Part 1

Synthesis

STRUCTURE OF THE REPORT

This report outlines the results of a research program conducted between 1984 and 1988. The program aimed to investigate the biology of dugongs and other large vertebrates within the GBR region, as a basis for the development of effective management strategies.

The report consists of five parts of which this is the first. This part is a synthesis of the results of the project in the context of our knowledge of dugong biology. It evaluates the current status of the dugong in the GBRMP, and makes recommendations for future research, monitoring, and management.

Parts 2 and 3 are collections of the papers and reports that have resulted from the project. Most of the papers are either in press or in review. Part 2 comprises the results of the dedicated aerial surveys. There are two papers on aerial survey methodology (Marsh and Sinclair, manuscripts a and b); two papers and a report on the distribution and abundance of dugongs in the northern and southern regions of the GBR region (Marsh and Saalfeld, manuscripts a and b), and adjacent Torres Strait (Marsh and Saalfeld, 1988); and a paper on the distribution and relative abundance of sea turtles in the northern GBR (Marsh and Saalfeld, in press).

The remaining papers and report are in Part 3: a paper on dugong movements and habitat usage based on conventional and satellite telemetry (Marsh and Rathbun, manuscript), a paper on the management of traditional dugong hunting in the Park (Smith and Marsh, in press), and a report on the incidental sightings of dugongs in the Great Barrier Reef region (Spencer, manuscript).

Part 4 is a collection of maps illustrating the distribution of dugongs and seagrasses within the GBR region, and the distribution of sea turtles in the northern GBR. Part 5 contains the raw data from the aerial surveys, and the computer programs used in the aerial survey data collection, processing and analysis. A copy of the raw data has also been included on a floppy disk in Word Perfect 4.2 format.

The aerial surveys yielded data additional to the material covered in this report. Sightings of sea turtles, cetaceans and sea snakes were recorded on all surveys. I have obtained funding from James Cook University to process the remaining sea turtle data, and have additional funding from the GBRMPA to process the valuable baseline information on cetacean distribution and abundance.

5. Research

The GBRMPA should encourage research using an expanded program of satellite and conventional telemetry to monitor the movements of individual adult dugongs to determine whether they use specialized mating and calving areas. The initial phase of this research should be carried out in a clear water area such as Moreton Bay near Brisbane. The research should then be extended to key areas in the Far Northern Section of the Park. It would be particularly useful if time-depth recorders could be attached to the radio-tracked animals to document the proportion of time individual dugongs spend at the surface, so that the proportion of animals which are unavailable to observers due to water turbidity can be estimated more accurately.

The GBRMPA should fund research to maximize the information obtained form the dedicated surveys carried out to date. In particular, the valuable baseline information on the distribution and abundance of cetaceans and sea snakes should be analyzed and synthesized.

The GBRMPA should fund research to check the extent of the seagrass beds in important dugong habitats, particularly those in the Starcke River and Port Newry areas.

Natural mortality

Population models indicate that natural mortality must be low for a dugong population to be sustained (Marsh, 1986). There is little information available on causes of natural mortality and no information as to their relative importance. Dugongs bearing scars indicating that they have experienced and survived attacks by large sharks are occasionally sighted (Anderson, 1979; personal observation), and fatal shark (Patterson, 1939; Bradley in Marsh *et al.*, 1984c) and crocodile (unpublished data, 1988) attacks on dugongs have been observed in northern Australia. Storm surges associated with cyclones, such as that which devastated Bathurst Bay in 1899, can strand large numbers of dugongs (Marsh *et al.*, 1986); fortunately such events are probably rare.

Food and Feeding

Dugong food and feeding ecology have been reviewed by Lanyon *et al.*, (in press). Analyses of stomach and mouth contents indicate that seagrasses (families Potamogetonacae and Hydrocharitaceae) are their staple food and that they consume a wide variety of tropical and sub-tropical species. The genera eaten by dugongs in the GBRMP include *Halodule*, *Halophila*, *Cymodocea*, *Thalassia*, *Enhalus*, *Syringodium* and *Zostera* (Marsh *et al.*, 1982). *Thalassodendron*, the other genus which occurs in the Park, is eaten by dugongs in Torres Strait (Nietschmann, 1984) and probably in the GBR Region as well.

It is not known how selective dugongs are in choosing food. Marsh *et al.* (1982) found that *Halodule* (95% of stomachs), *Halophila* (89% of stomachs), and *Cymodocea* (61% of stomachs) are the genera most commonly found in dugong stomachs in north Queensland. These are also the most common seagrasses found in the shallow inshore waters of the GBR (Coles *et al.*, 1987) where most dugongs have been sighted during aerial surveys (Marsh and Saalfeld, manuscript a and b). When seagrasses are abundant, dugongs eat algae often but only in small amounts (% of food volume) and probably incidentally.

When feeding on soft and delicate seagrasses such as *Halodule* and *Halophila*, dugongs dig up the whole plant including the rhizomes leaving a distinctive feeding trail on the seagrass bed and causing a silty plume to form in the water (Heinsohn, *et al.*, 1977; Anderson and Birtles, 1978).

Diving behaviour

As bottom feeders, dugongs spend little time at or near the surface, although most animals surface to breathe at frequent intervals. Anderson and Birtles (1978) timed dives in Shoalwater Bay where dugongs were digging up whole seagrass plants. The mean time for each dive was 73.3 sec with a maximum of 400 sec. Marsh and Rathbun (manuscript) obtained similar dive times for a dugong tagged with a conventional radio-transmitter; on average this dugong spent 3.2% of its time at the surface during their (daytime) observations. The radio-tracking studies indicate that dugongs spend much more time at the surface at night (Marsh and Rathbun, manuscript).

Given their essentially coastal distribution and dependence on seagrass for food, it is doubtful that dugongs dive to any considerable depth. The deepest dive that I know of is an anecdotal account of a diver meeting a dugong in 20m of water in a bed of *Halophila spinulosa* in western Torres Strait (T. Skewes in Marsh, 1988). *Halophila decipens* is the only seagrass recorded at depths of greater than 11m in the GBR lagoon (Coles *et al.*, 1987) where it has been recorded at depths of 68m (P.K. Arnold in Lanyon, 1986). During aerial surveys in the GBR region, I have observed dugongs near the surface in water up to 37 m deep (Marsh and Saalfeld, manuscript a).

Movements

As detailed by Marsh and Rathbun (manuscript), techniques were developed during this project for tracking individual dugongs using buoyant, tethered, conventional and satellite radio transmitters, and

subsequently applied to six dugongs caught in the GBR region. The dugongs (one immature, one pubertal and four mature males) were caught by bull-dogging or hoop-netting and tracked for between one and 16 months.

All spent most of their time in the vicinity of inshore seagrass beds using overlapping home ranges of 4 to 23 km^2. The only dugong to undertake long-distance movements was the pubertal male which journeyed between core areas in two bays about 140 km apart three times in nine weeks, completing the journey in as little as two days. One of the adult animals made several journeys about 10 km up the tidal reaches of a creek. The results of the two dedicated aerial surveys of the region between Cape Bedford and Cape Melville also indicate that dugongs undergo local movements (Marsh and Saalfeld, manuscript a).

These results support the GBRMPA's policy of conserving dugongs by giving a high level of protection to some inshore seagrass beds that support large numbers of animals. However, the results also indicate that it is important that such areas extend to both the seaward and landward margins of the seagrass beds. For example, the movements of dugongs monitored by satellite in the Starcke River region showed that the Scientific Zone is too close to the coast to give adequate protection to the dugongs (Figure 1). One animal made several journeys 10 km up the tidal sections of an adjacent creek, indicating the need for complementary zoning of the coastal areas in Queensland adjacent to areas zoned to protect dugongs in the GBRMP.

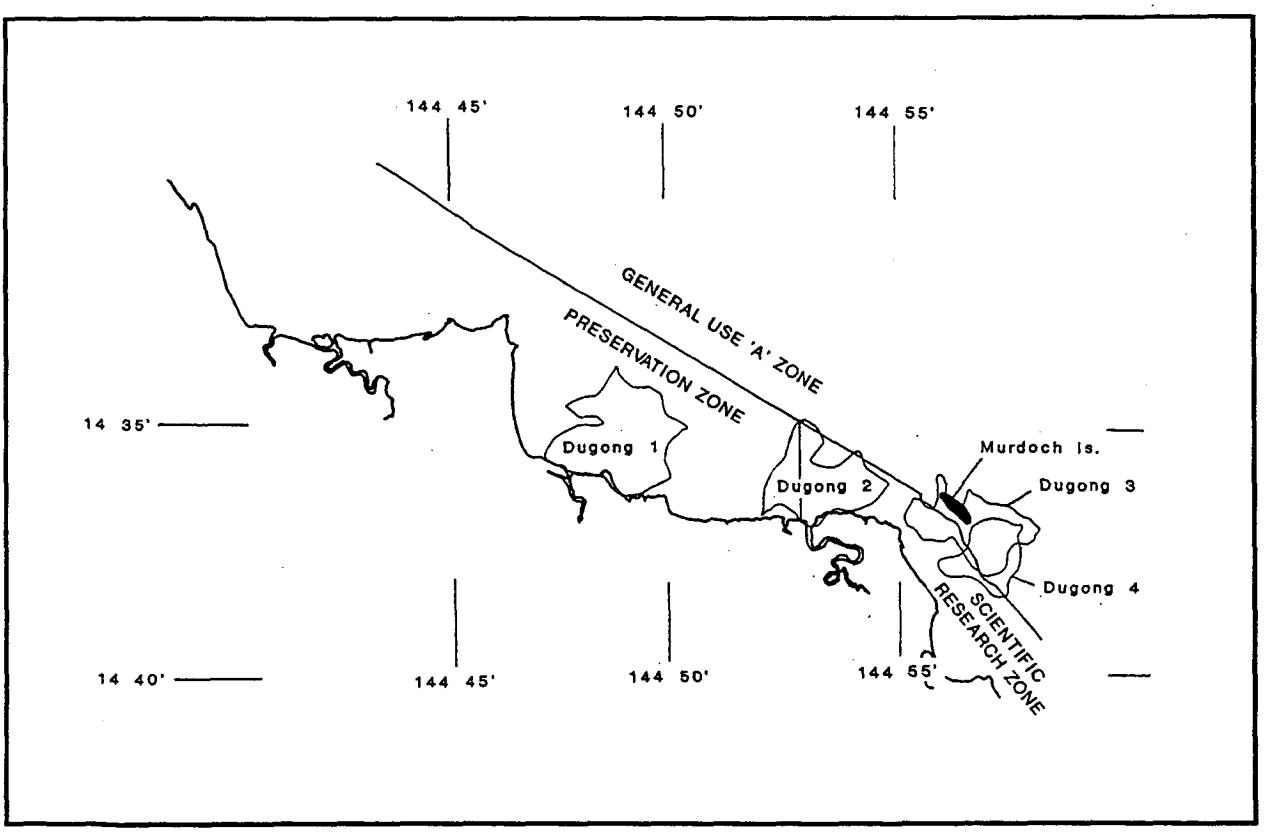

Figure 1. The seaward boundaries of the Scientific Research Zone and the Preservation Zone in the Starcke River area are too close to the coast to protect dugongs as shown by the home ranges of four mature males whose locations were monitored by satellite in the summer of 1987-88.

Abundance

During this project, procedures were developed for the large scale aerial census of dugongs (Marsh and Sinclair, manuscripts a and b). Correction factors for perception bias (groups of dugongs visible

in the transect that were missed by observers) and availability bias (groups of dugongs that were unavailable to observers because of water turbidity), and their associated coefficients of variation were calculated as outlined in Marsh and Sinclair (manuscript a). The resultant population estimates are probably underestimates because the standard used to correct for the number of dugongs which were not available to observers due to water turbidity is likely to be conservative (see Marsh and Sinclair, manuscript a).

As summarized in Table 1, surveys were conducted between the coast and the outer barrier reefs from Dunk Island (17°59'S., 146°14'E.) at the boundary of the Cairns and Central Sections of the GBRMP to Hunter Point (11°30'S., 142°50'E.) in the Far Northern Section, and over the inshore waters to about 20 km offshore in the remainder of the GBR region (Marsh and Saalfeld 1988, manuscripts a and b).

Table 1. Details of dedicated aerial surveys for dugongs conducted in the Great Barrier Reef region 1984-87.

Survey	Date	Area km^2
Cape Melville to Cape Bedford	November 1984	7952
Hunter Point to Campbell Point	April 1985	15497
Hunter Point to Cape Bedford	November 1985	31288
Cape Bedford-Dunk Is	October 1987	11528
Dunk Is -Cape Cleveland	September 1986 October 1987	5480
Cape Cleveland- Repulse Bay	December 1985 October 1987	6298
Repulse Bay - southern boundary of the GBRMP	November 1986	16090
TOTAL		94133

These surveys were conducted at sampling intensities ranging from 7.9 to 12.2% and represent more than 250 hours of flying.

When the results of the surveys are summed (Table 2), the dugong population estimate for the GBR Region is about 11,600 $\pm$ 1170 animals, more than two thirds of which occur from Cape Bedford (near Cooktown) north.

Distribution and Habitat Usage

Consistent with the results of the tracking studies (Marsh and Rathbun, manuscript) which indicated that dugongs spend most of their time in the vicinity of inshore seagrass beds, about 60% of dugong sightings on the dedicated aerial surveys were associated with known seagrass beds. This figure is probably an underestimate reflecting our incomplete knowledge of seagrass distribution away from the coast.

Between 1984 and 1988, Dr R G Coles and his co-workers in the Queensland Department of Primary Industries mapped the seagrass beds in the inshore waters of the Great Barrier Reef Marine Park between the tip of Cape York and Water Park Point (22°56'S, 150°47'E). Because of the huge area involved, this was a broad-scale mapping exercise in which the transects were spaced at 5 nautical mile

(Hopley, 1982). This is also the most important dugong area in the Park, with more than half the dugongs in the GBR region. Dugongs are distributed all along this coast, especially in the sheltered bays (Figure 2a). Dugongs also use the inshore and midshelf reefs in this Section, particularly the large platform reefs such as Corbett Reef in Princess Charlotte Bay and the mid-shelf reefs near the Howick Islands.

The Starcke River region which straddles the Cairns and Far Northern Sections of the GBRMP is the most important dugong area in the Park. I estimate that about 20% of the region's dugongs occur in this area. The estimated area of seagrass in this region (129 km^2) is almost certainly seriously underestimated (see Figure 4 and Table 4 below), especially at its seaward margin.

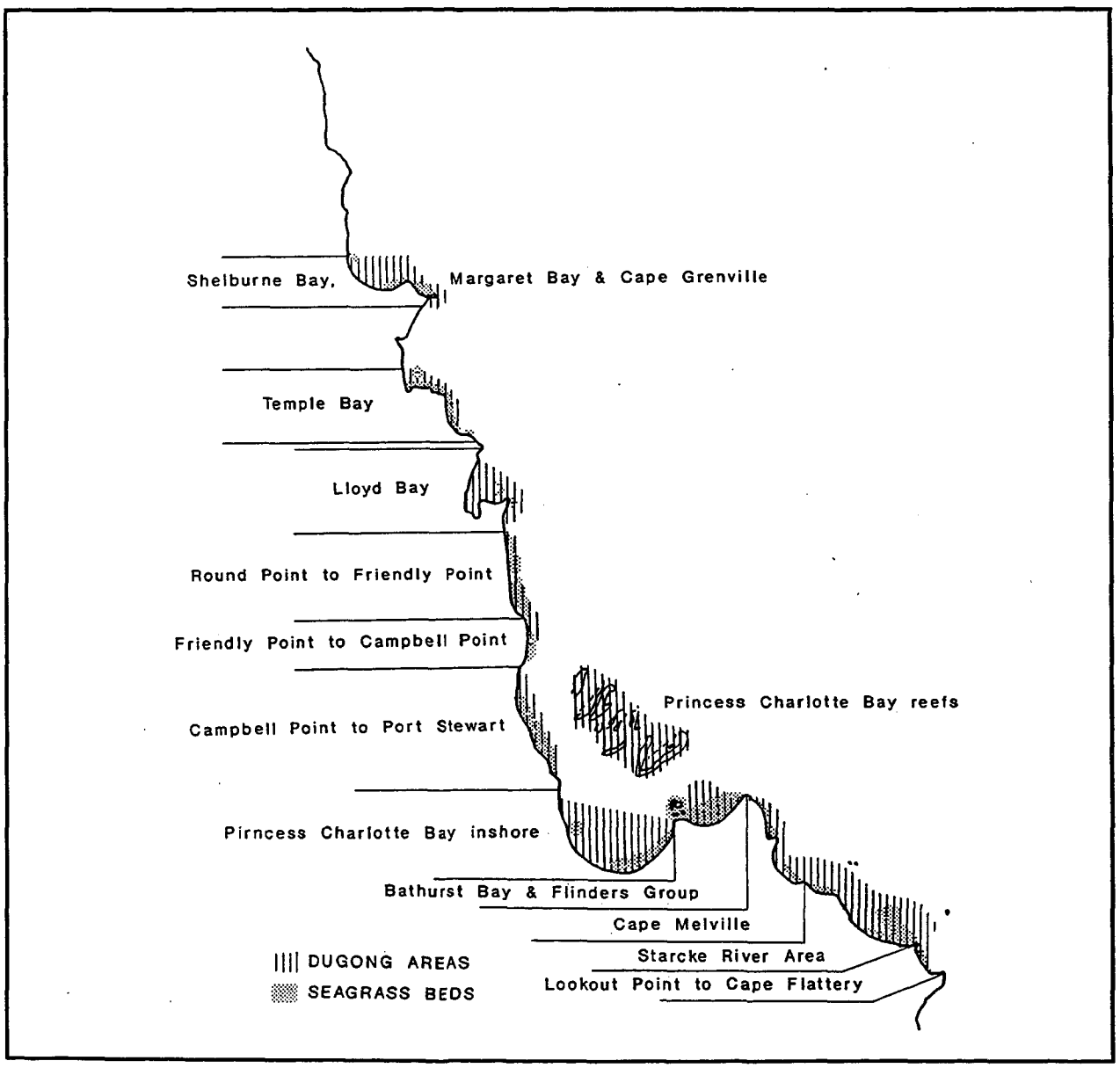

Figure 2a. The distribution of known major dugong and inshore seagrass areas in the Far Northern Section of the GBRMP and the Cairns Section north of Cape Bedford. The distribution of dugongs suggests that the seaward margins of some of the seagrass beds have been underestimated. Seagrasses also occur on the planar reefs in Princess Charlotte Bay (Hopley, 1982).

Cairns Section

South of Cape Bedford, the Cairns Section has little seagrass (about 34 km^2), and although dugongs occur along this coast in low densities there are probably no areas of great significance. Dugongs are occasionally sighted on the mid-shelf reefs in the Cairns Section.

Central Section

The estimated area of seagrass in the Central Section is 357 km^2, and this Section is estimated to contain about 13% of the dugongs in the GBR. Of particular importance are the sheltered areas such as the Hinchinbrook Island area, Cleveland Bay, Upstart Bay and Edgecumbe Bay (Figure 2b). I know of no reports of dugongs using the mid-shelf reefs in this region, but they are seen around some of the offshore islands such as the Whitsundays.

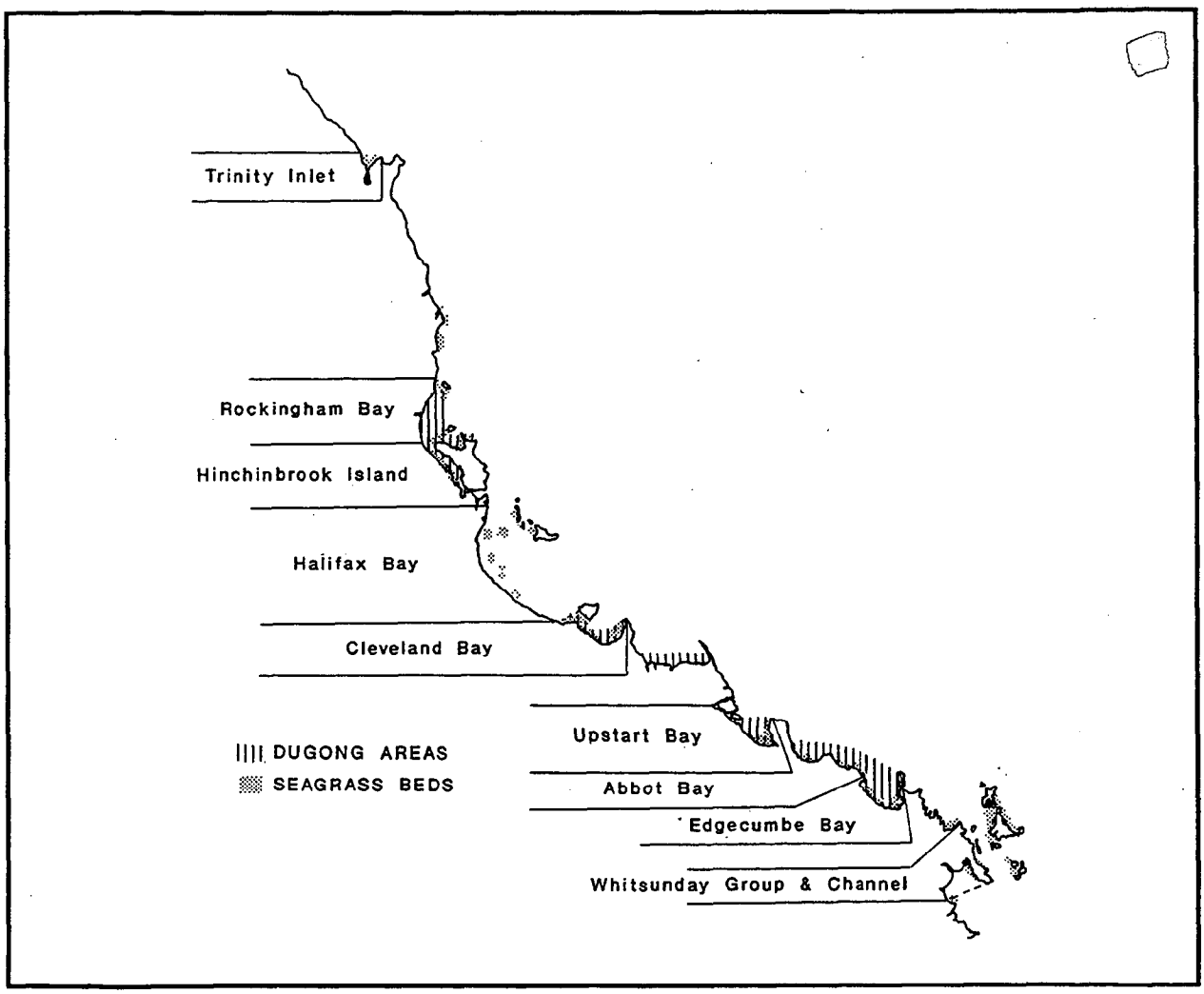

Figure 2b. The distribution of known major dugong and inshore seagrass areas in the Cairns Section of the GBRMP south of Cape Bedford and the Centrl Section. The distribution of dugongs suggests that the seaward margins of some of the seagrass beds have been underestimated.

Mackay/Capricorn Section

The pattern of dugong distribution in the Mackay/Capricorn Section (Figure 2c) is very similar to that in the Central Section, and the estimated dugong population is about 17% of that in the GBR region. The area of seagrass (186 km^2) is underestimated as figures are not available from Water Park Point south. The most important dugong areas are the Port Newry area (where the distribution and abun-

dance of dugongs suggest that the area of seagrass is probably seriously underestimated), Llewellyn and Ince Bays, Shoalwater Bay, Port Clinton, and Rodd's Bay. Dugongs have occasionally been sighted around some of the offshore islands such as North West and Lady Elliott.

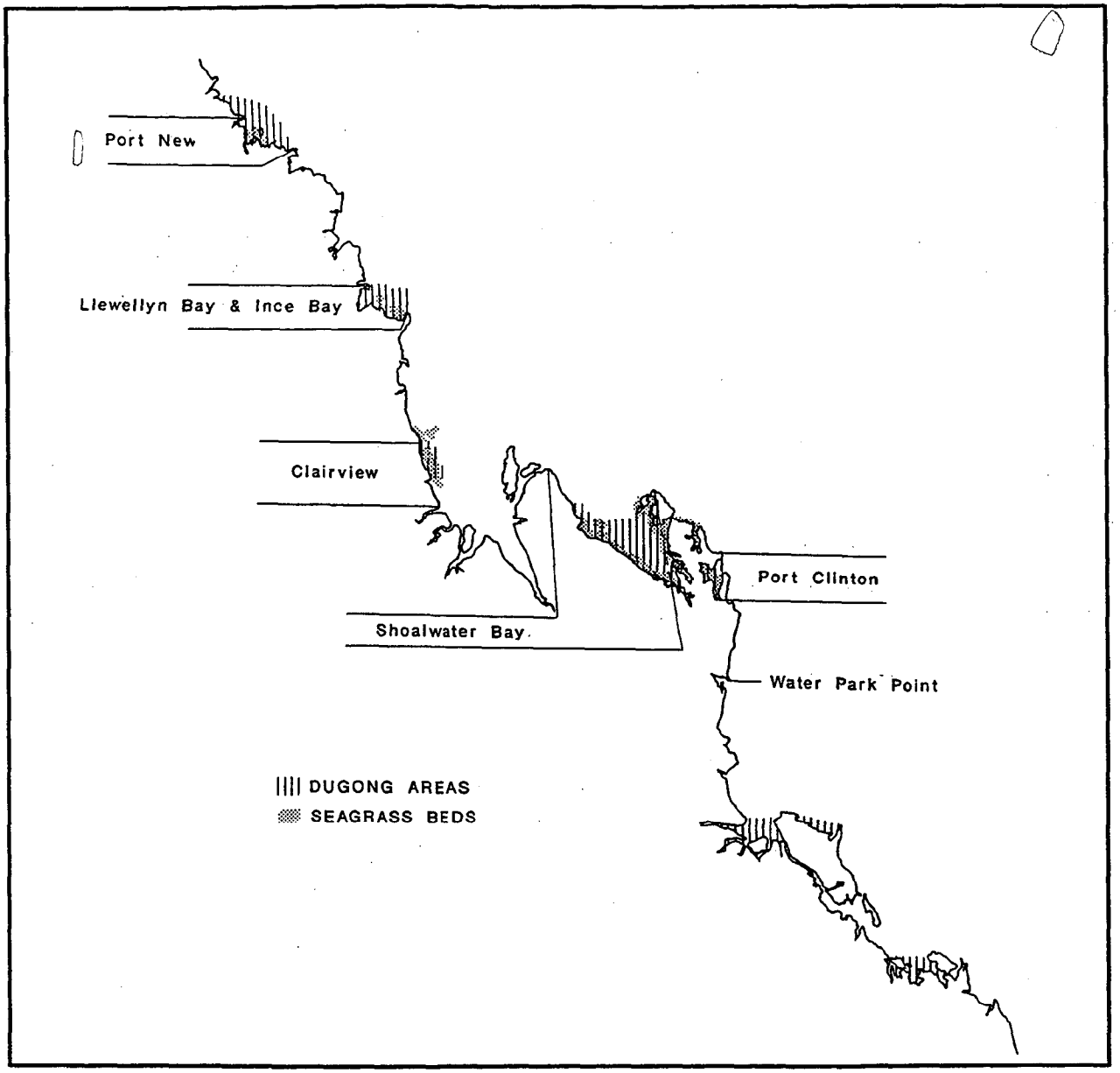

Figure 2c. The distribution of known major dugong and inshore seagrass areas in the Mackay/Capricorn Sectionof the GBRMP. The distribution of dugongs suggests that the seaward margins of some of the seagrass beds have been underestimated. To date the area south of Water Park Point has not been surveyed for seagrasses.

Group size

Although dugongs have been observed in tightly clustered herds of up to several hundred animals (e.g Heinsohn, *et al.*, 1978; Spencer, manuscript; personal observations), during our dedicated aerial surveys in the GBRMP (Marsh and Saalfeld, manuscripts a and b), the largest group sighted was of 20, and only about 13% of animals sighted were in groups of greater than five. Sixty-one percent of animals sighted were cow/calf pairs or single dugongs, suggesting that the cow/calf pair is the only long-lasting social unit.