elucidate the movements (short-term and seasonal), and the selection of habitats by both individual dugongs and the dugong population. Chapter 6 deals with the feeding ecology of dugongs in Moreton Bay. Aspects addressed include the characteristics of feeding sites, methods of foraging, diet and food preferences and the effects of grazing on the seagrass communities. In Chapter 7, I return to the results of the aerial surveys to examine the gregariousness of Moreton Bay dugongs, a characteristic that relates to their feeding ecology. Chapter 8 considers the ecological significance of dugongs, and other large herbivores in the seagrass system. Chapter 9 summarises the major findings of the study. Conservation implications are discussed and management recommendations presented.

To facilitate cross-referencing between chapters, tables and figures have been compiled at the end of each chapter.

Throughout the thesis I compare and contrast the results from sub-tropical Moreton Bay with what is known from tropical areas, where the vast majority of dugongs are found. I also relate my results to what is known of the Florida sub-species of the West Indian manatee (T. m. latirostris) whenever possible and appropriate. There are many parallels between the behaviour and ecology of these two species (Anderson and Birtles, 1978; Bengtson, 1981; Hartman, 1979; Nishiwaki and Marsh, 1985; Preen 1989b; Rathbun and O'Shea, 1984). However, many aspects of manatee ecology are also poorly known, so I draw on the literature on large, herd-forming mammalian grazers, which I view as terrestrial analogues of dugongs.