The Century Project

Environmental Studies

**DUGONGS,
SEA TURTLES AND DOLPHINS**

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TABLE OF CONTENTS

FIGURES

EXECUTIVE SUMMARY

- Dugongs, sea turtles and cetaceans were counted from the air in December 1991 at an overall sampling intensity of 8.2% over an area of 8,850 km^2 in the coastal waters in the vicinity of the proposed loading facilities for ore from the Century mine at Point Parker and Burketown in the Gulf of Carpentaria.

- Estimates for all taxa were corrected for perception bias (the proportion of animals visible in the transect that are missed by observers). Estimates for dugongs and sea turtles were also corrected for availability bias (the proportion of animals not visible due to water turbidity). Correction factors are survey and taxon specific.

- Most of the turtles sighted during this survey were probably large green turtles.

- All the cetaceans sighted were dolphins. Most of the animals appeared to be bottlenose dolphins, *Tursiops truncatus*. No Irrawaddy River dolphins were sighted despite reports of a high density of this species around the Sir Edward Pellew Islands in the southwestern Gulf of Carpentaria.

- The minimum population estimates for the survey area in December 1991 were as follows:

dugongs:	4067 ± s.e. 723
sea turtles:	8391 ± s.e. 1295
dolphins:	836 ± s.e. 199

- Based on this survey and the extensive data from other areas, we rate the survey area with an estimated 4000 dugongs as the third most important habitat for dugongs in Queensland and among the top six dugong areas in Australia along with Torres Strait (24,000, Marsh and Lawler, 1992); Shark Bay (10,000, Marsh *et al.*, 1991), the northern Great Barrier Reef (8000, Marsh and Saalfeld, 1989) and the Sir Edward Pellew Island area (6000, Bayliss and Freeland, 1989).

- The survey area is also an important feeding ground for green turtles and supports green and flatback turtle rookeries.

- Both the dugongs and green turtles from the survey area are an important part of the culture and diet of the local Aboriginal people.

- From the point of view of dugongs and turtles, the major concern about exporting ore from the Century mine through Point Parker or Burketown is the risk of heavy metal pollution. The effect of such pollution is likely to be much more serious for the fauna of the seagrass beds than on the seagrass *per se*. The heavy metal status of both dugongs and sea turtles reflects that of the seagrass on which they feed and the levels of several metals (including zinc) in dugongs from this region are higher than recorded in marine mammals from other parts of the world.

- Populations of dugongs, dolphins and sea turtles are sensitive to small changes in the survivorship of large juveniles and adults. However, because of the difficulties in the census techniques and the distribution of the animals, declining trends in abundance will be impossible to detect for many years. The only practicable way to manage stocks of these animals is to minimise deleterious impacts on their survivorship. Although the effects of increasing the concentrations of lead and zinc in dugongs and sea turtles above natural values have not been documented, this risk is of concern given that both species are (1) an important component of the diet of the local Aboriginal people; and (2) listed as threatened with extinction.

Conclusions

The Mornington Island area is the third most important habitat for dugongs in Queensland and among the top six dugong areas in Australia. It is also an important feeding ground for green turtles and supports green and flatback turtle rookeries. There was considerable evidence of dugongs feeding in the coastal region in the vicinity of Point Parker.

Heavy metal pollution on the seagrass beds of this region resulting from the export of ore from the Century Project through Point Parker or Burketown could cause potentially serious impacts. Such pollution is likely to pass up to the dugongs and turtles via their seagrass food. The levels of several metals, including zinc, in dugongs from this region are higher than recorded in marine mammals from other parts of the world.

1.0 INTRODUCTION

Three localities in the southern Gulf of Carpentaria region of Queensland are under consideration as potential ports for the export of the lead-zinc concentrate from the Century Project: Point Parker, Burketown and Karumba. Aerial surveys in the 1970's indicated that the coast adjacent to the Wellesley Islands supported the largest number of dugongs on the Gulf of Carpentaria coast of Queensland (Marsh *et al.*, 1980, Marsh, 1988). In contrast, the density of dugongs in the Karumba area is much lower (Heinsohn, 1977).

Large numbers of sea turtles were also seen in the Wellesley Island area and adjacent coast during the surveys conducted in the 1970's (unpublished data). Green turtles and dugongs are of considerable cultural and dietary importance to Aboriginal people in this area (Marsh *et al.*, 1980, unpublished data). It is considered that the Australian maritime estate offers the best chance of survival for both dugongs and green turtles (House of Representatives Standing Committee, 1992). Thus Australia has a major responsibility for the conservation of dugongs and green turtles, both of which are listed in the IUCN Red Data Book of Threatened Species (IUCN, 1990).

Aerial survey techniques for dugongs and sea turtles have improved greatly since the 1970's (Marsh and Sinclair, 1989, a and b) and much of the coast of northern Australia has been surveyed using the new techniques (Bayliss and Freeland, 1989; Marsh and Saalfeld, 1989, 1990, 1991, Marsh *et al*, 1989, 1991, Marsh and Lawler, 1992). The Queensland coast of the Gulf of Carpentaria is one of the few regions of northern Australia which had not been resurveyed. In order to determine the current importance of the coastal region off Burketown and Point Parker to dugongs, dolphins and sea turtles, an aerial survey of the Wellesley Islands and adjacent coastline was conducted in December 1991 as part of the Environmental Impact Assessment for the Century Project. The results of that survey are presented in this report.

The survey was conducted by Professor Helene March, Director of Environmental Studies, James Cook University of North Queensland for Hollingsworth Dames & Moore.

2.0 METHODS

The waters surrounding Mornington Island were surveyed from December 11 to 14 inclusive 1991. Apart from December 14 (on which only three transects were flown over water), weather conditions for the survey were generally good. Conditions are summarised in Table 2.1.

Table 2.1
Weather Conditions Encountered during the Survey

Wind speed (km h^{-1})	≤10
Cloud cover (oktas)	0–7
Minimum cloud height (m)	2000–8000
Beaufort sea state	1.7(0–4)
Glare North/West	1.5(0–3)
Glare South/East	2.1 (0–3)
Visibility (km)	≥20

Values for Beaufort sea state and glare are the mean of the modes for each transect with range in parentheses.
Glare is measured as: 0, none; 1, <25% of field of view affected; 2, 25–50%; 3 >50%.

2.1 Survey design

East–west transects were flown at intervals of 2.5' of latitude within most of the region bounded by the coast of the Gulf of Carpentaria, 139°E, 139°55'E and 16°18'45"S (Figure 1). A region around the Bountiful Islands to the east of Mornington Island (Figure 1) was not surveyed due to the bad weather on December 14. However, as the water in this region is beyond the depth range for sea grasses in this area (Poiner *et al.*, 1987), it is unlikely to be significant for dugongs or turtles.

The intertidal seagrass beds along the coast between 138° 30' E and 193° 55' E were surveyed from the air at a groundspeed of 185 km h^{-1} (100 kn.) at an altitude of 137 m (450 feet) ASL at low tide (0.79 m at Karumba) on December 14 to check for the presence of seagrasses and dugong feeding trails.

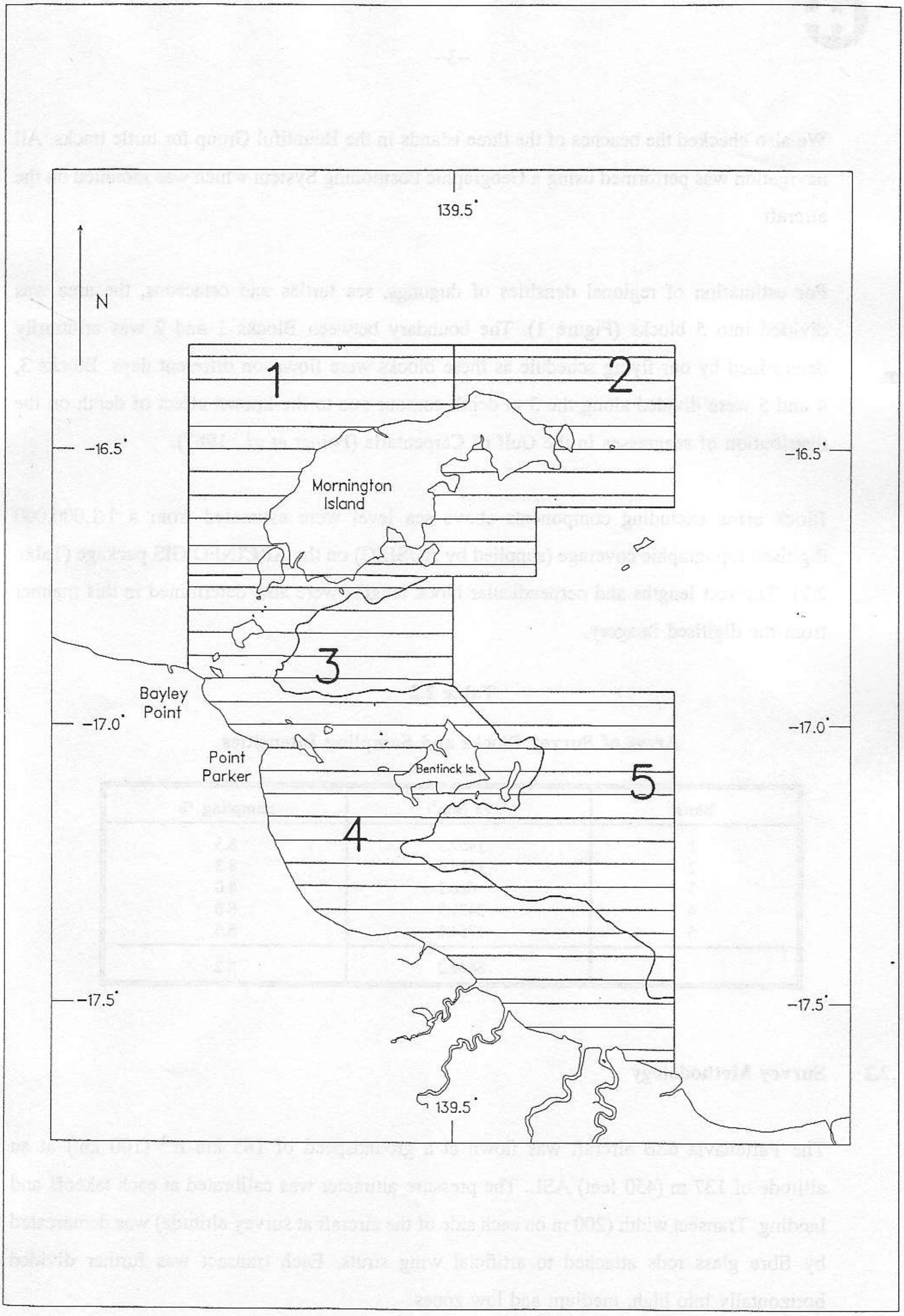


Figure 1. Survey area, showing the survey blocks (1-5) and transect lines for the December 1991 survey.

We also checked the beaches of the three islands in the Bountiful Group for turtle tracks. All navigation was performed using a Geographic Positioning System which was mounted on the aircraft.

For estimation of regional densities of dugongs, sea turtles and cetaceans, the area was divided into 5 blocks (Figure 1). The boundary between Blocks 1 and 2 was arbitrarily determined by our flying schedule as these blocks were flown on different days. Blocks 3, 4 and 5 were divided along the 3 m depth contour due to the known effect of depth on the distribution of seagrasses in the Gulf of Carpentaria (Poiner *et al.*, 1987).

Block areas excluding components above sea level were estimated from a 1:1,000,000 digitised topographic coverage (supplied by AUSLIG) on the ARCINFO GIS package (Table 2.2). Transect lengths and perpendicular block lengths were also determined in this manner from the digitised imagery.

Table 2.2

Areas of Survey Blocks and Sampling Intensities

Block	Area (km^2)	Sampling %
1	1457.3	8.3
2	1584.6	8.3
3	620.2	8.0
4	3431.9	8.0
5	1754.2	8.6
	8848.2	8.2

2.2 Survey Methodology

The Partenavia 68B aircraft was flown at a groundspeed of 185 km h^{-1} (100 kn.) at an altitude of 137 m (450 feet) ASL. The pressure altimeter was calibrated at each takeoff and landing. Transect width (200 m on each side of the aircraft at survey altitude) was demarcated by fibre glass rods attached to artificial wing struts. Each transect was further divided horizontally into high, medium and low zones.

The actual width of each transect was determined in the analysis by interpolating the altimeter correction at landing (assumed to accrue linearly) to the midtime of the transect and adding it to the mean recorded height for that transect. The transect width was then adjusted for an assumed transect width of 400 m at an altitude of 137 m. The overall sampling intensity was 8.2%, the sampling intensity for each Block ranged from 8–8.6% (Table 2.2).

The crew comprised a pilot navigator, a front right survey leader/recorder, and two tandem observing teams, who occupied the middle and rear seats on opposite sides of the aircraft.

The observers reported their observations of dugongs, turtles (not to species), cetaceans (not to species), sharks, rays, and sea snakes in standard format into an intercom connected to a two track tape recorder. We recorded the zone within the transect in which each sighting occurred in order to increase the probability of distinguishing between different observations reported simultaneously by both members of a tandem team.

Rear seat observers were visually screened from the mid seat observers and acoustically isolated from the remainder of the crew apart from each other. The rear seat observers and the mid seat observers reported their (independent) observations into separate tracks of the tape recorder. Data including aircraft height and position, weather conditions, the starting and finishing timers for each transect, and the sightings of the mid seat observers were recorded by the survey leader using a microcomputer programmed as a data logger and timer.

The methodology is detailed in Marsh and Saalfeld (1989) and Marsh and Sinclair (1989 a and b).

2.3 Correction Factors

Correction factors were calculated separately for dugongs, dolphins and turtles to compensate for perception bias (proportion of groups visible in the transect that were missed by observers) and for dugongs and turtles to compensate for availability bias (proportion of groups of animals that were unavailable to observers because of water turbidity) and their associated coefficients of variation as outlined in Marsh and Sinclair (1989a) (see Tables 2.3,2.4,2.5).

The corrections for perception bias were calculated on the basis of the proportion of the relevant sightings seen by one (specified) member or both members of each tandem team using the Petersen mark-recapture model. The data on which the perception correction factors were based included sightings from a survey of part of Torres Strait which was conducted immediately prior to this survey using the same observers.

The corrections for availability bias were calculated separately for each taxon.

2.3.1 Dugongs

The availability correction factors (Table 2.3) were calculated by standardising the proportion of dugongs sighted during the survey against the proportion on the surface in a clear water area where all dugongs were potentially available (Marsh and Sinclair, 1989a).

Table 2.3

Details of Group Size Estimates and Correction Factors used in the Population Estimates for Dugongs

Blocks	Group size mean (c.v.)	Numbers of observers		Perception Correction Factor estimate (c.v.)		Availability Correction Factor estimate (c.v.)
		Port	Starboard	Port	Starboard	
1, 2, 3, 4, 5	1.2551 (0.0568)	2	2	1.0634 (0.0158)	1.0814 (0.0182)	2.4878 (0.1480)

2.3.2 Turtles

The corrections for availability bias (Table 2.4) were calculated by standardising the proportion of turtles sighted during the survey against data from the November 1985 survey of blocks 8 to 13 in the northern waters of the Great Barrier Reef Marine Park (Marsh and Saalfeld, 1989). The proportion of turtles sighted at the surface on that survey was the lowest of any survey we have undertaken, and has been used to standardise the minimum population estimates on turtles on other surveys of the Great Barrier Reef Marine Park and Torres Strait.

Table 2.4

Details of Group Size Estimates and Correction Factors used in the Population Estimates for Turtles

Blocks	Group size mean (c.v.)	Numbers of observers		Perception Correction Factor estimate (c.v.)		Availability Correction Factor extimate (c.v.)
		Port	Starboard	Port	Starboard	
1, 2, 3, 4, 5	1.0855 (0.0228)	2	2	1.1015 (0.0178)	1.2970 (0.0388)	1.7508 (0.0929)

It was not possible to correct for availability bias for dolphins because of the lack of suitable data to use as a standard. The perception correction factors for dolphins are summarised in Table 2.5.

Table 2.5

Details of Group Size Estimates and Correction Factors used in the Population Estimates for Dolphins

Blocks	Group size mean (c.v.)	Numbers of observers		Perception Correction Factor estimate (c.v.)		Availability Correction Factor extimate (c.v.)
		Port	Starboard	Port	Starboard	
1, 2, 3, 4, 5	2.3214 (0.3173)	2	2	1.0989 (0.0523)	1.1200 (0.0518)	1.0000 (0.0000)

2.4 Analysis

Because transects were variable in area, the Ratio Method (Jolly 1969; Caughley and Grigg 1981) was used to estimate separately for each block the density, population size and their associated standard errors for dugongs, dolphins and turtles. Any statistical bias resulting from this method is considered inconsequential in view of the relatively high sampling intensity (Table 2.2; see Caughley and Grigg 1981). Input data were the estimated number of dugongs, turtles or dolphins for each tandem team per transect calculated using the correction factors described above.

The resultant standard errors were adjusted to incorporate the errors associated with the appropriate estimates of the perception and availability correction factors and mean group size (Tables 2.3,2.4,2.5) following the method of Jolly and Watson (1979) as outlined in Marsh and Sinclair (1989a).

Density diagrams, adjusted for sampling intensity, were produced using the ARCINFO GIS package. A 5 x 5 nm grid coverage was combined with the coastline coverage and then the corrected number of dugongs, turtles and cetaceans and the transect length flown were calculated for each grid cell. Density within each grid cell was then calculated as:

Density = Corrected No. Dugongs (dolphins or turtles)/(transect length in km * 0.4)

where 0.4 km is the approximate transect width.

3.0 RESULTS

3.1 Dugongs

As is usual in northern Australia, most sightings (63.4%) were of solitary dugongs (Figure 2). The mean group size was 1.26 (+/– 0.057 s.e.). The largest group seen was one group of four individuals.

Figure 3 shows the distribution of dugong sightings in the Mornington Island region. Dugong density (Table 3.1) was highest in the coastal region within the 3 m depth contour (Block 4). The intertidal seagrass beds along the coast between 138° 55' E and the mouth of the Leichhardt River were heavily used by dugongs at the time of the survey as evidenced by the very high density of feeding trails observed at low tide. The other survey blocks had low, similar densities of dugongs. Table 6 summarises the estimates of dugong density and population size for each block. The total population estimate for this survey is 4067 ± s.e. 723 dugongs at an overall density of 0.46 ± s.e. 0.082 dugongs per km^2.

Table 3.1

Estimated Densities and Number of Dugongs for the Survey.

Block	Density per km^2	Numbers
1	0.08 +/– 0.060	120.8 +/– 87.1
2	0.10 +/– 0.038	161.8 +/– 60.2
3	0.20 +/– 1.209	124.6 +/– 73.3
4	1.03 +/– 0.206	3542.0 +/– 707.1
5	0.07 +/– 0.045	117.4 +/– 78.1
Total	0.46 +/– 0.082	4066.6 +/– 722.6

The values are +/– standard error incorporating the errors resulting from sampling and in estimating mean group size and correction factors.

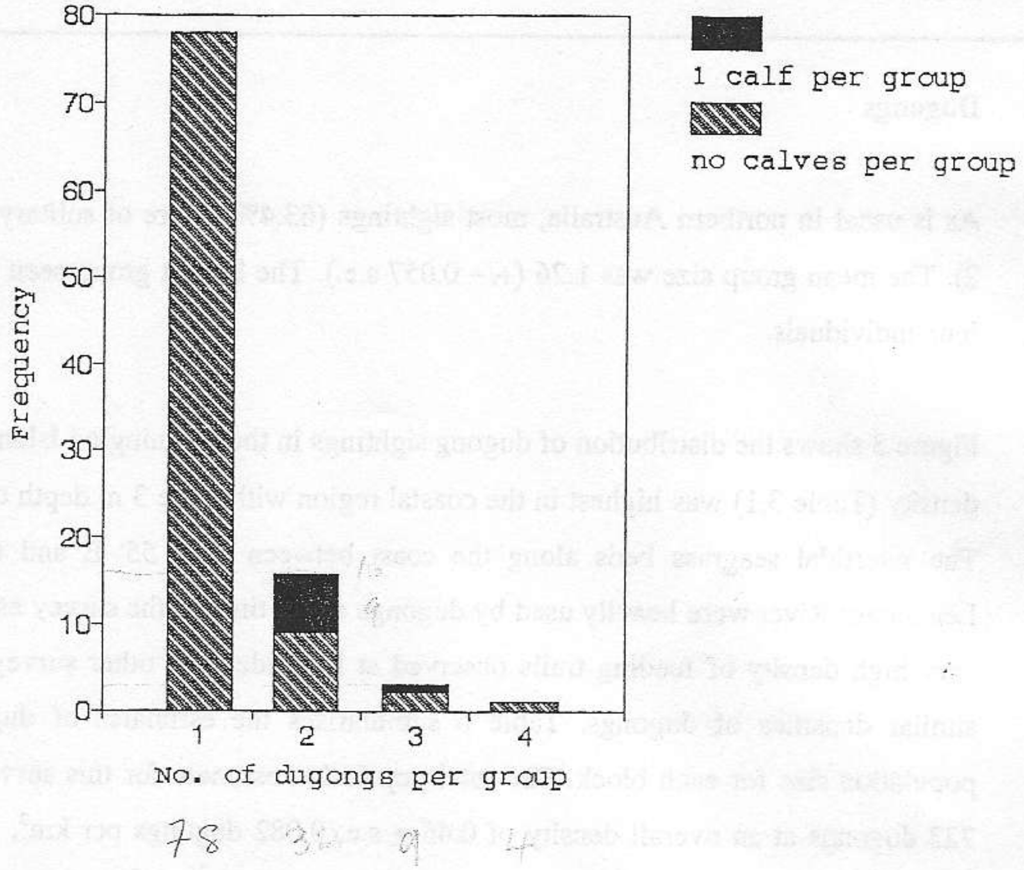
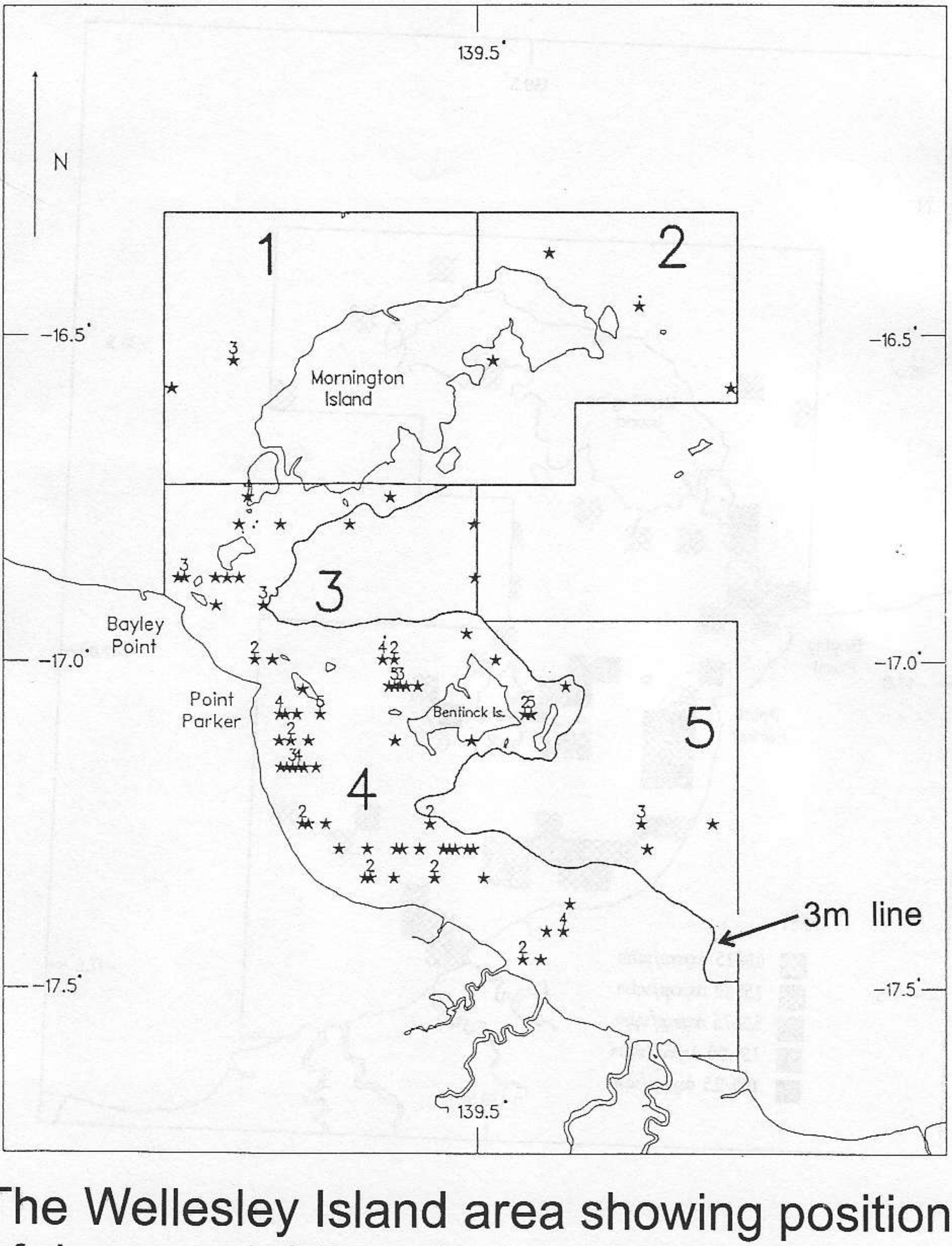


Figure 2. Frequency histogram illustrating the sizes of the groups of dugongs seen during the survey.



The Wellesley Island area showing positions of dugong sightings in December 1991

~~Figure 3.~~ The survey area showing the positions of dugong sightings in December 1991. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

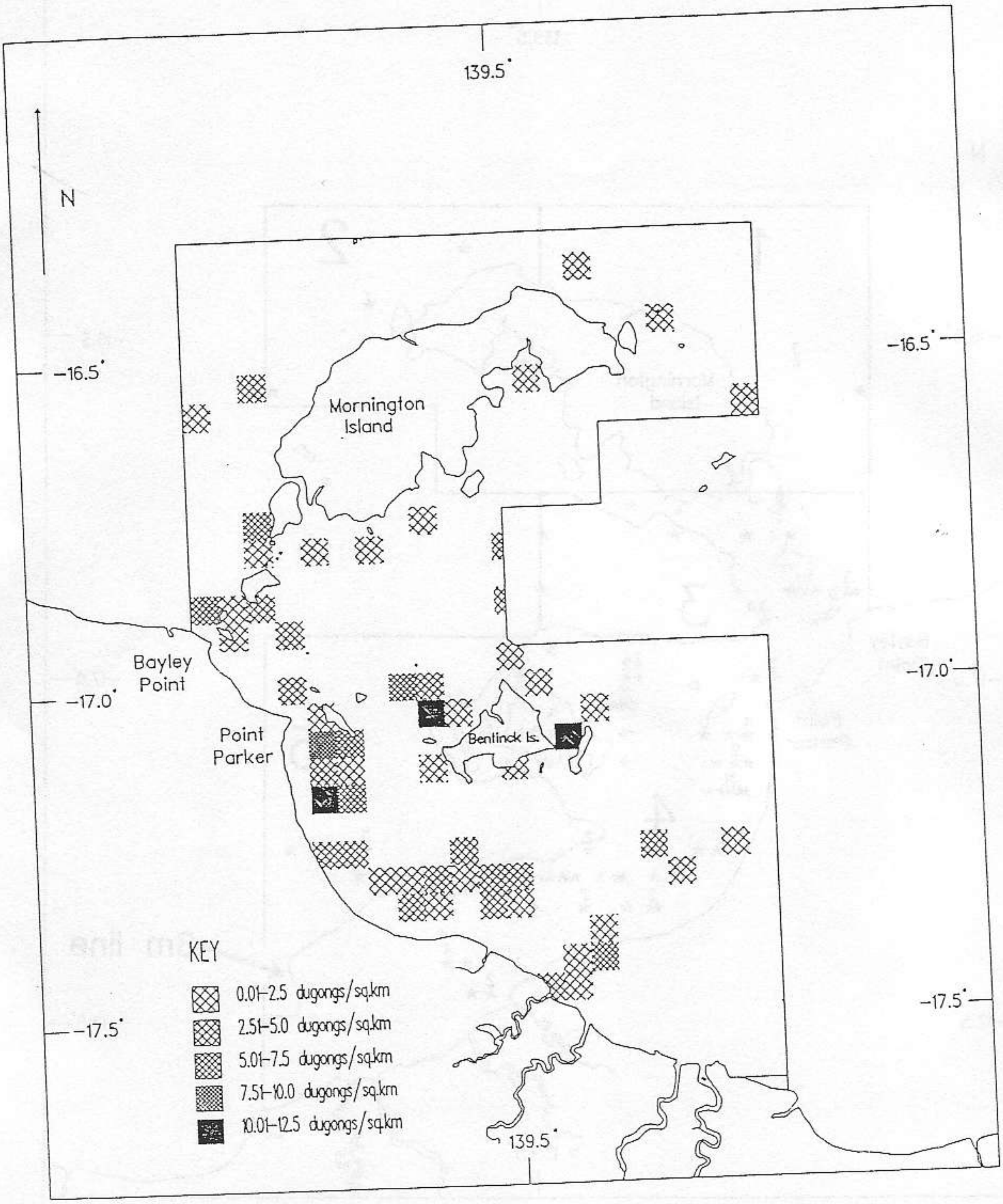


Figure 4. The survey area showing dugong density, adjusted for sampling intensity, calculated on a 5 x 5 nm square grid.

3.2 Turtles

Most of the turtles sighted were probably large green turtles. Figure 5 shows the distribution of turtle sightings in the Mornington Island area. Turtle density was highest in Blocks 2 and 4 (Figure 6) and concentrated in shallow waters along parts of the coast and around Mornington and Bentinck Islands. The total estimated population of sea turtles for the region was 8391 ± s.e. 1295 turtles at an overall density of 0.95 ± s.e. 0.146 turtles per km^2. Table 3.2 summarises the estimates of turtle density and population size for each block.

Table 3.2

Estimated Densities and Number of Turtles for the Survey

Block	Density per km^2	Numbers	
1	0.61 +/- 0.148	890.4 +/- 216.4	10.6
2	1.35 +/- 0.362	2143.5 +/- 574.2	25.5
3	0.18 +/- 0.111	108.8 +/- 69.0	1.3
4	1.31 +/- 0.325	4492.5 +/- 1113.9	53.5
5	0.43 +/- 0.135	755.4 +/- 236.6	9.0
Total	0.95 +/- 0.146	8390.6 +/- 1295.4	99.9

The values are +/- standard error incorporating the errors resulting from sampling and in estimating mean group size and correction factors.

Numerous turtle tracks were observed on the beaches of all three Bountiful Islands indicating that turtles were nesting on these beaches at the time of the survey. These were probably a mixture of green and flatback turtles (J. Miller, pers comm).

3.3 Dolphins

All the cetaceans sighted were dolphins. Most appeared to be bottlenose dolphins, *Tursiops truncatus*. We did not see any Irrawaddy River dolphins despite reports of a high density of this species around the Sir Edward Pellew Islands in the southwest Gulf of Carpentaria (Freeland and Bayliss, 1989).

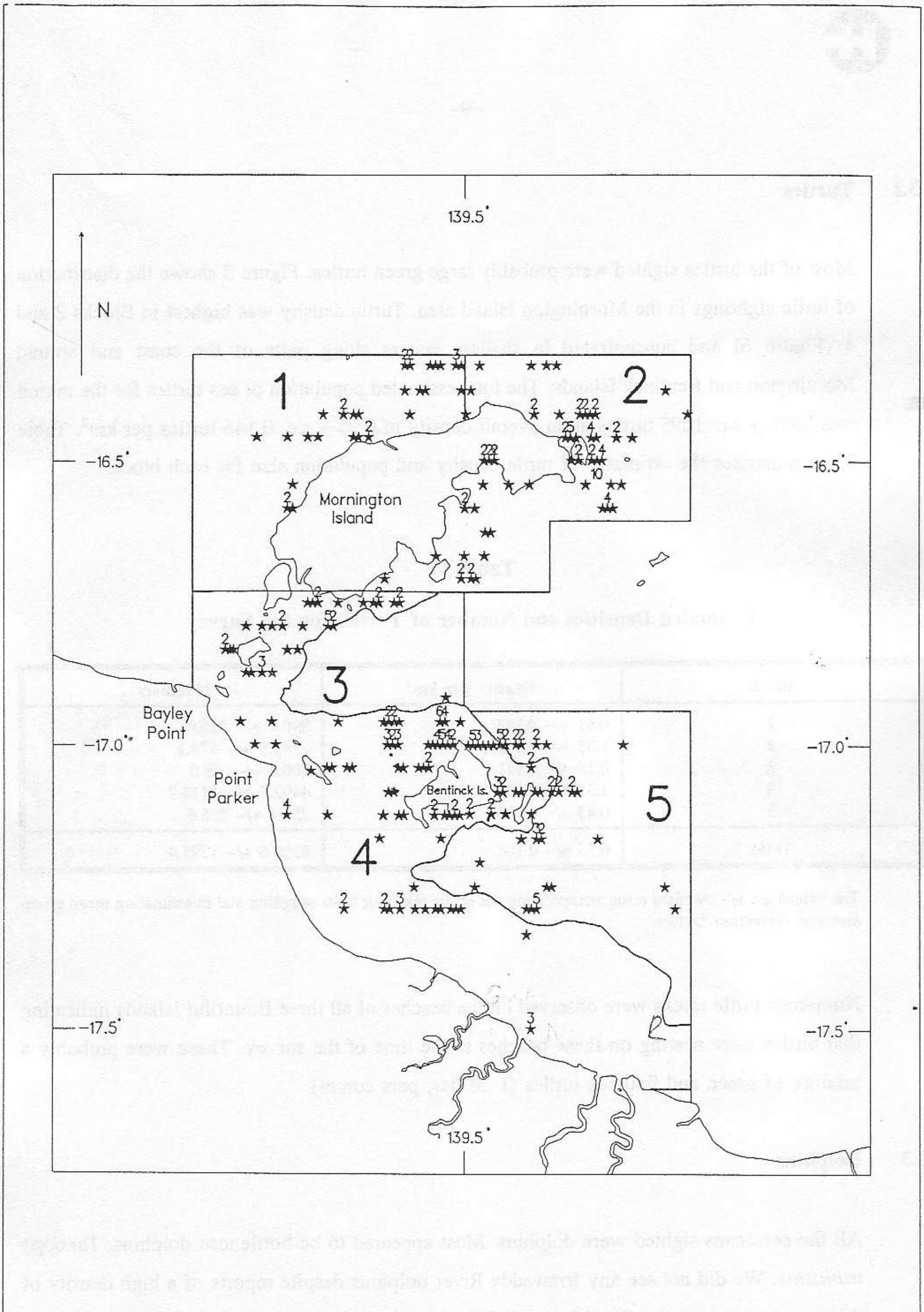


Figure 5. The survey area showing the positions of turtle sightings in December 1991. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

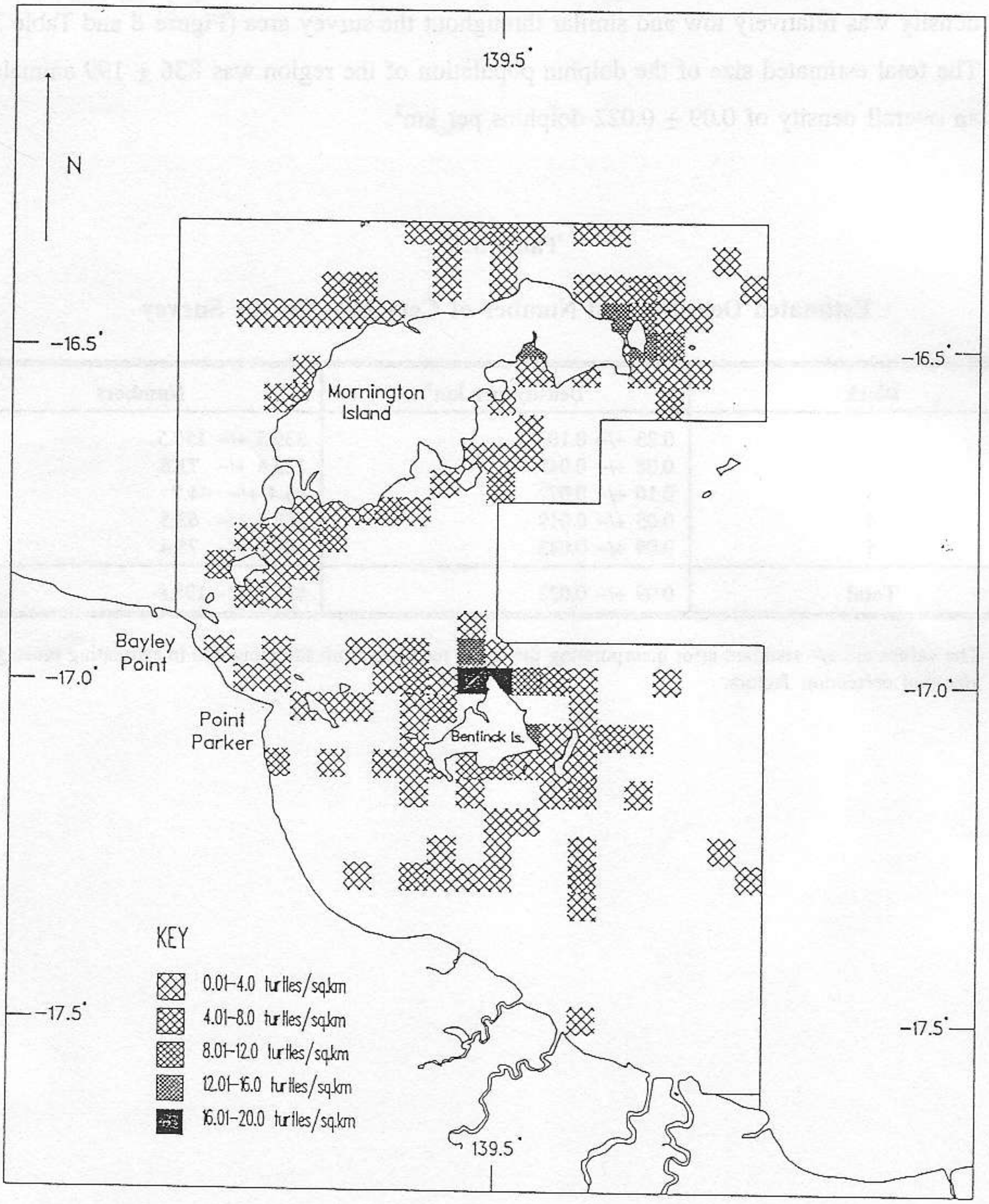


Figure 6. The survey area showing the density of sea turtles, adjusted for sampling intensity, calculated on a 5 x 5 nm square grid.

Figure 7 shows the distribution of dolphin sightings in the Mornington Island area. Dolphin density was relatively low and similar throughout the survey area (Figure 8 and Table 3.3). The total estimated size of the dolphin population of the region was 836 ± 199 animals at an overall density of 0.09 ± 0.022 dolphins per km^2.

Table 3.3

Estimated Densities and Number of Cetaceans for the Survey

Block	Density per km^2	Numbers
1	0.23 +/- 0.103	339.3 +/- 150.5
2	0.08 +/- 0.045	123.4 +/- 71.8
3	0.10 +/- 0.072	63.4 +/- 44.7
4	0.05 +/- 0.019	159.8 +/- 63.5
5	0.09 +/- 0.043	149.8 +/- 75.4
Total	0.09 +/- 0.022	835.7 +/- 198.8

The values are +/- standard error incorporating the errors resulting from sampling and in estimating mean group size and correction factors.

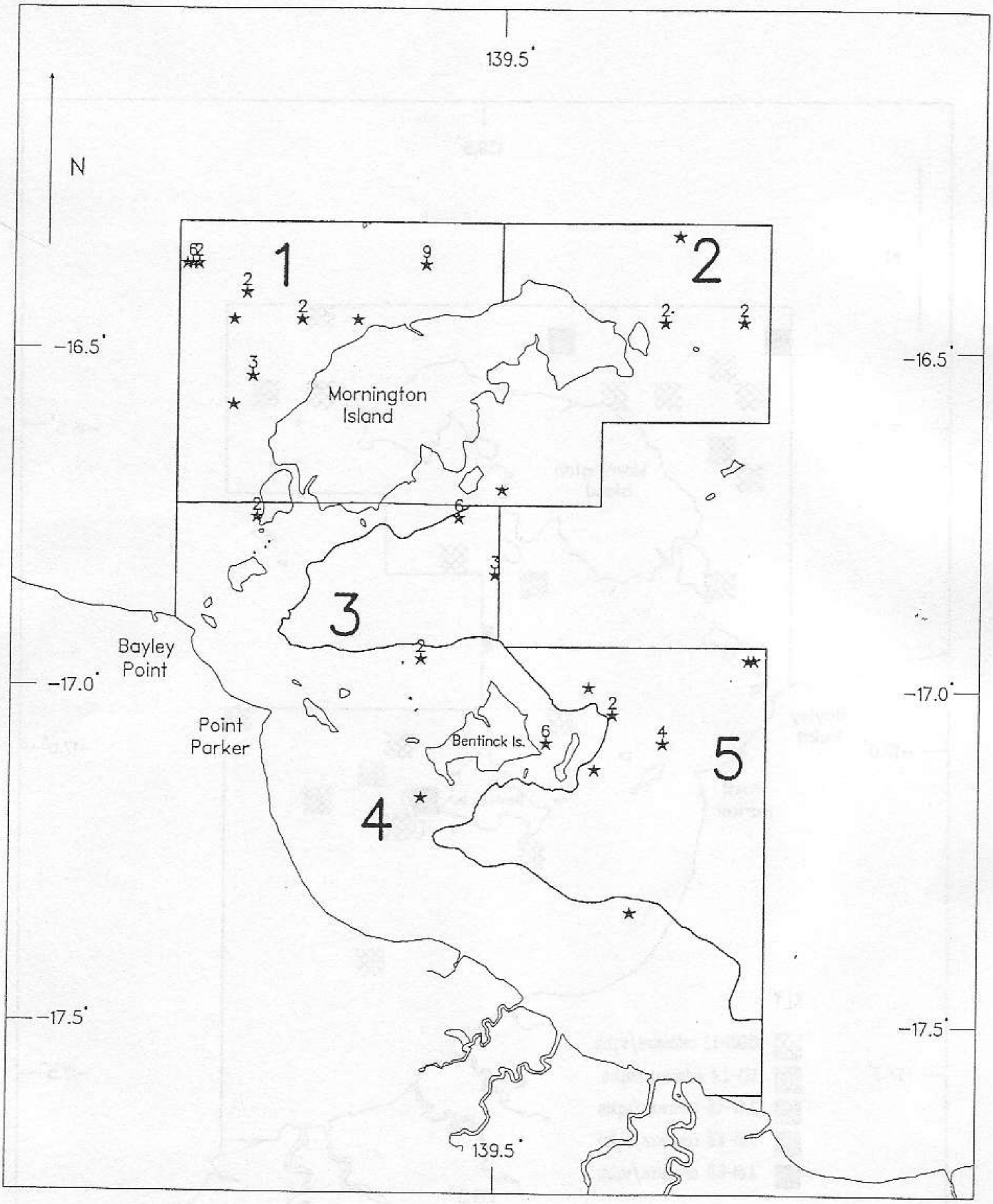


Figure 7. The survey area showing the positions of dolphin sightings in December 1991. The numbers associated with the sightings do not necessarily reflect the sizes of the actual ...

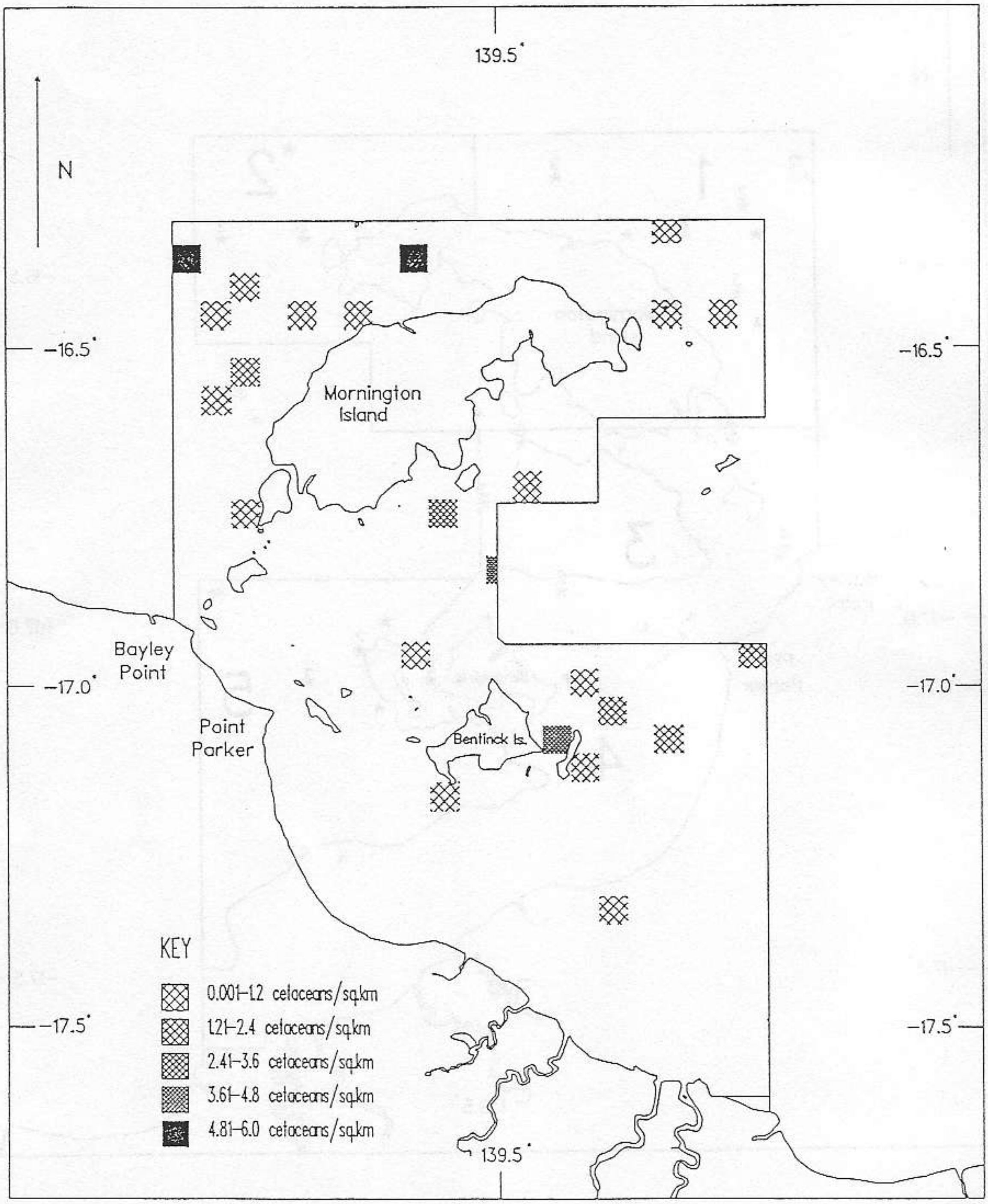


Figure 8. The survey area showing dolphin density, adjusted for sampling intensity, calculated on a 5 x 5 nm square grid.

4.0 REGIONAL AND NATIONAL SIGNIFICANCE OF THE SURVEY AREA

4.1 Dugongs

The range of the dugong extends throughout the tropical and subtropical coastal and island water of the Indo-West Pacific from East Africa to the Solomon Islands and Vanuatu, between 26-27° north and south of the equator (Nishiwaki and Marsh, 1985). This range spans 43 countries and over much of it dugongs are now believed to be represented by relict populations separated by large areas in which they are close to extinction or extinct. This assessment is, however, based almost entirely on anecdotal information and the actual extent to which their range has diminished is unknown.

A significant proportion of remaining dugong stocks is thought to occur in the waters of northern Australia between Moreton Bay (near Brisbane) in the east, and Shark Bay in the west. Many scientists believe Australia to be `the last bastion of the dugong' and to represent the best chance for its survival.

Extensive aerial surveys of dugong populations have been conducted in the following areas in Australia:

> Shark Bay, Exmouth Gulf-Ningaloo (Western Australia); entire Northern Territory coast, Wellesley Island area, Torres Strait, entire east coast of Queensland.

The only areas which are likely to be important and which have not been surveyed using the upgraded technique are the Gulf of Carpentaria coast of Queensland east of the Wellesley Islands and the Kimberley coast of Western Australia.

On the basis of the extensive data available, I rate the study area (estimated population about 4000 dugongs) as the third most important habitat for dugongs in Queensland and among the top six dugong areas in Australia along with Torres Strait (24,000, Marsh and Lawler, 1992); Shark Bay (10,000, Marsh *et al.*, 1991), the northern Great Barrier Reef (8000, Marsh and Saalfeld, 1989) and the Sir Edward Pellew Island area (6000 , Bayliss and Freeland, 1989).

Dugongs are also of great cultural and dietary significance to the local Aboriginal people living in the Wellesley Islands (Marsh *et al.*, 1980), Burketown and Doomadgee.

4.2 Sea Turtles

Green (*Chelonia mydas*), flatback (*Natator depressus)*, Hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*) and olive ridley (*Lepidochelys olivacea*) turtles have been formally recorded from the southern Gulf of Carpentaria (see Limpus and Reed, 1985; Poiner *et al.*,1990). The other sea turtle which occurs in Australian waters is the leatherback, *Dermochelys coriacea*. It is an oceanic species which may be an occasional visitor to the area.

With the exception of the flatback, all the species of sea turtle that occur in the study area are listed as endangered (green, hawksbill, olive ridley) or vulnerable (loggerhead)(IUCN, 1990). The flatback is listed as potentially vulnerable by Kennedy (1990). All species are listed in Appendix 1 or Appendix 2 of CITES. All species of sea turtle are protected in Australia except for localised harvesting by Aborigines and Torres Strait Islanders.

The principal species nesting in the areas are probably flatbacks and greens. Their nesting appears confined to the islands. Nesting probably occurs year-round with a winter peak (Limpus and Reed, 1985).

Like dugongs, green turtles are of considerable cultural and dietary significance to the local Aboriginal people (unpublished data). The two species are often hunted together.

4.3 Cetaceans

Although all dolphins sighted appeared to be *Tursiops truncatus*, the most common dolphin in Australian inshore waters, other species almost certainly occur in the area. Extrapolating from other parts of tropical Australia, the cetacean fauna of the study area probably includes:

(a) Two other inshore species, the Irrawaddy River dolphin, *Orcaella brevirostris*, and the Indo-Pacific hump-back dolphin, *Sousa chinensis*.

and

(b) Oceanic species which pass through the region such as the false killer whale, *Pseudorca crassidens* (a pod of false killer whales was stranded north of Weipa during a cyclone in January 1992) and the short-finned pilot whale, *Globicephala macrorhynchus*.

5.0 POTENTIAL IMPACTS RESULTING FROM THE PROJECT

5.1 Dugongs

5.1.1 Background

Studies of over 600 dugong carcasses have shown that dugongs are very long-lived animals which breed only rarely (Marsh, 1980; Marsh *et al.*, 1984, a,b,c). Individuals reach a maximum age of approximately seventy years, but females do no breed until at least 10 years of age and then bear only a single calf every three to five years, with a gestation period of about 13 months. Population simulations (Marsh, 1986) have shown that dugong populations have a maximum rate of increase of approximately 5% per year. Their rate of increase in this area is likely to be lower than this due to mortality from traditional hunting and incidental drowning in gill nets set for barramundi. Thus even a small reduction in adult survivorship can result in chronic decline in the population. Such a decline will take decades to detect, by which time the population will have been reduced substantially (see Marsh and Saalfeld, 1989).

5.1.2 Boat traffic

Preen (1992) found that in shallow water ≤ 2 m, dugongs actively avoid passing boats, even if up to a kilometre away, the reaction being stronger the shallower the water. The reaction is stronger in areas where boat traffic is normally low. The dugongs tend to move towards deeper water even if it takes them closer to the path of the boat.

If Point Parker or Burketown were used as ports for the Century Mine, the barges associated with the project would have to travel across areas of high dugong density. However, we expect that the amount of traffic would be lower than for Preen's sites in Moreton Bay near Brisbane. Given the expected low level of barge traffic and the proximity of water over 2 m deep, we do not expect any significant problems associated with boat traffic.

5.1.3 Heavy metal pollution

The heavy metal status of the dugong is unusual (Denton *et al.*, 1980). The levels of iron and zinc in the liver tissue of dugongs in various parts of north Queensland, including areas remote from sites of urbanisation and industrialisation, were exceptionally high compared with reported values for other marine mammals. Levels of copper, cadmium, cobalt and silver were also consistently high in several samples while nickel, lead and chromium were consistently undetected. *Denton et al.* concluded that the metal status of the dugongs sampled reflected the levels of metals in their seagrass food (Marsh *et al.*, 1982) rather than anthropogenic activities.

We are concerned about the potential impact of lead–zinc concentrate entering the sediments of the Gulf of Carpentaria as a result of spillage from barges or from a stockpile of ore being submerged by one of the tidal surges to which this area is prone (Marsh, 1989). This lead and zinc is likely to be taken up by the seagrasses and accumulate in dugongs and other fauna associated with seagrass beds including sea turtles and commercial prawns.

The accumulation of metals by seagrass beds was reviewed by Ward (1989). Studies on metals (mainly cadmium, copper, lead and zinc) have been carried out in seagrass systems at several sites in southern Australia. The work of Denton *et al.* (1980) and the Torres Strait Baseline Study being conducted by the Great Barrier Reef Marine Park Authority on the effects of the Ok Tedi mine on communities in Torres Strait are the only similar studies in Northern Australia. Thus it is necessary to rely on the information from temperate systems summarised by Ward (1989).

Studies in Australia and overseas show that seagrasses accumulate metals up to high concentration (Ward, 1989). Even systems thought to be uncontaminated have measurable levels of cadmium, copper, lead and zinc. Concentrations of these metals in seagrass leaves may show pronounced seasonal variability related to leaf age (Ward, 1987) and any study of the background levels of metals in the seagrasses in the study area should be replicated at several times during the year to take this into account. It will also be important to record levels in roots and rhizomes as well as leaves as dugongs eat whole seagrass plants.

Data from *Halodule* and *Halophila* in Texas indicate that the concentrations of iron and zinc were higher in the roots than in the leaves (Pulich *et al.*, 1976).

Seagrasses can absorb metals from water and sediments (Ward, 1989). Although the seagrasses themselves appear to moderately resistant to the direct effect of metals, the high concentrations of metals in their tissues mean that herbivores such as the dugong (and green turtle: see below), omnivores and detritivores (e.g. prawns) are most at risk (Ward, 1989). Given the dietary importance of dugongs and green turtles to the local Aboriginal people and the potentially serious effect of even a small decrease in rate of change of dugong populations, the potential for heavy metal contamination of the study area as a result of the Century project is of concern.

5.1.4 Habitat damage

Seagrass ecosystems are very sensitive to human impacts (Fonesca, 1987). Seagrasses in this region are also subject to extreme natural disturbances such as cyclones. Seagrass beds in the McArthur River region were seriously damaged by Cyclone Sandy in 1985 and have been slow to recover. Thus potential impacts associated with the Century project must be considered in conjunction with natural disturbances that may affect the seagrass ecosystem. If the area of seagrass destroyed by dredging is of the same order as that predicted for the McArthur River project (0.2 km^2), the impact of dredging on seagrass will be insignificant in a regional context (Hollingsworth, Dames and Moore, 1992).

5.2 Sea Turtles

5.2.1 Background

Sea turtles live in widely dispersed feeding grounds, but migrate to aggregate most of their breeding at a few traditional rookeries (Limpus and Nicholls, 1988; Limpus *et al.*, 1992). Migrations are typically for hundreds of kilometres but may exceed 3000 km. For example, tags from loggerhead turtles tagged in the southern Great Barrier Reef have been recovered from Gulf of Carpentaria (Limpus *et al.*, 1992).

Genetic studies are demonstrating that the major breeding aggregations of sea turtles are essentially genetically discrete and should be regarded as separate breeding units (J. Norman, pers comm).

Typical sea turtle life history parameters are illustrated for loggerhead turtles (C.J. Limpus, pers comm).

estimated age at first breeding:	35 years
egg production:	128 eggs per clutch four years between breeding seasons
reproductive life expectancy:	probably about five breeding seasons
eggs and hatchling survivorship:	low and variable between rookeries with perhaps 40% survivorship to the open waters
pelagic phase survivorship:	not quantified
benthic feeding stage survivorship:	
(1) juveniles and young adults	probably >95% per year
(2) adults	probably >95% per year

Population models (e.g. Crouse *et al.*, 1987) show that the key to improving the outlook for turtle populations is to maximise survivorship on the benthic feeding grounds, particularly of large juveniles and young adults.

If the Century project reduces the survivorship of green turtles on their feeding grounds in the study area, it will affect the turtles at the stage of their life cycle which is most vulnerable to small changes in survivorship.

5.2.2 Boat traffic

The impact on turtles resulting from barge traffic associated with this project is likely to be minimal.

5.2.3 Heavy metal pollution

The heavy metal profile of the green turtles in the study area is likely to be similar to that of the dugongs as both species feed on seagrasses. The only information available on the heavy metal status of green turtles from north Queensland is for iron. Like dugongs, green turtles have extraordinary high iron levels in their livers (Denton *et al.*, 1980) presumably as a results of eating seagrass rich in iron. We expect the impact of lead–zinc pollution to have the same effect on green turtles as on dugongs.

5.2.4 Habitat damage

The effect of damage to the coastal seagrass habitats through dredging would be detrimental to green turtles as well as dugongs. Examination of the stomach contents and/or faeces of green turtles killed in the Sir Edward Pellew Islands to the west as a result of Cyclone Kathy indicated that, like the dugongs, they were predominantly feeding on the seagrass *Halodule pinifolia*. *Halodule uninervis* and *Halophila ovata* were also present in small amounts.

5.3 Dolphins

5.3.1 Background

Claims have been made of dramatic local changes in bottlenose dolphin populations caused by human activities. However, most such claims are difficult to evaluate and definitive research has not been carried out to test the effects of chemical pollution or harassment on bottlenose dolphins (Klinowska, 1991).

Although detailed life history information is not available for many species, all the species of dolphin so far studied are long-lived animals with a low reproductive rate. For example, female bottlenose dolphins do not mature until they are about 12 years old and females typically bear only one calf at a time at intervals of three to six years (for details see Klinowska, 1991). Population models indicate that species with this type of life history are particularly sensitive to changes in adult survivorship and calving interval (Eberhart and Siniff, 1977). Thus even small changes in these parameters may lead to a low-level chronic decline in dolphin abundance. Because the population of each of the three species of dolphin is likely to be low (few hundreds of animals) in the study area, such a decline may be almost impossible to detect (Taylor and Gerrodette, submitted) until a serious reduction in numbers has occurred.

5.3.2 Heavy Metal Pollution

The potential impact of heavy metal pollution from the Century project is of concern (see the discussion on dugongs) but cannot be evaluated without knowledge of the effect of elevated metal levels on the dolphins and their prey. The only significant system-level study of the effects of metals on seagrass habitats was carried out near the Port Pirie lead-zinc smelter by Ward *et al.* (1984) who concentrated on the epibenthic swimming fauna (the prey of dolphins). Their study indicated that the abundance of 20 species of fish and crustaceans was negatively correlated with distance from the smelter. Contaminated sites also supported fewer species than uncontaminated sites. Ward *et al.*, (1984) concluded that long-term processes such as uptake of metals from food, effects on behaviour, reproductive success, food capture and evasion of predators may be the critical processes that affect the success of species at a metal-contaminated site.

5.3.3 Prey Habitat Damage

Mangroves and seagrass beds are the key structural components of the ecosystem along this coast. Although dolphins are predators and do not feed directly on these plants, destruction of seagrasses through dredging (see section on dugongs) could indirectly impact the dolphins as the seagrasses provide food and shelter for the food chain on which they depend.

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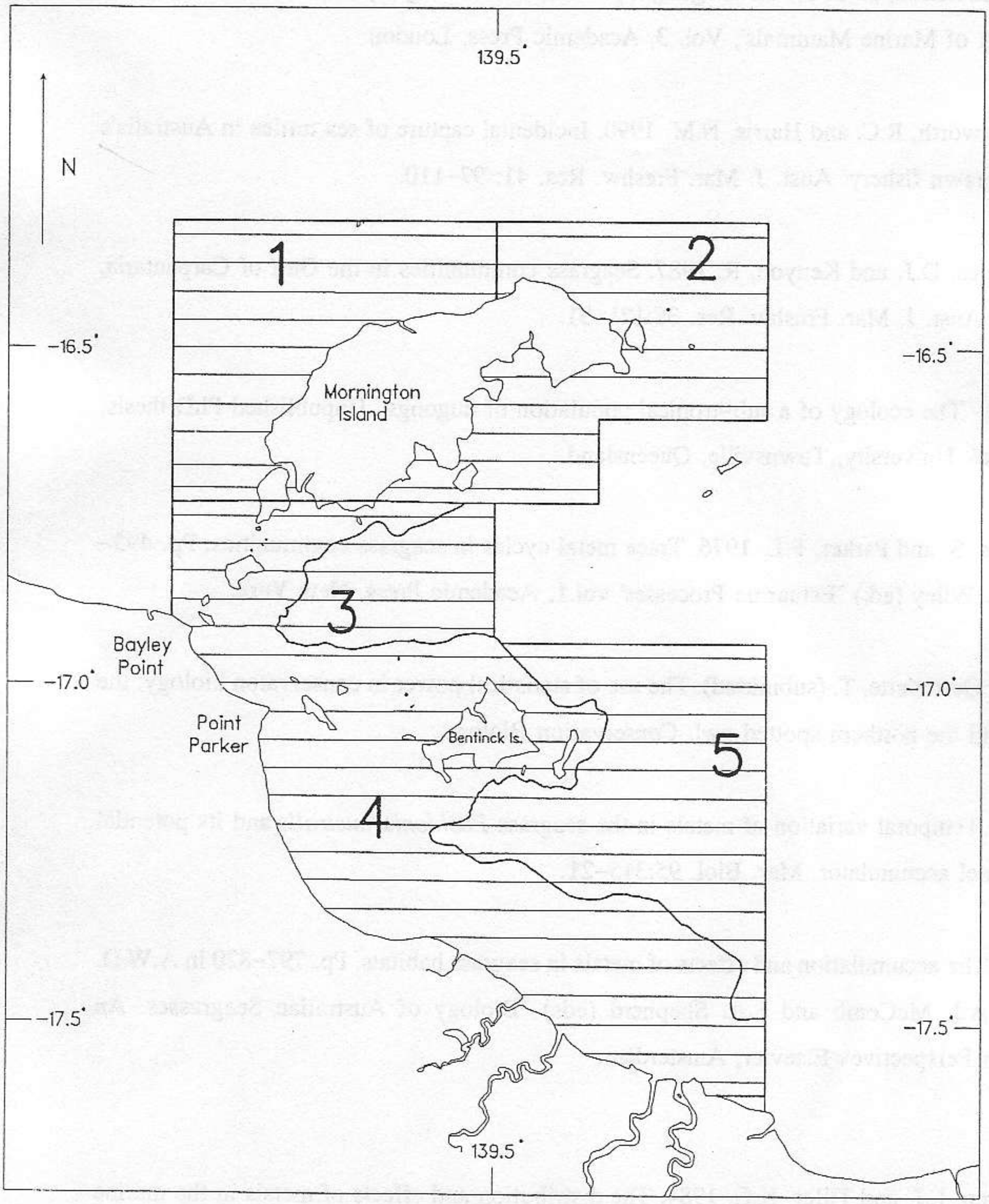

Figure 1. Survey area, showing the survey blocks (1-5) and transect lines for the December 1991 survey.

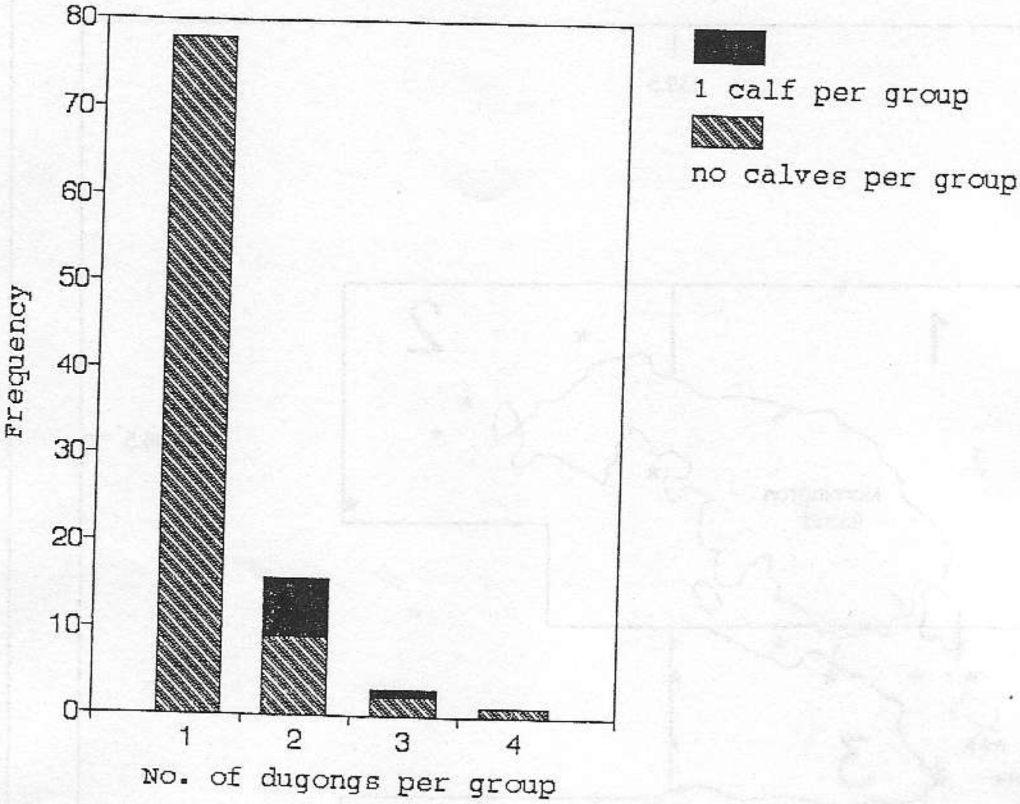

Figure 2. Frequency histogram illustrating the sizes of the groups of dugongs seen during the survey.

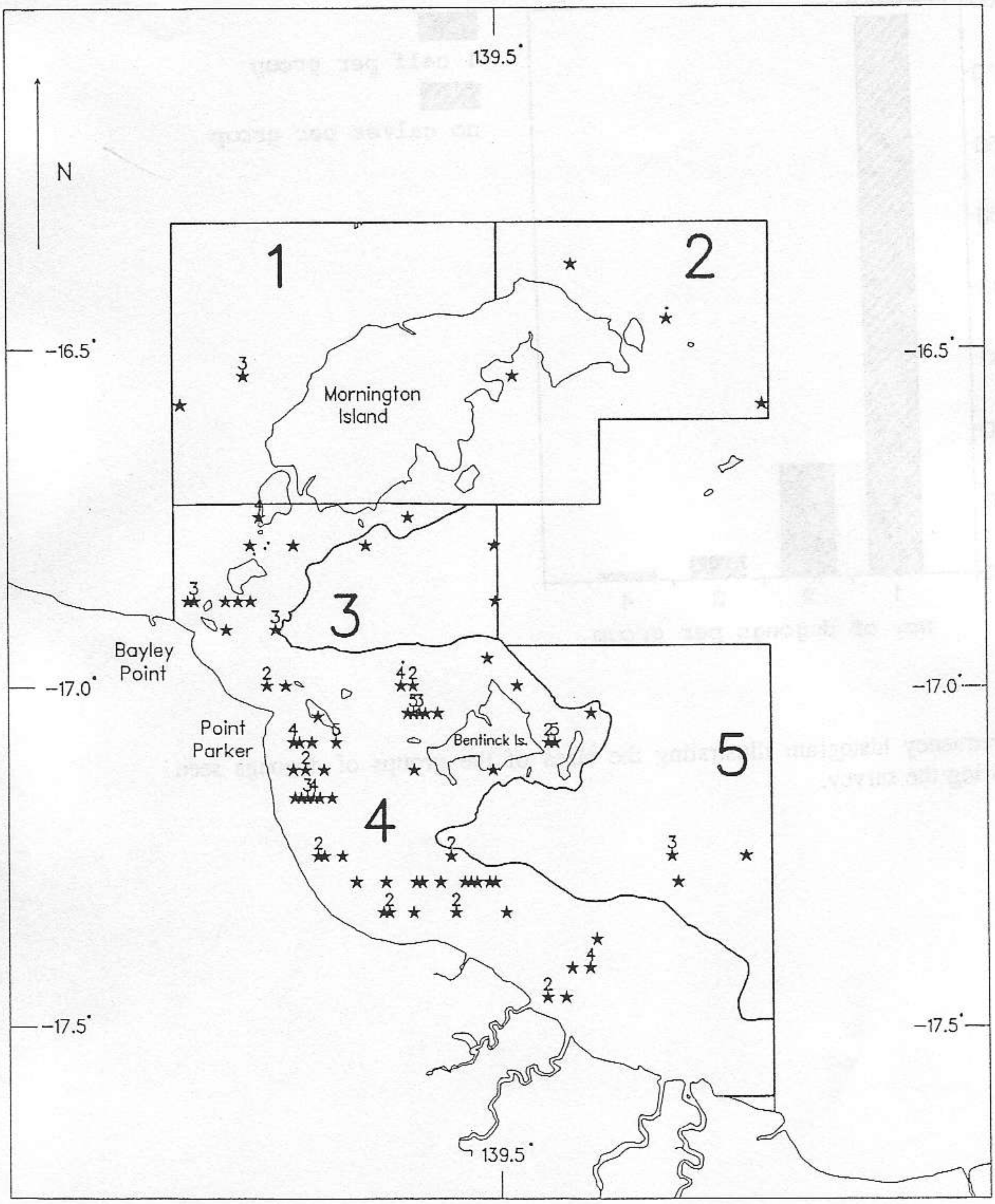

Figure 3. The survey area showing the positions of dugong sightings in December 1991. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

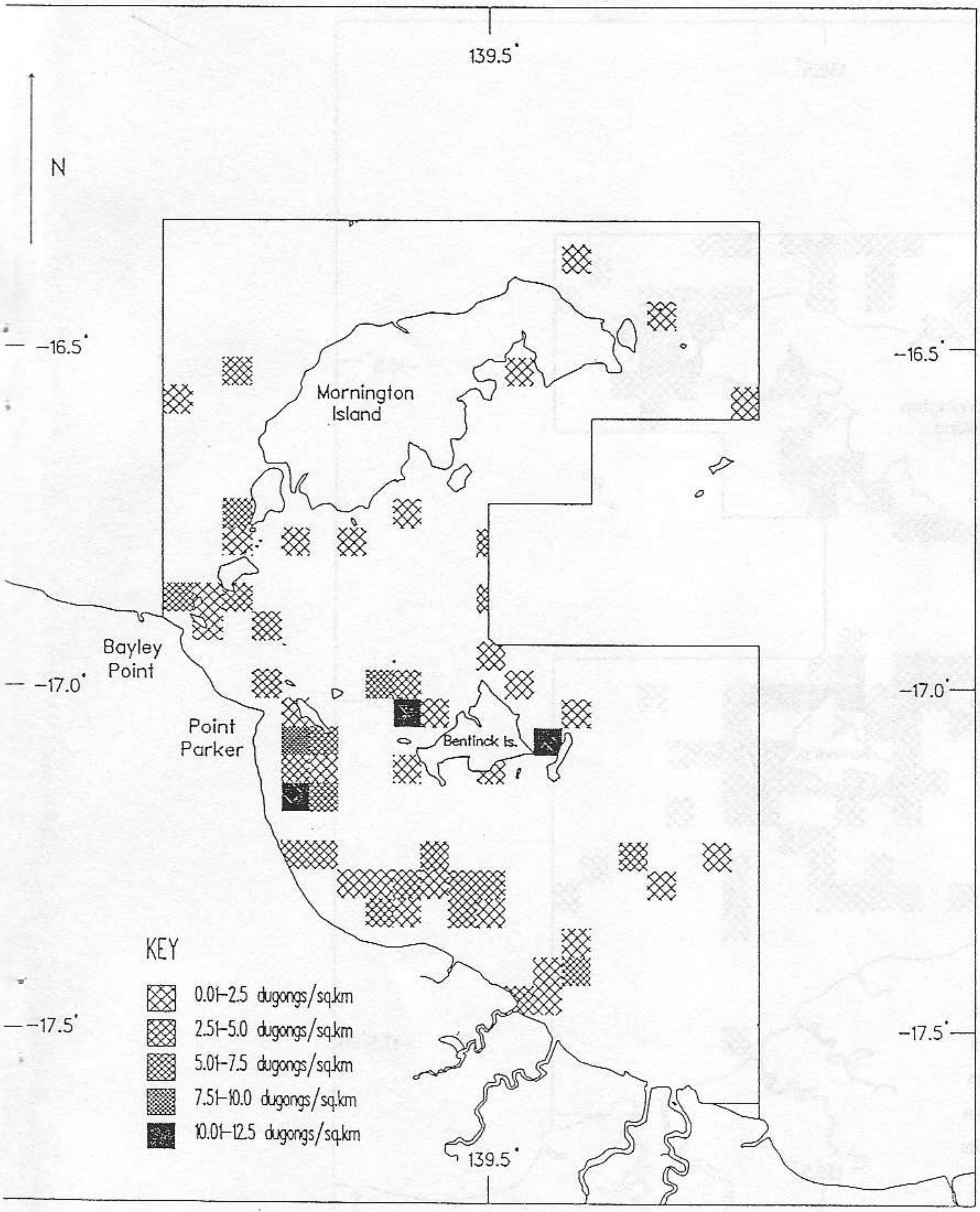

Figure 4. The survey area showing dugong density, adjusted for sampling intensity, calculated on a 5 x 5 nm square grid.

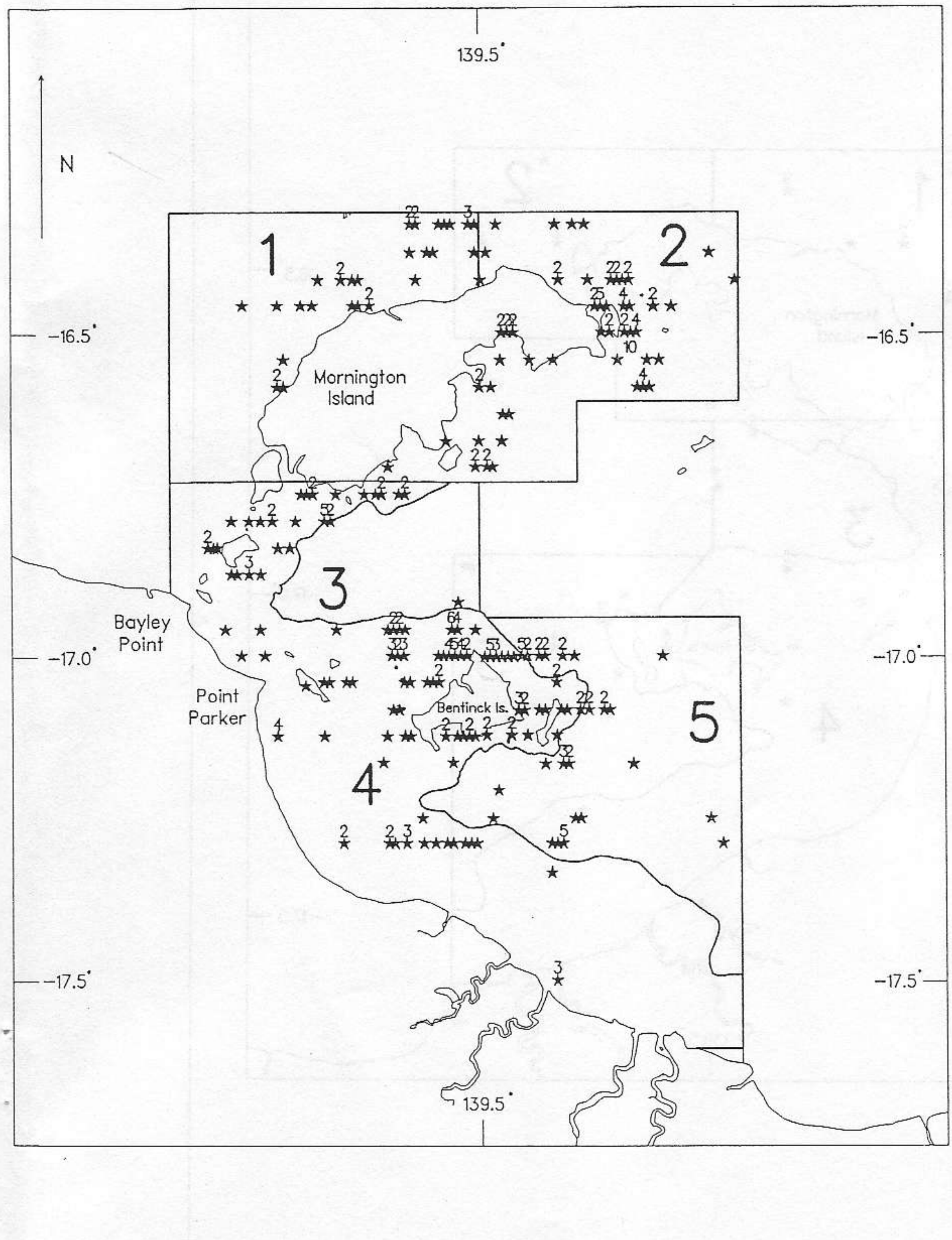

Figure 5. The survey area showing the positions of turtle sightings in December 1991. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

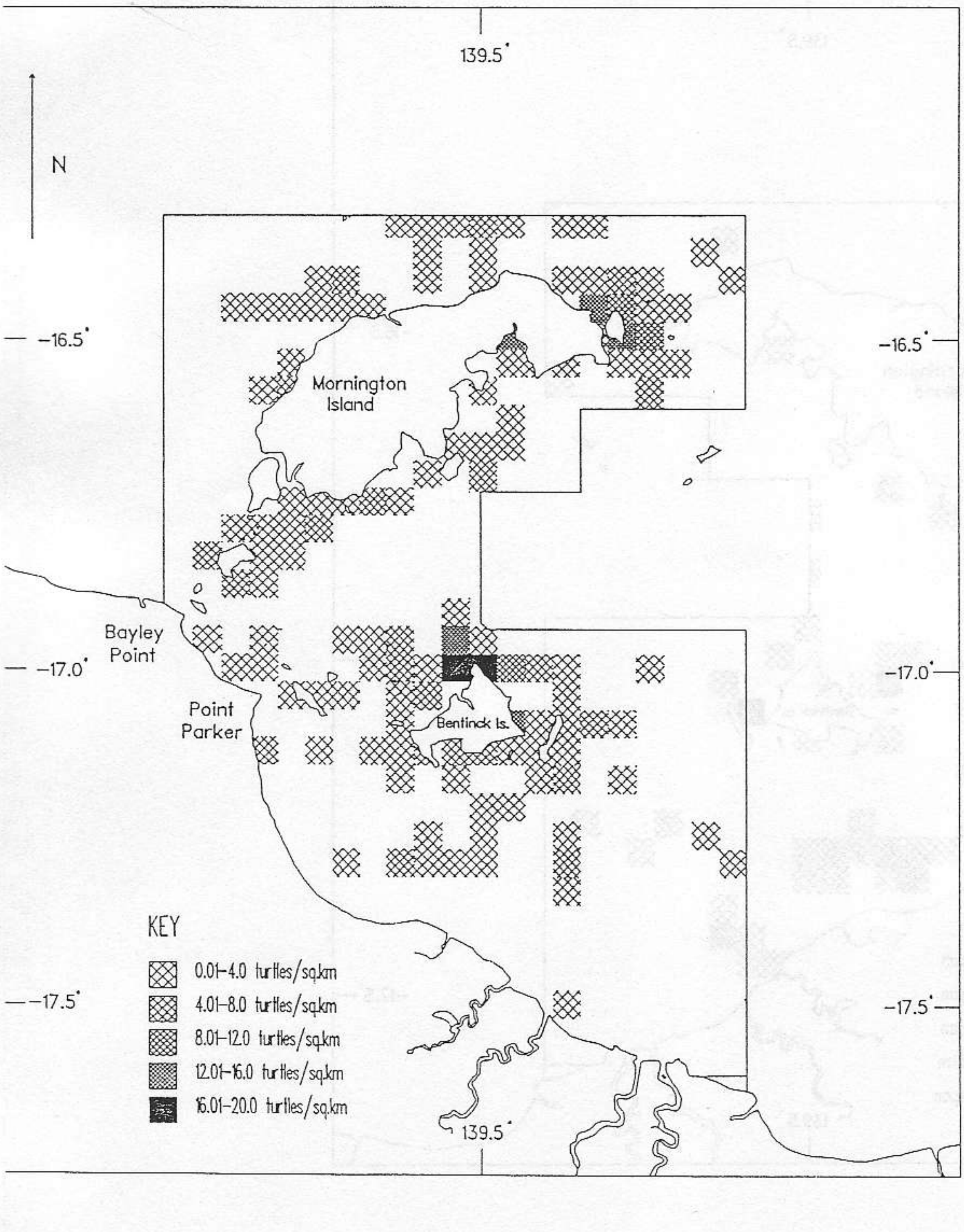

Figure 6. The survey area showing the density of sea turtles, adjusted for sampling intensity, calculated on a 5 x 5 nm square grid.

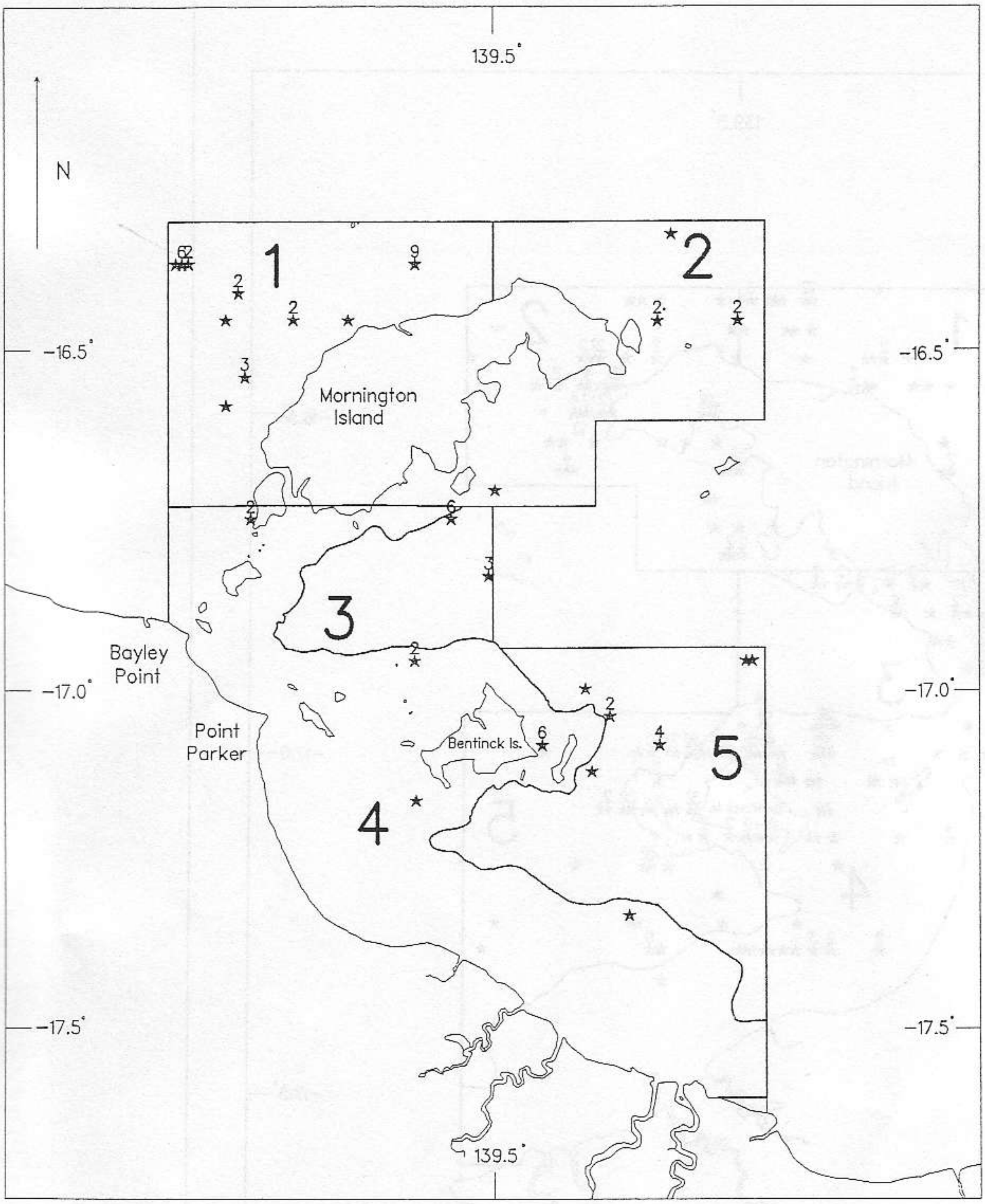

Figure 7. The survey area showing the positions of dolphin sightings in December 1991. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

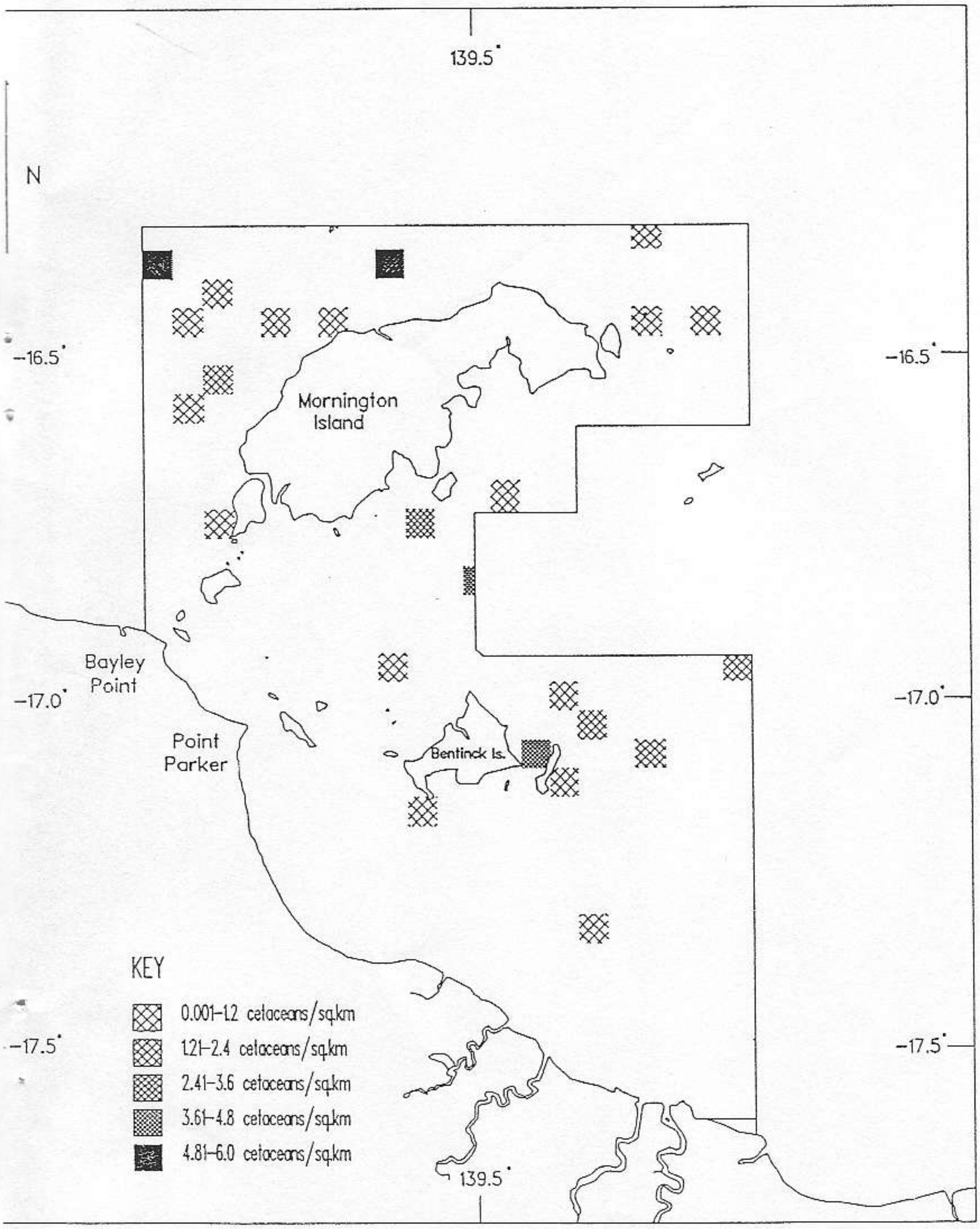

Figure 8. The survey area showing dolphin density, adjusted for sampling intensity, calculated on a 5 x 5 nm square grid.