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The distribution and abundance of dugongs in southern Queensland waters: implications for management.

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EXECUTIVE SUMMARY

In 1988, dugongs were counted from the air at an overall sampling intensity of 9.9% over a total area of 9170 km^2 in the inshore waters of Queensland, south of the Great Barrier Reef Marine Park. The survey area included Moreton Bay, Tin Can Bay, Great Sandy Strait and Hervey Bay and much of the open coastline in the region.

We corrected sightings for perception bias (the proportion of animals visible in the transect which are missed by observers), and standardised them for availability bias (the proportion of animals that are invisible due to water turbidity) with survey-specific correction factors. The resultant minimum population estimate was (mean $\pm$ s.e.) 2429 $\pm$ 365 dugongs at an overall density of 0.26 $\pm$ 0.04 km^{-2} (15% precision).

The survey indicated that Hervey Bay including Great Sandy Strait is a dugong area of international significance. It is the most important dugong area on the eastern coast of Queensland south of Cape York, and the most notable dugong habitat in Australia likely to be subjected to significant human impact in the next decade. (The other dugong habitats of equal or greater importance are all in remote regions of northern Australia).

The South Passage area and associated sandbanks in Moreton Bay is another dugong habitat of international significance. It one of the few areas where large herds of dugongs can be seen in clear water and is probably the only major dugong habitat in the world close to a major city.

This report includes maps of dugong density and distribution, and recommendàtions regarding the timing of future surveys and on the management of the dugong population of this region.

RECOMMENDATIONS

(These recommendations are those of the authors rather than the Queensland Department of Primary Industries).

1. Marine Parks

That the main strategy for managing dugong populations in south-east Queensland be through protection of seagrass habitats which support substantial numbers of dugongs via extensions of the proposed North Moreton Bay Marine Park and the Hervey Bay Marine Park.

The boundaries of the proposed North Moreton Bay Marine Park should be extended to include all the sandbanks and sandbars of South Passage as well as the surrounding waters east to a further distance of at least five kilometres. This would ensure that the marine park management agency had jurisdiction over this area in the event of proposals to dredge and stabilise a deep water channel through South Passage. The recommended boundaries are therefore approximately enclosed by latitudes 27° 19' and 27° 28'S and longitude 153° 18' and 153° 30'E. In addition, the marine park should include a buffer zone of deep water at least two kilometres wide around all the major sandbanks in the Moreton and Amity Banks to provide a low-tide refuge for dugongs.

The North Moreton Bay Marine Park should be developed with maximum public participation as part of the Strategic Management Plan for Moreton Bay.

The Hervey Bay Marine Park should be extended to include western Hervey Bay (including the proposed Wongarra Coast Marine Park) and all of Great Sandy Strait and Tin Can Bay. Zoning plans should be prepared for the remainder of this region as soon as possible and made available for public review.

In the light of the correlative evidence that boat traffic per se seriously degrades the value of an area as dugong habitat, the development of marinas or anchorages should not be permitted on the west coast of Moreton Island south of the Big Sandhills, between Amity and Myora on the west coast of North Stradbroke Island, and in south-western Hervey Bay between Elliott Heads and Point Vernon. To discourage boat traffic through important dugong feeding areas, a speed limit of 4 knots should be imposed over the Moreton Bank complex south of the Blue Hole, the Chain Bank, the Rous Channel south of the Chain Banks, the Warragamba Bank and the Maroom Banks in Moreton Bay. The introduction of similar speed limits in Hervey Bay should await more detailed information on boat traffic and dugong habitat usage.

2. Permit and Licence Conditions

Another major strategy for managing dugong populations should be through support and extension of existing arrangements to minimise man-induced mortality.

The relevant management authorities should take the following steps to monitor the human-induced mortality of dugongs and sea turtles in south-east Queensland:

Request the Queensland Department of Harbours and Marine to require that shark meshing contractors collect information on (a) the size and sex of dugongs, and (b) the location of the relevant net as part of their contract. If the meat of any dugong carcass is edible, an arrangement should be made with the local Aboriginal and Islander community so that it can be made available to them.

Ask the fishing industry to make available log-book statistics so that the extent of commercial gill-netting in important dugong areas such as the Moreton and ~~Maroom~~/Amity Banks, Hervey Bay and Great Sandy Strait can be monitored.

Evaluate the gill netting regulations introduced to minimise dugong mortality in Hervey Bay. Restrict gill-netting on the Moreton Bank complex and on the Maroom and Warragamba Banks in Moreton Bay to the period between tide half out and half in.

Encourage the Queensland Department of Harbours and Marine to use drum lines where there is a perceived need to introduce measures to protect bathers from sharks within or adjacent to major dugong habitats.

3. Public Education

A dugong public education program should be developed to target (1) urban Aborigines and Islanders who frequently resent not being able to hunt dugongs legally, (2) commercial gill-netters and trawler skippers operating in high density dugong areas, and (3) the recreational boating public. The program should emphasise the vulnerability of dugongs to human-induced mortality, the illegality of selling their meat, the current restrictions on hunting, and the netting regulations designed to minimise incidental capture. Fishing operators should be supplied with maps illustrating high density dugong areas and encouraged to avoid fishing in such areas.

4. Monitoring

In view of the dugong's sensitivity to low temperatures, this aerial survey should be repeated as soon as possible during summer in order to compare the distribution and abundance of dugongs in the region in summer and winter.

The success of the measures taken to protect dugongs in this region should be evaluated by monitoring their distribution and abundance via dedicated aerial surveys using the procedures and designs developed in this project. The surveys should be carried out at five-yearly intervals at the time of year when favourable weather conditions are most likely. The first such survey should be carried out in 1993, five years after this initial survey.

The Queensland Department of Primary Industries should conduct further research to (1) document the extent of the deepwater seagrass beds in Hervey Bay and the importance of these areas as prawn nursery habitats, and (2) monitor the effects of trawling on seagrass beds.

INTRODUCTION

The dugong, Dugong dugon, the only herbivorous mammal which is strictly marine, is one of only four surviving members of the Order Sirenia or seacows. It is the only extant member of the Family Dugongidae; its nearest living relative, the giant Steller's sea cow, was exterminated by man in the eighteenth century. Dugongs are listed as vulnerable to extinction in the IUCN Red List of Threatened Species (1986). Trade in dugong products is regulated or banned (depending on the dugong population involved) by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Dugongs are vulnerable to over-exploitation because they are long-lived animals (maximum lifespan >70 years) which do not breed until at least 10 years of age. A female dugong bears only one calf at a time at intervals of 3-5 years. Population models indicate that the maximum rate of increase of an unharvested dugong population is likely to be less than 5% per year (Marsh et al., 1984; Marsh, 1986).

The range of the dugong extends throughout the tropical and subtropical coastal and island waters of the Indo-West Pacific from East Africa to the Solomon Islands and Vanuatu, and between about 26-27° north and south of the equator (Nishiwaki and Marsh, 1985). Over much of this range which spans the waters of 42 countries, dugongs are now believed to be represented by relict populations separated by large areas where they are close to extinction or extinct. This assessment is, however, almost entirely based on anecdotal information and the actual extent to which their range has contracted is unknown.

A significant proportion of dugong stocks is believed to occur in northern Australian waters between Moreton Bay in the east and Shark Bay in the west, and the international focus of dugong research has been in Australia since the early 1970's.

As part of a program to determine the distribution and abundance of the dugong in Australian waters, we present the results of an aerial survey of the coastal waters of Queensland, between the southern boundary of the Great Barrier Reef Marine Park (24° 35'S.) and the Queensland - New South Wales border (28° 10'S). Bayliss (1986), Bayliss and Freeland (1989) and Marsh and Saalfeld (1988, 1989, 1990) present the results of similar surveys of the Northern Territory coasts, Torres Strait and the Great Barrier Reef region respectively.

METHODS

The survey was conducted between July 26 and August 4 1988. Most transects ran east-west extending across the embayments or out to 12.3 km from the open coast. (The latter is the distance flown in four minutes at 185 km h^{-1} [100 kn.]). The open coastline off Bribie and Fraser Islands was not surveyed because weather conditions were unsuitable. As in our other surveys (Marsh and Saalfeld, 1988, 1989, 1990), the transect lines were spaced at intervals of 5° latitude except in areas of known seagrass beds and/or known high dugong density where they were spaced either 2.5° or 1.25° apart (Figures 1a and 2a). For estimation of regional densities of dugongs, the survey areas were divided into blocks (Figures 1a and 2a). The area of each block and the intensity with which it was sampled are summarised in Table 1. The overall sampling intensity was 9.9%.

Daily schedules were arranged to minimise severe glare associated with a low or mid-day sun. Although the glare on the north side of the aircraft on some transects was severe (Appendix Table 1), it had no detectable affect on the number of groups of dugongs sighted ($F=0.14$; 1,22 d.f; $p=0.712$). Repeatability was also increased by surveying only when weather conditions were good; the conditions encountered are summarised in Table 2 and detailed in Appendix Table 1.

Survey methodology, data handling and analysis techniques were similar to those used in previous surveys as outlined by Marsh and Saalfeld (1988, 1989, 1990) and Marsh and Sinclair (1989 and b). Correction factors for perception bias (groups of dugongs visible in the transect that were missed by observers) and their associated coefficients of variation were calculated as outlined in Marsh and Sinclair (1989a) based on the raw data in Appendix Tables 2 and 3. Their methodology was also used to correct the dugong counts for availability bias (groups of dugongs that were unavailable to observers because of water turbidity).

The population and density estimates and the distribution maps were based on corrected dugong densities. The standard errors of the population and density estimates were adjusted to incorporate the errors associated with the appropriate estimates of the perception and availability correction factors and the mean group size (as outlined in Marsh and Sinclair, 1989a).

Image data for the survey area with a resolution of 1.1 km^2 were obtained at 1550 hours EST on August 7 1988, and transmitted from the NOAA 9 satellite equipped with advanced very high resolution radiometers (channels 4 and 5) to a receiver at the NASIS Centre at James Cook University. The data were converted by computers at the Australian Institute of Marine Science and James Cook University using the T45 algorithm from the DISIMP software developed by the CSIRO Division of Information Technology to produce maps of absolute thermal temperatures correct to approximately 0.2°C.

RESULTS

Group Size and Composition

Two hundred and twenty five dugongs were sighted in the transects during the survey. The size and composition of these groups are summarised in Figure 3 and Table 3. Sixty-four percent of animals sighted in the transects were single dugongs or cow/calf pairs. Two groups of more than 10 dugongs were also sighted out of the transects: a group of at least 22 including 5 calves was sighted about 6 km south-east of the mouth of the Burrum River in Hervey Bay, another of at least 140 including at least 13 calves was sighted and in Moreton Bay on the northern edge of the Maroom Banks. As in the other surveys (eg. Marsh and Saalfeld, 1989), the total counts of the groups with more than 10 animals were obtained from photographs and included in separate strata of large herds (Table 1).

The proportion of calves (based on sightings in groups of less than 10) was 22.1% in Hervey Bay - Great Sandy Strait, 7.7% in Moreton Bay. The latter figure is likely to be an underestimate because of the high proportion of animals in Moreton Bay which were seen in the large herd for which we could not obtain an accurate calf count.

Population and Density Estimates

The values of the mean group sizes and correction factors used in obtaining these estimates are summarised in Table 3. The positions of actual sightings are illustrated in Appendix Figures 1 and 2. Table 1 gives estimates of the density and numbers of dugongs per block together with the standard errors of these estimates. These estimates sum to 2429 dugongs for the entire region, with an estimated 458 dugongs in Moreton Bay, and 1971 dugongs in the Hervey Bay - Great Sandy Strait - Tin Can Bay area. These are likely to be underestimates of the number of dugongs present because the standard used to correct for those dugongs which were not available to observers due to water turbidity is probably conservative (see Marsh and Sinclair, 1989a).

The highest densities of dugongs were seen in southern Hervey Bay and in the areas on either side of South Passage in Moreton Bay, especially the Moreton and Amity Banks (Figures 1b and 2b). Apart from those seen outside South Passage, no dugongs were seen on the open coasts. However, they certainly use these areas as they occasionally drown in shark nets at the Gold and Sunshine coasts (Paterson, 1979 and pers. comm. 1983).

Overall 56% of dugong sightings (75% if the stratified herds of >10 animals are included) were in the vicinity of known seagrass beds (Figures 1 and 2). Six groups of dugongs were seen up to 4 km offshore in the oceanic waters outside South Passage. All but 9% of the dugongs sighted in Moreton Bay and the area outside South Passage were in depths of 5.5 m or less (Figure 4). In contrast, 68% of the dugong sightings in the Hervey Bay - Great Sandy Strait - Tin Can Bay area were in waters between 5.5 and 18 m deep.

On the basis of the temperatures estimated from satellite imagery taken on a flooding mid-afternoon tide several days after the survey, the dugongs sighted would have been experiencing the following sea surface temperatures (Figures 1c and 2c):

Moreton Bay	17-19°C
outside South Passage	20-21°C
Hervey Bay	18-20°C
Great Sandy Strait	18-20°C

Thus the large herds of dugongs sighted during the survey would probably have been experiencing sea surface temperatures of 17- 18°C in Moreton Bay and 18-19 °C in Hervey Bay.

DISCUSSION

The importance of the region for dugongs

The inshore waters of south-east Queensland support significant numbers of dugongs at densities comparable to those in the northern Great Barrier Reef Marine Park (Table 4). The Hervey Bay area is outstanding and is the most important dugong area south of Cape York. Although the number of dugongs in Moreton Bay is similar to that in several other large embayments along the Queensland coast (see Marsh, 1989), the area is of particular significance: (1) it is the southernmost major dugong habitat on the east coast of Australia; (2) it is the only area in the world which supports significant numbers of dugongs close to a major city (Heinsohn et al., 1978); (3) it is one of very few locations where large herds of dugongs can be predictably seen in clear water.

The discrete group of 140+ dugongs seen out of the transects during our survey of Moreton Bay contrasts with the maximum group size seen on our other surveys (Table 4). Apparent group sizes may be an artefact of survey conditions. If a herd is loosely grouped, only a small portion may be seen at once from a low flying aircraft, even in clear water. Larger groups of 100 or so dugongs have been observed in the Great Barrier Reef region by observers on Coastal Surveillance aircraft (Spencer, in Marsh, 1989). However, the available data suggest that dugongs form large herds much more often in Moreton Bay (see Heinsohn et al., 1978, Nishiwaki and Marsh, 1985, Lanyon et al., 1989, unpublished data) than in areas of equal or greater dugong density further north. The reason for this is unknown.

The proportion of dugong calves sighted in Hervey Bay (22%) was much higher than that seen during similar surveys of the Great Barrier Reef region and Torres Strait most of which were conducted between September and November inclusive (Table 4). This is unlikely to be an artefact of the time of year. Calving in eastern Queensland is diffusely seasonal; most calves are born between September and November inclusive. Calves can suckle for at least 18 months (Marsh et al., 1984). Thus we would expect the proportion of calves to be higher for surveys conducted later in the year than in July - August. This is the reverse of the observed trend (Table 4), and strengthens the importance of the Hervey Bay region as dugong habitat.

Threats to dugongs in the region

The threats to dugongs and their habitats is probably greater in south-east Queensland than anywhere else in Australia because human population density is much higher than in tropical Australia.

(1) Direct mortality

Dugongs were killed for food by coastal Aborigines for thousands of years. They were netted commercially for their oil in southern Queensland in transient cottage industries from the middle of the nineteenth century (Lack, 1968) until 1944 in Moreton Bay and until 1969 in Hervey Bay. The magnitude of this harvest is unknown. The maximum catches recorded by the Queensland Department of Harbours and Marine in their annual reports between 1893-4 and 1944 were 45 in Moreton Bay in 1904-5 and 240 in Hervey Bay in 1941. However, most recorded annual catches were much lower than this.

Dugongs were protected by law in Queensland in 1969 (Bertram and Bertram, 1973). They are currently protected by the Queensland Fisheries Act (1976-1984). Indigenous people living in Trust Territories are exempt from the provisions of the Act and thus can engage in traditional hunting. There are no Trust Territories in coastal southern Queensland, however, indigenous people in this region can technically apply to the Queensland Government for a permit to take a specified number of dugongs. In practice, such permits are rarely granted and there is effectively no legal harvesting of dugongs in southern Queensland.

(2) Incidental mortality during commercial fishing activities

We know of only two instances of dugongs drowning in trawls and believe it to be a rare event. However, during the 1980's, there were several highly publicised incidents of dugongs drowning in commercial gill nets in Hervey Bay. Most incidents occurred in the winter months when seasonal concentrations of dugongs apparently occur in the same areas as similar concentrations of commercial fish, particularly school mackerel. In consultation with local fishermen, these incidents have resulted in the following changes to the fishing regulations in key dugong areas in south-western Hervey Bay: (1) the specifications of offshore set gill or drift nets have been altered to increase the chances of dugongs escaping from nets if incidentally captured; (2) each master fisherman can set only one net and must remain at the net at all times to increase the chances of dugongs being released alive after incidental capture; (3) netting has been banned between 4pm and 4am in the months of July, August and September to reduce the chances of incidental capture.

In Moreton Bay, dugongs graze in the areas most commonly used for gill-netting only at the top of the high tide (Preen, unpublished data). Overlap of the use of these areas by dugongs and fishermen could virtually be eliminated if netting were restricted to the period between tide half out and half in.

Although it is probably futile to attempt to obtain a reliable estimate of the magnitude of the incidental take of dugongs in southern Queensland, the existing compulsory log book program should give some idea of the number of operators fishing in high density dugong areas. In Hervey Bay, the major problem results from fishermen who operate in these areas only occasionally and without the benefit of detailed local knowledge. It would be desirable for the relevant management authorities to supply fishermen with maps of high density dugong areas, to advise them to avoid them in order to minimise damage to their nets, and to increase the policing of fisheries regulations. It would also be advantageous if measures could be devised to discourage or ban operators from fishing in unfamiliar areas of high conservation value.

The impact of commercial gill-netting on dugong stocks in southern Queensland is unknown. However, this mortality is of concern to Aborigines and Islanders who resent their hunting being restricted whilst dugongs drown in gill-nets. It is also used by people opposed to commercial gill-netting in efforts to close this fishery.

(3) Incidental mortality from recreational activities

A shark-netting program has operated on major recreational beaches in Queensland since the mid 1960's. There is considerable public support for this practice as a swimmer has never been attacked by a shark on a meshed beach. As detailed by Paterson (1979), shark meshing kills other marine vertebrates including dugongs. The combined toll caught in shark nets at the Gold Coast, Point Lookout, Sunshine Coast, Rainbow Beach, Hervey Bay and Bundaberg from 1964 to 1977 was 67 dugongs. Shark netting should not be introduced to additional areas which support large numbers of these animals.

There is correlative evidence from the Great Barrier Reef region that dugong density is lower than expected in seagrass areas with high boat traffic (Marsh, 1989). Aboriginal dugong hunters frequently claim that dugongs do not frequent areas with noisy boats. Dugongs are also vulnerable to boat strikes in areas of high boat usage, and are occasionally killed by boats in Moreton Bay (unpublished data). The incidence of such deaths is likely to increase as boat traffic increases. In Florida, where the dugong's closest relative, the manatee, must coexist with very high boat traffic, boat strikes account for a third of manatee deaths (R.K. Frohlich, unpublished data 1988). In the light of this evidence that boat traffic per se seriously degrades the value of an area as dugong habitat, marinas and boat anchorages should not be developed in areas of high dugong density.

A vessel speed limit of 4 knots should be introduced in major dugong feeding areas in Moreton Bay such as the Moreton Bank complex south of the Blue Hole, the Chain Bank, the Rous Channel south of the Chain Banks, the Warragamba Bank and the Maroom Bank. Assessment of the desirability of similar limits in Hervey Bay will require more detailed information on boat traffic and dugong habitat usage.

(4) Habitat damage

Most species decline because of destruction of their habitat (Caughley, 1985), and thus the destruction of seagrass beds in northern Australia will inevitably threaten the survival of the dugong. Shepherd et al. (1989) discuss likely causes of the major man-induced declines of seagrass beds that have occurred in temperate Australia. Several primary and secondary causes are implicated in virtually every case. Shepherd et al. hypothesise that seagrass decline is generally caused by a reduction in the light reaching seagrass chloroplasts. This can result from increased turbidity arising from living and non-living particulates in the water, or increased shading by the deposition of silt or the growth of epiphytes on leaf surfaces or stems. Turbidity may be increased directly by the injection or resuspension of fine material in the water column (sludge discharge, dredging, erosion, harbour or groyne construction) or indirectly through enhanced nutrient levels which increase phytoplankton (sewage, industrial wastes, agricultural chemicals). Nutrient enrichment can also lead to enhanced growth of algae of the surfaces of seagrass leaves.

Even though some seagrass beds are protected in Fish Habitat Reserves, the proximity of the city of Brisbane makes the seagrasses of Moreton Bay more vulnerable to damage from increased turbidity, nutrients or pollution than those of any other area on the Queensland coast. In addition, there are localised threats to the high conservation value dugong areas in the eastern Bay. A sand mining lease is held on the western edge of Rous Channel, and there has been a proposal to construct a submerged oil pipeline from Moreton Bay through South Passage to an offshore buoy mooring for large oil tankers. Both these impacts are accommodated in the Moreton Bay Strategic Draft Report (Department and Environment and Conservation, Queensland, 1989) despite their potentially disastrous effects on dugongs.

Like other sirenians, dugongs appear to be sensitive to low water temperatures (Anderson, 1986). Moreton Bay is thermally marginal for dugongs and they use South Passage often in winter to travel between the warm oceanic water up to twelve kilometres outside the Bay and their feeding areas on the Moreton and Amity Banks

(Figure 1). It is vital for the future of dugongs in Moreton Bay that their access to South Passage be unrestricted and that South Passage the associated sandbank areas are protected from pollution. Rous Channel is the most important dugong area in Moreton Bay particularly in winter. It is the pathway that all dugongs must use on their regular travels in and out of the Bay; the channel through which warm oceanic water floods onto the seagrass beds in the eastern Bay; and an important low tide refuge and feeding area.

Marine Parks

We believe that the most effective way to protect dugongs in south-eastern Queensland will be to incorporate the major dugong habitats in marine parks which are designed to manage the whole ecosystem through a system of differential zoning of various activities. This is a more effective method of managing dugong stocks than specialised marine protected areas such as Fish Habitat Reserves. The latter are specifically designed to protect nursery and feeding habitats of commercially important fish species and have limited capacity to control boat traffic, recreational activities, and fishing activities which do not disturb the benthos.

Marine parks have already been proposed for some of the key dugong habitats in south-east Queensland. In order to effectively protect dugongs, the boundaries of the proposed North Moreton Bay Marine Park would need to be extended to include the following: (1) all the sandbanks and sandbars of South Passage as well as the surrounding waters for a further distance of at least five kilometres; and (2) all the channels through the major seagrass beds plus a buffer zone of deep water at least two kilometres wide around all the major seagrass beds to provide a low-tide refuge.

The Hervey Bay Marine Park would also need to be extended to include all of western Hervey Bay including the proposed Wongarra Coast Marine Park, and all of Great Sandy Strait.

Future surveys

Marsh and Saalfeld (1989) calculated that it was likely to be at least a decade before it could be established whether dugong numbers in the northern Great Barrier Reef region were deceasing, increasing or stable. This conclusion was based on a statistical power analysis using the precision of the surveys carried out to date and the estimated rate of change of an unharvested dugong population. They recommended that the northern half of the Great Barrier Reef region be surveyed every five years in order to monitor trends in dugong numbers as they considered that if there was a decade between surveys most of the necessary expertise could be lost. Both the Great Barrier Reef Marine Park Authority and the Australian Fisheries Service have now decided to schedule dugong surveys every five years, and we suggest that this pattern should also be followed in the inshore waters of southern Queensland.

Given the mounting evidence that low water temperatures influence the local movement of dugongs (Anderson, 1986; Marsh and Rathbun, 1990; Marsh and Sinclair, 19989b; unpublished data), it would also be useful to repeat this survey of southern Queensland waters in summer to see whether there is a seasonal change in the distribution of dugongs in this region.

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Table 1: Estimated standardized minimum densities and numbers of dugongs for each block. The values are ± standard error incorporating the errors resulting from sampling and in estimating mean group size and correction factors. The area of each block and the intensity with which it was sampled are also given.

Block	Area (km^2)	Sampling Intensity %	Dugongs Density (no. per km^2)	Dugongs Numbers	
Moreton Bay					square the, add them & take √ of total to get overall SE
2	650	17.0	0.46 ± 0.0	301 ± 69	
4	275	17.0	0.06 ± 0.07	17 ± 20	95% CL = 313 to 603
5	798	8.8	0.00 ± 0.00	0 ± 0	
6	120	15.5	0.00 ± 0.00	0 ± 0	[illegible]
stratified herd[a]				140	1988 ± 72
Hervey Bay and Great Sandy Strait					1992
(7) 8	599	8.7 16.5%	0.49 ± 0.22 1.09 ± 0.45	291 ± 135	655.6 ± 271.6
(8) 9	1215	18.8 14.4	1.21 ± 0.27 .04 ± .03	1466 ± 326	49.9 ± 33.3
(9) 10	1258	9.4 ~~.0078~~ 8.6	0.12 ± 0.05 .007 ± .007	153 ± 59	9.[illegible] ± 9.2
(10) 11	1521	7.2 7.0%	0.03 ± 0.02 .05 ± 0.03	39 ± 32	72 ± 40.8.
stratified herd[a]				22	1971 ± 359
Open coastline					
1	754	5.4	0.00 ± 0.00	0 ± 0	786.6 ± 276.81
3	447	4.5	0.00 ± 0.00	0 ± 0	
7	1451	5.3	0.00 ± 0.00	0 ± 0	
Total			0.26 ± 0.04	2429 ± 365	
precision			0.15		

[a] total counts of herds of >10 animals not included in population model.

Table 2: Details of weather conditions encountered during the survey.

Date	Session	Wind Speed (knots)	Wind Direction	Cloud Cover (oktas)	Cloud Height (ft)	Beaufort Sea State mode(range)	Glare* North/East mode(range)	Glare* South/West mode(range)	Tide Time
*26/07/88	1	10	W	0	-	1.0(0.0-3.0)	1.0-2.0(0.0-3.0)	0.0(0.0-2.0)	High 0754
*185W → 199 = 1 221 – 218,127,222 = 2	2	10	NW	0	-	2.5(0.0-3.0)	3.0(0.0-3.0)	0.0	Low 1151
29/07/88 127E → 222W	1	0	-	8	5500	0.5(0.0-0.5)	0.0(0.0-2.0)	0.0(0.0-2.0)	High 0948
30/07/88	1	10	SE	3	8000	2.0(0.0-2.5)	1.0(1.0-2.5)	0.0(0.0-2.0)	High 0947
117 W - 140E – 136	2	5	SW	0	-	1.0(0.0-2.5)	2.0(0.0-3.0)	0.0(0.0-2.0)	
113 – 102	3	8	SW	1	3000	1.0(1.0-2.5)	2.0(0.0-2.5)	0.0(0.0-1.5)	Low 1448
*31/07/88 145E – 156W	1	0	-	0	-	2.0(1.0-4.0)	0.0-3.0	0.0(0.0-2.5)	High 1047
* 185W – 348S	2	5	S	2	3500	2.0(0.0-4.0)	2.0(1.0-3.0)	0.0	Low 1535
*2/08/88 197 – 198,211	1	5	S	5,4	2500,10000	2.0(0.0-2.5)	2.0(0.0-3.0)	0.0(0.0-3.0)	High 1129
	2	5	E	5	6500	2.0(1.5-2.5)	0.0-2.0	0.0	Low 1725
3/08/88	1	8	SE	3	8000	2.0(0.0-3.0)	3.0(0.0-3.0)	0.0(0.0-3.0)	High 1223
4/08/88	1	15	E	4	2500	3.0(1.0-4.0)	3.0(1.0-3.0)	0.0	High 1247

* Scale: 0 = no glare; 1 = 0 ≤ 25% field of view obscured by glare; 2 = 25 ≤ 50%; 3 = > 50%.

Table 3: Details of group size estimates and correction factors for dugongs used in the population model. All estimates were based on two observers.

	Dugongs	
	P[a]	S[a]
Mean group size (s.e./x)	1.64 (0.14)[c]	
Perceptual Correction Factor estimate (C_p[b])	1.03 (0.01)	1.04 (0.01)
Availability Correction Factor estimate (C_a[b])	1.68 (0.15)[c]	

[a] P = port; S = starboard.
[b] Coefficient of variation of associated correction factor.
[c] mean group size estimate and availability correction factors based on port and starboard observer teams combined.

Table 4: Comparison of the results of this aerial survey for dugongs in the inshore waters of south-east Queensland with the results of similar surveys along other parts of the Queensland coast (see Marsh and Saalfeld, 1988, 1989 and 1990). The values are ± s.e The seagrass data are from Poiner and Marsh (unpublished in Poiner et al., 1989), Coles et al., 1985, 1987, and unpublished, and Hyland et al 1989.

Region	Torres Strait	G.B.R. Region		SE. Qld
		North	South	
Months of surveys	Nov., Mar	Nov., Apr.	Sept., Oct.	Jul.- Aug.
Area (km^2)	30533	31288	39396	9170
Known area (km^2) of seagrass	3579	2178+	577	1374+
Dugongs				
Density (km^{-2})	0.41±0.05	0.26±0.03	0.09±0.01	0.26±0.04
Number	12522±1644	8110±1073	3479±459	2429±365
% calves	13.6 - 14.3	10.4 - 16.3	7.7 - 14.8	20.4
Max. group size	6	20	10	140+

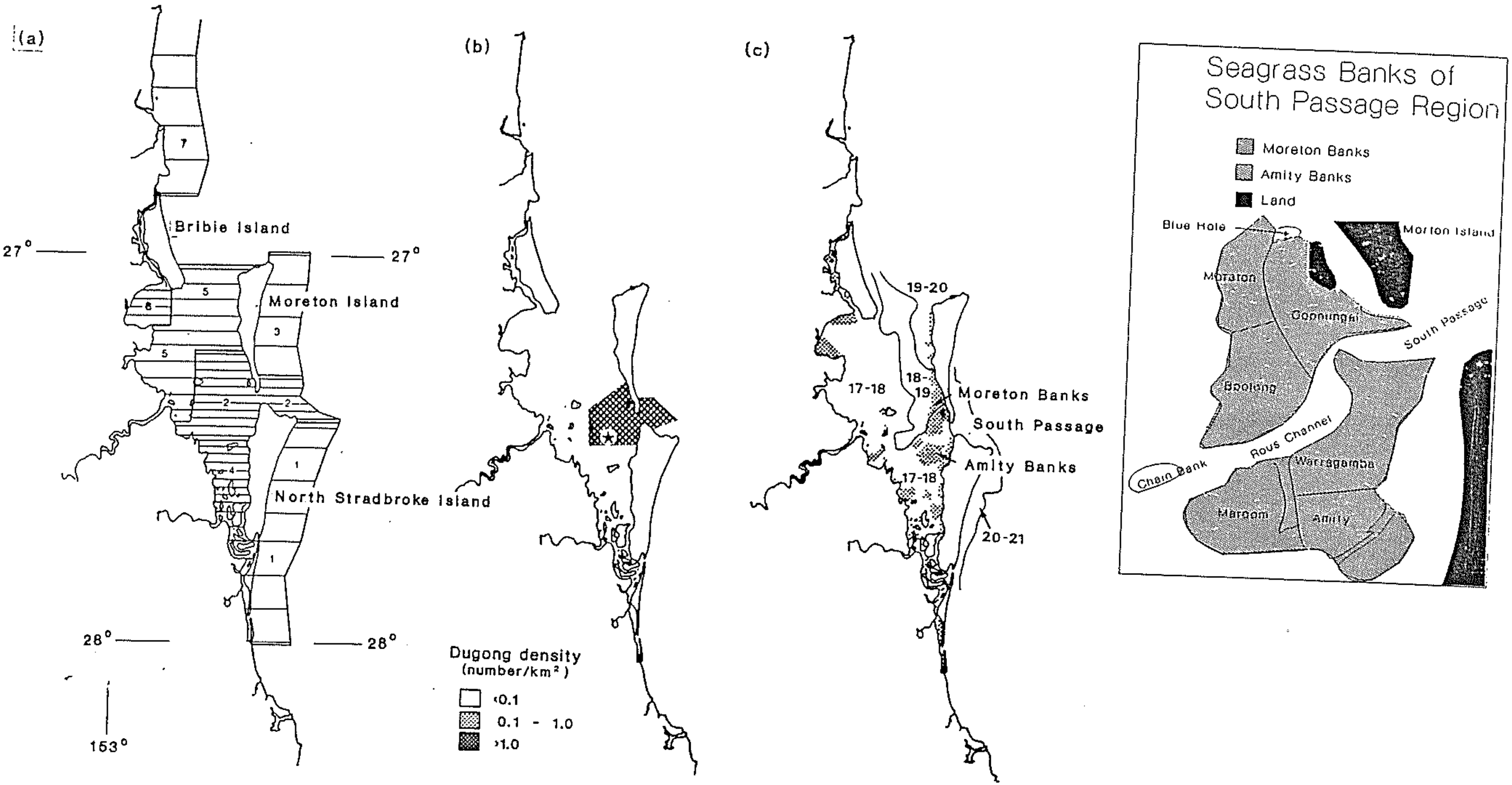

Figure 1: The Moreton Bay survey area showing (a) the survey blocks (1-7) and transect lines, (b) the distribution of dugong density (★represents a herd of 140+ animals seen on the Maroom Bank), (c) the approximate distribution of seagrass beds from Hyland *et al.* (1989) and the approximate temperature isotherms for August 7, 1988 (temperatures are in °C). The inset details the names of the main sandbanks and channels in the important dugong area.

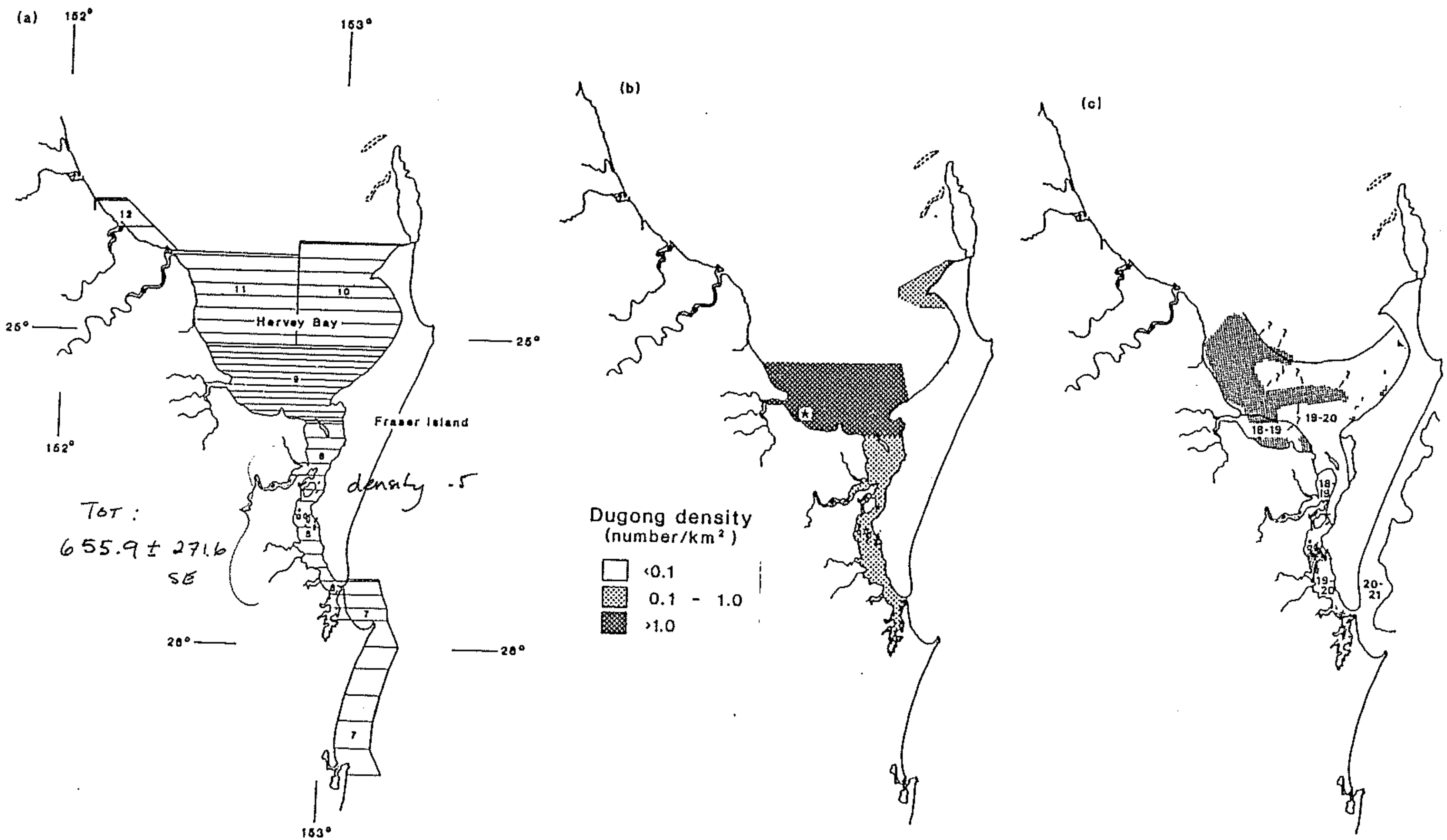

Figure 2: The Great Sandy Strait and Hervey Bay survey area showing (a) the survey blocks (7-12) and transect lines, (b) the distribution of dugong density (★ represents a herd of 22+ animals seen approximately 6 km south-east of the mouth of the Burrum River), (c) the approximate distribution of seagrass beds from Coles *et al.* (1989) and the approximate temperature isotherms for August 7, 1988 (temperatures are in °C).

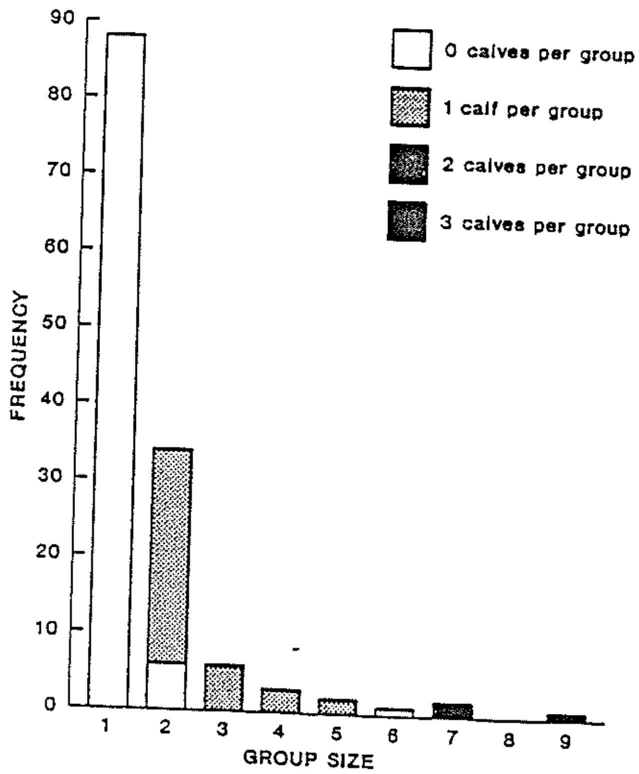

Figure 3: Frequency histogram showing details of dugong group size and composition for the total survey area. Data from the two large stratified herds (140+ in Moreton Bay and 22+ in Hervey Bay) have been excluded due to the difficulties in obtaining accurate total and calf counts for large herds.

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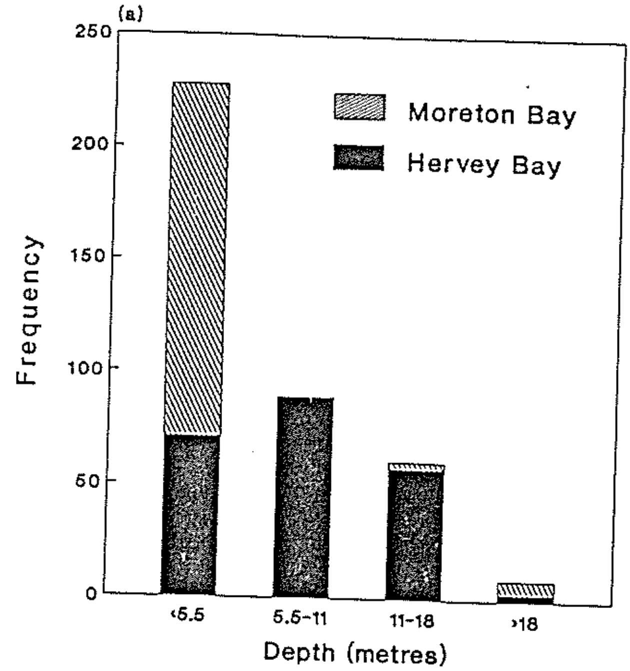

Figure 4: Frequency histogram showing the depths of water in which dugongs were sighted. Depth information is based on marine charts and has not been corrected for tidal levels at the time of the survey.

APPENDIX

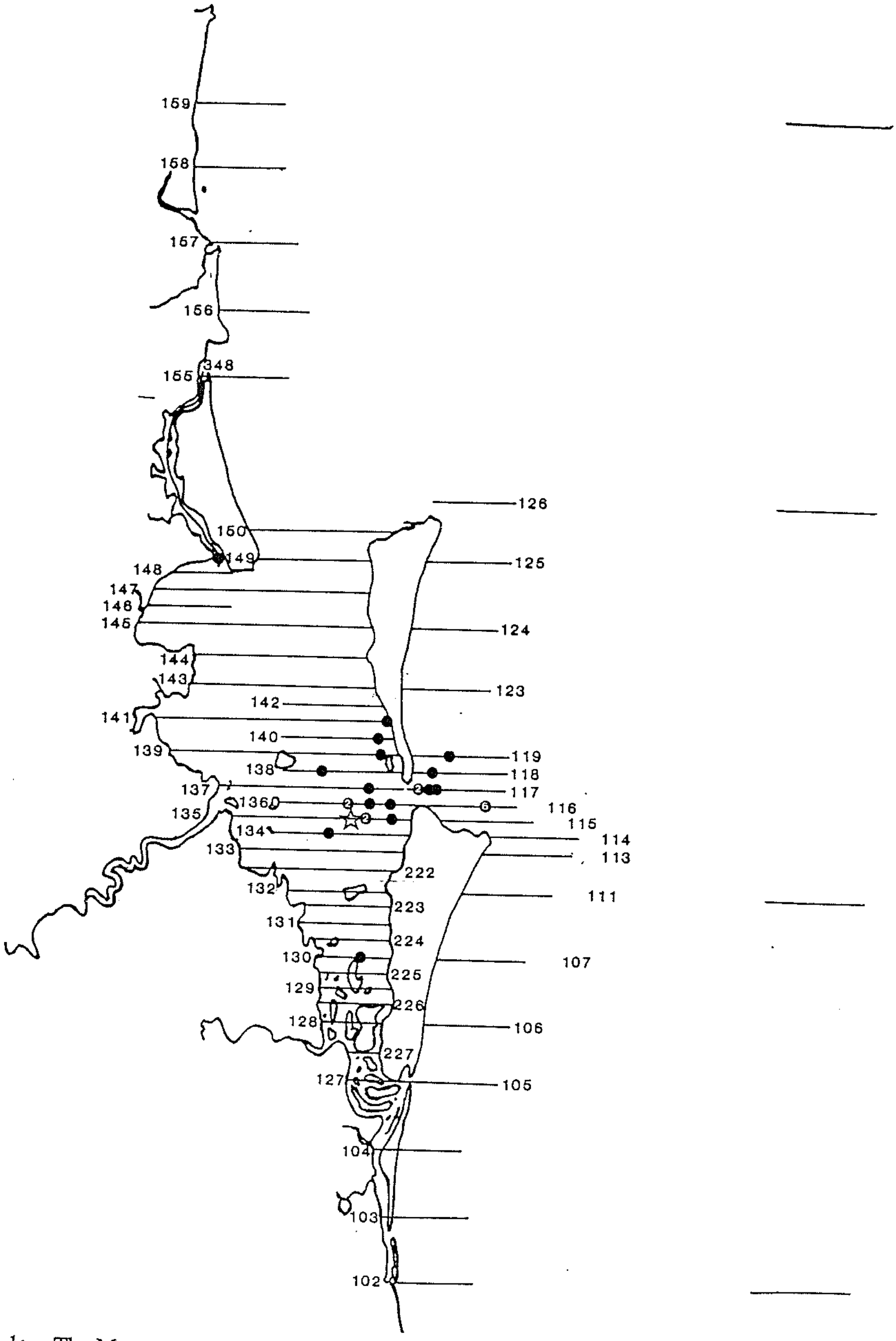

Figure 1: The Moreton Bay survey area showing the numbers and positions of the transects and dugong sightings (represents a herd of 140+ animals seen on the Maroom Bank) in July/August 1988.

Table 1: Beaufort Sea State and glare (for the north/east and south/west sides of the aircraft) for each transect.

Scale : 0 - no glare
1 - 0 ≤ 25% field of view glare affected
2 - 25 ≤ 50% field of view glare affected
3 - > 50% field of view glare affected

Transect No.	Beaufort Sea State mode(range)	Glare North/East mode(range)	Glare South/West mode(range)
102	1.5	2.5	0.0
103	1.0	2.0	0.0-1.5
104	1.0	1.5	0.0
105	1.0-2.0	0.0(0.0-2.0)	1.0(0.0-1.0)
106	-	2.0	0.0
107	1.5	1.0-1.5	0.0-1.0
111	1.0	2.0	0.0
113	1.5-2.5	1.0	0.0
114	2.0-3.0	1.0-2.0	1.0-2.0
115	2.0(1.0-2.5)	1.0-2.5	0.0
116	1.0-2.0(0.0-2.0)	2.0	1.0
117	1.0(1.0-2.5)	2.0	0.0
118	2.0	1.0-2.0	1.0-1.5
119	1.0-2.0	2.0	0.0
123	1.0	1.0	1.0
124	2.0(2.0-2.5)	1.5-2.0	0.0
125	2.0	1.5	1.0
126	2.0	2.5	0.0
127	0.0-0.5	0.0	0.0
128	0.0(0.0-0.5)	0.0	0.0
129	0.5	0.0	0.0
130	0.5(0.0-0.5)	0.0	0.0
131	0.5(0.0-0.5)	0.0-1.0	1.0(0.0-2.0)
132	0.5(0.0-0.5)	0.5-2.0	0.0-1.0
133	1.0(0.0-1.0)	1.0	0.0
134	0.0-1.0	2.0	0.0
135	1.0(0.5-1.0)	0.0	2.0
136	1.0	2.0-3.0	0.0
137	1.0	1.0-3.0	0.0
138	1.0	0.0	2.0
139	1.0(0.5-2.5)	2.0	0.0
140	0.5-2.0	1.0-3.0	0.0
141	2.0(2.0-2.5)	0.0-2.0	0.0
142	1.5	2.0	0.0-1.0
143	2.0-2.5(1.0-2.5)	2.0	0.0
144	2.0-2.5(1.0-2.5)	1.0-2.0	0.0
145	1.0-2.0(1.0-3.0)	0.0-3.0	0.0-2.5
146	1.0-2.5	3.0	0.0
147	2.0(1.0-3.0)	1.0	0.0
148	1.0(1.0-2.0)	1.0	0.0
149	2.0(1.5-2.0)	0.0	2.5
150	2.0(2.0-4.0)	1.5	0.0
155	1.0-2.5	2.5	0.0
156	2.0(1.5-2.5)	2.0	0.0

Table 1: continued.

Scale : 0 = no glare
1 = 0 ≤ 25% field of view glare affected
2 = 25 ≤ 50% field of view glare affected
3 = > 50% field of view glare affected

Transect No.	Beaufort Sea State mode(range)	Glare North/East mode(range)	Glare South/West mode(range)
157	2.5(2.5-3.0)	2.5	0.0
158	2.0	3.0	0.0
159	2.5	2.5	1.0
160	2.0	3.0	0.0
161	2.0	2.0	0.0
162	2.0	3.0	0.0
163	2.0	1.0-2.0	0.0
164	2.0-3.0	3.0	0.0
165	2.0-3.0	1.0-2.0	0.0
166	2.0(1.0-3.0)	3.0	0.0
167	1.0-3.0	1.0-3.0	0.0
168	1.0-3.0(1.0-4.0)	1.0-2.0	0.0
185	1.0	2.0	0.5
186	1.0	1.0-2.0	0.0
187	1.0	1.0-2.0	0.0
188	1.0	1.0	0.0
189	1.0(0.5-1.0)	1.0	0.0
190	1.0(0.0-1.0)	1.0-2.0	0.0
191	1.0(0.0-1.0)	1.0-2.0	0.0
192	1.0(1.0-3.0)	2.0	0.0
193	3.0(2.0-3.0)	2.0	0.0
194	3.0(2.0-3.0)	2.0	0.0
195	2.0(1.0-3.0)	3.0	0.0
196	2.0(1.0-3.0)	2.0	0.0
197	1.0(0.0-2.0)	2.0(2.0-3.0)	0.0-1.5
198	0.0-2.0	2.0(2.0-3.00)	0.0
199	0.0-1.0(0.0-2.0)	1.0(0.0-2.0)	0.0(0.0-1.5)
200	1.0-2.5(0.0-2.5)	0.0(0.0-2.0)	0.0-3.0
201	2.0(0.5-2.5)	3.0	0.0
202	2.0(1.0-2.5)	3.0	0.0
203	1.0-2.0	2.0(2.0-3.0)	0.0
204	2.0(1.0-2.5)	2.0-3.0	0.5
205	2.0(1.0-2.0)	2.0-3.0	0.0
206	3.0(1.5-3.0)	2.0-3.0(1.0-3.0)	0.0
207	2.5-3.0(2.0-3.0)	2.0-3.0	0.0(0.0-1.0)
208	3.02.5-3.0)	1.0-3.0	0.0
209	2.0-3.0	1.0-3.0	0.0(0.0-1.5)
210	2.5-3.0(1.0-3.0)	2.5-3.0	0.0
211	-	-	-
212	2.0	3.0	0.0
213	2.5	1.0-2.5	0.0-1.0
214	2.0-3.0	0.0-3.0	0.0
215	3.0(2.5-3.0)	0.0-2.0	0.0-2.5
216	2.0(2.0-2.5)	0.0	0.0
217	2.5(1.5-2.5)	2.0	0.0

Table 1: continued.

Scale : 0 - no glare
1 - 0 ≤ 25% field of view glare affected
2 - 25 ≤ 50% field of view glare affected
3 - > 50% field of view glare affected

Transect No.	Beaufort Sea State mode(range)	Glare North/East mode(range)	Glare South/West mode(range)
218	3.0(2.5-3.0)	3.0	0.0
219	3.0(0.0-3.0)	2.5	0.0
220	2.5	3.0	0.0
221	2.5(2.0-2.5)	0.0-0.5	0.0
222	0.5(0.0-0.5)	0.0-1.5	0.0
223	0.5	0.0-2.0	0.0-1.0
224	0.5	0.0-1.0	0.0
225	0.5	0.0	0.0
226	0.5(0.0-0.5)	0.0	0.0
227	0.5	0.0	0.0
302	1.0(0.0-2.0)	3.0	1.0(0.5-2.0)
303	2.0(1.5-3.0)	2.0(0.0-3.0)	0.0(0.0-3.0)
348	0.0-1.0	-	-
365	0.0	2.0	0.0
366	0.5-3.0	2.0	0.0
397	1.0-2.5	2.0-3.0	0.0
398	2.0(2.0-2.5)	0.0(0.0-1.0)	1.0(0.0-1.0)
399	2.0	3.0(2.0-3.0)	2.0(0.0-2.0)

Table 2: Raw data used to calculate correction factors.

(a) Correction for perception bias

Blocks : lines	No. of groups					
	Port			Starboard		
	Mid	Rear	Tandem	Mid	Rear	Tandem
All blocks and lines	10	9	48	7	17	46

(b) Correction for availability bias

Blocks : lines	No. of animals in groups of less than 10		
	Surface	Under	Total
All blocks and lines	63	162	225

Table 3: Raw data for survey: dugong sightings.

Transect No.	No. of observers Port	No. of observers Starboard	No. of groups of dugongs Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
102	2	2	0	0	0	0	0	0
103	2	2	0	0	0	0	0	0
104	2	2	0	0	0	0	0	0
105	2	2	0	0	0	0	0	0
106	2	2	0	0	0	0	0	0
107	2	2	0	0	0	0	0	0
111	2	2	0	0	0	0	0	0
113	2	2	0	0	0	0	0	0
114	2	2	0	0	0	0	0	0
115	2	2	0	0	0	0	0	0
116	2	2	0	0	1	0	0	0
117	2	2	0	0	0	0	0	0
118	2	2	0	0	1	0	2	2
119	2	2	0	0	1	0	0	0
123	2	2	0	0	0	0	0	0
124	2	2	0	0	0	0	0	0
125	2	2	0	0	0	0	0	0
126	2	2	0	0	0	0	0	0
127	2	2	0	0	0	0	0	0
128	2	2	0	0	0	0	0	0
129	2	2	0	0	0	0	0	0
130	2	2	0	0	0	0	0	0
131	2	2	0	0	0	0	0	1
132	2	2	0	0	0	0	0	0
133	2	2	0	0	0	0	0	0
134	2	2	0	0	0	0	0	0
135	2	2	0	0	1	0	0	0
136	2	2	0	0	0	1	0	1
137	2	2	2	0	1	0	0	0
138	2	2	0	0	0	0	0	1
139	2	2	0	0	0	0	0	1
140	2	2	0	0	1	0	0	0
141	2	2	0	0	1	0	0	0
142	2	2	0	0	1	0	0	0
143	2	2	0	0	0	0	0	0
144	2	2	0	0	0	0	0	0
145	2	2	0	0	0	0	0	0
146	2	2	0	0	0	0	0	0
147	2	2	0	0	0	0	0	0
148	2	2	0	0	0	0	0	0
149	2	2	0	0	0	0	0	0
150	2	2	0	0	0	0	0	0
155	2	2	0	0	0	0	0	0
156	2	2	0	0	0	0	0	0
157	2	2	0	0	0	0	0	0
158	2	2	0	0	0	0	0	0
159	2	2	0	0	0	0	0	0
160	2	2	0	0	0	0	0	0
161	2	2	0	0	0	0	0	0
162	2	2	0	0	0	0	0	0

Table 3: dugong sightings continued.

Transect No.	No. of observers Port	Starboard	No. of groups of dugongs Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
163	2	2	0	0	0	0	0	0
164	2	2	0	0	0	0	0	0
165	2	2	0	0	0	0	0	0
166	2	2	0	0	0	0	0	0
167	2	2	0	0	0	0	0	0
185	2	2	0	0	0	0	0	0
185[1]	2	2	0	0	0	0	0	0
186	2	2	0	0	0	0	0	0
187	2	2	0	0	0	0	0	0
188	2	2	0	0	0	0	0	1
189	2	2	0	0	0	0	0	0
190	2	2	0	1	0	0	0	0
191	2	2	0	0	0	0	0	0
192	2	2	0	0	0	0	0	0
193	2	2	0	0	0	0	0	0
194	2	2	0	0	0	0	0	0
195	2	2	0	0	2	0	0	0
196	2	2	0	0	0	0	0	0
197	2	2	0	1	0	0	0	0
197[1]	2	2	0	0	0	0	0	3
198	2	2	0	0	0	0	0	0
198[1]	2	2	0	0	1	0	0	5
199	2	2	0	0	3	0	0	1
199[1]	2	2	1	0	3	1	1	3
200	2	2	3	3	9	0	3	5
201	2	2	1	1	5	0	4	2
202	2	2	0	0	5	0	1	2
203	2	2	0	0	0	0	0	0
204	2	2	0	0	0	0	0	0
205	2	2	0	0	0	0	0	0
206	2	2	0	0	0	0	0	0
207	2	2	0	0	0	0	0	1
208	2	2	0	0	1	0	0	0
209	2	2	0	0	0	0	1	0
210	2	2	0	0	0	0	1	0
211	2	2	0	0	0	0	0	1
212	2	2	0	1	1	0	0	0
213	2	2	0	0	0	0	0	0
214	2	2	1	0	0	0	0	0
215	2	2	0	0	0	0	0	0
216	2	2	0	0	0	0	0	0
217	2	2	0	0	0	0	0	0
218	2	2	0	0	0	0	0	0
219	2	2	0	0	0	0	0	0
220	2	2	0	0	0	0	0	0
221	2	2	0	0	0	0	0	0
222	2	2	0	0	0	0	0	0
223	2	2	0	0	0	0	0	0
224	2	2	0	0	0	0	0	0
225	2	2	0	0	0	0	0	0

Table 3: dugong sightings continued.

Transect No.	No. of observers Port	Starboard	No. of groups of dugongs Port Mid	Rear	Tandem	Starboard Mid	Rear	Tandem
226	2	2	0	0	0	0	0	0
227	2	2	0	0	0	0	0	0
302	2	2	1	1	3	3	0	9
303	2	2	1	0	3	0	0	4
348	2	2	0	0	0	0	1	0
365	2	2	0	0	0	0	0	0
366	2	2	0	0	0	0	1	0
397	2	2	0	0	0	0	0	0
398	2	2	0	0	0	1	0	0
399	2	2	0	0	4	1	1	1

[1] repeat transects flown due to poor weather on first flight.