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# The Status of the Dugong in the Southern Great Barrier Reef Marine Park

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A REPORT TO THE GREAT BARRIER REEF MARINE PARK AUTHORITY

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## EXECUTIVE SUMMARY


- Australia has international responsibilities for the management of dugongs in the Great Barrier Reef Region. One of the World Heritage values of the Region is that it "provides major feeding grounds for large populations of the endangered species *Dugong dugon*". In addition, the dugong has high biodiversity value as the only species in the Family Dugongidiae and one of only four species in the Order Sirenia, all of which are listed as vulnerable to extinction by the World Conservation Union.

- Aerial surveys for dugongs have been conducted over an area of some 39,000 $km^2$ in the inshore waters of the Great Barrier Reef Marine Park (GBRMP) south of Cape Bedford in 1986/87, 1992 and 1994. Survey specific correction factors have been used to correct for perception bias (the proportion of animals visible in the transect which are missed by observers) and to standardise for availability bias (the proportion of animals that are invisible due to water turbidity).

- These surveys indicate that the number of dugongs in the region has declined by approximately 50% over the past eight years from an estimated 3479+ s.e. 459 in 1986/87 to 1682 $\pm$ s.e. 236 in 1994. Over a large section of the region, this decline is over 80%. This change does not appear to be due to emigration out of the region. It is most likely to be due to unsustainable dugong mortality within the region. Dugongs have a life-span of more than 70 years and bear only one calf at a time at intervals of three years or more. Population models indicate that a dugong population reproducing optimally will increase at only about 5% per year. Thus dugong populations can sustain only a very low level of anthropogenic mortality (1-2% of females).

- Dugongs in this region are threatened by habitat loss, traditional hunting and incidental mortality in commercial gill-nets and in shark nets set for bather protection. These impacts are unquantified and their relative importance probably varies in different parts of the region.

- We believe that unless these problems are addressed as a matter of urgency, dugong numbers will continue to decline in this region with a consequent reduction in its World Heritage values.

## RECOMMENDATIONS

### Overall Approach

- That the management of dugongs in the southern Great Barrier Reef be directed at reducing all threatening processes so that their mortality does not exceed sustainable levels. Threatening processes include habitat loss, mortality from fishing, shark meshing and Indigenous hunting. This approach corresponds with that advocated by the "Turtle and Dugong Conservation Strategy for the Great Barrier Reef Marine Park" (Ellis 1994) and the draft of "A Management Program for the Conservation and Management of the Dugong *(Dugong dugon)* in Queensland" (Queensland Department of Environment and Heritage 1994) being produced under the Nature Conservation Act 1992 (Queensland). Further, management needs to recognise that focussing on these problems in the context of dugong conservation alone may lead to an increase in the threatening processes affecting populations of other threatened species, particularly green turtles.

### Marine Park Management

- That the Great Barrier Reef Marine Park Authority, the Queensland Department of Environment and Heritage and the Queensland Fish Management Authority collectively review the management regimes in the Central and Mackay-Capricorn Sections of the Great Barrier Reef Marine Park, adjacent State Marine Parks and Fisheries Habitat Areas with a view to assessing their capacity to protect dugongs and their habitats particularly in key areas such as the Hinchinbrook Island area and Cleveland, Upstart, and Shoalwater Bays.

### Indigenous Management

- That Councils of Elders similar to those established between Mackay and Dunk Island be established in other centres where there are significant numbers of Indigenous people who wish to hunt dugongs and turtles. These Councils should be informed of the decline in dugong numbers throughout the southern Great Barrier Reef and encouraged to minimise traditional hunting in this region in a culturally acceptable manner which involves the entire local Indigenous community. Also, discussions should be held with the traditional owners of key dugong areas, such as the Hinchinbrook Island area, Cleveland Bay, Upstart Bay, and Shoalwater Bay, in order to facilitate these areas being listed as critical areas under the Nature Conservation Act 1992 (Queensland).

- That the Councils of Elders be offered assistance to develop a culturally appropriate education program to further encourage their people to take responsibility for managing their dugong harvest.

- That research results be relayed back to Indigenous communities.

**Fishery interactions**

- That fishery logbook data be used to identify areas where gill-netting occurs and dugongs are relatively abundant. In these areas, consultations should be held with the relevant Management Advisory Committees and Zonal Advisory Committees to negotiate management arrangements appropriate for each area. These arrangements may include:

  (a) the use of fishing gear and fishing practices which reduce the dugong take, such as has been instituted in Hervey Bay,
  (b) zonal closure in areas which cannot be patrolled effectively by managers because of their remoteness.

- That the Tropical Finfish Management Advisory Committee give consideration to management measures to protect dugongs in developing the management plan for gill-netting such as:

  (a) reducing latent effort through a buy-back scheme or restricting gill-netting endorsements to fishers "who could demonstrate a significant commercial level of involvement over a three year period" (The Recreational Fishing Consultative Committee 1993, p. 18).
  (b) introducing area restrictions on individual gill-netting endorsements,
  (c) reducing the use of illegal gill-nets by tagging commercial gill-nets with individual identifiers,
  (d) introducing an amnesty period for the surrender of illegal gill-nets,
  (e) closing areas where dugongs occur and where gill-netting has not occurred in the last three years.

- That an appropriate education program be put in place to inform commercial fishers on aspects of dugong conservation biology and management and on methods to minimise dugong take. This should take the form of workshops on dugong conservation biology and fishing methods run by the Queensland Commercial Fishers Organisation, the Fisheries Industry Training Council, James Cook University and the Queensland Department of Primary Industry. These workshops could include the following:

  (a) scientific advice on aspects of the biology of dugongs,
  (b) instruction on how to remove struggling dugongs from nets by experienced gillnetters,
  (c) local information on dugongs from experienced fishers.

  Attendance at workshops could be compulsory for re-endorsements of gill-netting licences.

- That mechanisms be developed to enable commercial fishers to donate accidentally drowned dugongs to local Indigenous groups.

- That the cost and logistics of an experiment to evaluate the potential of acoustic alarms to reduce entanglement of dugongs in gillnets be investigated as a desk top study which should also address the logistics of introducing such alarms if they were found to be effective.

### Shark-meshing for bather protection

- That the Queensland government, through consultation with local Focus Groups, organise for all shark meshing nets remaining in the waters of the Great Barrier Reef Region to be replaced with drumlines, and that an appropriate education program be established to advise the public on ways to avoid contact with dangerous sharks.

### Research

- That culturally appropriate research programs be established to collect and/or collate data on the take of dugongs by commercial gill-netting, the Queensland Shark Meshing Program and Indigenous hunters. These data should include (for each fishery):
  - (a) number and fate of animals caught,
  - (b) data and circumstances of catch,
  - (c) size and sex of animals caught,
  - (d) total fishing effort.

- That detailed studies of dugong movements and habitat use in key regions such as Shoalwater Bay be conducted to determine the appropriateness of netting closures by:
  - (a) satellite tracking individual dugongs, and
  - (b) an analysis of dugong sightings from the aerial surveillance flights conducted by Queensland Department of Environment and Heritage and Coastwatch surveillance data.

- That the aerial survey of dugongs, turtles and cetaceans in the inshore waters of the Central and Mackay-Capricorn Sections of the Great Barrier Reef Marine Park be repeated in November 1999.

- That the surveys conducted by Coles and his co-workers in the 1980's (Lee Long et al. 1993) be repeated to determine if there has been any loss of seagrasses at a regional scale.

- That a workshop be held with seagrass workers from CSIRO Division of Fisheries (Cleveland Laboratory), the Queensland Department of Primary Industries Northern Fisheries Centre, James Cook University and the University of Queensland to discuss the development and standardisation of cost-effective techniques to monitor intertidal and subtidal tropical seagrass beds at both local and regional scales.

### Distribution of this report

That copies of this report be made available to interested parties including (but not limited to):

* the Queensland Fish Management Authority,
* the Chair of the Tropical Finfish Management Advisory Committee,
* the Queensland Department of Primary Industries,
* the Queensland Department of Environment and Heritage,
* the Queensland Department of Family Services,
* the Queensland Commercial Fishermen's Association,
* the Australian Nature Conservation Agency, and
* all Councils of Elders in the Great Barrier Reef region
* the Co-operative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef.

## INTRODUCTION

Australia has international responsibilities for the management of dugongs in the Great Barrier Reef Region. One of the World Heritage values of the Region is that it "provides major feeding grounds for large populations of the endangered species *Dugong dugon*" (Great Barrier Reef Marine Park Authority (GBRMPA) 1981, p. 7). In addition, the dugong has high biodiversity value as the only species in the Family Dugongidiae and one of only four species in the Order Sirenia. All four extant species of Sirenian are listed as vulnerable to extinction by the IUCN (IUCN 1990).

In 1986 and 1987, Marsh and Saalfeld (1990 a) counted dugongs, dolphins and sea turtles during an aerial survey over an area of some 39,000 km$^2$ in the inshore waters of the Great Barrier Reef Marine Park south of Cape Bedford. Survey-and-taxon specific correction factors were used to correct for perception bias (the proportion of animals visible in the transect which are missed by observers) and to standardise for availability bias (the proportion of animals that are invisible due to water turbidity).

The area was resurveyed in November 1992 using the same technique. The minimum dugong population estimated for the Mackay-Capricorn and Central Sections of the Great Barrier Reef Marine Park (hereafter referred to as the southern Great Barrier Reef) was significantly lower than the corresponding values in 1986/87 (Marsh *et al.* 1994). Comparison of the results of the 1986/7 and 1992 surveys suggested that the decline in dugong numbers was spread throughout much of the region, but was pronounced between Cape Cleveland and Broad Sound (Central Section Blocks 1-7 and Mackay-Capricorn Section Blocks 6-8, Figure la, b). Marsh *et al.* (1994) concluded that there was a strong likelihood that there has been a decline in dugong numbers in coastal waters adjacent to and in the Central and Mackay-Capricorn Sections of the GBRMPA and that this was unlikely to be due to emigration either south or north of the survey area. Emigration to the north of the survey area would presumably have been inhibited by the low availability of habitat between Dunk Island and Cape Bedford, and to the south, there was a massive dieback of seagrasses accompanied by a high level of dugong mortality in Hervey Bay just outside of the southern boundary of the Great Barrier Reef Marine Park (Preen and Marsh 1995).

Marsh *et al.* (1994) recommended that their aerial survey be repeated in 1994 to assess whether the apparent trend detected in the 1992 survey was a real effect rather than an artefact of the weather conditions which were slightly worse in 1992 than in the 1986/7 surveys. Following this recommendation, the southern Great Barrier Reef was resurveyed in November 1994. This report compares the results of this survey with those of the earlier surveys to present an overview of the current status of dugongs in this region.

## METHODS

The inshore waters between Dunk Island (17° 58'S) and the southern boundary of the Great Barrier Reef Marine Park (24° 30'S) were surveyed between 2nd and 18th November 1994. In order to increase repeatability, the survey was conducted only when the weather conditions were good (usually Beaufort Sea State < 3; Table 1 and Appendix Table 1). Whenever possible, daily schedules were arranged to: (1) avoid severe glare associated with a low or midday sun, and (2) ensure that very shallow areas (e.g. Missionary Bay, off Hinchinbrook Island) were surveyed at high tide.

During the survey, it became apparent that the numbers of dugongs being sighted were low. Accordingly, the Great Barrier Reef Marine Park Authority agreed to extend the survey beyond the southern boundary of the Great Barrier Reef Marine Park to the Hervey Bay region (Hervey Bay and the Great Sandy Straits) to investigate whether there was any evidence of a large-scale movement of dugongs from the southern Great Barrier Reef to this region. This part of the survey was conducted from 25th November to 27th November 1994 using the same design as that used in previous surveys by Preen and Marsh (1995) except that five extra transects were added north of the bay (Block 5, Figure 2).

### Survey methodology

Aerial survey methodology has been detailed by Marsh and Sinclair (1989 a and b) and Marsh and Saalfeld (1989 a). The transect width (200 m on either side of the aircraft at survey altitude) was demarcated with fibre glass rods attached to artificial wing struts on either side of the aircraft. Each sighting was recorded as being made in the upper, middle or bottom third of the transect to facilitate deciding whether simultaneous sightings by tandem observers were of the same group of animals.

Transects were flown in an east-west direction and usually extended 21.6 km from the coast and/or offshore islands except between Hinchinbrook Island and the mainland where mountains made east-west flying dangerous. Transects were spaced 5' latitude apart, except where sampling intensity was increased due to the presence of large seagrass beds. The design of the survey was exactly the same as that used in 1992 except that: (1) the area north of Dunk Island was excluded as there were too few dugongs to make a population estimate in either of the previous two surveys, and (2) extra transects were added in the Shoalwater Bay and Port Clinton area due to the known high density of dugongs in those bays. Figures la, b show the locations of transects in the Mackay-Capricorn and Central Sections of the GBRMP respectively. Figure 2 shows the design of the Hervey Bay survey. A global positioning system mounted in the aircraft facilitated accurate navigation. The aircraft was also fitted with a radar altimeter for accurate height control.

### Correction factors

Population estimates were corrected for perception bias (the groups of animals visible on the transect line that were missed by observers) and availability bias (the groups of animals unavailable to the observers due to water turbidity). The corrections for perception bias were calculated using the Peterson Mark-Recapture Model on the basis of the proportion of the relevant sightings seen by one (specified) or both members of each tandem team (Marsh and Sinclair, 1989 a). Availability bias corrections for dugongs were calculated by standardising the proportion of dugongs sighted during the survey to the number seen on the surface in clear water where all dugongs were potentially available (Marsh and Sinclair, 1989 a). The corrections for availability bias for dugongs make the untested assumption that a constant proportion of the target species is at the surface.

## Analysis

As the transects were variable in area, the Ratio Method (Jolly, 1969; Caughley and Grigg, 1981) was used to estimate the density, population size and associated standard errors for each taxon for each block. Any statistical bias resulting from this method is considered inconsequential due to the relatively high sampling intensity (Table 2, see also Caughley and Grigg, 1981). The standard errors of the population estimates were adjusted to incorporate the errors associated with the various correction factors as outlined in Marsh and Sinclair (1989 a).

Differences between this survey and the previous surveys in the densities of dugongs were tested using analysis of variance with and without modal Beaufort Sea State for each transect as the covariate. Fixed factors in the model were time and block. Transect was treated as a random factor nested within block. The densities were log transformed ($\log_{10}(x+1)$) in order to equalise the error variances. All significance tests were two tailed.

Density diagrams, adjusted for sampling intensity, were produced using the Arc/Info GIS package. A coverage of 5 x 5 nm square grids overlaying the survey area was used to calculate the densities of dugongs. Density in each cell was calculated as:

$$Density\ km^{-2} = \frac{Corrected\ no.\ animals\ in\ each\ cell}{(Area\ surveyed\ in\ each\ cell)}$$

where, Area surveyed in cell = ΣTransect lengths in km * Transect width (i.e. 0.4 km).

## RESULTS

*Group size and Composition*

Southern Great Barrier Reef

A total of 102 dugongs was sighted in the southern Great Barrier Reef during the 1994 aerial survey. The size and composition of groups are summarised in Figure 3a. There were 57 individuals, 19 groups of two (11 of which were female-calf pairs), one group of three animals and one of four. This largest group was in Port Clinton. The percentages of calves were 11.4% in the Southern Section, 10.3% in the Central Section (Repulse Bay to Dunk Island), and 10.8% overall for the southern Great Barrier Reef.

Hervey Bay region

A total of 130 dugongs were seen in the Hervey Bay region. The size and composition of groups are summarised in Figure 3b. Seventy-six of these were single, 13 groups of two (of which two were cow-calf pairs), and one group each of sizes three, four, five, seven and nine. Only 1.54% of the dugongs seen in Hervey Bay were calves.

*Population and density estimates*

The mean group sizes and correction factors used to calculate the population and density estimates in 1994 are given in Table 3. Appendix Table 2 lists the raw data.

Southern Great Barrier Reef

The estimates of density and numbers of dugongs in the various blocks in the survey area for this survey and those in 1986/87 and 1992 are given in Table 4. Appendix Figures 1 through 6 are maps of the dugong sightings in the southern Great Barrier Reef in 1994.

The highest densities of dugongs were associated with inshore seagrass beds (Figures 4a and 5a). Shoalwater Bay (southern Section Block 5) was confirmed as the most important dugong habitat in the Great Barrier Reef region south of Cape York (Table 4). The Central Section north of Townsville also supports several hundred dugongs (Table 4). A minimum population estimate of 1682 $\pm$ s.e. 236 dugongs at an overall density of 0.06 $\pm$ s.e. 0.008 dugongs $km^{-2}$ was calculated for the region on the basis of the 1994 survey (Table 4).

Hervey Bay Region

The estimates of density and numbers of dugongs in the various blocks in the survey area for this survey and those in 1988, 1992 and 1993 are given in Table 4. Appendix Figures 6 and 7 are maps of the dugong sightings in the Hervey Bay region in 1994. The highest densities of dugongs were associated with the Great Sandy Straits and the southern part of Hervey Bay (Table 4). A minimum population estimate of 807 $\pm$ s.e.151 dugongs at an overall density of 0.15 $\pm$ s.e. 0.03 dugongs $km^{-2}$ was calculated for the region on the basis of the 1994 survey (Table 4).

*Differences between surveys*

Southern Great Barrier Reef

Dugong group sizes were small in 1994, a result similar to those in 1986-87 (Marsh and Saalfeld, 1990 a) and 1992 (Marsh *et al.* 1994). In addition, densities were generally low in the southern half of the Great Barrier Reef Marine Park in both 1986/7 and 1992 compared with the other regions surveyed in northern Australia (Table 4). This can, at least partially, be attributed to differences in habitat availability. The area of known seagrass in the southern Great Barrier Reef Marine Park is small (e.g. approximately 550 $km^2$) in comparison with the northern regions of the Park (over 4400 $km^2$; Lee Long *et al.* 1993, Coles *et al.* 1995) and individual beds are relatively small. While it is possible that large undiscovered beds occur in the southern Great Barrier Reef, we regard this as unlikely due to the regional differences in bathometry and water turbidity.

The dugong population estimates for the southern Great Barrier Reef differ significantly between the 1986/87, 1992 and 1994 surveys (see Table 5). The population estimate derived from the 1994 surveys was only 48.4% of the 1986/87 population estimate. Comparison of the results of the 1986/87 and 1994 surveys (Table 4 and Figures 4b, 5b and 6), indicates that the decline in dugong numbers was spread throughout much of the region, but was pronounced between Cape Cleveland and Broad Sound (Central Section Blocks 1-7 plus Mackay-Capricorn Section Blocks 6-8).

Some of these changes in dugong numbers must be due to movements of animals within the region (Figures 4b and 5b, and Table 4) even though the interaction between block and time in the ANOVA was not significant (Table 5). In particular, the population estimates for the four northernmost blocks varied over the four surveys conducted between 1986 and 1994.

| Year | Dugong Population Estimate ± s.e. |
|---|---|
| 1986 | 1024 ± 170 |
| 1987 | 644 ± 273 |
| 1992 | 590 ± 165 |
| 1994 | 824 ± 331 |

Such changes cannot be due to natural change in the absence of migration. As there are few dugongs immediately north of Block 11 in the Central region (Marsh and Saalfeld 1990 a, Marsh *et al.* 1994), the immigrants are most likely to have come from the area south of Cape Cleveland.

The reduction in dugong population estimates in the waters south of Cape Cleveland is marked and includes a reduction in the number of dugongs in Shoalwater Bay, the block with the largest population of dugongs in 1987 (Block 5, Figure 4b). To ensure that this reduction was not responsible for the significance of the reduction overall, the data for Shoalwater Bay were removed from the analyses. Without Shoalwater Bay, the minimum dugong population estimated for the southern Great Barrier Reef still differs significantly between the 1986/87, 1992 and 1994 surveys (Table 6).

Hervey Bay

The number of dugongs in the Hervey Bay region estimated on the four surveys since 1988 is as follows:

| Year | Dugong Population Estimate ± s.e. |
|---|---|
| 1988 | 1971 ± 359 |
| 1992 | 1109 ± 383 |
| 1993 | 579-679 ± 126 |
| 1994 | 807 ± 151 |

These figures suggest that the reduction in dugong numbers following the seagrass dieback in 1992 (Preen and Marsh 1995) has stabilised.

## DISCUSSION

*Significance of differences between surveys*

The results of the 1994 surveys confirm the findings of the 1992 survey and indicate that the reduction of dugong numbers in the southern Great Barrier Reef is real and not a sampling artefact. This change cannot be explained by emigration to Hervey Bay although the possibility of there being some movement of dugongs between Hervey Bay and the southern Great Barrier Reef Marine Park cannot be eliminated. However, estimates of dugong numbers in the Great Barrier Reef region south of Shoalwater Bay are generally so low and imprecise that fluctuations in the population estimates need to be interpreted with caution.

Comparison of the present situation with Bertram and Bertram's (1973) anecdotal account of dugongs in the region suggest that dugong numbers have been on the decline in the region for decades. Aboriginal elders in the southern Great Barrier Reef also consider that dugong numbers have been in decline for at least 20 years, something that elders in the northern Great Barrier Reef do not claim (Ross Williams *pers. comm*). The extent of the dugong kill in the shark meshing program (Paterson 1990, Anon 1992) also suggests that dugong numbers have been declining at least since the 1960s.

This decline in dugong numbers in the southern Great Barrier Reef region is also likely to have an adverse impact on dugong numbers in south-east Queensland. Molecular techniques used to investigate the stock structure of dugongs in Australian waters (Dani Tikel *pers. comm.* 1994) suggest partial isolation of dugongs in south-eastern Queensland from animals in Torres Strait and a possible unidirectional gene flow in a southern direction along the east Australian coast.

Applying the criteria of the latest IUCN Red List Categories (IUCN 1995), the population of dugongs in the southern Great Barrier Reef is Critically Endangered, the worst of the threatened categories. These categories "can be applied to any taxonomic unit at or below the species level" (IUCN 1995, p3). Inclusion in the Critically Endangered category means that a taxon is "facing an extremely high risk of extinction in the wild in the immediate future" (IUCN 1995, p13), so this highlights the considerable cause for concern over the status of the dugong in this region. The surveys suggested that the number of dugongs in the southern Great Barrier Reef has declined by approximately 50% over the past eight years. Over a large section of the region, this decline is over 80%. According to IUCN criteria, a population is Critically Endangered if it has an "observed, estimated, inferred or suspected reduction of at least 80% over the last 10 years or three generations, whichever is longer" (IUCN. p 15). Three generations of dugongs (using IUCN Red List criteria) equates to over 100 years.

Another problem for management is that if the decline continues, the power of surveys to provide worthwhile data will decline also (Taylor and Gerrodette 1993, Marsh 1995a). This is already a problem between Broad Sound and Cape Bowling Green.

The processes affecting dugong numbers in the southern Great Barrier Reef were identified by Marsh *et al.* (1994) as: loss of seagrass habitat; incidental catch in nets (particularly commercial gill-nets); and Indigenous hunting. Here, we present recent information on these threatening processes, all of which must be considered in the context of the dugong's life history. Population models (Marsh 1995 b) show that the maximum rate of increase of a dugong population is only of the order of 5% per annum. Thus for a dugong population of two hundred animals to be maintained, the anthropogenic mortality from all causes must certainly be less than five females per year. The sustainable loss is probably smaller than this and of the order of only 1-2% per annum.

*Possible causes of the decline in dugong numbers*

Loss of seagrass due to coastal development

No diebacks of seagrass meadows of the magnitude recorded from Hervey Bay (Preen and Marsh 1995) have been reported in the southern Great Barrier Reef between 1986 and 1994, although the absence of such reports does not mean that diebacks have not occurred. In this region, only the meadows in Bowling Green, Upstart and Shoalwater Bays are relatively free from anthropogenic disturbance (Marsh *et al.* 1994). Our dugong surveys are not designed to provide population estimates for specific management purposes at the bay level. However, as an initial attempt to assess the effects of the threatening processes, we examined the survey results from these areas.

Densities of dugongs declined in all three bays as follows:

| **Location** | **Date** | **Dugong Population Estimate ± s.e.** |
|---|---|---|
| Upstart Bay | 1987 | 171 ± 87 |
| | 1994 | 19 ± 19 |
| Bowling Green Bay | 1987 | 136 ± 120 |
| | 1984 | 54 ± 38 |
| Shoalwater Bay | 1987 | 765 ± 161 |
| | 1994 | 406 ± 78 |

Both Upstart Bay and Bowling Green Bay are fed by major rivers (the Burdekin and Haughton respectively), and so seagrass there could be affected by floods similar to that which apparently caused the seagrass dieback in Hervey Bay (Preen and Marsh 1995). The Burdekin River flooded in February 1991 (flood height reached 12.53m on 3rd February 1991). There are no records of strandings of emaciated dugongs such as were recorded in Hervey Bay (Preen and Marsh 1995). The proportion of dugongs with calves declined in Hervey Bay from 22% in 1988 to 2.2% in 1993 (Preen and Marsh 1995) and 1.5% in 1994. In contrast the proportion of calves in the southern Great Barrier Reef region was: 11.4% in 1986/87; 13% in the northern Central Section; and 11% in the Mackay-Capricorn Section in 1992; and 10.8% in 1994. However, in 1992, no calves were observed in the southern Central section (south of Cape Cleveland to Repulse Bay).

These results suggest that a dieback of seagrass of the magnitude and intensity of that in Hervey Bay has occurred in this area recently. The Burdekin flood of 1991 may have caused some seagrass die off and resultant local lowering of the calving rate.

The available data suggest that reduction in their seagrass habitat is not the sole cause of the decline in dugong numbers in the southern Great Barrier Reef. However, of the meadows known to support dugongs, 27% are within 5 km of a development or a waste outlet (Morissette, 1992) and the current protection of dugong habitats in the southern Great Barrier Reef region is low compared with the northern region of the marine park (Marsh *et al.* 1994). There have been anecdotal reports of loss of seagrass beds in the region during recent years. This is coincident with a period of rapid coastal development and resultant expansion of boating facilities (Morissette 1992). The most prominent industrial sources occur near Lucinda (sugar loading jetty), Townsville (Greenvale Nickel Refinery), Abbott Point (coal loading facility), Mackay (sugar mills) and Gladstone (refineries and port). Future developments in the region are outlined below (mostly from Morissette, 1992):

**Hinchinbrook Channel:** The proposed marina at Oyster Point (the construction of which is banned at present) could threaten dugong populations through increased vessel traffic in the sheltered waters of the channel if it were allowed to proceed. Increased nutrient output and turbidity from the proposed expansion of fish farms may have an effect on the existing seagrass meadows that currently support dugong populations in this region.

**Cleveland Bay:** The dredging associated with expansion of the port of Townsville and the projected human population increase in the region are likely to have an effect on the seagrass meadows that support dugong populations in Cleveland Bay.

**Abbot Bay:** The increase in boat traffic and bilge water dumping around the coal loading jetty may have detrimental effects on seagrass beds in the area.

**Whitsunday Islands:** This region is an increasingly popular tourist destination with numerous resorts and boating facilities. The resultant nutrient input into the region is high. As boat traffic increases, some disturbance to dugongs in the surrounding waters is likely.

As the aerial survey estimates of dugong numbers have decreased dramatically (i.e. to less than 20% of their 1986/87 estimates) over a large area (from south of Broad Sound to Cape Cleveland, excluding Bowling Green Bay), we consider that it is unlikely that point sources of habitat degradation are responsible for this decline. However, point sources may be important in particular areas (e.g. Cleveland Bay and the Hinchinbrook Channel).

Indigenous hunting

There are no historical data on the magnitude of Indigenous hunting in this region. After dugongs were protected in 1967, Indigenous people who were not resident at reserves such as Yarrabah and Palm Island were allowed to hunt only under permits which were rarely issued. However, policing this law would have been ineffective throughout most of this region. In recent years, Aborigines and Torres Strait Islanders have been advised that they can hunt as long as they are accompanied by a reserve resident. Currently, if they wish to hunt in the Great Barrier Reef Marine Park or a State Marine Park, they require a permit. The draft of "A Management Program for the Conservation and Management of the Dugong *(Dugong dugon)* in Queensland" (Queensland Department of Environment and Heritage 1994) discusses the use of Traditional Use Authorities issued through co-operative management arrangements with Aboriginal or Torres Strait Islander communities.

Some ten thousand Indigenous males reside in the southern Great Barrier Reef region (Ponte *et al.* 1994). This is almost ten times the number in the northern Great Barrier Reef. How many of these men aspire to hunt dugongs, or actually do so, is unknown. Many are Torres Strait Islanders who are used to having dugong in their diet (Johannes and MacFarlane 1991; Harris *et al.* 1993). Over approximately 30 months in the early 1990s, 70 permits were issued for the traditional hunting of approximately 87 dugongs between Cape Bedford and the southern boundary of the GBRMP.

Most hunters applied for a permit only once suggesting that hunting is not overtly dominated by a few individuals. Most of these permits allowed for the hunting of only one dugong. The number of dugongs captured using these permits is not known but, if the number taken approached the number for which permits are issued, the take was almost certainly unsustainable. In the southern Great Barrier Reef, most of these permits were issued for hunting between: (a) Cape Cleveland and Upstart Bay and (b) Midge Point and Clairview. Populations in both these areas appear to have declined precipitously between 1987 and 1994 (Figure 4b and 5b, Table 4). We conclude that Indigenous hunting probably contributed to the decline in dugong numbers in at least some parts of the region.

Recently, the situation has changed dramatically. In 1994/95, almost no permits were issued to take dugongs from north of Cooktown to Clairview. Permits to take three dugongs in the area around Palm Island have been issued to the Burukaman Council of Elders, and permits have been issued that have resulted in the take of approximately two dugongs in the past two years by the Yarrabah community, near Cairns. The Mackay Council of Elders (Torres Strait Islanders) applied for a permit to take six dugongs in October 1995. This suggests that the strategy of co-management involving Councils of Elders is having some success.

Incidental catch by fishing operations

Commercial gill-netting

The information available suggests that bycatch of dugongs in commercial gill-nets is a significant source of anthropogenic mortality for these animals in the southern Great Barrier Reef. The magnitude of this impact has not been quantified. The claims of an unsustainable take of dugongs by commercial gill-netting operations in Shoalwater Bay reported in Marsh *et al.* (1994) have been supported recently with at least four deaths reported in one month (June - July 1995), although the magnitude of this mortality is still uncertain. The gillnetting effort for Queensland waters between Cooktown and the southern boundary of the Great Barrier Reef Marine Park (in kilometer net days per year), including Shoalwater Bay, was approximately 6802 km net days per year. The effort for Shoalwater Bay was 276 km net days[1] per year. The combination of the known size of the population of dugongs in Shoalwater Bay, the lack of other anthropogenic impacts in the Bay, and the relative gillnetting effort in the Bay compared with the rest of the southern Great Barrier Reef combine to provide unequivocal, albeit circumstantial, evidence that commercial gillnetting is a significant source of anthropogenic mortality throughout the region.

There is little seagrass below the low tide mark in Shoalwater Bay. This means that dugongs and gill-netters are probably forced to utilise the same resource at the same time (i.e. intertidal areas at slack water on the high tide), which presumably increases the chances that dugongs will be caught in nets there. There are other relatively shallow bays on the coast of central Queensland where the combination of large tidal fluctuations and high turbidity make it likely that dugongs and gill-netters use the same habitat at the same time. These areas should be identified using GIS as one of the initial steps towards managing the incidental take of dugongs in gillnets.

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[1]based on effort in net days for 1994 obtained from QFMA Log Book Program and assuming a net length of 600m; many fishers set less net than this, particularly in regions where tidal range is large such as Shoalwater Bay, so these figures may be overestimated.

[1]The northern region referred to here is the region north of Cape Bedford. The southern region is the region south of Cape Bedford.

Recreational gill-netting

Anecdotal evidence suggests that recreational gill-netting is relatively common in northern Queensland waters despite its illegality. There are no data on these nets as a source of dugong mortality but we regard some such mortality as inevitable.

The Queensland shark meshing program.

Marine mammals die in nets set to protect bathers from sharks. In South Africa, the shark meshing program has been identified as a source of unsustainable mortality for coastal bottlenose *(Tursiops truncatus)* and Indo-Pacific humpback *(Sousa chinensis)* dolphins (IWC 1994). The Queensland government spends in the order of $1,000,000 per year on shark meshing contracts (Anon 1992). Since nets were introduced in the mid 1960's, over 800 dugongs have been caught (Anon 1992), most of which died (Paterson 1990). Between 1962 and 1978, 101 dugongs were killed in nets off Cairns (Paterson 1979), an area where there are now so few dugongs that the population cannot be estimated (Marsh and Saalfeld 1990, Marsh *et al.* 1994). Between 1963 and 1978, 229 dugongs were killed in nets off Townsville (Paterson 1979).

Dugongs are still being caught in the shark meshing program in northern Queensland waters (Paterson 1990, Anon 1992 Appendix 10). The numbers of dugongs taken (either animals which died or are recorded as "unknown", Anon 1992) in the Queensland Shark Meshing Program between 1988 and 1992 inclusive are: Cairns - 6, Townsville - 25, Mackay - 4, Rockhampton 2, Bundaberg - 0, Tannum Sands - 0. All nets have been removed from Tannum Sands, Bundaberg and Rockhampton in the last three years. Currently, the fishing effort of this program in the Great Barrier Reef Region is 733 km net days per year as summarised in Table 7. Although in most areas the numbers taken are small, most of these takes are from very small and declining populations.

*Options for management*

Monitoring the status of dugongs in the area has demonstrated that the threatening processes at work are having a serious impact on dugong populations and that the current management regime is failing. Unless the objective of the monitoring program is to document the pattern of local extinction of dugongs, it is time to institute greater controls on threatening processes.

Management options for dugongs in the southern Great Barrier Reef region include:

(1) reducing the threatening processes as soon as possible;
(2) increasing the monitoring of current levels of gill-netting and Indigenous hunting;
(3) conceding that dugongs will become locally extinct in the southern Great Barrier Reef region with resultant reduction to the World Heritage values of the area.

Monitoring threatening processes helps us to understand, quantify and document a problem but does not in itself solve the problem. Donovan (1994) acknowledges the importance of monitoring programs and outlines the logistic difficulties of monitoring artisinal fisheries for catches of marine mammals. The "prime attribute of monitoring is that it must be systematic, unambiguous and part *of a control process*" (MacGarvin 1994,p75, our italics). Monitoring of levels of gillnetting and Indigenous hunting at a suitable level of intensity to provide useful information would be prohibitively expensive, and we believe that funding would be better spent on the control process.

Dugongs are culturally important to Indigenous people in the southern Great Barrier Reef. Australia as a signatory to the World Heritage and Biodiversity Conventions also has international commitments to conserve dugongs. The last option is clearly inappropriate.

Reducing the processes which threaten dugongs in the southern Great Barrier Reef is clearly the only acceptable option. However, it is important to recognise that focussing on these processes in the context of dugong conservation alone may lead to an increase in the threatening processes (particularly gill-netting and Indigenous hunting) to populations of other threatened species (particularly green turtles). We suggest that efforts to reduce these processes should address their impact on green turtles as well as dugongs.

Habitat protection

Seventy-two percent of the known seagrass meadows in the southern half of the Great Barrier Reef region are protected by Queensland Marine Parks, the Great Barrier Reef Marine Park Authority (GBRMPA) or Queensland Fisheries Habitat Reserves (Morissette 1992). In addition, the Commission of Inquiry into the Shoalwater Bay area, established under Section 11 of the Commonwealth *Environment Protection (Impact of Proposals) Act* 1974 recommends that the marine parts of the Shoalwater Bay area should be incorporated into marine parks and management responsibility should be shared between the Great Barrier Reef Marine Park Authority and the Queensland Department of Environment and Heritage according to existing agreements between those agencies. When Shoalwater Bay is rezoned, the proportion of seagrass meadows in the southern Great Barrier Reef which are incorporated into marine parks will increase.

However, 38% of the habitats where dugongs have been sighted during aerial surveys are not currently protected from trawling as they lie outside of a Marine Park or Reserve or within General Use 'A' zones. Only 4% of the seagrass beds where dugongs have been sighted have a protection of greater than General Use B as compared to 32% in the northern Great Barrier Reef.[1] Dugong habitats in this region are not nearly as well protected as in the northern Great Barrier Reef. In fact, results of a Log-Linear Chi-Squared test on the levels of protection in each region, indicated that the levels of zoning (e.g. ≤General Use B vs. >General Use B) in areas of dugong sightings were significantly dependent on the region ($p \geq 0.0001$). For instance, a dugong sighted in the northern region was 11 times more likely to be protected by a zone with a protection greater than or equal to General Use B than a dugong in the southern region of the Great Barrier Reef.

We find it inappropriate that the proportion of seagrass beds given high protection is so much higher in the remote regions of the Great Barrier Reef than in the southern part of the region where anthropogenic impacts are greater (Figure 7). This suggests that the marine park managers are making some of the same mistakes as terrestrial park managers in the placement of protected areas (i.e. protecting areas that are not wanted for some other human usage, Recher 1994). Steps should be taken to upgrade the protection of seagrass meadows known to support dugong populations south of Cooktown. The Great Barrier Reef Marine Park Authority, the Queensland Department of Environment and Heritage and the Queensland Fish Management Authority should collectively review the zoning in the Central and Mackay-Capricorn Sections of the Great Barrier Reef Marine

Park, adjacent State Marine Parks and Fisheries Habitat Areas with a view to assessing their capacity to protect dugongs and their habitats particularly in key areas such as the Hinchinbrook Island area and Cleveland, Upstart, and Shoalwater Bays. Integrated catchment management should also be a high priority as recommended by Brodie (1995).

Indigenous hunting

In recent years, there have been some encouraging steps towards co-management of dugong and green turtle hunting in the southern Great Barrier Reef region with seven Councils of Elders now established between Clairview and Dunk Island:

| Council of Elders | Jurisdiction |
|---|---|
| Juperdilli | Clairview to Midge Point (Aborigines) |
| Mackay | Clairview to Midge Point (Torres Strait Islanders) |
| Girradalla | Midge Point to Cape Upstart |
| Birra Gubba | Cape Upstart to Cape Cleveland |
| Wulguru Gubba | Cape Cleveland to Herald Island |
| Warragumauy | Rollingstone to Lucinda |
| Burukman | Palm Island area out to the reef |
| Bandjin | Lucinda to Dunk Island |

In response to advice from the Great Barrier Reef Marine Park Authority, all but the Burukman and Mackay Councils of Elders have decided that they do not want to hunt dugongs in 1994/95. The Burukman Council has applied for a permit to take three dugongs. The Mackay Council of Elders (Torres Strait Islanders) applied for a permit to take six dugongs in October 1995. This was not granted. We understand that some other Torres Strait Islanders based in provincial cities have reservations about the hunting ban.

We recommend that Councils of Elders similar to those established between Mackay and Dunk Island be established in other centres where there are significant numbers of Indigenous people who wish to hunt dugongs and turtles. These Councils should be informed of the decline in dugong numbers throughout the southern Great Barrier Reef and encouraged to minimise traditional hunting in this region in a culturally acceptable manner which involves the entire local Indigenous community.

Gill-netting

Commercial gill-netting

Regulations on commercial gill-netting operations (i.e. no fisher can set more than three nets and must be within 800 m of all nets while they are set) should help ensure that the operations do not cause excessive mortalities of air breathing animals (dugongs, cetaceans, turtles). On the evidence available for the southern Great Barrier Reef, however, these regulations are not working for dugongs. This may be because: (a) fishers fail to adhere to the regulations, or (b) fishers adhere to the regulations but the regulations are inadequate. It is important to distinguish which of these two reasons applies in the southern Great Barrier Reef. If the regulations are inadequate, then new regulations appropriate for the protection of dugongs are required. If it is because fishers fail to adhere to the regulations, then efforts must be undertaken to increase education, monitoring and enforcement of the industry. This will entail a substantial increase in costs to management agencies.

Fishers prefer not to catch dugongs because of the resultant net damage. However, most east coast gill-netters hold multiple endorsements (i.e. they can fish using several different types of gear) and are permitted to fish along the entire east coast of Queensland. This management regime has several consequences:

(a) fishers who use gill-nets only occasionally may be more likely to kill dugongs through inexperience than fishers who net regularly;

(b) fishers who work areas away from where they normally fish may kill dugongs through a lack of local knowledge;

(c) there is considerable latent fishing effort in the gill-net fishery which, if taken up, could result in a significant increase in gill-netting effort along the east coast of Queensland.

Solutions to these problems include restricting gill-netters to certain areas and restricting gill-netting endorsements to fishers who gill-net regularly. The State Government Inquiry into Recreational Fishing recommended that endorsements be limited to fishers "who could demonstrate a significant commercial level of involvement over a three year period" (The Recreational Fishing Consultative Committee 1993, p. 18).

Ted Loveday, Chair of the Queensland Commercial Fishermen's Organisation recently suggested that workshops on dugong conservation biology and fishing methods be held to minimise incidental takes of dugongs. These workshops could be conducted by the Queensland Commercial Fishermen's Organisation, the Fishing Industry Training Council and James Cook University and could include salient information on the biology of dugongs and practical instruction by endorsed fishers on best practices. Such workshops would ensure that the considerable local knowledge that experienced fishers have on how to avoid catching dugongs can be formalised for the benefit of those less experienced (and dugongs!). Attendance at workshops could be compulsory for re-endorsements of gill-netting licences. Such workshops could also lead to the development of a Code of Fishing Ethics for dugongs and turtles caught in gill-nets similar to that developed for turtles caught in trawls.

Areas where high levels of gill-netting effort and high densities of dugongs overlap should be identified and managed through regulation. In particular, areas where tidal and turbidity conditions are such that gill-netters and dugongs are likely to be using the same habitat at the same time should be identified. In some remote areas, it may be impossible to police such regulations effectively and closure may be the only effective solution. This has already been recognised in Shoalwater Bay. In developing solutions to this problem, it is important to recognise that international initiatives with respect to biodiversity and ecologically sustainable development have resulted in major changes in attitudes to fisheries bycatch. The onus is now on the fishers to prove that their current levels of bycatch are unavoidable (Elmer 1995).

Recreational gill-netting

Anecdotal evidence suggests that recreational gill-netting is relatively common in northern Queensland waters despite its illegality. If commercial nets were tagged with individual identifiers in some way, recreational nets could be confiscated on sight by management agencies. Materials to make gill-nets should be available only to suitable endorsed commercial fishers, and materials should be identifiable to individual fishers (to prevent the resale of materials from commercial fishers to amateurs). The Queensland Government Inquiry into Recreational Fishing recommended an amnesty period for three months to provide an opportunity for illegal fishing nets to be surrendered without penalty and then for penalties for the use of illegal nets to "be increased significantly" (Recommendation 41, Anon 1993, p 20). We encourage the Queensland Fisheries Management Authority to implement this recommendation as soon as possible.

Shark meshing

The Committee of Inquiry established to review the operation and maintenance of shark meshing equipment in Queensland waters stated that "the value of the program is not so much the protection it affords but the public perception, shared by tourists and locals alike, of a high degree of safety to bathers from shark attack" (Anon 1992, p.1). The economic results of this perception led the Committee to conclude "that whilst the risk of shark attack was extremely small, there were no grounds to suggest a neutral effect from termination of the program and that the cost savings from the termination of the order of $1 million per year, potential would be quickly eroded, in a macro-economic sense, by a fall in tourist expenditure at beaches targeted by the Program" (p. 44).

The Committee noted also that "the need to minimise by-catch must be considered against the imperative of public safety" (p. 48), but that "there is no way to assess the potential impact on human safety if the (meshing) program were to be terminated, mainly because no data is (sic) available on remaining shark population dynamics" (p. 44). Catch per unit effort data indicate that tiger shark *(Galeocerdo cuvier)* populations in the waters off Townsville have not been reduced by the local meshing program (Simpendorfer 1992, 1993) although populations of whalers *(Carcharhinus* spp.) appear to have declined (Simpendorfer 1993). Off Townsville, drumlines catch more tiger sharks, and more large (and by definition dangerous) sharks generally than shark nets (Simpendorfer 1993). Published data on the catch of bull sharks (*C. leucas),* the only other likely human predator in the region, in either nets or drumlines are not available. Replacing nets with drumlines has been used to reduce the bycatch of turtles and marine mammals at several localities on the Queensland coast (Anon 1992). There have been no human fatalities after this change has been made. Opposition to replacing nets with drumlines is based on the supposition that drumlines attract dangerous sharks to the vicinity of people (Paterson 1990), but there has been no data analysis to address this question. Also, there have been occasions when entrapped marine mammals appear to have attracted large numbers of sharks to nets (Paterson 1990).

The proposal to replace nets with drumlines in areas where marine mammal bycatch is recognised as a problem is not new (Heinsohn 1972, Paterson 1979). However, the issue needs to be reconsidered in the context of Australia's International Obligations to the World Heritage and Biodiversity Conventions.

As shark-meshing is under its control, it should be possible for the Queensland government, through consultation with local Focus Groups, to organise for all shark meshing nets remaining in the waters of the Great Barrier Reef to be replaced with drumlines. An education program would need to be established concurrently to educate people on the feeding behaviour of particular shark species to reduce their likelihood of encountering a dangerous shark. For example, tiger sharks are likely to move into shallow waters adjacent to deeper water at night (Simpendorfer 1993).

Modifying nets to make them more detectable by dugongs

There have been suggestions that it should be possible to modify gill-nets to make them more detectable by marine mammals. Serious practical and theoretical difficulties with this approach have already been demonstrated for small cetaceans even though they have the capacity to echo-locate (see Au 1994, Dawson 1994 for details). The ability of dugongs which cannot echo-locate to detect nets is likely to be far less than that of echo-locating cetaceans. We consider that modifying nets to make them more detectable by dugongs is unlikely to be feasible. However, acoustic alarms have recently been shown to reduce the incidence at harbour porpoises entangling in nets (Kraus *et al.* 1995). Experiments to determine the effectiveness of this approach are very expensive and probably should be limited to areas where other methods are impracticable.

*Priorities for research*

Can we evaluate the relative impact of different threatening processes?

Theoretically, it might be possible to design a large-scale field experiment (McCallum 1995) to tease apart the relative impacts of the different threatening processes. In reality this would be impossible. The experiment would involve organising total, enforceable bans on the following activities in various bays for an appropriate timescale (possibly twenty years in the first instance):

(a) gill-netting;
(b) hunting;
(c) development;
(d) gill-netting and hunting;
(e) gill-netting and development;
(f) hunting and development; and
(g) hunting, gill-netting and development.

The results of this experiment would have to be measured by monitoring dugong numbers using a variety of sophisticated and expensive techniques. The major problems are the timescale and prohibitive cost of the experiment and the fact that the project would involve imposing a management regime on the entire inshore southern Great Barrier Reef. Such a regime would not control land based inputs, the major likely cause of habitat loss. Other problems relating to the experimental design would include addressing issues of replication and randomisation, and the difficulties inherent in quantifying impacts over periods useful to management.

Rather than attempt to quantify the relative importance of the processes that are reducing dugong numbers in the southern Great Barrier Reef, we believe that it would be more effective to conduct research to address each of them separately as outlined below.

Following the recommendations of the report on the workshop on mortality of cetaceans in passive fishing nets and traps (IWC 1994), we suggest that a research program be established to collect and collate data on the take of dugongs by commercial gill-netting, the Queensland Shark Meshing Program and Indigenous hunters. These data should include (for each fishery): catch rates, the age and sex composition of the catch, and the total fishing effort. Data for this research program could be collected in conjunction with the management actions outlined above. The difficulties inherent in requiring fishers and Indigenous hunters who work in remote areas to provide data which is likely to reflect badly on their activities and threaten their lifestyle must be recognised when addressing this issue.

Habitat status

A gross indication of the extent of any loss of seagrass habitat could be obtained by repeating the surveys conducted by Coles and his co-workers in the 1980's (Lee Long *et al.* 1993). We understand that this has already been done in Shoalwater Bay. However, this approach may not provide adequate indication of local losses. Cost-effective techniques need to be developed to monitor intertidal and subtidal tropical seagrass beds at both local and regional scales.

Gill-netting

Commercial gill-netting

The relationship between gill-netting effort and dugong deaths is unclear. In the first instance, a project should assess the temporal and spatial distribution of commercial gill-netting by comparing the Queensland Fish Management Authority logbook data on gill-netting effort with the dugong density data using GIS techniques. Particular attention should be paid to the areas of greatest decline in dugong numbers. Analysis of the 6' grid data has been approved by the Queensland Fish Management Authority subject to certain restrictions to respect the confidentiality of fishers. A joint Great Barrier Reef Marine Park Authority - James Cook University project to analyse these data is being developed under the aegis of the CRC Reef Research. The results of this project can be used as the basis for negotiations with fishers to reduce their impacts

Indigenous hunting

The nature and extent of Indigenous hunting of dugongs in the southern Great Barrier Reef is unknown. In a correlative study similar to the estimation of gill-netting effort, a project could assess the distribution and abundance of hunting permit applications relative to the density of dugongs and the areas of greatest decline. If such a correlative study suggested "hot spots" corresponding to areas of great declines in dugong numbers, this information should be shared with the relevant Councils of Elders.

Movements of dugongs

There have been some changes in the distribution of dugongs in the southern Great Barrier Reef over the course of the surveys, but data on dugong movements are scarce. How much time do dugongs spend away from their seagrass habitat? How much do dugongs use the tidal areas of creeks? Do dugongs move away from areas where threatening processes are greatest, and if so, why? Will dugongs move back to areas where they were once abundant once the threatening processes are removed, and if so, how and over what timescale? Some movements of dugongs appear due to social factors (Marsh and Rathbun 1990, Preen 1995), but our understanding of dugong social behaviour is poor. More data are required on the movements of individual dugongs and on their social behaviour. This could be achieved through additional satellite telemetry. Research along these lines is being planned by the CRC Reef Research and The Great Barrier Reef Marine Park Authority in Shoalwater Bay.

*Conclusions*

The confirmation of a decline in dugong numbers provides the opportunity to turn around the processes which threaten them. We do not know the relative importance of these threatening processes. Therefore, something must be done about all of them as a matter of urgency.

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**Table 1: Weather conditions encountered during the survey. 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%.**

(values for SGBR for 1987 and 1992 are taken from the 1992 report)

| Variable | | SGBR | | | Hervey Bay | |
|---|---|---|---|---|---|---|
| | | 1987 | 1992 | 1994 | 1993 | 1994 |
| Wind Speed (km h-1) | | <37 | <37 | ≤15 | <20 | ≤10 |
| Cloud cover (oktas) | | 0-4 | 0-5 | 0-5 | 1-4 | 1-3 |
| Minimum Cloud height (m) | | 300 | 2500 | 2000-5000 | 460-1800 | 2000-5000 |
| Beaufort sea state | | 1.0 (0-3) | 1.0 (0-4) | 1.87 (0-4) | 1.2 (0-3) | 1.94 (1-3) |
| Glare | North | | | 1.44 (0-3) | | 0.92 (0-2) |
| | South | | | 1.29 (0-3) | | 1.08 (0-2) |
| | Overall | 2.0 (0-3) | 2.0 (0-3) | 1.36 (0-3) | 1.4 (0-3) | |
| Visibility (km) | | >20 | N/A | ≥ 15 | N/A | ≥20 |

**Table 2: Areas of survey blocks and sampling intensities**

| Block | Area ($km^2$) | Sampling % |
|---|---|---|
| Mackay-Capricorn Section | | |
| 1 | 1390 | 9.6 |
| 2 | 836 | 9.8 |
| 3 | 1021 | 16.4 |
| 4 | 3242 | 11.4 |
| 5 | 1347 | 16.0 |
| 6 | 6498 | 8.4 |
| 7 | 1567 | 9.4 |
| 8 | 796 | 9.3 |
| Central Section | | |
| 1 | 371 | 11.9 |
| 2 | 665 | 9.7 |
| 3 | 2048 | 13.2 |
| 4 | 466 | 17.0 |
| 5 | 2087 | 8.0 |
| 6 | 244 | 18.0 |
| 7 | 579 | 18.6 |
| 8 | 620 | 18.8 |
| 9 | 3829 | 8.1 |
| 10 | 288 | 20.0 |
| 11 | 746 | 16.9 |
| Total GBRMP | 28564 | 10.9 |
| Hervey Bay | | |
| 1 | 512 | 19.63 |
| 2 | 1402 | 16.09 |
| 3 | 1222 | 8.75 |
| 4 | 1235 | 8.66 |
| 5 | 621 | 7.4 |
| Total | 4992 | 11.74 |

Table 3: **Details of group size estimates and correction factors used in the population estimates for dugongs in the 1994 survey of southern Great Barrier Reef Marine Park and Hervey Bay**

Due to the high number of sightings in Hervey Bay, separate availability correction factors and mean group sizes were calculated. Perception correction factors were the same for the entire survey except where teams changed.

| Blocks: Transects | Group size (C.V) | Numbers of observers | | Perception Correction factor Estimate (C.V) | | Availability correction factor estimate (C.V.) |
|---|---|---|---|---|---|---|
| | | Port | Starboard | Port | Starboard | |
| SGBR<br>Southern All blocks and transects | 1.3077<br>(0.0640) | 2 | 2 | 1.0342<br>(0.0072) | 1.0860 (0.0160) | 2.4706<br>(0.1563) |
| Central<br>3; 180-188, 4, 5, 6, 7, 8, 9, 10, 11; 283 | | | | | 1.0860 (0.0160) | |
| Central<br>1, 2, 3; 157-179 | 1.3077<br>(0.0640) | 1 | 2 | 1.1746<br>(0.0072) | 1.3833 (0.0160) | 2.4706<br>(0.1563) |
| Central<br>11: 294-284 | 1.3077<br>(0.0640) | 2 | 1 | 1.0342<br>(0.0072) | 1.0860 (0.0160) | 2.4706<br>(0.1563) |
| Hervey Bay<br>All Blocks and Transects | 1.4904<br>(0.1509) | 2 | 2 | 1.0342<br>(0.0072) | | 0.8903<br>(0.2178) |

**Table 4a: Estimates of dugong numbers for each survey block in the southern Great Barrier Reef marine Park and in Hervey Bay in three aerial surveys. Areas referred to by block numbers are shown in Figure 1. se = standard error**

| Block | 1987 Population | se | 1992 Population | se | 1994 Population | se |
|---|---|---|---|---|---|---|
| **Population** Mackay-Capricorn Section | | | | | | |
| 1 | 48 | 46 | 122 | 71 | 0 | |
| 2 | 0 | | 94 | 50 | 0 | |
| 3 | 301 | 95 | 91 | 60 | 104 | 56 |
| 4 | 51 | 48 | 42 | 40 | 67 | 44 |
| 5 | 765 | 161 | 566 | 185 | 406 | 78 |
| 6 | 542 | 293 | 34 | 33 | 82 | 60 |
| 7 | 0 | | 0 | | 0 | |
| 8 | 240 | 104 | 24 | 22 | 38 | 37 |
| Central Section | | | | | | |
| 1 | 31 | 35 | 70 | 59 | 0 | |
| 2 | 65 | 69 | 0 | | 0 | |
| 3 | 0 | | 35 | 27 | 27 | 21 |
| 4 | 173 | 77 | 40 | 24 | 20 | 17 |
| 5 | 312 | 122 | 0 | | 44 | 38 |
| 6 | 171 | 87 | 91 | 46 | 19 | 19 |
| 7 | 136 | 120 | 58 | 50 | 54 | 38 |
| 8 | 360 | 92 | 106 | 56 | 183 | 29 |
| 9 | 0 | | 257 | 105 | 157 | 77 |
| 10 | 184 | 110 | 141 | 89 | 377 | 154 |
| 11 | 100 | 71 | 86 | 72 | 107 | 71 |
| Total | 3479 | 459 | 1857 | 292 | 1682 | 236 |
| Hervey Bay | 1992 | | 1993 | | 1994 | |
| 1 | 943 | 377 | 168-218 | 52 | 287 | 79 |
| 2 | 71 | 40 | 257 | 85 | 408 | 115 |
| 3 | 21 | 22 | 22 | 21 | 49 | 50 |
| 4 | 74 | 50 | 74 | 74 | 31 | 22 |
| 5 | | | | | 32 | 21 |
| Total | 1109 | 383 | 579-629 | 126 | 807 | 151 |

**Table 4b: Estimates of dugong densities for each survey block in the southern Great Barrier Reef Marine Park and in Hervey Bay in three aerial surveys. Areas referred to by block number are shown in Figure 1. se = standard error.**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Density** | | | | | | |
| Mackay Capricorn Section | | | | | | |
| 1 | 0.03 | 0.03 | 0.09 | 0.05 | 0.00 | 0.00 |
| 2 | 0.00 | 0.00 | 0.11 | 0.06 | 0.00 | 0.00 |
| 3 | 0.29 | 0.09 | 0.09 | 0.06 | 0.10 | 0.05 |
| 4 | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 |
| 5 | 0.60 | 0.13 | 0.45 | 0.15 | 0.32 | 0.06 |
| 6 | 0.08 | 0.05 | 0.01 | 0.01 | 0.01 | 0.01 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 8 | 0.30 | 0.13 | 0.03 | 0.03 | 0.05 | 0.05 |
| Central Section | | | | | | |
| 1 | 0.08 | 0.09 | 0.19 | 0.16 | 0.00 | 0.00 |
| 2 | 0.10 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.00 | 0.00 | 0.02 | 0.01 | 0.01 | 0.01 |
| 4 | 0.37 | 0.17 | 0.09 | 0.05 | 0.04 | 0.04 |
| 5 | 0.15 | 0.06 | 0.00 | 0.00 | 0.02 | 0.02 |
| 6 | 0.70 | 0.36 | 0.37 | 0.19 | 0.08 | 0.08 |
| 7 | 0.23 | 0.21 | 0.10 | 0.09 | 0.09 | 0.07 |
| 8 | 0.58 | 0.15 | 0.17 | 0.09 | 0.29 | 0.05 |
| 9 | 0.00 | 0.00 | 0.07 | 0.03 | 0.04 | 0.02 |
| 10 | 0.64 | 0.38 | 0.49 | 0.31 | 1.31 | 0.53 |
| 11 | 0.13 | 0.10 | 0.12 | 0.10 | 0.14 | 0.10 |
| Total GBRMP | 0.12 | 0.02 | 0.07 | 0.01 | 0.06 | 0.01 |
| Hervey Bay | | | | | | |
| 1 | 1.66 | 0.66 | 0.30-0.38 | 0.09 | 0.50 | 0.14 |
| 2 | 0.05 | 0.03 | 0.17 | 0.05 | 0.26 | 0.07 |
| 3 | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | 0.04 |
| 4 | 0.05 | 0.04 | 0.05 | 0.05 | 0.02 | 0.02 |
| 5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.04 |
| Total | | | | | 0.15 | 0.03 |

**Table 5: Summary of analysis of variance comparing observed dugong density in the southern GBR in 1986/87, 1992 and 1994. (1) Without covariates (2) Without Beaufort sea state as a covariate. Data were transformed by log (x+1).**

| Sources of Variation | DF | | F | | Significance of F | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 1 | 2 | 1 | 2 |
| Blocks** | 18 | 18 | 7.55 | 7.15 | >0.0001 | >0.0001 |
| Time* | 2 | 2 | 18.33 | 13.97 | >0.0001 | >0.0001 |
| Transect nested in Block* | 282 | 282 | 1.45 | 1.45 | >0.0001 | >0.0001 |
| Block by Time* | 36 | 36 | 1.34 | 1.34 | 0.095 | 0.093 |
| Residual | 562 | 561 | | | | |
| Regression* | | 1 | | 1.6 | | 0.207 |

* Tested against Residual
** Tested against Transect nested in Block

**Table 6: Summary of analysis of variance comparing observed dugong density in the southern GBR in 1986/87, 1992 and 1994 (without Beaufort sea state as a covariate). Data were transformed by log (x+1) Shoalwater Bay is omitted from the dataset.**

| Sources of Variation | DF | F | Significance of F |
|---|---|---|---|
| Blocks** | 17 | 6.97 | <0.0001 |
| Time* | 2 | 12.94 | <0.0001 |
| Transect nested in Block* | 257 | 1.36 | 0.002 |
| Block by Time* | 34 | 1.14 | 0.278 |
| Residual | 513 | | |
| Regression* | | | |

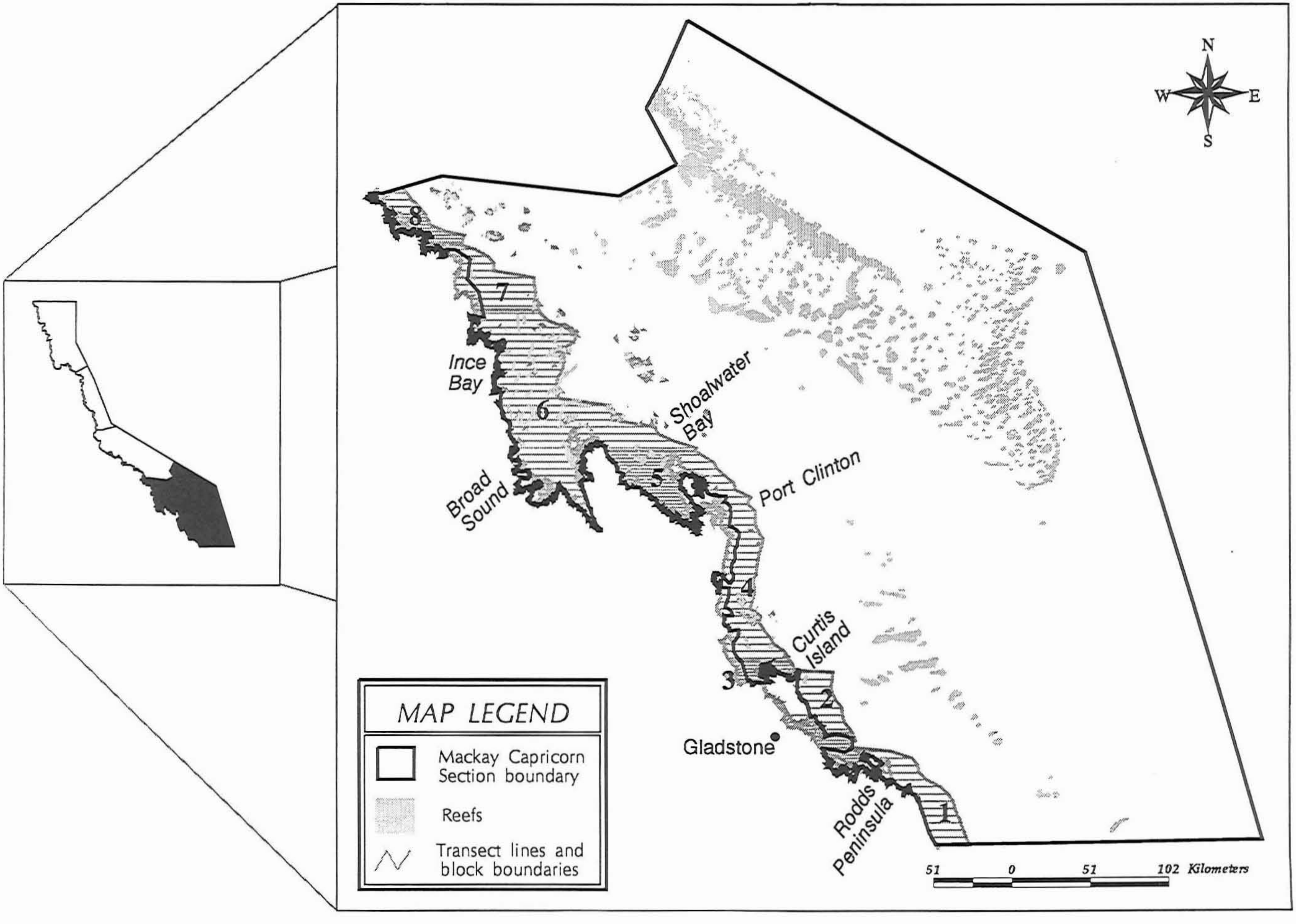
* Tested against Residual
** Tested against Transect nested in Block

**Table 7: Details of shark nets set for bather protection in GBR region.**

| Region[1] | No. of Locations | Net Length (m) | No. of days set per year | km net days/yr |
|---|---|---|---|---|
| Cairns | 5 | 3 x 68 | 365 | 372.3 |
| | 1 | 1 x 68 | 365 | 24.82 |
| Magnetic Island | 2 | 3 x 68 | 365 | 148.92 |
| Mackay | 2 | 3 x 68 | 365 | 148.92 |
| | 1 | 3 x 68[2] | 184 | 37.54 |
| TOTAL | | | | 732.5 |

1 Data provided to GBRMPA by Baden Lane, Senior Project-Officer Sharks, QDPI.
2 Eimio Beach net removed 1 September - 1 March to avoid sea turtle activity

Figure la: The transect lines in blocks (1-8) flown in November 1994 in the inshore waters of the Mackay-Capricorn Section of the Great Barrier Reef Marine Park.



N
S
E
W
8
7
6
5
4
3
2
1
Ince Bay
Shoalwater Bay
Broad Sound
Port Clinton
Curtis Island
Gladstone
Rodds Peninsula
MAP LEGEND
Mackay Capricorn Section boundary
Reefs
Transect lines and block boundaries
51 0 51 102 Kilometers

Figure lb: The transect lines in blocks (1-11) flown in November 1994 in the inshore waters of the Central Section of the Great Barrier Reef Marine Park.

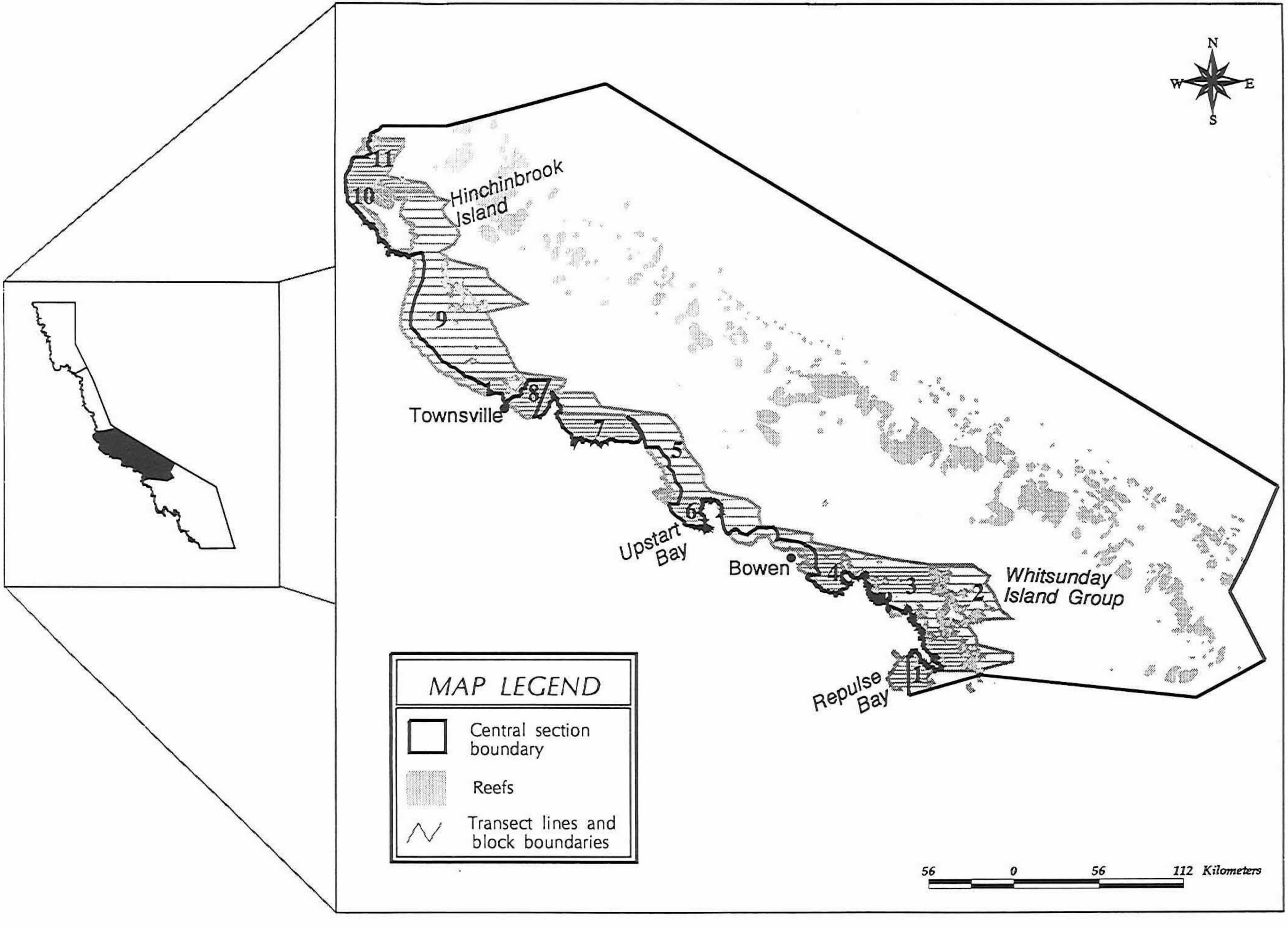

N
W
E
S
Hinchinbrook Island
Townsville
Upstart Bay
Bowen
Whitsunday Island Group
Repulse Bay
1
2
3
4
5
6
7
8
9
10
11
MAP LEGEND
Central section boundary
Reefs
Transect lines and block boundaries
56
0
56
112 Kilometers

Figure 2: The transect lines flown in November 1994 in the inshore waters of Hervey Bay and the Great Sandy Straits.

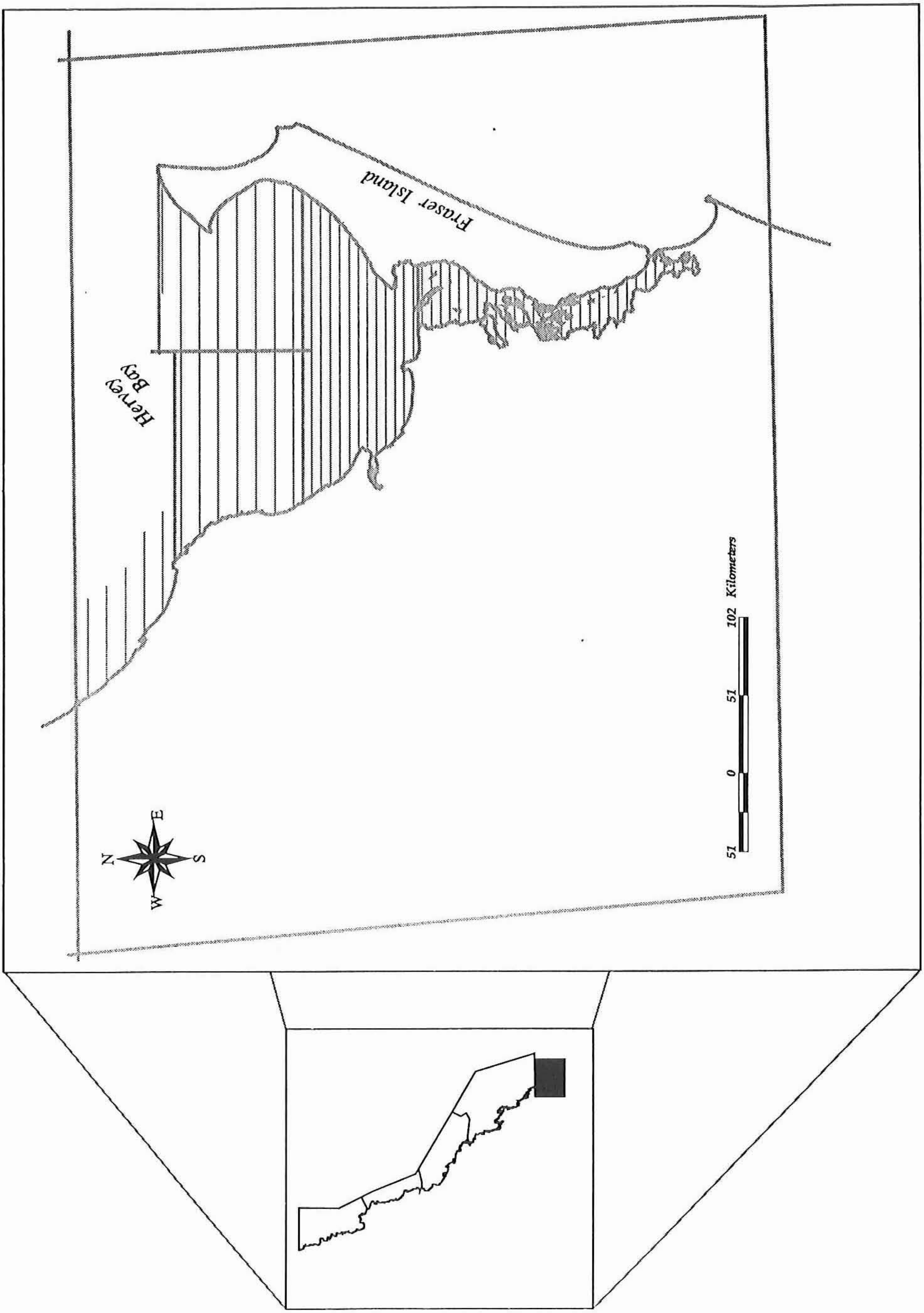

Fraser Island
Hervey Bay
51 0 51 102 Kilometers
N
E
S
W

Figure 3a: The numbers of groups of dugongs in the Great Barrier Reef Marine Park of various sizes with calves (light stippling) and without calves (dark stippling).

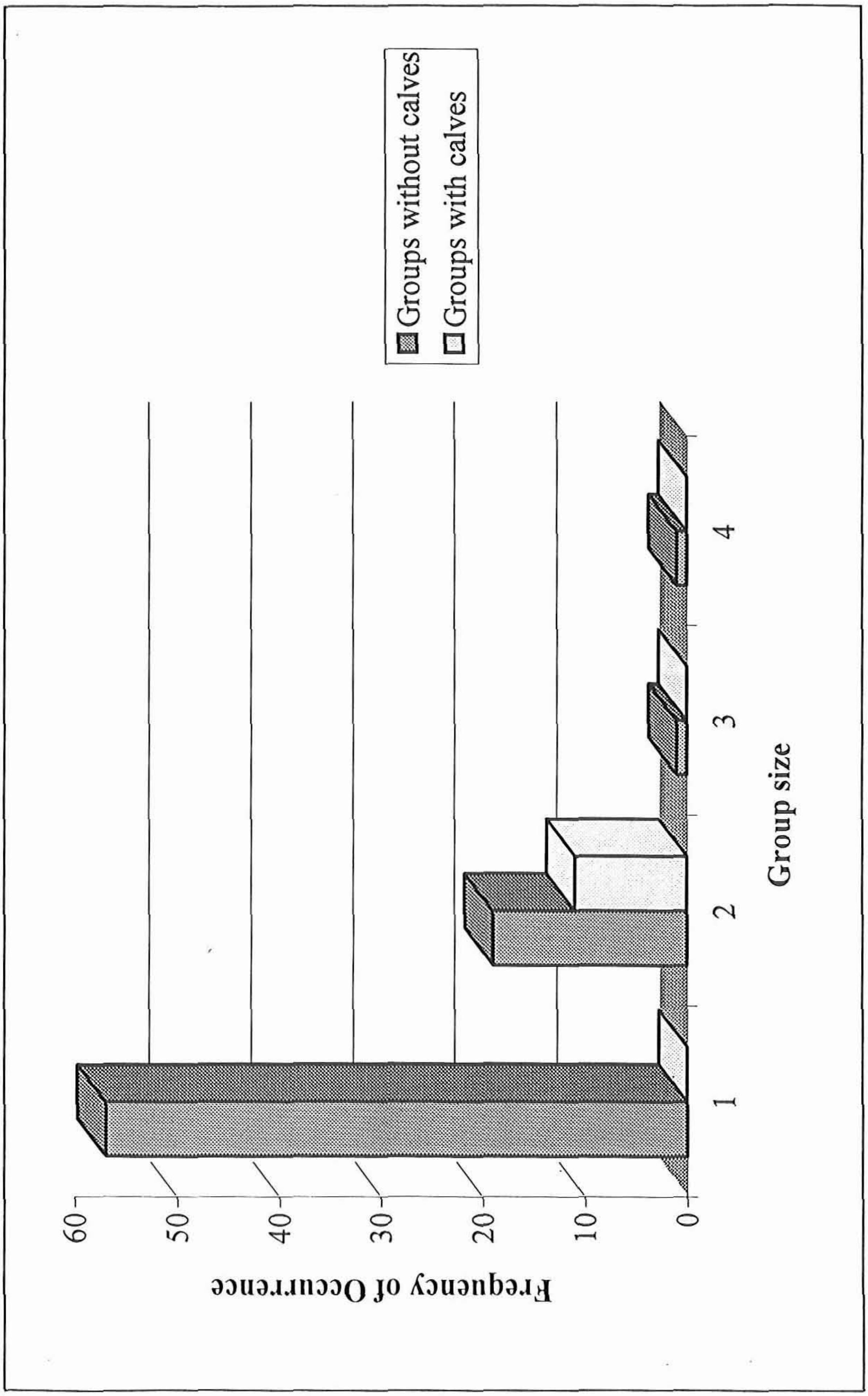

Groups without calves
Groups with calves
Frequency of Occurrence
0
10
20
30
40
50
60
Group size
1
2
3
4

Figure 3b: The numbers of groups of dugongs in Hervey Bay and the Great Sandy Straits of various sizes with (light stippling) and without (dark stippling) calves.

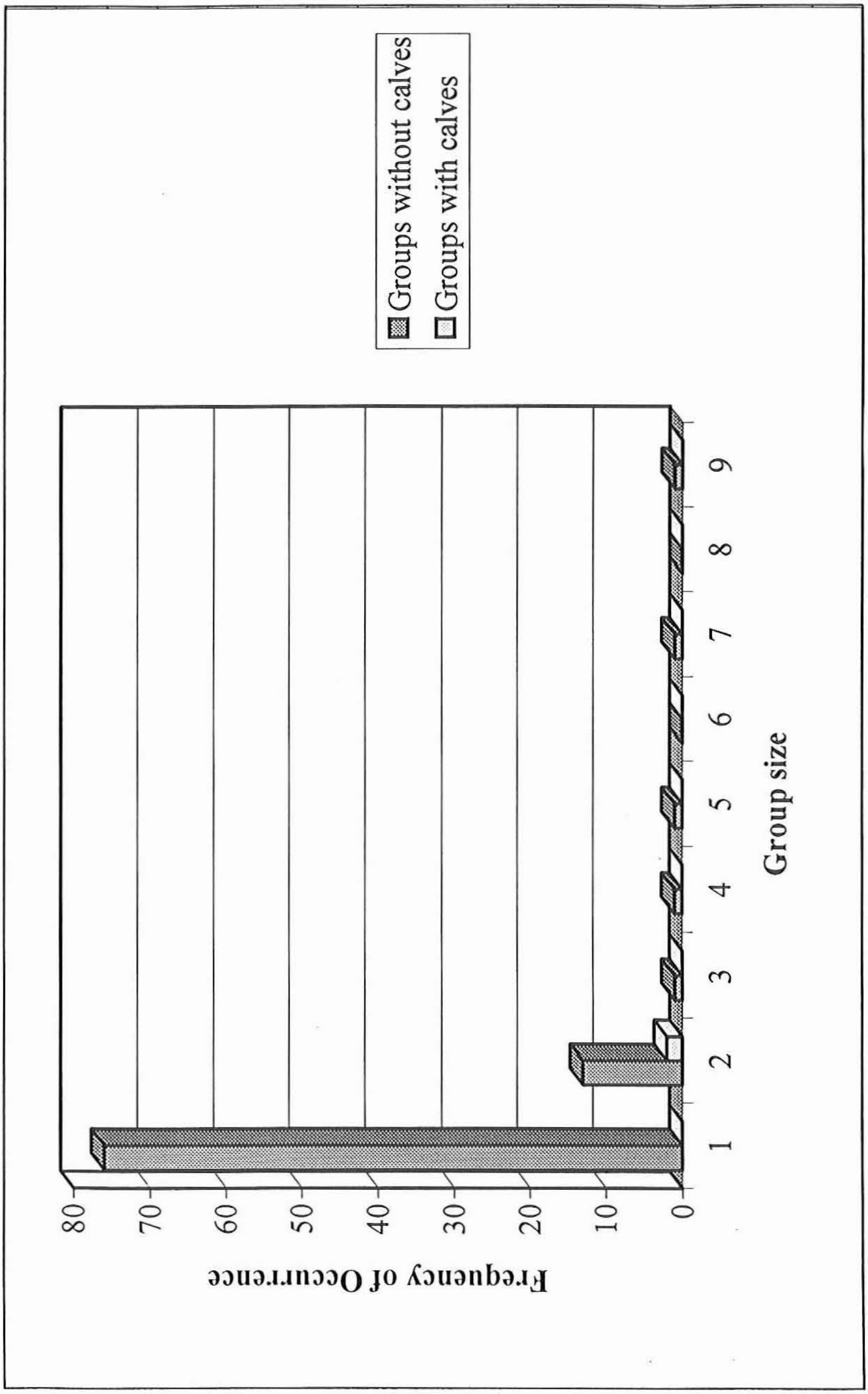

Groups without calves
Groups with calves
Frequency of Occurrence
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
Group size

Figure 4a: Dugong density in the inshore waters of the Mackay-Capricorn Section of the Great Barrier Reef Marine Park in November 1994 calculated on a 5 x 5 nm square grid and adjusted for sampling intensity.

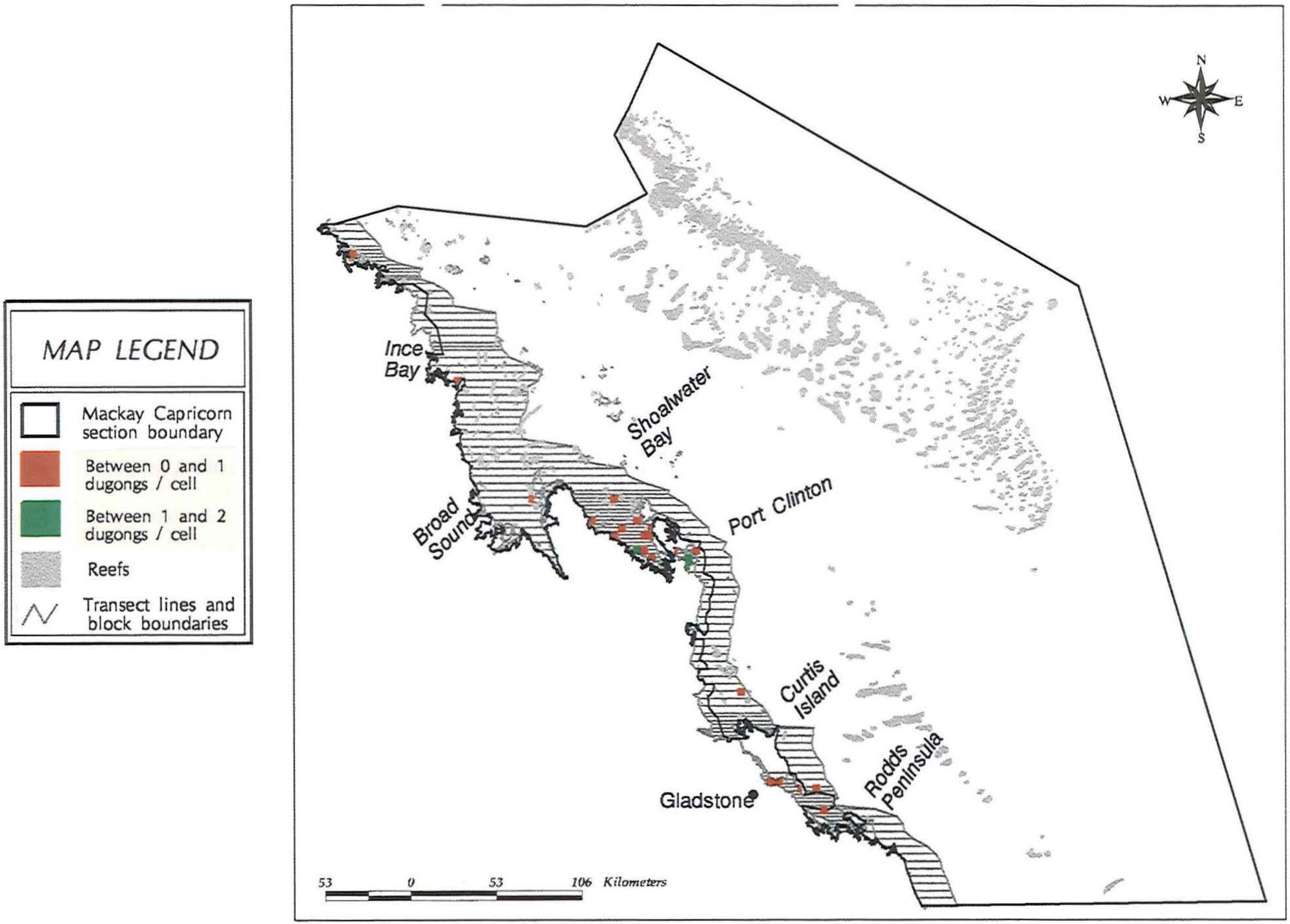

MAP LEGEND
Mackay Capricorn section boundary
Between 0 and 1 dugongs / cell
Between 1 and 2 dugongs / cell
Reefs
Transect lines and block boundaries
Ince Bay
Shoalwater Bay
Broad Sound
Port Clinton
Curtis Island
Rodds Peninsula
Gladstone
N
W
E
S
53 0 53 106 Kilometers

Figure 4b: A comparison of the presence and absence of dugong sightings within a 5 x 5 nm square grid in the inshore waters of the Mackay-Capricorn Section of the Great Barrier Reef Marine Park in 1986 and 1994. Red areas show where dugongs were sighted in 1986 only, yellow areas show where dugongs were sighted in 1994 only and green areas show where dugongs were sighted during both surveys.

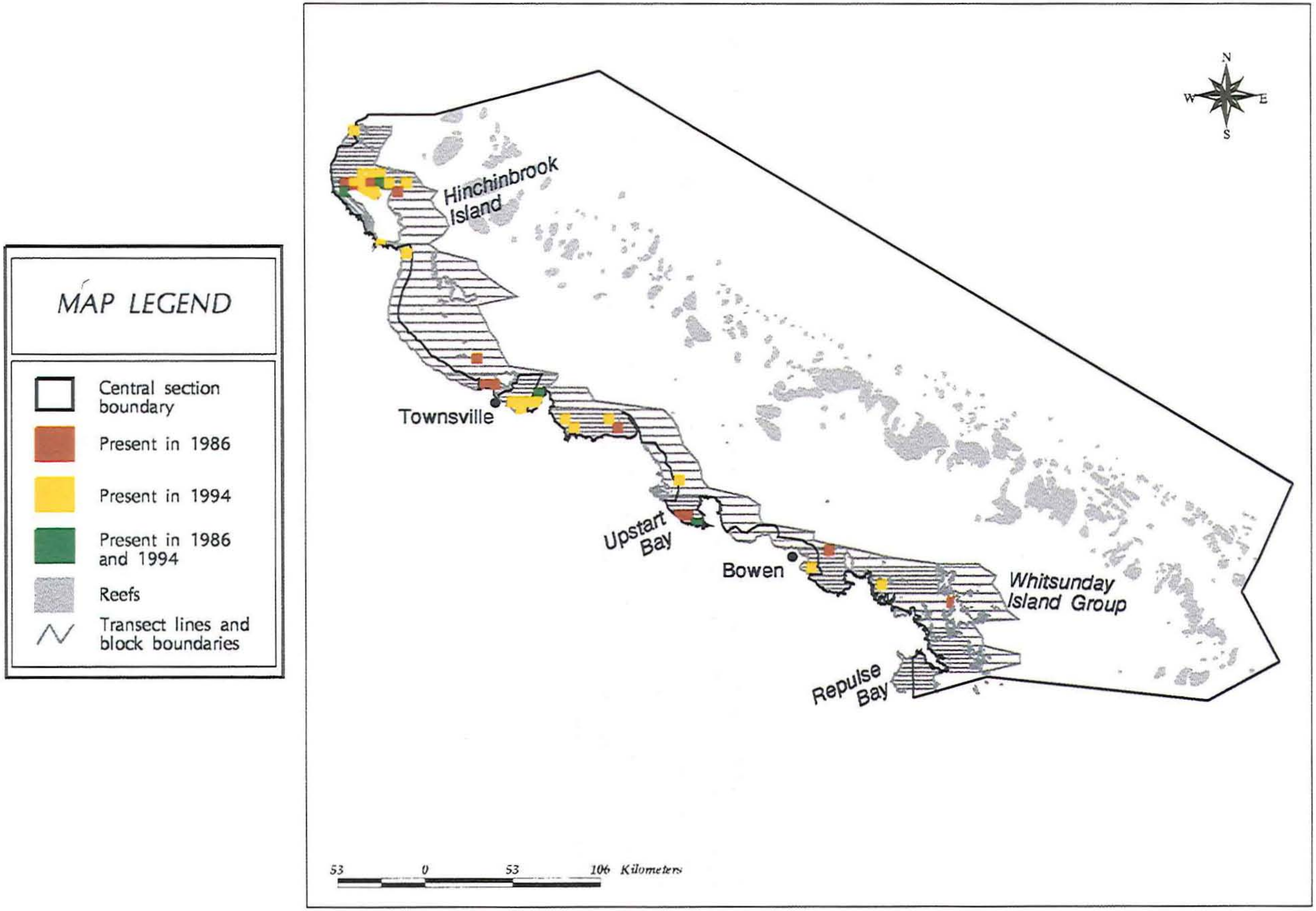

MAP LEGEND
Central section boundary
Present in 1986
Present in 1994
Present in 1986 and 1994
Reefs
Transect lines and block boundaries
Hinchinbrook Island
Townsville
Upstart Bay
Bowen
Whitsunday Island Group
Repulse Bay
N
W
E
S
53 0 53 106 Kilometers

Figure 4c: Protection of dugong habitats in the inshore waters of the Mackay-Capricorn Section of the Great Barrier Reef Marine Park. Cells within a 5 x 5 nm grid in which dugongs were sighted in 1994 have been colour coded to show the current level of habitat protection. Red areas have a protection of General Use A or less, yellow areas are General Use B zones and green areas have a protection of greater than General Use B. Habitats protected by the Great Barrier Reef Marine Park Authority and the Queensland Department of Environment and Heritage and Fisheries Habitat Reserves have been included.

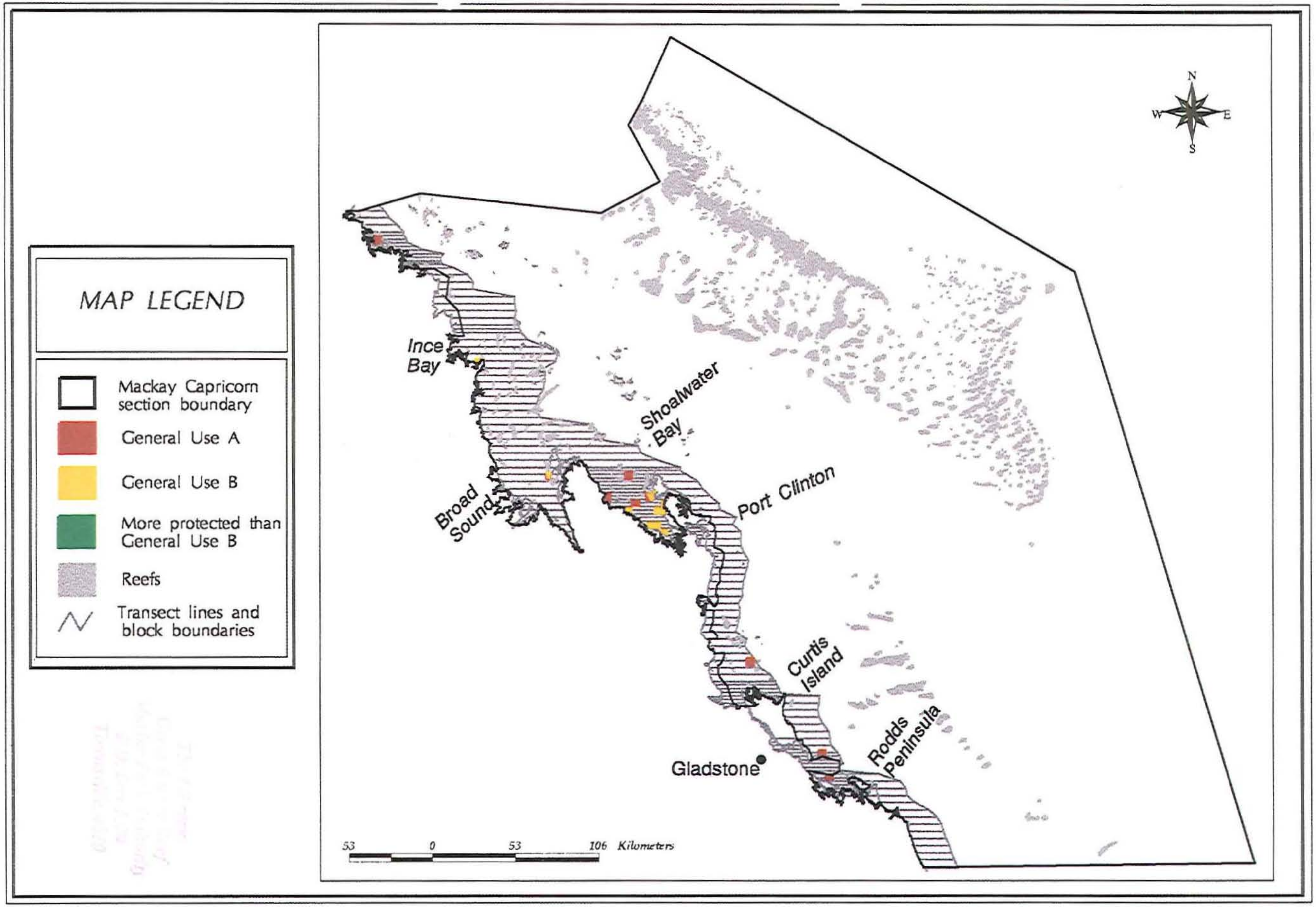

MAP LEGEND
Mackay Capricorn section boundary
General Use A
General Use B
More protected than General Use B
Reefs
Transect lines and block boundaries
Ince Bay
Shoalwater Bay
Broad Sound
Port Clinton
Curtis Island
Rodds Peninsula
Gladstone
N
S
E
W
53
0
53
106
Kilometers

Figure 5a: Dugong density in the inshore waters of the Central Section of the Great Barrier Reef Marine Park in November 1994 calculated on a 5 x 5 nm square grid and adjusted for sampling intensity.

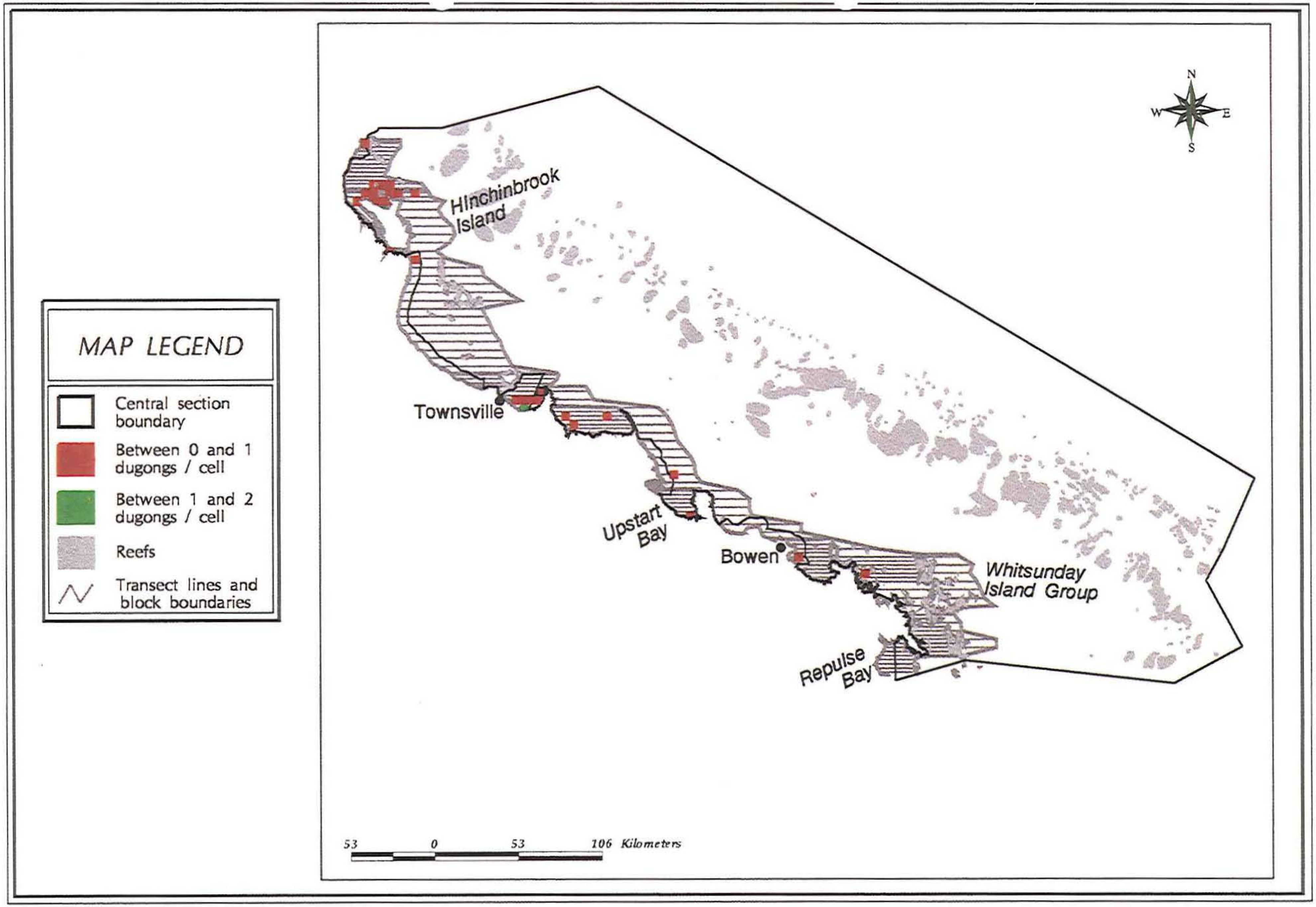

MAP LEGEND
Central section boundary
Between 0 and 1 dugongs / cell
Between 1 and 2 dugongs / cell
Reefs
Transect lines and block boundaries
N
S
E
W
Hinchinbrook Island
Townsville
Upstart Bay
Bowen
Whitsunday Island Group
Repulse Bay
53
0
53
106 Kilometers

Figure 5b: A comparison of the presence and absence of dugong sightings within a 5 x 5 nm square grid in the inshore waters of the Central Section of the Great Barrier Reef Marine Park in 1987 and 1994. Red areas show where dugongs were sighted in 1987 only, yellow areas show where dugongs were sighted in 1994 only and green areas show where dugongs were sighted during both surveys.

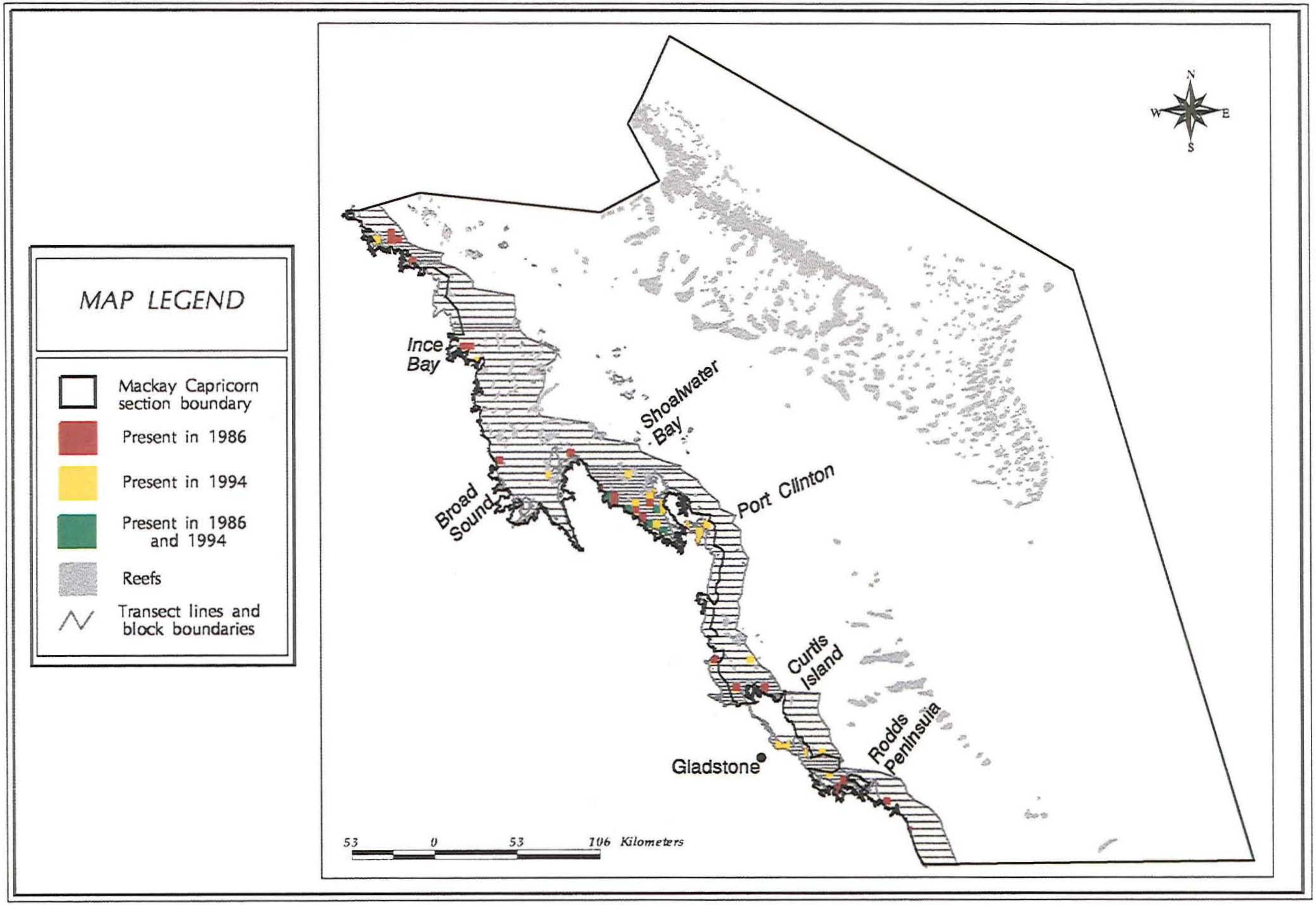

MAP LEGEND
Mackay Capricorn section boundary
Present in 1986
Present in 1994
Present in 1986 and 1994
Reefs
Transect lines and block boundaries
N
S
E
W
Ince Bay
Shoalwater Bay
Broad Sound
Port Clinton
Curtis Island
Rodds Peninsula
Gladstone
53 0 53 106 Kilometers

Figure 5c: Protection of dugong habitats in the inshore waters of the Central Section of the Great Barrier Reef Marine Park. Cells within a 5 x 5 nm grid in which dugongs were sighted in 1994 have been colour coded to show the current level of habitat protection. Red areas have a protection of General Use A or less, yellow areas are General Use B zones and green areas have a protection of greater than General Use B. Habitats protected by the Great Barrier Reef Marine Park Authority and the Queensland Department of Environment and Heritage as well as Fisheries Habitat Reserves have been included in the designation of zones.

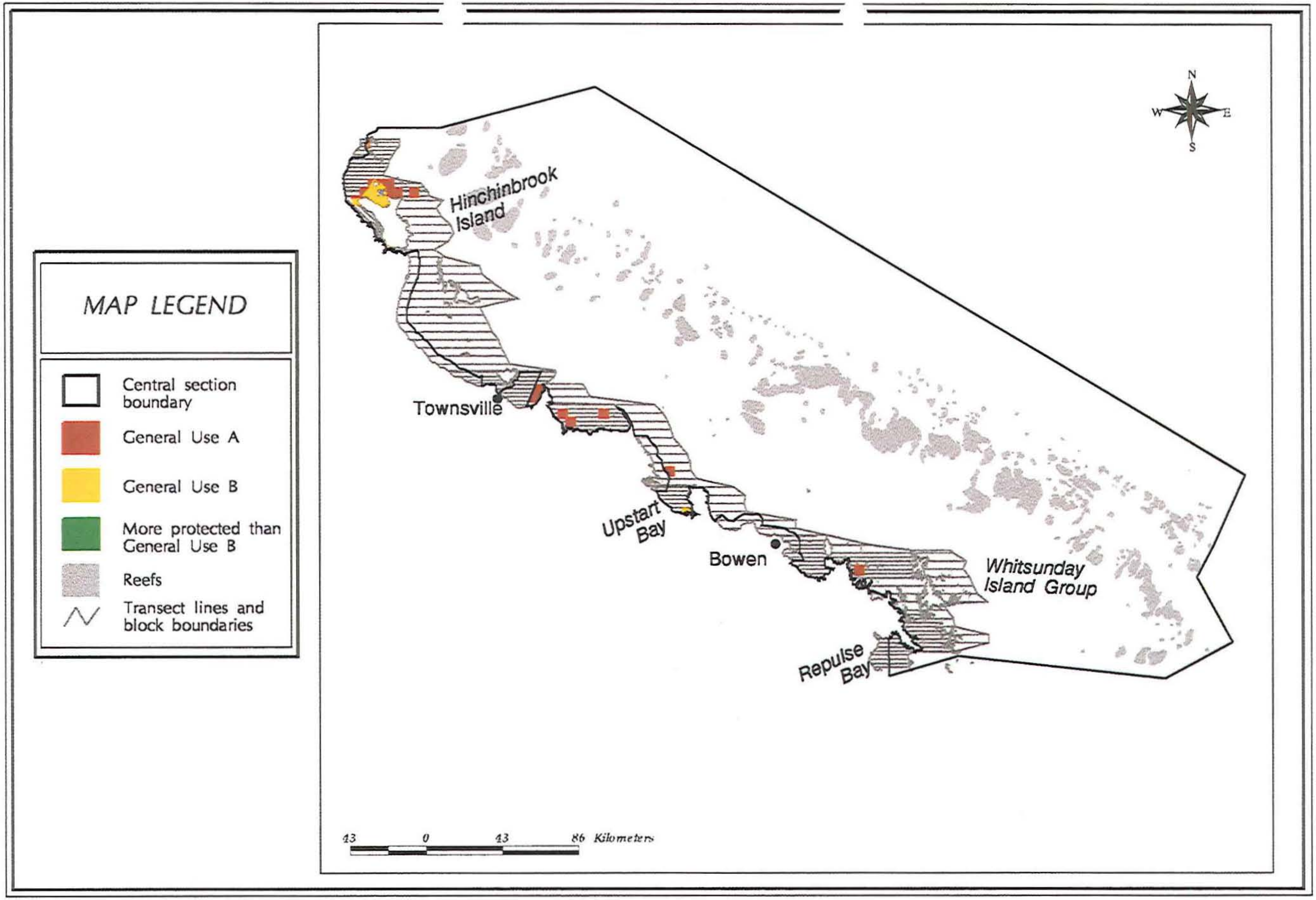

MAP LEGEND
Central section boundary
General Use A
General Use B
More protected than General Use B
Reefs
Transect lines and block boundaries
Hinchinbrook Island
Townsville
Upstart Bay
Bowen
Whitsunday Island Group
Repulse Bay
N
S
E
W
43
0
43
86 Kilometers

Figure 6. The mean density of dugongs/km$^2$ in each block in 1986/7 and 1994. The line represents equal densities on the two surveys. The blocks labelled S are in the Southern Section (Figure la); those labelled C in the Central (Figure lb) of the Great Barrier Reef Marine Park.

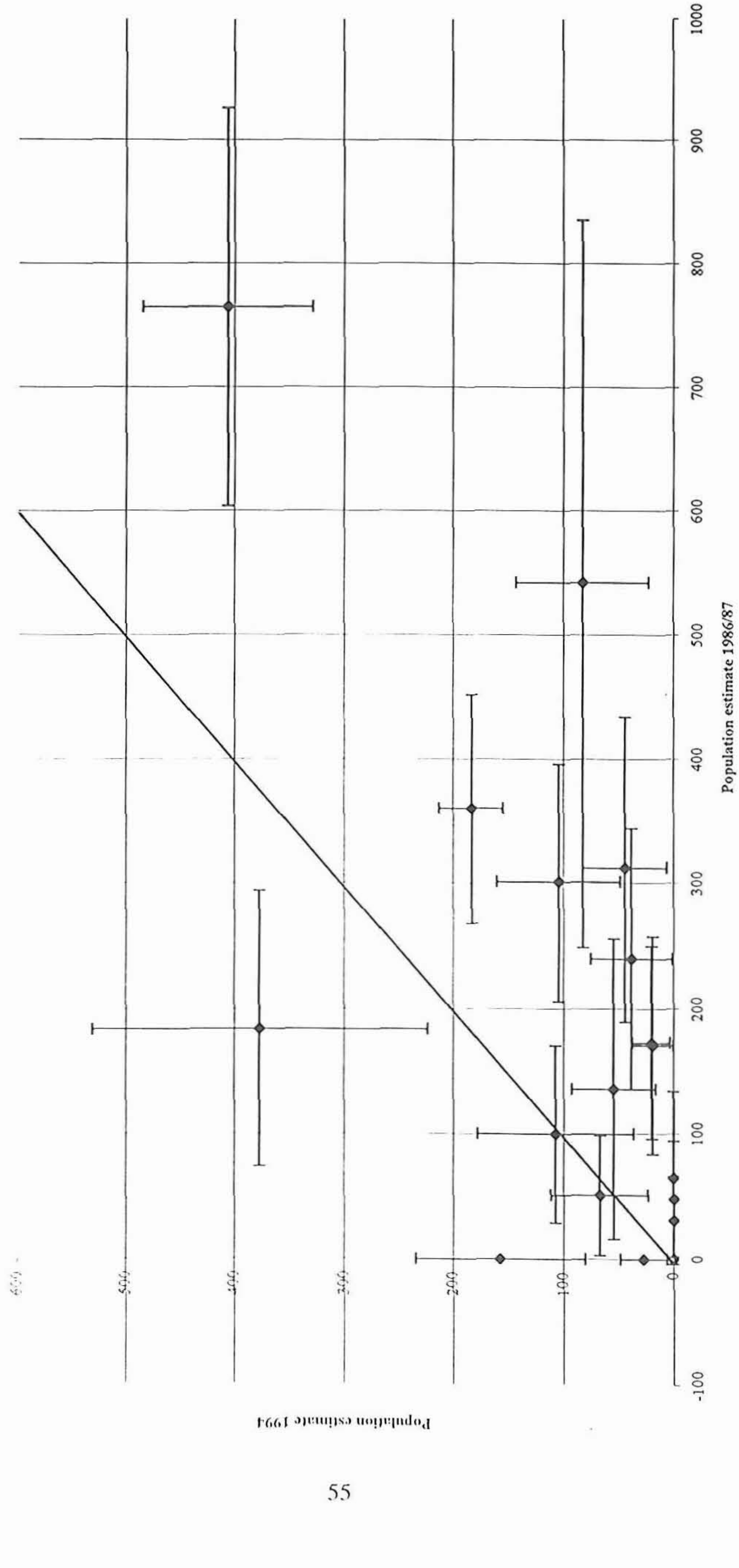
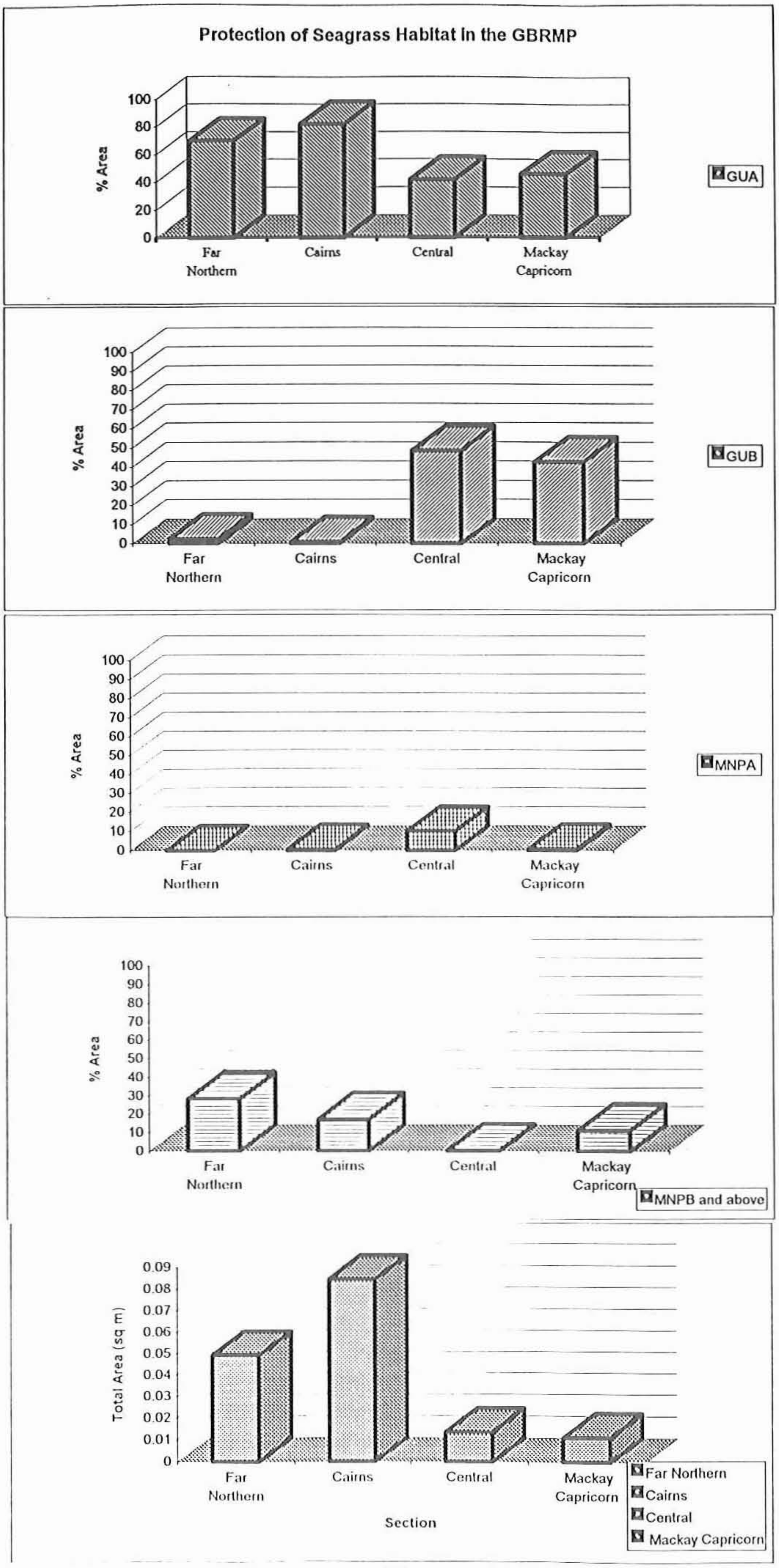
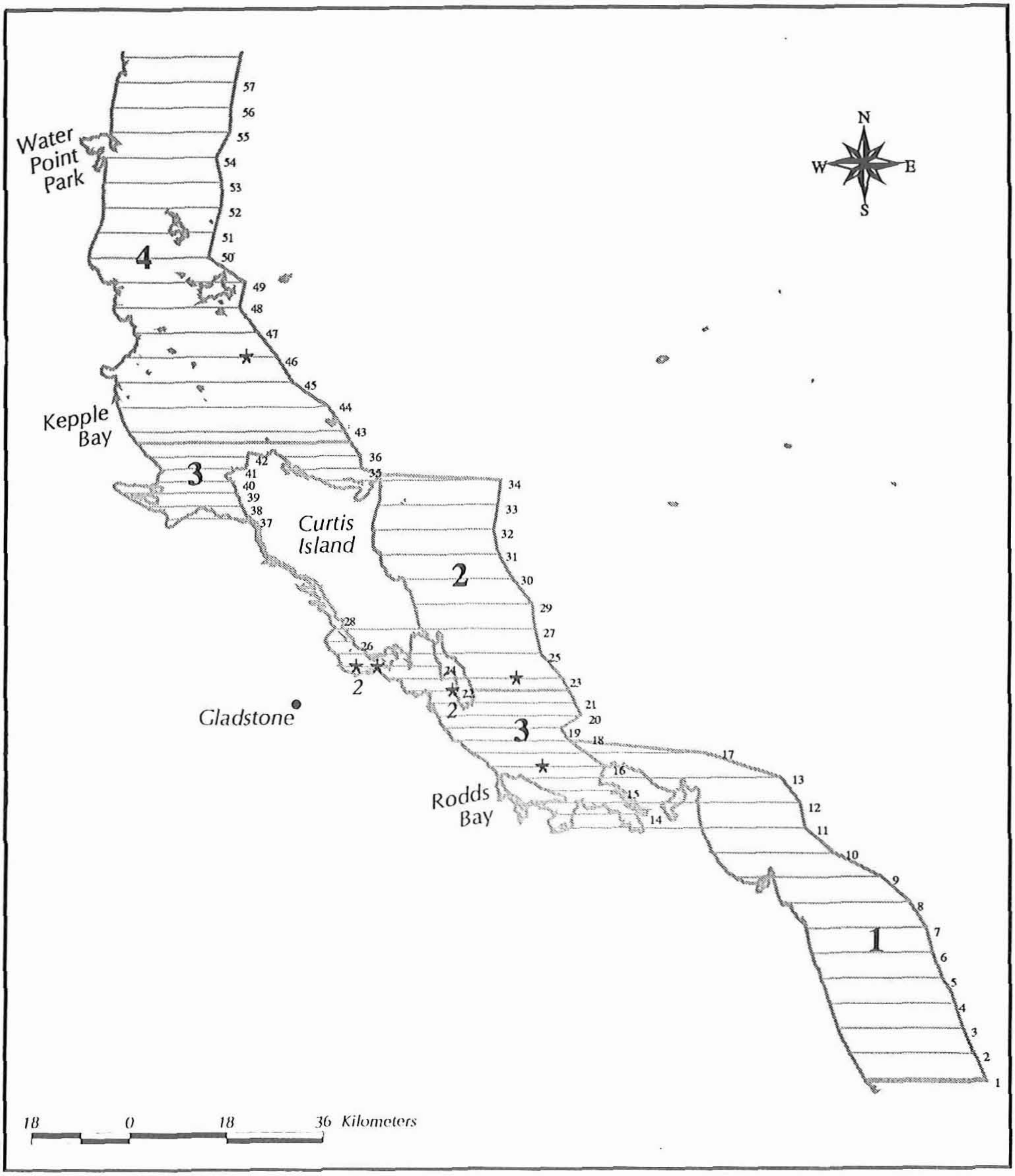

Population estimate 1986/87
Population estimate 1994
-100
0
100
200
300
400
500
600
700
800
900
1000
0
100
200
300
400
500
600

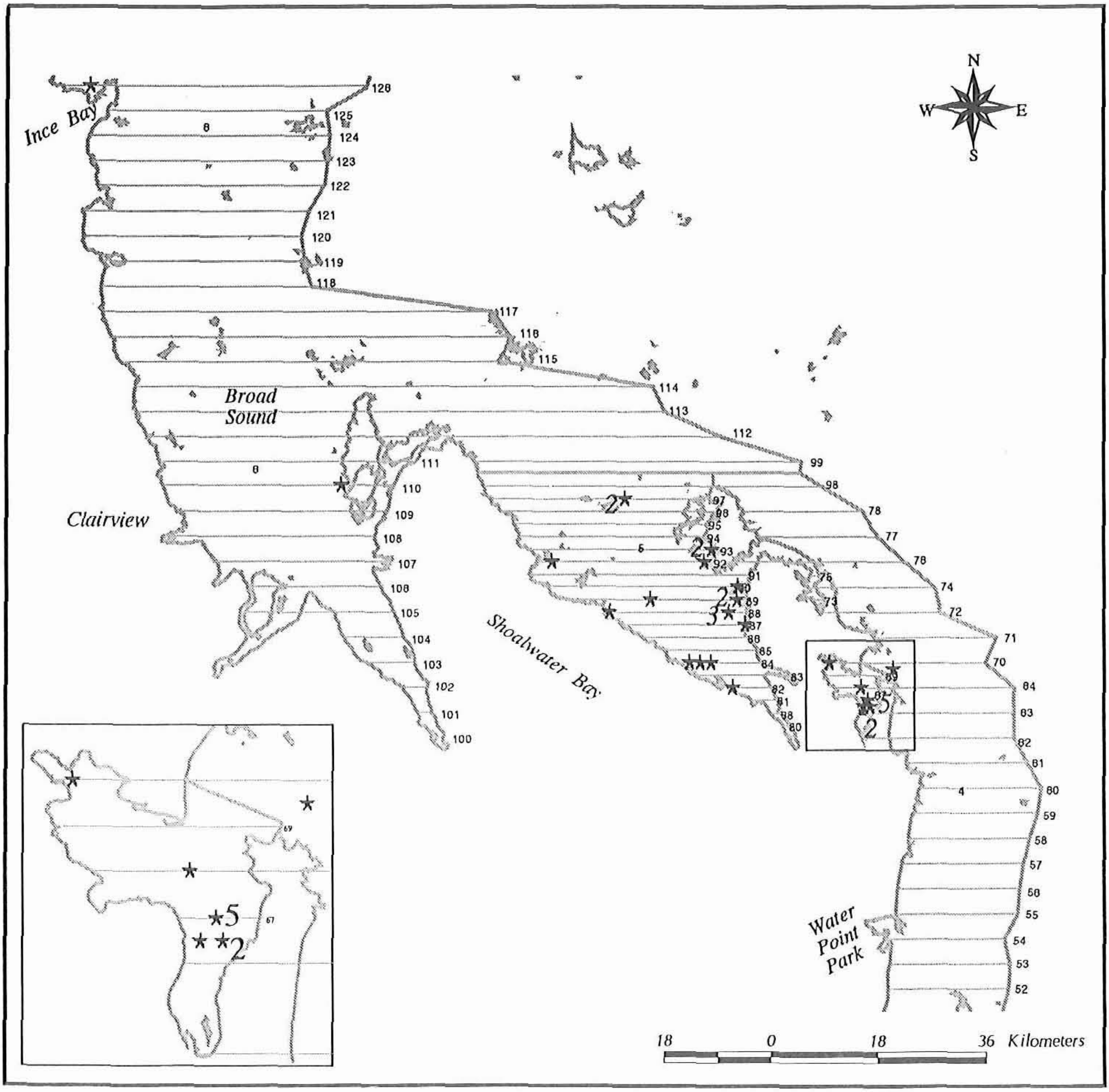
Figure 7. Protection of seagrass habitat in the Great Barrier Reef Marine Park. GUA refers to the area zoned General Use A; GUB refers to the area zoned General Use B; MNPA refers to the area zoned Marine National Park A; MNPB and above refers to the area zoned as Marine National Park B or zoning's offering higher protection. The data do not include the recent findings of large deepwater seagrass meadows in the Far Northern Section.


Protection of Seagrass Habitat in the GBRMP
% Area
GUA
Far Northern
Cairns
Central
Mackay Capricorn
% Area
GUB
% Area
MNPA
% Area
MNPB and above
Total Area (sq m)
Section
Far Northern
Cairns
Central
Mackay Capricorn

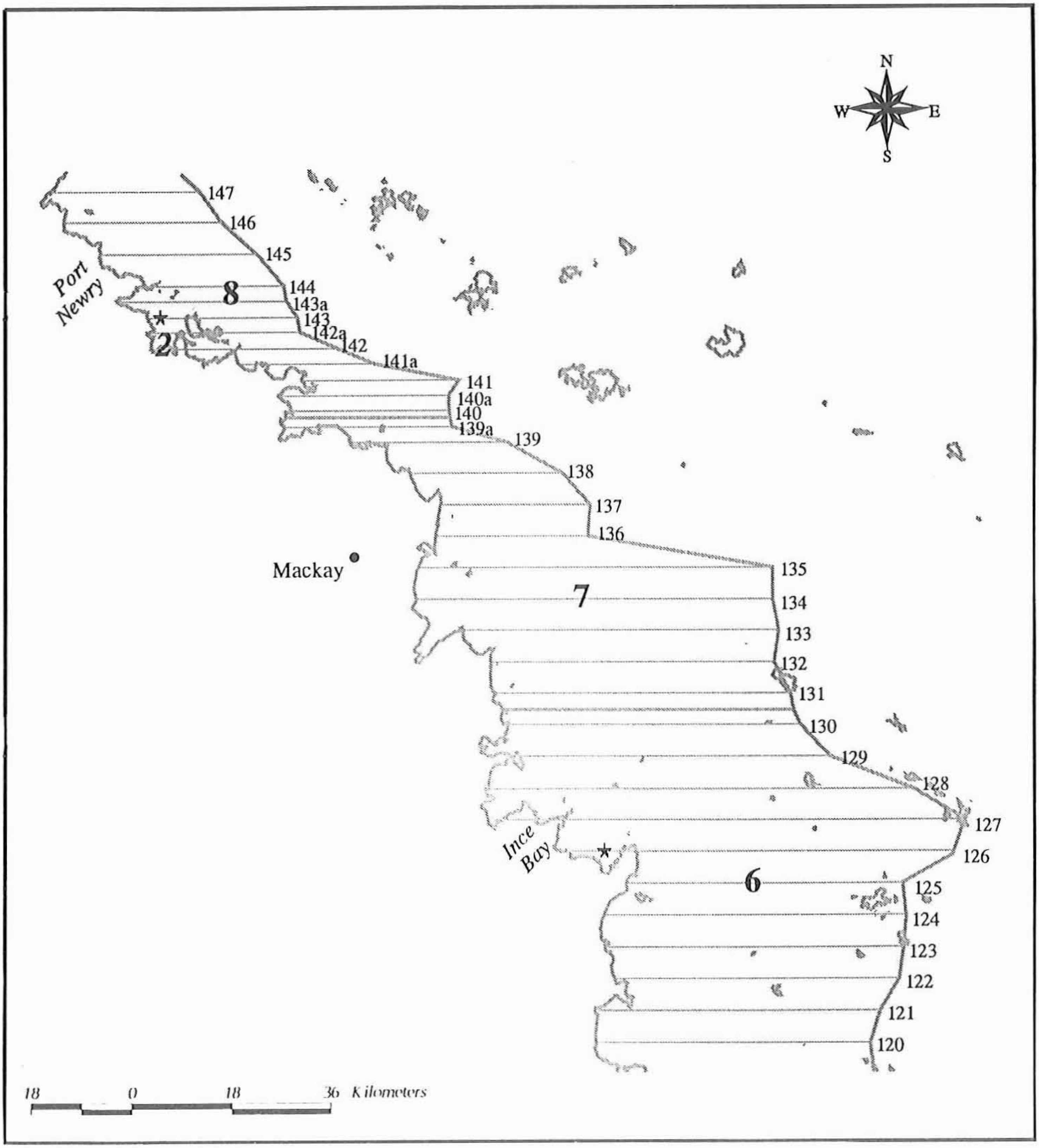
Appendix Figure 1: Survey area from Water Park Point to Rodds Bay (Mackay-Capricorn Section) showing the transect numbers and positions of dugong sightings in November 1994. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. Unnumbered stars represent a group of 1.


N
W
E
S
Water Point Park
Kepple Bay
Curtis Island
Gladstone
Rodds Bay
18 0 18 36 Kilometers

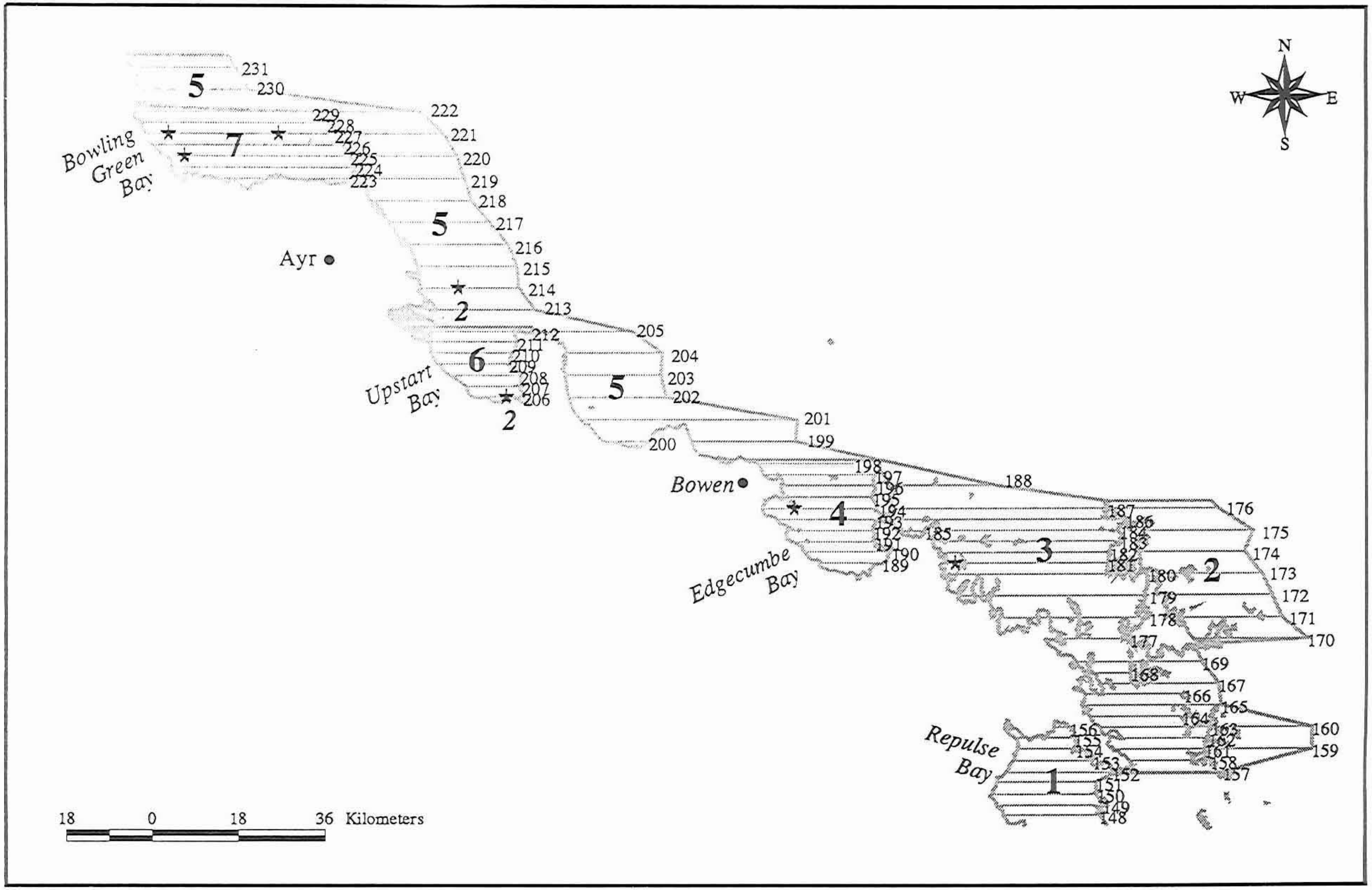
Appendix Figure 2: Survey area from Ince Bay to Water Park Point (Mackay-Capricorn Section) showing the transect numbers and positions of dugong sightings in November 1994. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. Unnumbered stars represent a group of 1.


Ince Bay
Broad Sound
Clairview
Shoalwater Bay
Water Point Park
N
S
E
W
18 0 18 36 Kilometers

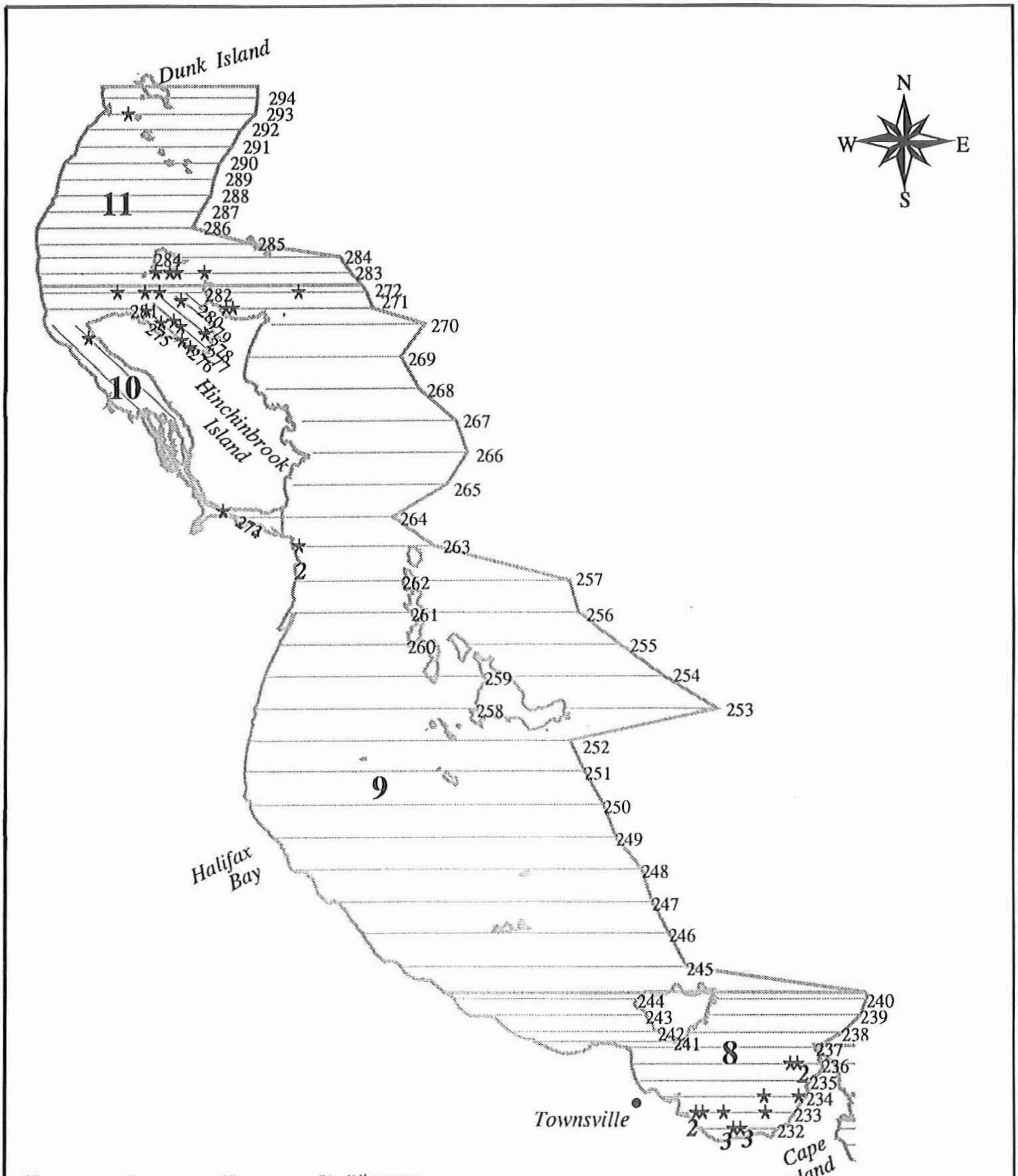
Appendix Figure 3: Survey area from Repulse Bay to Ince Bay (Mackay-Capricorn Section) showing the transect numbers and positions of dugong sightings in November 1994. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. Unnumbered stars represent a group of 1.


N
W
E
S
147
146
145
144
143a
143
142a
142
141a
141
140a
140
139a
139
138
137
136
135
134
133
132
131
130
129
128
127
126
125
124
123
122
121
120
Port Newry
8
2
Mackay
7
Ince Bay
6
18 0 18 36 Kilometers

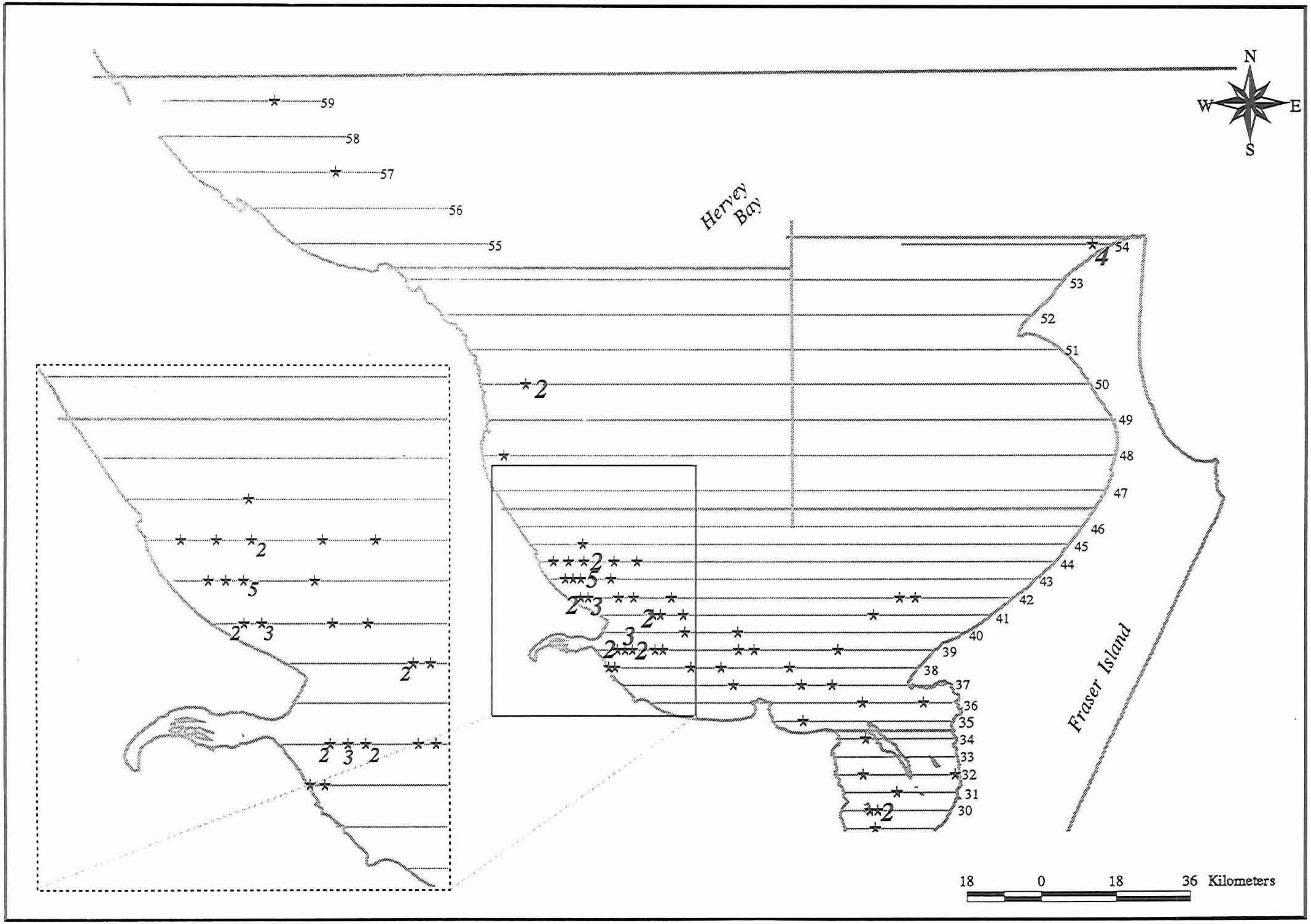
Appendix Figure 4: Survey area from Cape Cleveland to Repulse Bay (southern Central Section) showing the transect numbers and positions of dugong sightings in November 1994. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. Unnumbered stars represent a group of 1.


N
S
E
W
Bowling Green Bay
Ayr
Upstart Bay
Bowen
Edgecumbe Bay
Repulse Bay
18 0 18 36 Kilometers

Appendix Figure 5: Survey area from Dunk Island to Cape Cleveland (northern Central Section) showing the transect numbers and positions of dugong sightings in November 1994. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. Unnumbered stars represent a group of 1.


Dunk Island
N
W
E
S
11
10
9
8
Hinchinbrook Island
Halifax Bay
Townsville
Cape Cleveland
18 0 18 36 Kilometers

Appendix Figure 6: Survey area of Hervey Bay showing the transect numbers and positions of dugong sightings in November 1994. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. Unnumbered stars represent a group of 1.



N
W
E
S
Hervey Bay
Fraser Island
59
58
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41
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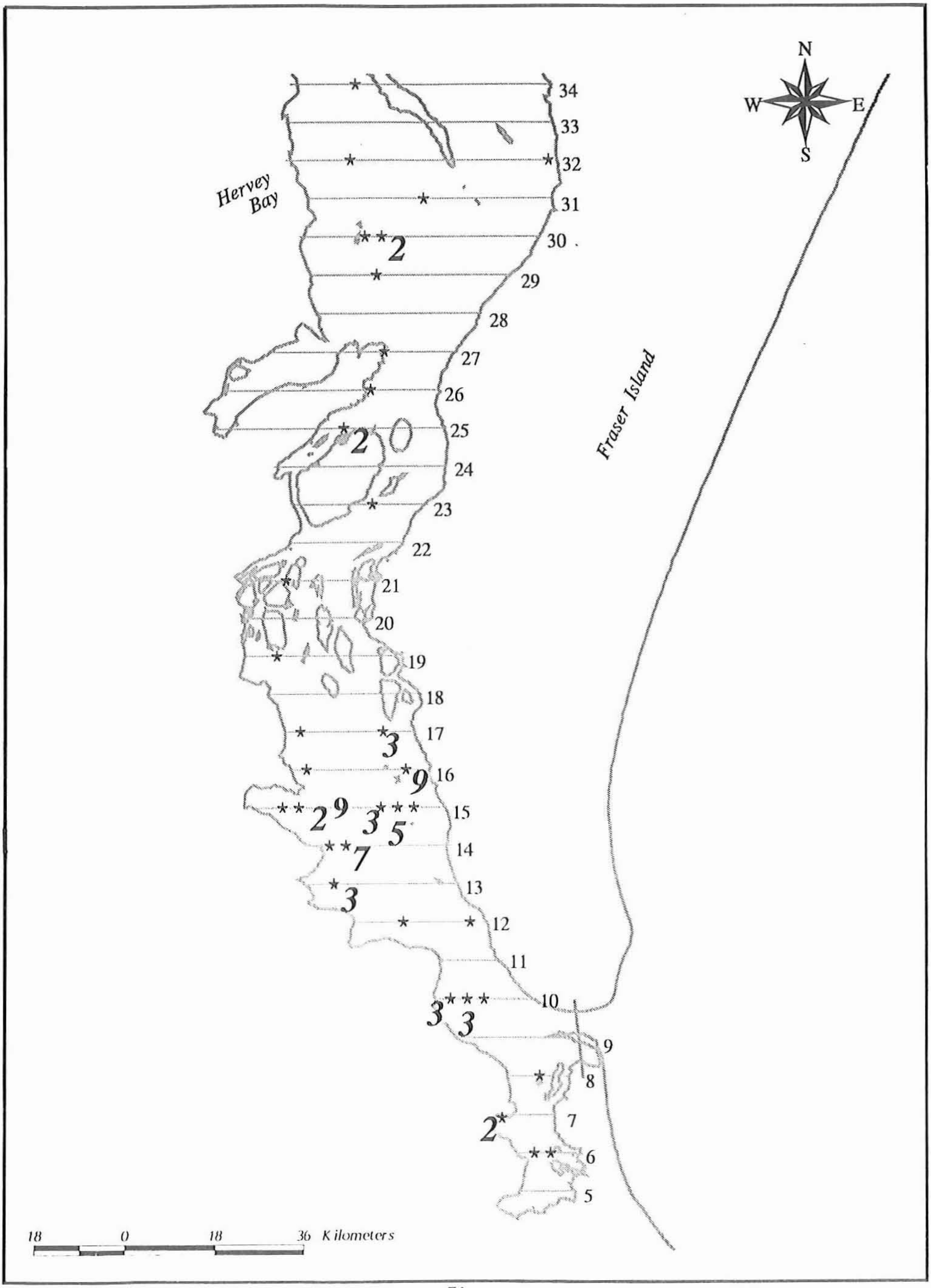
37
36
35
34
33
32
31
30
18 0 18 36 Kilometers

Appendix Figure 7: Survey area of the Great Sandy Straits showing the transect numbers and positions of dugong sightings in November 1994. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. Unnumbered stars represent a group of 1.


N
W
E
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Hervey Bay
Fraser Island
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33
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6
5
2
2
3
9
2
9
3
5
7
3
3
3
2
18 0 18 36 Kilometers

**Appendix Table 1:**

Beaufort sea state and glare for each transect.
The location of transects is indicated in Appendix Figures 1-7

**Scale:**
0 = no glare
1 = 0 ≤ 25%
2 = 25 ≤ 50%
3 = > 50%

| | | | | | | Glare | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | North | | | South | |
| Transect | Mode | Min | Max | Mode | Min | Max | Mode | Min | Max |
| **SGBR** | | | | | | | | | |
| 1 | 4 | 4 | 4 | 1 | 1 | 2 | 2 | 2 | 2 |
| 2 | 4 | 4 | 4 | 2 | 2 | 2 | 1 | 1 | 1 |
| 3 | 4 | 4 | 4 | 1 | 1 | 2 | 2 | 2 | 2 |
| 4 | 4 | 4 | 4 | 2 | 2 | 3 | 1 | 1 | 2 |
| 5 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| 6 | 4 | 4 | 4 | 2 | 2 | 3 | 2 | 2 | 2 |
| 7 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| 8 | 3 | 3 | 4 | 2 | 2 | 3 | 2 | 2 | 2 |
| 9 | 3 | 3 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| 10 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 11 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 12 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 13 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| 14 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 2 |
| 15 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 16 | 1 | 1 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 17 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 18 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 2 |
| 19 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 3 |
| 20 | 2 | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 2 |
| 21 | 3 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 1 |
| 22 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 23 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 24 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| 25 | 2 | 1 | 3 | 2 | 1 | 2 | 1 | 1 | 2 |
| 26 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 27 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 2 |
| 28 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 29 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 30 | 2 | 2 | 3 | 1 | 1 | 1 | 2 | 2 | 2 |
| 31 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 32 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 33 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 34 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 35 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 36 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| 42 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 43 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 44 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |

| | | | | | | Glare | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | North | | | South | |
| Transect | Mode | Min | Max | Mode | Min | Max | Mode | Min | Max |
| 45 | 0 | 0 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 46 | 2 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 2 |
| 47 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| 48 | 1 | 1 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 49 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 |
| 50 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 51 | 2 | 2 | 3 | 2 | 1 | 2 | 1 | 1 | 2 |
| 52 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 53 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 2 |
| 54 | 1 | 1 | 1 | 2 | 2 | 3 | 2 | 1 | 2 |
| 55 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 56 | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 3 |
| 57 | 2 | 1 | 3 | 2 | 2 | 3 | 1 | 1 | 3 |
| 58 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 59 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 2 |
| 60 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 61 | 2.5 | 2.5 | 2.5 | 3 | 2 | 3 | 2 | 2 | 3 |
| 62 | 1 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 63 | 1 | 1 | 3 | 2 | 1 | 2 | 2 | 2 | 2 |
| 64 | 1 | 1 | 3 | 2 | 2 | 3 | 1 | 1 | 1 |
| 67 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 1 |
| 68 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 69 | - | - | - | 1 | 1 | 2 | 2 | 2 | 2 |
| 70 | 2 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 71 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 72 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 73 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 74 | 1 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 75 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 1 |
| 76 | 3 | 2 | 3 | 1 | 1 | 1 | 2 | 2 | 2 |
| 77 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 78 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 79 | - | - | - | - | - | - | - | - | - |
| 80 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 81 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 1 |
| 82 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 83 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 84 | 2 | 2 | 2 | 0 | 0 | 1 | 1 | 1 | 1 |
| 85 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| 86 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 87 | 1 | 1 | 2 | 1 | 0 | 1 | 1 | 1 | 2 |
| 88 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 89 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| 90 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| 91 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 92 | 1 | 1 | 3 | 1 | 0 | 1 | 0 | 0 | 1 |
| 93 | 3 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 1 |
| 94 | 2 | 2 | 3 | 1 | 1 | 2 | 0 | 0 | 3 |
| 95 | 2 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 1 |
| 96 | 3 | 1 | 3 | 1 | 1 | 2 | 1 | 0 | 1 |
| 97 | 3 | 3 | 3 | 0 | 0 | 1 | 0 | 0 | 1 |
| 98 | 1 | 1 | 3 | 2 | 1 | 2 | 1 | 1 | 2 |

| | | | | | | Glare | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | North | | | South | |
| Transect | Mode | Min | Max | Mode | Min | Max | Mode | Min | Max |
| 99 | 4 | 4 | 5 | 1 | 1 | 1 | 2 | 2 | 2 |
| 103 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 104 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 105 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 106 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 107 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 108 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 109 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 110 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| 111 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| 112 | 4 | 3 | 5 | 1 | 1 | 2 | 2 | 1 | 2 |
| 113 | 4 | 1 | 4 | 1 | 1 | 1 | 1 | 1 | 2 |
| 114 | 3 | 3 | 3 | 1 | 1 | 2 | 1 | 1 | 1 |
| 115 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 116 | 1 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 1 |
| 117 | 2 | 1 | 3 | 2 | 1 | 2 | 2 | 1 | 2 |
| 118 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 119 | 2 | 1 | 3 | 2 | 2 | 2 | 2 | 1 | 2 |
| 120 | 2 | 2 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 121 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 122 | 2 | 2 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 123 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 124 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 125 | 2 | 2 | 4 | 1 | 1 | 2 | 2 | 2 | 2 |
| 126 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 127 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 1 | 2 |
| 128 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 2 |
| 129 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 2 |
| 130 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 131 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 132 | 2 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 1 |
| 133 | 1 | 1 | 3 | 2 | 1 | 2 | 2 | 1 | 2 |
| 134 | 2 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 2 |
| 135 | 3 | 2.5 | 3 | 1 | 1 | 1 | 2 | 2 | 2 |
| 136 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 137 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 3 |
| 138 | 4 | 4 | 4 | 1 | 1 | 1 | 2 | 2 | 2 |
| 139 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 |
| 140 | 4 | 4 | 4 | 1 | 1 | 2 | 2 | 2 | 2 |
| 141 | 3 | 3 | 3.4 | 2 | 2 | 3 | 3 | 3 | 3 |
| 142 | 3 | 3 | 3 | 1 | 1 | 1 | 2 | 2 | 2 |
| 143 | 3 | 3 | 3.5 | 2 | 2 | 2 | 2 | 2 | 2 |
| 144 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 145 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 146 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 147 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 148 | 1 | 1 | 3 | 0 | 0 | 1 | 1 | 1 | 1 |
| 149 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 150 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 1 |
| 151 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 152 | 2 | 2 | 3 | 0 | 0 | 1 | 1 | 1 | 2 |
| 153 | 3 | 3 | 3 | 1 | 1 | 1 | 2 | 2 | 2 |

| | | | | Glare | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | North | | | South | | |
| Transect | Mode | Min | Max | Mode | Min | Max | Mode | Min | Max |
| 154 | 3 | 1 | 3 | 0 | 0 | 2 | 1 | 1 | 2 |
| 155 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 2 |
| 156 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 157 | 2 | 2 | 3 | 2 | 1 | 2 | 2 | 1 | 2 |
| 158 | 1 | 1 | 3 | 0 | 0 | 1 | 1 | 1 | 1 |
| 159 | 2 | 2 | 2 | 0 | 0 | 2 | 1 | 1 | 2 |
| 160 | 2 | 1 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 161 | 1 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 1 |
| 162 | 3 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 163 | 1 | 1 | 3 | 2 | 1 | 2 | 2 | 2 | 2 |
| 164 | 1 | 1 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 165 | 1 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 166 | 2 | 1 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 167 | 3 | 1 | 3 | 2 | 1 | 2 | 1 | 1 | 2 |
| 168 | 1 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 169 | 0 | 0 | 3 | 2 | 0 | 2 | 1 | 1 | 2 |
| 170 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 171 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 |
| 172 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| 173 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 |
| 174 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |
| 175 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 2 |
| 176 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 177 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 2 |
| 178 | 1 | 1 | 2 | 2 | 1 | 2 | 2 | 1 | 2 |
| 179 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 |
| 180 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 |
| 181 | 1 | 1 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 182 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 183 | 1 | 1 | 3 | 1 | 1 | 2 | 1 | 1 | 1 |
| 184 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 185 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 186 | 2 | 1 | 3 | 1 | 1 | 2 | 2 | 2 | 2 |
| 187 | 1 | 1 | 3 | 2 | 2 | 2 | 2 | 1 | 2 |
| 188 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 |
| 189 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 190 | 3 | 3 | 3 | 1 | 1 | 2 | 1 | 1 | 1 |
| 191 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 192 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 193 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 194 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 195 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 196 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 |
| 197 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 198 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 2 |
| 199 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 |
| 200 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 201 | 1 | 0 | 2 | 0 | 0 | 2 | 1 | 0 | 2 |
| 202 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 1 |
| 203 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 2 |
| 204 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 3 |
| 205 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 3 |

| | | | | | | Glare | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | North | | | South | |
| Transect | Mode | Min | Max | Mode | Min | Max | Mode | Min | Max |
| 206 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 207 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 208 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 209 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 210 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 211 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 212 | 2 | 2 | 3 | 1 | 1 | 2 | 2 | 2 | 2 |
| 213 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 3 |
| 214 | 2 | 2 | 4 | 3 | 3 | 3 | 2 | 2 | 2 |
| 215 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| 216 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 2 |
| 217 | 3 | 3 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| 218 | 3 | 3 | 4 | 3 | 3 | 3 | 2 | 2 | 2 |
| 219 | 3 | 3 | 4 | 2 | 2 | 3 | 2 | 2 | 3 |
| 220 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| 221 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 2 |
| 222 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| 223 | 3 | 3 | 4 | 2 | 2 | 2 | 2 | 1 | 2 |
| 224 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 225 | 3 | 3 | 4 | 2 | 2 | 2 | 1 | 1 | 1 |
| 226 | 3 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 227 | 3 | 3 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| 228 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 2 |
| 229 | 3 | 3 | 3 | 1 | 1 | 2 | 1 | 1 | 1 |
| 230 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 231 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 232 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| 233 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| 234 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 235 | 1 | 1 | 3 | 1 | 0 | 1 | 1 | 1 | 2 |
| 236 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 237 | 3 | 3 | 4 | 1 | 1 | 3 | 2 | 1 | 2 |
| 238 | 3 | 3 | 4 | 3 | 3 | 3 | 2 | 2 | 2 |
| 239 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| 240 | 4 | 4 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| 241 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 242 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 243 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 244 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 245 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 246 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 247 | 2 | 2 | 2 | 1 | 0 | 1 | 0 | 0 | 1 |
| 248 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 249 | 3 | 1 | 4 | 2 | 2 | 3 | 1 | 1 | 2 |
| 250 | 2 | 1 | 4 | 1 | 1 | 2 | 1 | 1 | 2 |
| 251 | 3 | 1 | 4 | 2 | 1 | 2 | 1 | 0 | 1 |
| 252 | 3 | 1 | 3 | 1 | 0 | 2 | 1 | 1 | 2 |
| 253 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 2 |
| 254 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 255 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| 256 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 257 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 |

| | | | | | | Glare | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | North | | | South | |
| Transect | Mode | Min | Max | Mode | Min | Max | Mode | Min | Max |
| 258 | 2 | 2 | 3 | 1 | 1 | 2 | 1 | 0 | 1 |
| 259 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 260 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 261 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 262 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 263 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 264 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 265 | 1 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 1 |
| 266 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| 267 | 1 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 1 |
| 268 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 269 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 1 |
| 270 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 271 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| 272 | 3 | 3 | 4 | 3 | 3 | 3 | 2 | 2 | 2 |
| 273 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 |
| 274 | 1 | 1 | 3 | 1 | 1 | 1 | 2 | 1 | 3 |
| 275 | 1 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 1 |
| 276 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 277 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 278 | 1 | 1 | 3 | 1 | 1 | 1 | 0 | 0 | 0 |
| 279 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 280 | - | - | - | 1 | 1 | 1 | 0 | 0 | 0 |
| 281 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 282 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 2 | 2 |
| 283 | 3 | 3 | 4 | 2 | 2 | 3 | 2 | 2 | 2 |
| 284 | 3 | 2 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 285 | 1 | 1 | 3 | 2 | 2 | 2 | 2 | 1 | 2 |
| 286 | 1 | 1 | 3 | 1 | 1 | 2 | 2 | 0 | 2 |
| 287 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 0 | 2 |
| 288 | 3 | 2 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 289 | 3 | 3 | 3 | 2 | 2 | 3 | 2 | 1 | 2 |
| 290 | 2 | 2 | 4 | 2 | 1 | 2 | 1 | 1 | 2 |
| 291 | 3 | 3 | 4 | 2 | 2 | 2 | 2 | 2 | 2 |
| 292 | 2 | 2 | 3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 293 | 3 | 2 | 4 | 2 | 2 | 2 | 1 | 1 | 1 |
| 294 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| **ERVEY BAY** | | | | | | | | | |
| 5 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 3 | 3 | 3 | 1 | 1 | 1 | 0 | 0 | 0 |
| 7 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 |
| 8 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 9 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 10 | - | - | - | 1 | 1 | 1 | 1 | 1 | 1 |
| 11 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 13 | 1 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 1 |
| 14 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 15 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 2.5 | 2.5 | 2.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| 17 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |

| | | | | | Glare | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | | North | | | South | |
| Transect | Mode | Min | Max | Mode | Min | Max | Mode | Min | Max |
| 18 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| 19 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 20 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 21 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 23 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 24 | - | - | - | 1 | 1 | 1 | 1 | 1 | 1 |
| 25 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 26 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 27 | 1 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 1 |
| 28 | 1 | 1 | 2.5 | 1 | 1 | 2 | 1 | 1 | 2 |
| 29 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 30 | 3 | 3 | 3 | 1 | 1 | 2 | 1 | 1 | 1 |
| 31 | 2 | 2 | 2.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| 32 | 3 | 2.5 | 3 | 1 | 1 | 2 | 1 | 1 | 1 |
| 33 | 3 | 2 | 3 | 1 | 0 | 1 | 1 | 1 | 1 |
| 34 | 2 | 1 | 4 | 2 | 2 | 2 | 1 | 1 | 2 |
| 35 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 36 | 2.5 | 2 | 2.5 | 2 | 2 | 2 | 2 | 2 | 2 |
| 37 | 2 | 2 | 2.5 | 1 | 1 | 1 | 0 | 0 | 0 |
| 38 | 3 | 2.5 | 3 | 1 | 1 | 1 | 1 | 1 | 2 |
| 39 | 2 | 2 | 2.5 | 2 | 0 | 2 | 1 | 1 | 2 |
| 40 | 3 | 2 | 3 | 2 | 1 | 2 | 1 | 1 | 1 |
| 41 | 3 | 1.5 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 42 | 2 | 1 | 3 | 2 | 2 | 2 | 1 | 1 | 1 |
| 43 | 2 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 |
| 44 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 0 | 1 |
| 45 | 2 | 2 | 2.5 | 1 | 1 | 2 | 1 | 1 | 2 |
| 46 | 2 | 2 | 3 | 2 | 1 | 2 | 2 | 1 | 2 |
| 47 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 |
| 48 | 2 | 1 | 3 | - | - | - | - | - | - |
| 49 | 2.5 | 2 | 2.5 | 1 | 0 | 1 | 1 | 1 | 1 |
| 50 | 2.5 | 2.5 | 2.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| 51 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 1 | 2 |
| 52 | 2 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 2 |
| 53 | 2 | 1 | 3 | 2 | 0 | 2 | 2 | 1 | 2 |
| 54 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 55 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| 56 | 2 | 1.5 | 2.5 | 2 | 2 | 2 | 2 | 2 | 2 |
| 57 | 2 | 2 | 2.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| 58 | 2 | 2 | 2.5 | 1 | 1 | 1 | 2 | 2 | 2 |
| 59 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |

**Appendix**

**Table 2: Raw data used to calculate correction factors for dugongs for the survey.**

(a) Correction for perception bias

| Blocks: Lines | No. of groups of dugongs | | | | | |
|---|---|---|---|---|---|---|
| | Port | | | Starboard | | |
| | Mid | Rear | Tandem | Mid | Rear | Tandem |
| All blocks and lines except transects 294-284 for starboard team and 148-179 for port team[1] | 18 | 11 | 63 | 24 | 23 | 60 |

(b) Correction for availability bias

| Blocks: lines | No. of dugongs in groups of less than 10 | | |
|---|---|---|---|
| | Surface | Under | Total |
| **SGBR** | | | |
| All blocks and lines | 42 | 108 | 150 |
| **Hervey Bay** | | | |
| All blocks and lines | 23 | 155 | 178 |

[1]transects when trainee observers were being used.

See appendix figures for the location of numbered transects.