CR 25

Report to the Great Barrier Reef Marine Park Authority
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THE STATUS OF DUGONGS, SEA TURTLES AND DOLPHINS IN THE NORTHERN GREAT BARRIER REEF REGION

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EXECUTIVE SUMMARY

- In November-December 1990, dugongs, sea turtles and cetaceans were counted from the air at an overall sampling intensity of 9% over a total area of 31288 km^2 in the Great Barrier Reef region north of Cooktown. This survey was a repetition of the surveys conducted in 1984 and 1985.

- The population estimates for dugongs and sea turtles were corrected for perception bias (the proportion of animals visible in the transect which are missed by observers), and standardised for availability bias (the proportion of animals that are invisible due to water turbidity) using survey and species-specific correction factors. The estimates for cetaceans were corrected for perception bias only. Because the availability correction factors are conservative, the population estimates quoted here are underestimates. The corrections for availability bias do not completely compensate for differences in sightablity due to weather conditions and these were further adjusted for using Beaufort Sea State as a covariate when comparing the results of the 1985 and 1990 surveys.

- The minimum population estimate for dugongs for the survey area in November-December 1990 (10471 $\pm$ s.e.1578 dugongs), was not significantly different from the estimate for the same region in November 1985 using the same aerial survey technique (8110 $\pm$ s.e. 1073). The probability of there being no significant difference between surveys increased form 0.1 to 0.8 when the effect of weather was taken into account. The results of the two surveys for each survey block were remarkably consistent suggesting that the dugong population in the region is stable. However, the technique is not capable of detecting local declines in abundance unless they were considerable.

- Most of the turtles sighted during this survey were probably large green turtles. The minimum population estimate for the northern Great Barrier Reef region in November-December 1990 was 45644 $\pm$ s.e. 3501 turtles compared with 32187 $\pm$ 2532 for the same region in November 1985. Turtles were distributed differently on the two surveys even when differences in sighting conditions were taken into account. The difference between the minimum population estimates obtained in 1985 and 1990 was not significant when Beaufort Sea State was used as a covariate in the analysis suggesting that the observed difference in population size between surveys was an artefact of weather conditions. However, the agreement between the 1985 and 1990 surveys was not nearly as good for turtles as for dugongs, probably due to: (1) the sensitivity of turtle sightings to small changes in sighting conditions which cannot be completely removed in the analyses and (2) the tendency of turtles to migrate to breed coincident with the timing of the surveys.

- All the cetaceans sighted were dolphins. Most of the animals appeared to be bottlenose dolphins, *Tursiops truncatus,* or Indo-Pacific humpback dolphins, *Sousa chinensis*. The minimum population estimates for November-December 1990 sum to 4875 $\pm$ s.e. 500 dolphins for the whole region compared with 6609 $\pm$ s.e. 667 in November 1985. The difference in dolphin distribution was significantly different between the two surveys.

RECOMMENDATIONS

1. That a marine consultant with a good rapport with the commercial fishing industry, such as Brett Shorthouse, be funded to develop a scheme to **monitor and verify** the by-catch of dugongs and turtles by commercial fishers in the northern Great Barrier Reef region. The scheme should be developed in cooperation with the Queensland Commercial Fishermen's Organisation and Dr Ian Poiner of CSIRO who developed a similar program to monitor turtle catches by the northern prawn fishery. The scheme should encourage fishers to donate their incidental catch of dugongs and turtles to local Aboriginal communities whenever possible.

2. That the **collection and verification** of dugong and turtle catch statistics from Lockhart River and Hopevale communities by community rangers be given a high level of support by QDEH field staff. The rangers should be encouraged to send dugong tusks to James Cook University so that the age-sex composition of the catch can be verified.

3. That a culturally appropriate public education program about dugongs and turtles be developed for Aboriginal communities in Cape York. This program could be developed as part of a more general community-based video information service for Aboriginal people, a parallel to 'Deckhand' which provides management information to commercial fishermen. The segment on dugongs and turtles should emphasise the vulnerability of these species to over-harvesting, the illegality of selling their meat and the current restrictions on hunting in some regions of the Great Barrier Reef Marine Park.

4. That in order to monitor numbers, this survey be repeated in November 1995 and at five yearly intervals thereafter. (November is the month when favourable weather conditions are most likely and in view of the high cost of transporting a suitable aircraft and survey crew to the region, it is likely to be a waste of money to attempt a survey at another time of the year). The survey crew should include at least two suitably-trained Aboriginal observers (preferably from the staff of GBRMPA and QDEH).

5. That a copy of this report be made available to the Hopevale and Lockhart River Community Councils. The report should be distributed in association with a personal presentation by a suitably-briefed Aboriginal ranger as part of the public education program and should be accompanied by a summary written for non-scientists.

INTRODUCTION

In 1984 and 1985, Marsh and Saalfeld (1989a) used aerial surveys to document the distribution and abundance of dugongs over an area of 31288 km^2 in the northern sections of the Great Barrier Marine Park. They used survey-specific correction factors 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 resultant minimum population estimate in November 1985 was some 8100 dugongs at an overall density of 0.26 dugongs per km^{-2}.

Smith and Marsh (1990) concluded that the traditional dugong harvest in the northern Great Barrier Reef region was likely to be below the sustainable yield on the basis of: (1) the 1984-5 aerial surveys (Marsh and Saalfeld, 1989a: (2) the population models of Marsh (1986) and (3) their estimates of the number of dugongs caught by the Aboriginal communities at Hopevale and Lockhart River. However, this conclusion was tentative due to the lack of statistics on the other anthropogenic sources of dugong mortality in this region, such as incidental drowning in barramundi nets. Accordingly, Marsh and Saalfeld (1989a) recommended that the aerial survey be repeated at five-yearly intervals in order to monitor trends in the population. However, they pointed out on the basis of a power analysis (Gerrodette, 1987) that it would probably be at least a decade before a trend could be established statistically.

The first repeat survey was held in November-December 1990. As with the previous surveys, sightings of cetaceans (Marsh, 1990) and sea turtles (Marsh and Saalfeld, 1989b) were recorded as well as dugongs. Accordingly, this report compares the distribution and abundance of dugongs, sea turtles and cetaceans in 1990 with the results of the 1984-5 surveys (Marsh, 1990; Marsh and Saalfeld, 1989a and b).

METHODS

The coastal waters of Cape York between Cape Bedford (15° 15'S) and Hunter Point (11° 30'S) and the outer Barrier Reef (Figure 1) were surveyed between November 21 and 25, and December 3 through 10, 1990. Bad weather made it inappropriate to survey between November 26 and December 2. The weather conditions encountered during the 1990 survey are summarised in Table 1 along with those for the November 1985 survey. Weather conditions for each day of the 1990 survey are summarised in Appendix Table 1. The glare and Beaufort sea state for each transect are detailed in Appendix Table 2, the logistics of the 1990 survey in Appendix Table 3.

Survey design

The survey design (Figure 1) was similar to that used in November 1985 (Marsh and Saalfeld, 1989a) except that additional transects were flown in Temple Bay (Block 14) due to the interest in this region resulting from the proposed development of a space port.

For estimation of regional densities of dugongs, dolphins and sea turtles, the area was divided into 14 blocks (Figure 1) on the basis of sampling intensity and placement of transects. Block areas (Table 2) were estimated from 1:250,000 maps using a planimeter or digitising tablet. The areas of small (<3 km ^{2}) islands were included within the block areas. The length of each transect was estimated from the maps.

Survey methodology

The Partenavia 68B aircraft was flown at a groundspeed of 185 km h^{-1} (100 knots) and at an altitude of 137 m (450 feet) ASL. The pressure altimeter was calibrated at each takeoff and landing. Transect width (200 m on each side of the aircraft at a survey altitude of 137 m) was demarcated by fibre glass rods attached to artificial wing struts. Due to fluctuations in atmospheric pressure, a pressure altimeter tends to become increasingly inaccurate during a flight. This drift was estimated by recording the difference between the altimeter at each landing and the known height of the relevant airport. The actual width of each transect (at its midpoint) was then estimated by interpolation assuming that the rate of drift was constant during a flight and a combined transect width of 400 m at an altitude of 137 m.

The crew comprised a pilot navigator, a front right survey leader/recorder, and two tandem observing teams who occupied the middle and rear seats on opposite sides of the aircraft. Only two (or three) operational observers were available on some transects while inexperienced observers were being trained (e.g. see Tables 3,4,5).

The observers reported their observations of dugongs, turtles (usually not identified to species), cetaceans (not to species), sharks, rays, and sea snakes in standard format into an intercom connected to a two track tape recorder. They recorded whether each sighting occurred in the top (furthest from aircraft), middle, or bottom third of the transect in order to increase the probability of distinguishing between different observations reported simultaneously by both members of a tandem team. Operational rear seat observers were visually screened from the mid seat observers and acoustically isolated from the remainder of the crew apart from each other. The rear seat observers and the mid seat observers reported their (independent) observations into separate tracks of the tape recorder. Trainee rear seat observers could hear the reports of the mid seat observers. Data including aircraft height and position, weather conditions, the starting and finishing times for each transect, and the sightings of the mid seat observers were recorded by the survey leader using a microcomputer programmed as a data logger and timer.

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

Correction factors

Correction factors were calculated separately for dugongs, dolphins and turtles to compensate for perception bias (groups of animals visible on the transect line that were missed by observers) and for dugongs and turtles to compensate for availability bias (groups of animals that were unavailable to observers because of water turbidity) and their associated coefficients of variation as outlined in Marsh and Sinclair (1989a). The corrections for perception bias were calculated on the basis of the proportion of the relevant sightings seen by one (specified) member or both members of each tandem team using the Petersen mark-recapture model. As in the other surveys, the corrections for availability bias were calculated as follows:

Dugongs:
By standardising the proportion of dugongs sighted during the survey against the proportion on the surface in a clear water area where all dugongs were potentially available (Marsh and Sinclair, 1989a);

Turtles:
By standardising the proportion of turtles sighted during the survey against data from the November 1985 survey of blocks 8 to 13 (Marsh and Saalfeld, 1989a). The proportion of turtles sighted at the surface on this survey was the lowest of any survey we have undertaken, and has been used to standardise the minimum population estimates of turtles on other surveys of the Great Barrier Reef Marine Park and Torres Strait.

Dolphins:
It was not possible to correct for availability bias for dolphins because of the lack of suitable data to use as a standard.

Analysis

Because transects were variable in area, the Ratio Method (Jolly 1969; Caughley and Grigg 1981) was used to estimate separately the density, population size and their associated standard errors for dugongs, dolphins and turtles for each block for each survey. Any statistical bias resulting from this method is considered inconsequential in view of the relatively high sampling intensity (Table 2; see Caughley and Grigg 1981). Input data were the estimated number of dugongs, turtles or dolphins for each tandem team per transect calculated using the correction factors described above. The resultant standard errors were adjusted to incorporate the errors associated with the appropriate estimates of the perception and availability correction factors and the mean group size following the method of Jolly and Watson (1979) as outlined in Marsh and Sinclair (1989a).

The significance of the differences between the surveys conducted in 1985 and 1990 in the densities of (a) dugongs, (b) turtles and (c) cetaceans were tested using analysis of variance both with and without the modal Beaufort sea state for each transect as the covariate. Blocks and times were treated as fixed factors and transect as a random factor nested within block. Input data for all analyses were corrected densities per square kilometre based on mean group sizes and the estimates of the correction factors for perception and availability bias, each line contributing one density per survey based on the combined corrected counts of both tandem teams. The densities were transformed ($\log_{10} x + 1$) for analysis to equalise the error variances.

Density diagrams, adjusted for sampling intensity, were produced using the Arcinfo GIS package. A 2.5 x 2.5 nm grid coverage was combined with the coastline coverage and then the corrected number of dugongs, turtles and cetaceans, as well transect length, calculated for each grid cell. Density within each grid cell was then calculated as:

Density per km^2 = Corrected no. dugongs sighted in cell / Area surveyed in cell

where

Area surveyed = Transect length in km * Transect width i.e. 0.4 km

DUGONGS

Results and Discussion

Group sizes

A total of 503 dugongs were sighted during the 1990 survey. Group sizes (Figure 2) were within the range of values observed in 1984 and 1985 (Marsh and Saalfeld, 1989a). The largest group (subjectively distinct clumping) seen on the transects in 1990 was five. In addition, a herd of 23 or 24 dugongs was seen outside the transects in water 22 m deep and about 22 km east of Port Stewart (14° 04'S; 143° 41'E) in Princess Charlotte Bay on the 12 December 1990. Seven groups of greater than five dugongs (including one of 20) were sighted in 1984-1985. Fifty-nine percent of the groups sighted in 1990 contained only one dugong compared with 68% in 1984-85. These results are typical of the group sizes observed in aerial surveys of dugongs in tropical waters (Preen, 1992) even in areas of comparatively high density.

The configuration and behaviour of the herd of 23 or 24 dugongs observed in 1990 closely resembled the mating herds described from subtropical Moreton Bay (153° 18'E; 27° 30' S) by Preen (1989). A tight group of five or six animals was surrounded by a loose aggregation of 18 other dugongs. The animals in the central group were creating a great deal of splash as four or five of them attempted to cling to and mount the focal animal, presumably a female in oestrus. This animal was in a horizontal position with its dorsal surface uppermost and just below the surface. The two animals closest to the mating group were also very active and we photographed one ramming the other with its head. The other animals were swimming actively and showed no evidence of feeding behaviour. Such a herd has not previously been recorded during an aerial survey in tropical Australia.

As in the previous surveys of the northern Great Barrier Reef region, most calves and their mothers were not accompanied by any other dugongs (Figure 2 and Marsh and Saalfeld, 1989a Figure 2). The proportion of calves seen in 1990 (12.8%) was within the range observed in the 1984-85 surveys (10.4 to 16.3%; Marsh and Saalfeld, 1989a). Calving is diffusely seasonal in northern Australia and the calves stay with their mothers for at least 18 months (Marsh *et al.*,1984). The proportion of calves seen during aerial surveys is very variable ranging from 3% to 24% (Table 6). The reasons for these large temporal and spatial fluctuations in the proportion of calves are poorly understood.

Distribution

As in the 1984 and 1985 surveys (Marsh and Saalfeld, 1989a), dugong density was highest in Block 2 and Block 6 (Table 7). The density distribution map (Figure 3) indicates high local densities of dugongs in inshore waters sheltered from the south-east trade winds and on offshore reefs particularly in Princess Charlotte Bay. Dugong sightings are mapped in the Appendix (Figures 1 through 6).

Population and density estimates

The values of the mean group sizes and correction factors used in obtaining the population estimates are summarised in Table 3. The raw data have been listed in the Appendix (Tables 4, 5 and 6). Table 7 in the main report gives estimates of the density and numbers of dugongs per block for the 1985 and 1990 surveys together with the standard errors of these estimates. The population estimates for November-December 1990 sum to 10471 $\pm$ s.e. 1578 dugongs for the whole region at an overall density of 0.33 $\pm$ 0.05 dugongs per km^2 compared with the estimate for the same region in November 1985 of 8110$\pm$ s.e. 1073 dugongs at an overall density of 0.26$\pm$ s.e. 0.03 dugongs per km^2; Table 7). In general, the density estimates for each block in 1990 were very similar to those in 1985 (Table 7 and Figure 4). There was no significant difference in the results for the two surveys. The probability of there being no significant difference between the two surveys was increased from 0.1 (no covariate) to 0.8 when Beaufort Sea State was used as a covariate in the analyses (Table 8) to compensate for the differences in weather conditions which were slightly better in 1990 than in 1985 (Table 1). The time by block interaction was not significant (Table 8 and Figure 4). The increase in density in Block 6 from 1.76$\pm$ s.e. 0.94 per km^2 in 1985 to 3.71$\pm$ s.e. 2.30 per km^2 in 1990 (Table 7) was due to more dugongs being sighted in the region of Friendly Point (13° 23'S; 143° 34'E) (compare Appendix Figure 1 with Marsh 1989, Volume 4, Section 1 Figure 4).

Status of the dugong in the northern Great Barrier Reef Region

Comparison of the results of the surveys in 1984 and 1985, suggests that dugong numbers are being maintained in the northern Great Barrier Reef Region, one of the most important dugong areas in northern Australia (Table 6). However, as Figure 5 clearly illustrates, the survey technique is designed to monitor the status of the dugong over the whole region and is not capable of detecting trends in abundance at a local spatial scale e.g. the area hunted by the people of Lockhart River (Block 8). This problem is common to most endangered species with local populations of a few hundred animals (Taylor and Gerrodette, in press).

Taylor and Gerrodette (in press) suggest that in such cases it may be more useful to use a demographic approach. This technique can be applied to the region hunted by the people of Lockhart River as follows. The population estimate for Block 8 in 1990 is about 800 dugongs, or 400 females assuming that 50% of the population is female (which is likely, Marsh *et al.*,1984). According to the records of then local QDEH ranger, Mark Geyle, at least 27 female dugongs were caught by the Lockhart River community between September 1989 and December 1990. This equates to 20 females per year or 5% of the female population. The population model of Marsh (1986) suggests that a dugong population reproducing maximally is likely to increase at no more than about 5% per year. Thus these estimates suggest that the take in 19989-90 was worryingly close to the sustainable yield.

Mark Geyle believes that his records of the dugong take of the Lockhart community were an underestimate and that a significant proportion of the take was by residents of Weipa who came over to Lockhart River to catch dugongs in return for bringing alcohol in to the community. We consider that the population estimate for Block 8 is a also minimum rather than an absolute estimate because of the uncertainty regarding the assumptions underlying the availability correction factor (Marsh and Sinclair 1989a). However, the closeness of the estimates of dugong harvest and sustainable yield reinforces the need to:
(1) obtain accurate data on the traditional and incidental take of dugongs from the Great Barrier Reef region;
(2) mount culturally appropriate public education campaigns to warn Aboriginal communities and fishers about the potential for over-harvesting dugongs; and
(3) improve the method of estimating the availability correction factor.
We believe that, unless initiatives (1) and (2) are developed in parallel for fishers and Aboriginal communities, it will be impossible to convince Aborigines to limit their take.

The precision of the population estimate obtained from this survey (15%) was marginally worse than that obtained in 1986 (13%). Gerrodette (1987) outlines procedures for estimating the minimum number of samples required to detect a trend in numbers using linear regression.

His technique has been used to investigate how long it would take to detect with acceptable levels of confidence that a dugong population which was decreasing at say 5% per year was in fact declining i.e. that the slope of the regression line was significantly less than 0.

The following assumptions were made:
(1) that the population estimate would have a precision of 15% (as for this survey);
(2) that the coefficient of variation is inversely related to the square root of abundance as predicted for strip transects by Seber (1982).

The probability of both a Type I error α and a Type II ß error was set at 0.05.

It is estimated that if surveys were held every year, it would take 10 years i.e. 11 surveys to be able to detect a 5% decline with 95% confidence. After 10 years a dugong population declining at 5% per year would have been reduced to 60% of its size at the time of the first survey. A preliminary indication of such trends could be obtained more quickly by allowing α and/or ß to assume larger values. Of course, a decline more rapid than these would be detected more quickly with the same frequency of surveys.

As Gerrodette (1987) points out, annual surveys are probably not the optimum frequency of sampling for a population that is changing relatively slowly. As the interval between surveys increases, the effective rate of change per interval increases, and the required number of surveys therefore decreases (see Gerrodette, Table 2).

Any sampling strategy will be a compromise between information and cost. The Great Barrier Reef Marine Park Authority is required to revise zoning plans every five years, and we recommend that dugong surveys be repeated in the Park at five-yearly intervals.

TURTLES

Results and Discussion

Sea turtles (especially large animals) can often be seen clearly from the air during low-level surveys particularly in calm seas and in clear water. However, with the exception of the leatherback, turtles are difficult for the non-specialist observer to identify to species from the air.

Six species of sea turtles occur within the northern Great Barrier Reef region: loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), flatback (*Natator* (*Chelonia*) *depressus*), olive ridley (*Lepidochelys olivacae*), and leatherback (*Dermochelys coriacea*) (Cogger, 1984). The leatherback and the olive ridley occur only rarely, but the region contains significant feeding grounds for the other four species. Greens and hawksbills are the most common turtles found on the coral reefs of the northern Great Barrier

Reef (Limpus, 1978); green turtles are also found on the inshore seagrass beds in this region. Most of the turtles sighted during this survey were probably large green turtles.

Distribution

As in 1984-5, the highest densities of turtles were associated with mid-and some outer shelf reef complexes and large expanses of sub-tidal seagrass beds (Figure 6, Appendix Figures 7 through 12). A high concentration of internesting turtles was sighted in the Raine Island area on December 4. They were not included in the population estimate as they were too numerous to count.

Minimum population and density estimates

The values of the mean group sizes and correction factors used in obtaining the population estimates are summarised in Table 4. The raw data have been listed in the Appendix Tables 7 through 9. Table 9 gives estimates of the density and numbers of turtles per block for the 1985 and 1990 surveys together with the standard errors of these estimates. The population estimates for November-December 1990 sum to 45644 $\pm$ S.E. 3501 turtles for the whole region at an overall density of 1.46 $\pm$ S.E. 0.11 turtles per km^2. The corresponding estimates obtained in November 1985 were 32187 $\pm$ S.E. 2532 turtles at an overall density of 1.03 $\pm$ S.E. 0.08 turtles per km^2 (Table 9). Compared with other areas surveyed using the same technique, the density of sea turtles in the northern Great Barrier Reef region is high, but not as high as Torres Strait (Table 10).

Aerial censuses of turtles present a number of major difficulties in addition to the problem of species identification and these results are certainly underestimates. While even neonatal dugongs are large enough to be seen from our survey height (see Marsh and Sinclair, 1989b), an unknown and variable proportion of turtles is too small to be seen from the air. For example, Parmenter (in Limpus and Parmenter, 1986) found that coral reef habitats in eastern Torres Strait support green turtles as small as 40cm curved carapace length (C.C.L.). Most (79.6%) were immature i.e. < 91cm C.C.L. In addition, Marsh and Sinclair (1989b) showed that in contrast to dugongs, the observed density of turtles depends on sea state even over a relatively small range of conditions; fewer turtles are seen in rougher seas.

Comparison of results of surveys conducted in 1985 and 1990

The agreement between the results of the 1985 and 1990 surveys was not nearly as good for turtles as it was for dugongs. Irrespective of the inclusion of Beaufort Sea State for each transect as a covariate in the analyses, there was a significant interaction between Block and Time (Table 11). Figure 7 suggests that the greatest regional difference between surveys was for Block 3 (Figure 1), the inshore region south of Cape Melville. Indeed the densities of turtles were higher for most Blocks in 1990 than in 1985; the results for Blocks 1, 5 and 6 were very similar in both years. Overall, there was no significant difference in density in 1990 and 1985 when Beaufort Sea State was used as a covariate.

The discrepancies between the 1985 and 1990 survey results can be explained by : (1) the sensitivity of turtle sightings to small changes in sighting conditions which cannot be completely removed in the analyses; and (2) the tendency of turtles to migrate to breed coincident with the timing of the surveys. Aerial surveys such as these are not suitable for detecting other than gross trends in turtle numbers over long timespans. Their chief value is the resultant large scale density distribution maps which can be used as an aid in the development of management plans.

DOLPHINS

Results and Discussion

All the cetaceans sighted were dolphins. We were generally unable to confirm specific identifications: most of the animals appeared to be bottlenose dolphins, *Tursiops truncatus,* or Indo-Pacific humpback dolphins, *Sousa chinensis*.

The values of the mean group sizes and correction factors used in obtaining the population estimates are summarised in Table 5. Six groups of more than 16 dolphins (Figure 8) were observed including one group of 40. The raw data have been listed in Appendix Tables 10 through 12. The population estimates for November-December 1990 sum to 4875 $\pm$ S.E. 500 dolphins for the whole region at an overall density of 0.16 $\pm$ S.E. 0.02. The corresponding values for November 1985 were 6609 $\pm$ S.E. 667 dolphins at an overall density of 0.21 $\pm$ S.E. 0.08 (Table 12).

Overall, the density of dolphins observed in the northern Great Barrier Reef region was comparable to that observed in other parts of northern Australia using the same technique (Table 13). In both 1985 and 1990, the highest density observed was in Block 13 especially over the midshelf reefs in the cross-shelf Marine National Park B Zone between about 11° 30′ and 13° S (Table 12 and Figures 9 and 10). This block has the highest dolphin density of those parts of the Great Barrier Reef region that have been surveyed from the air (Marsh 1990 and this study). The dolphins in this area generally occurred in relatively small groups and those identified were mainly *T. truncatus* (Marsh 1990 and this study Appendix Figure 13). Williams (1983) observed that the fish on these reefs were more similar to the inshore communities elsewhere in the Great Barrier Reef region, a result consistent with the lack of sightings of oceanic dolphins in this region.

Irrespective of whether or not Beaufort Sea State was used as a covariate in the analyses, there was a significant interaction ($p<0.001$) between Block and Time (Table 14 and Figure 10). The largest discrepancy between the two surveys was in Blocks 9, 12 and 13. Blocks 9 and 13 are the offshore regions of the survey area north of Night Island (13° 11'S; 143° 34'E); Block 12 is the inshore area north of Shelburne Bay. The reasons for these temporal differences are unknown except that dolphins are thought to be more vagile than dugongs. Corresponding differences were not observed for dugongs or turtles suggesting that they were not due to sighting conditions *per se* (which were generally better in 1990 than in 1985 anyway). However, there was no significant difference overall between the results for the 1985 and 1990 surveys providing Beaufort Sea State was used as a covariate in the analyses (Table 14).

We do not recommend the funding of dedicated aerial surveys of dolphins in the Great Barrier Reef Marine Park at present as there is no evidence that dolphins present a management problem in this area. These results provide a baseline for future monitoring. We consider it appropriate to continue monitoring dolphins on dugong surveys.

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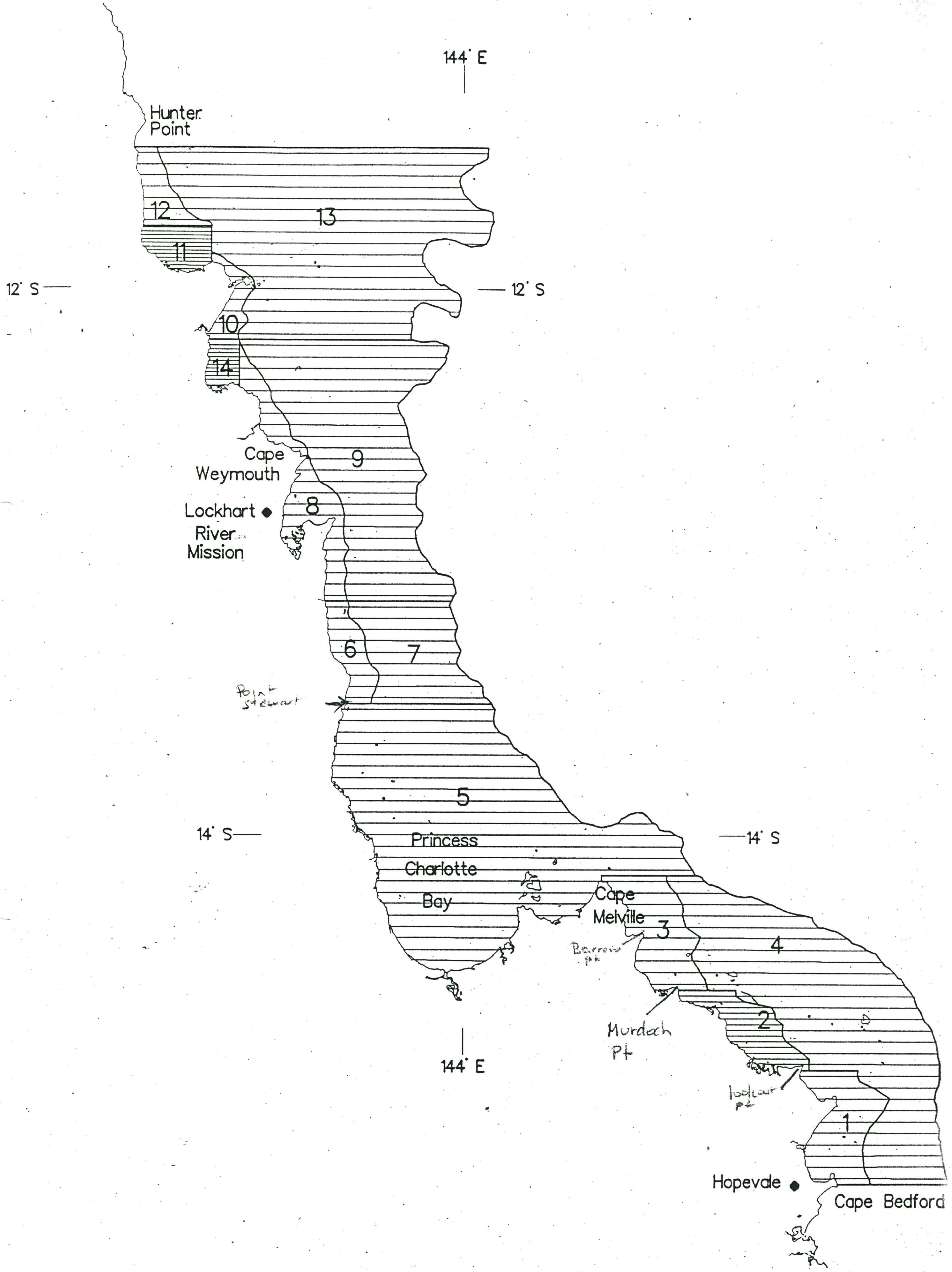

Figure 1. The survey area showing the survey blocks (1-14) and transect lines for the November-December 1990 survey.

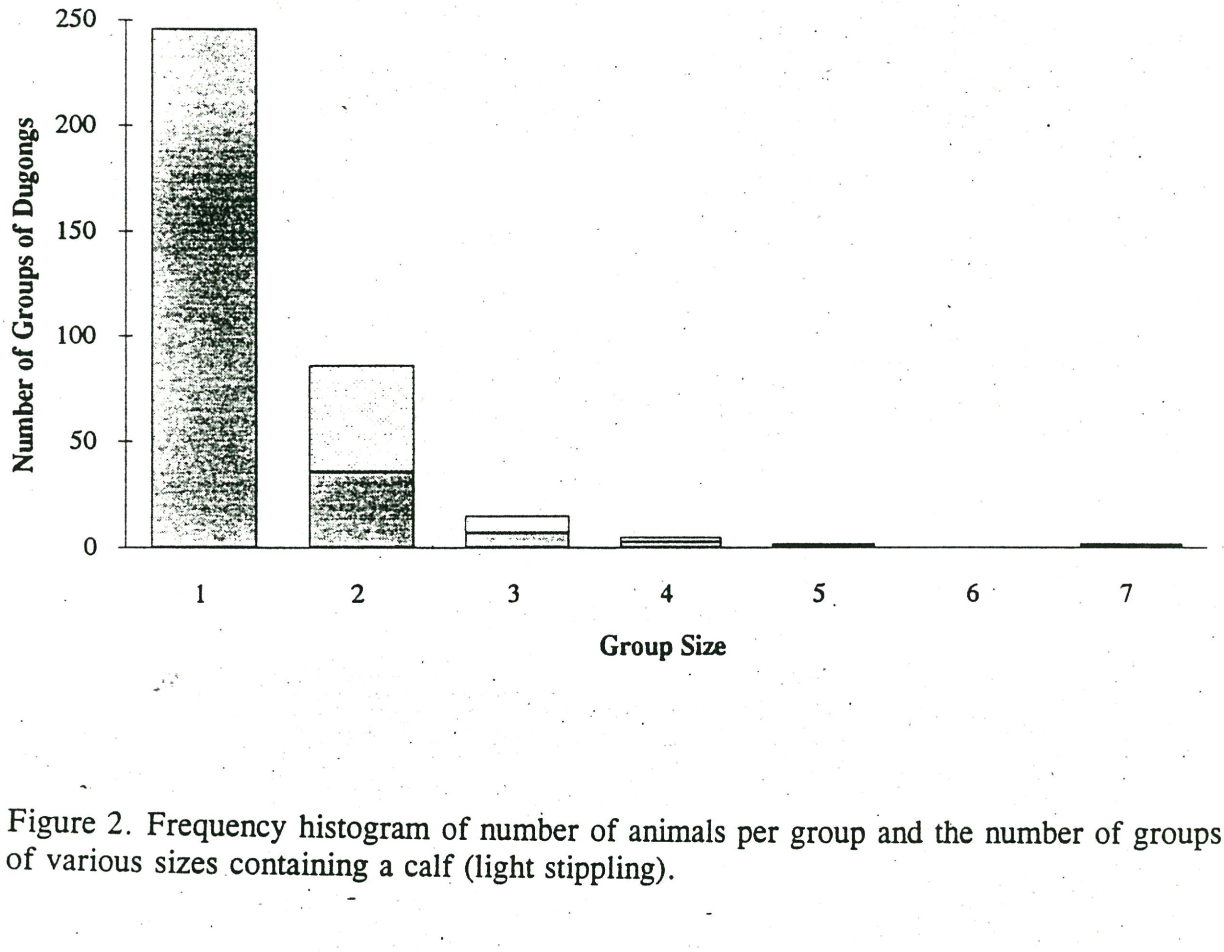

Figure 2. Frequency histogram of number of animals per group and the number of groups of various sizes containing a calf (light stippling).

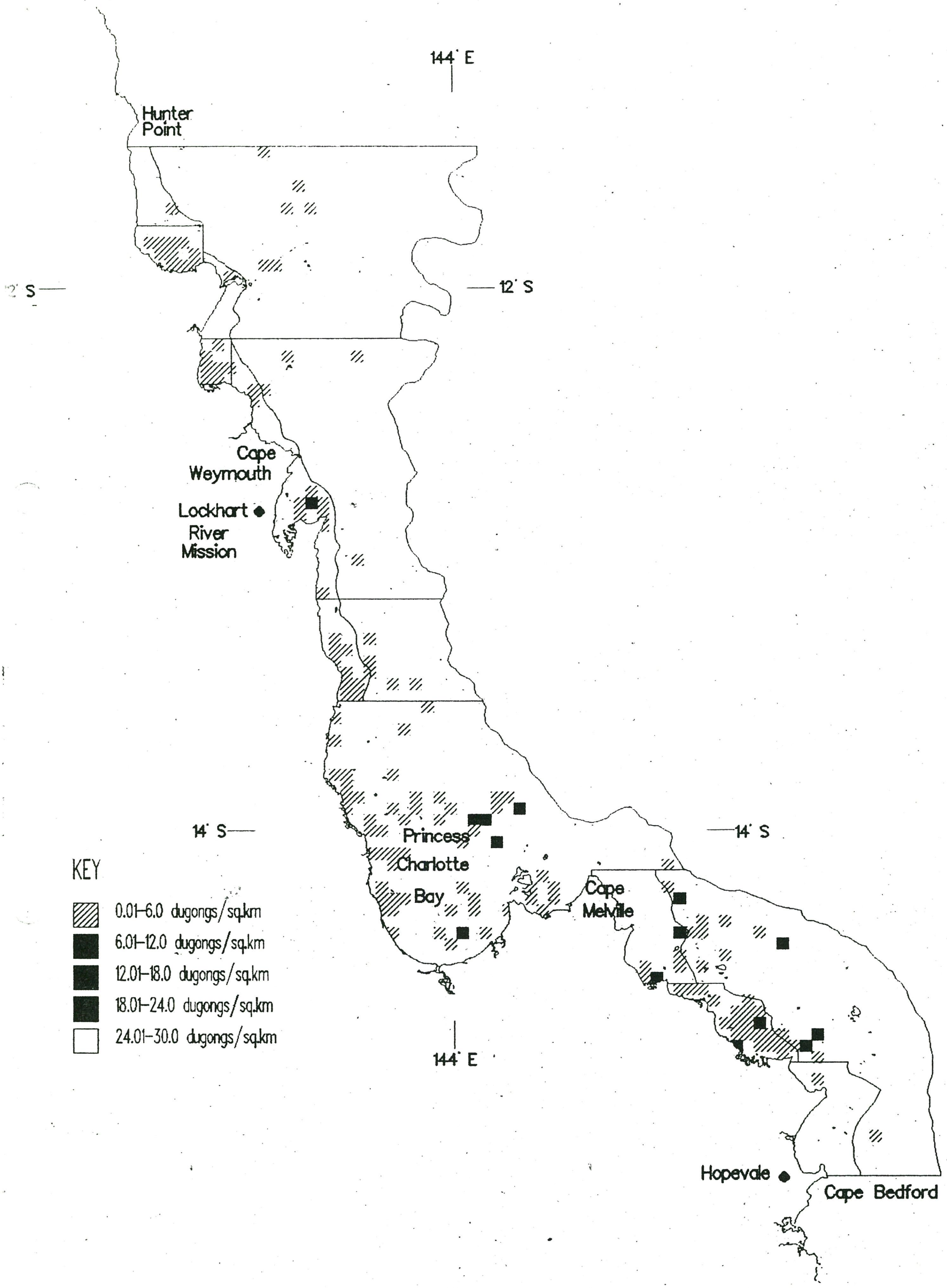

Figure 3. The survey area showing dugong density based on the results of the 1990 survey, adjusted for sampling intensity, calculated on a 2.5 x 2.5 nm square grid.

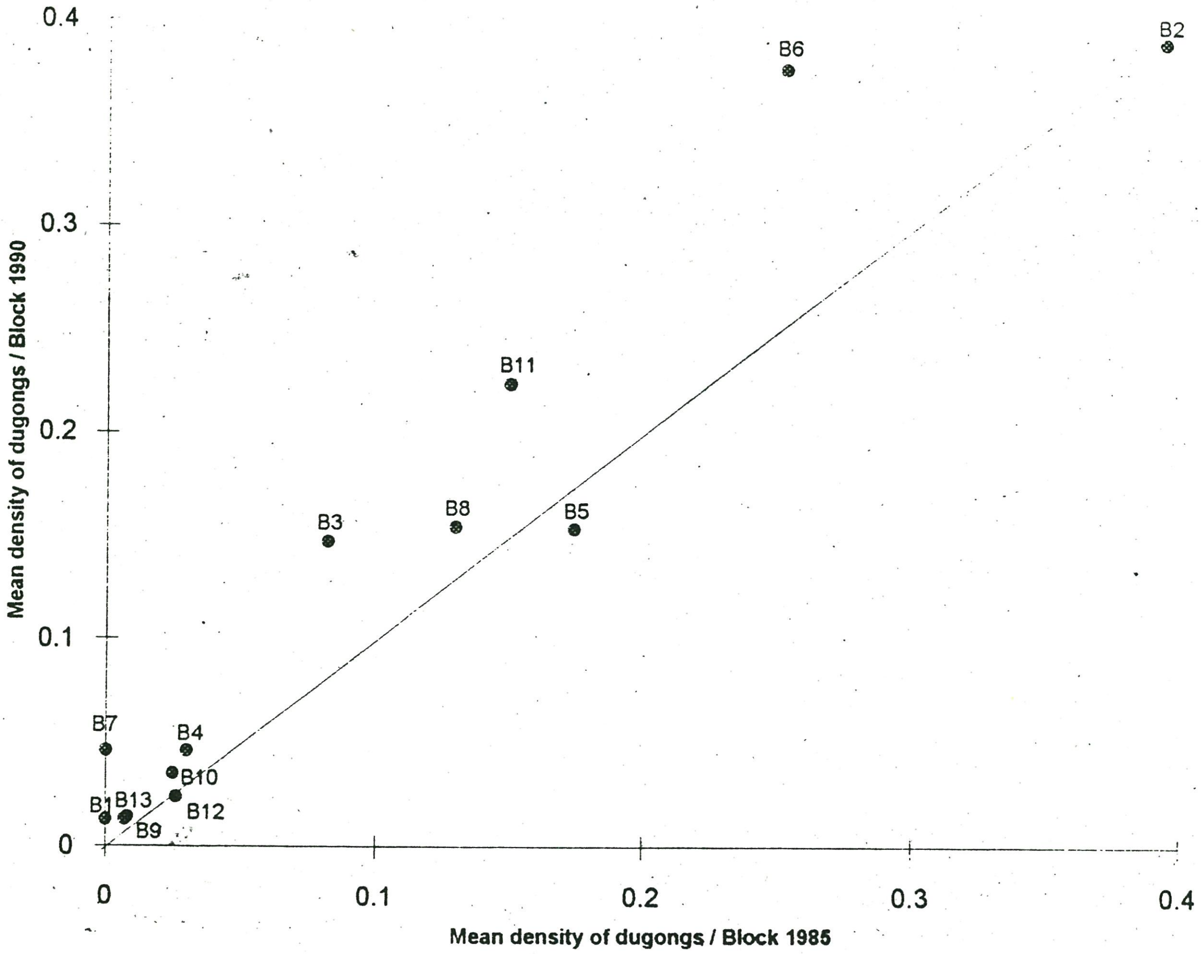

Figure 4. The mean [log (x+1)] density of dugongs in each block in 1985 and 1990. The line represents equal densities on the two surveys.

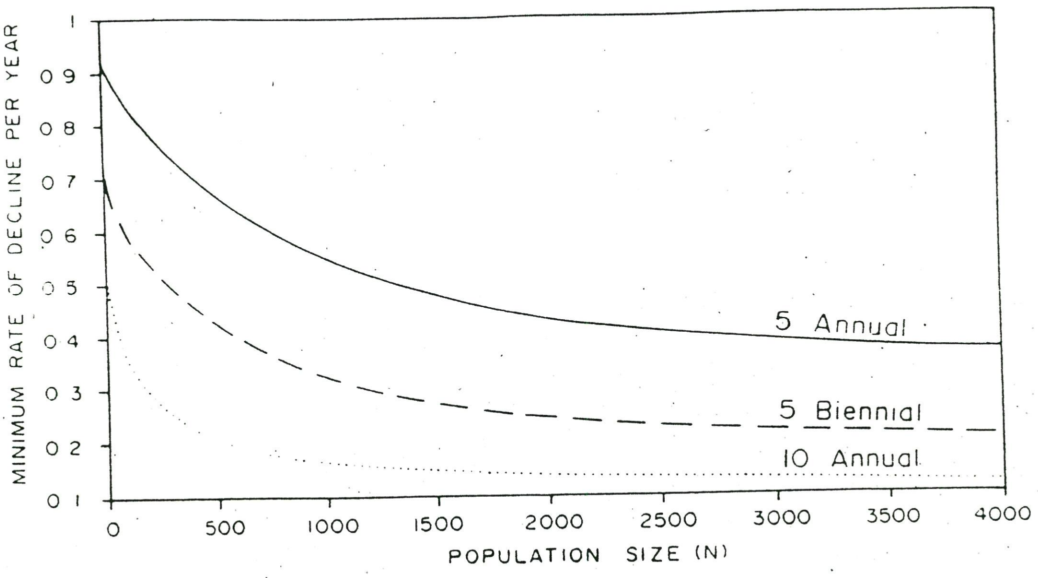

Figure 5: The minimum rate of decline which would be detectable with high power (chances of both Type 1 and Type 11 errors = 0.5) as a function of initial population size for three different numbers and frequencies of surveys (5 annual; 5 biennial and 10 annual). Values have been computed for these survey regimes using the relationship between precision and population size that was empirically derived from dugong aerial survey data collected by Marsh in Australian waters.

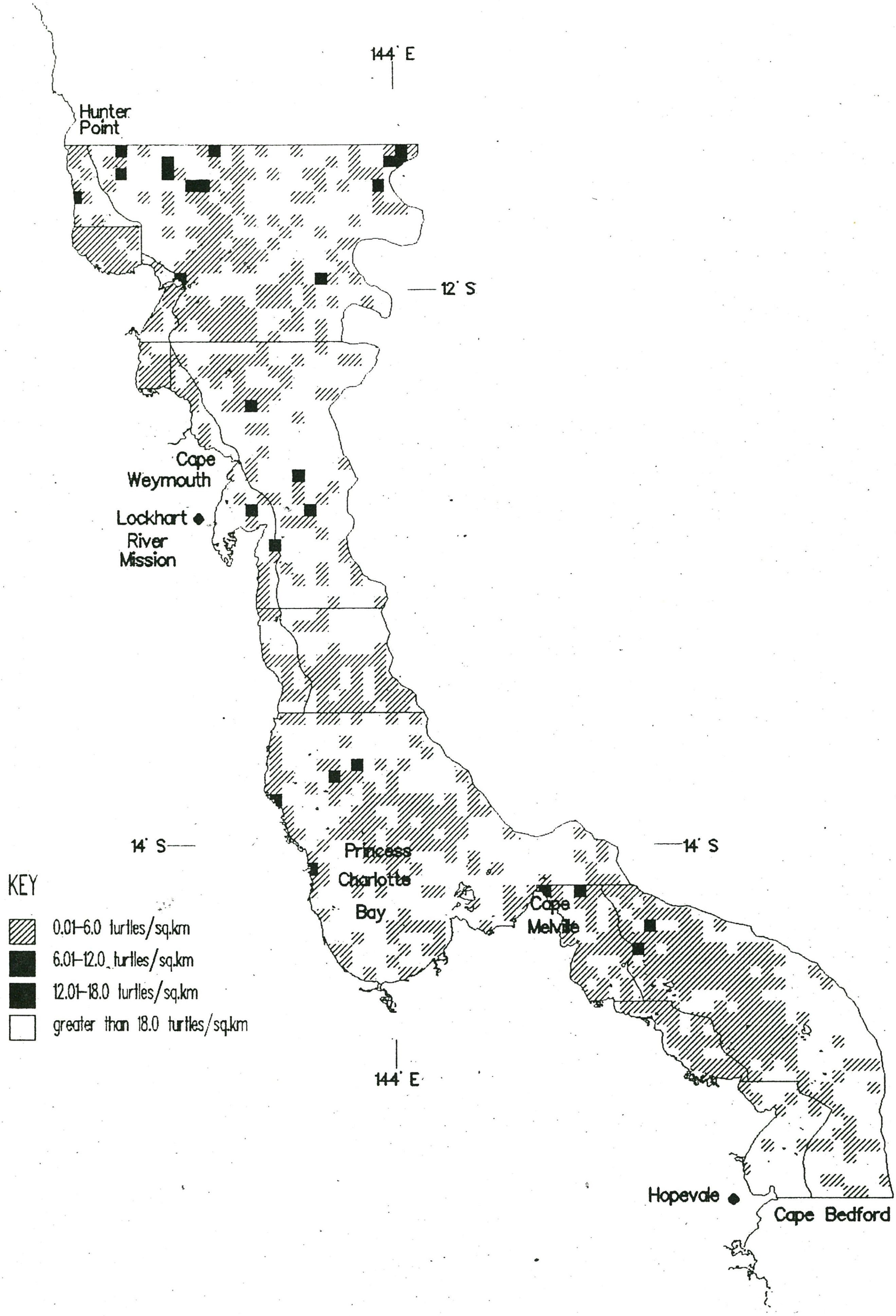

Figure 6. The survey area showing turtle density based on the results of the 1990 survey, adjusted for sampling intensity, calculated on a 2.5 x 2.5 nm square grid.

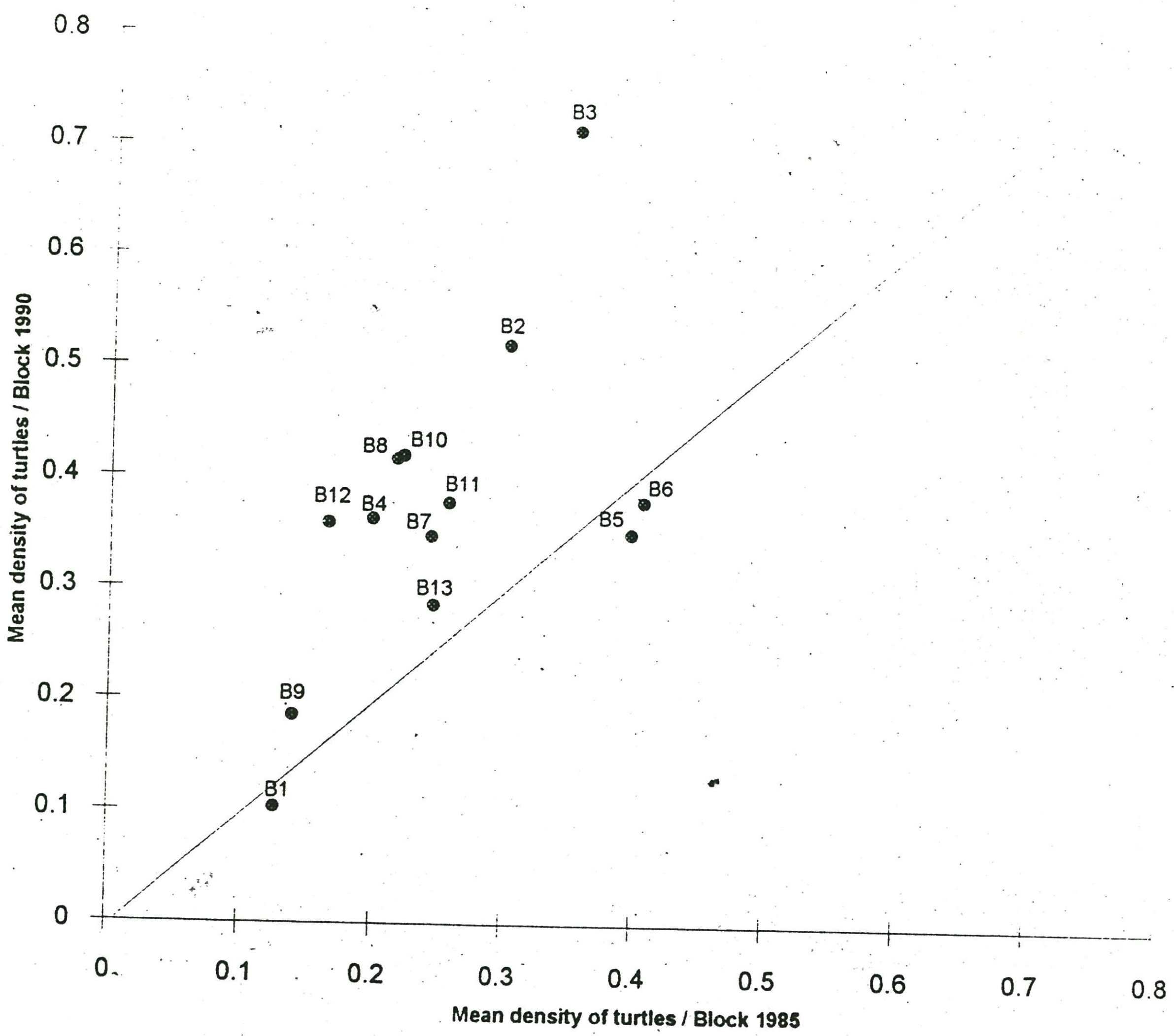

Figure 7. The mean [log (x+1)] density of turtles in each block in 1985 and 1990. The line represents equal densities on the two surveys.

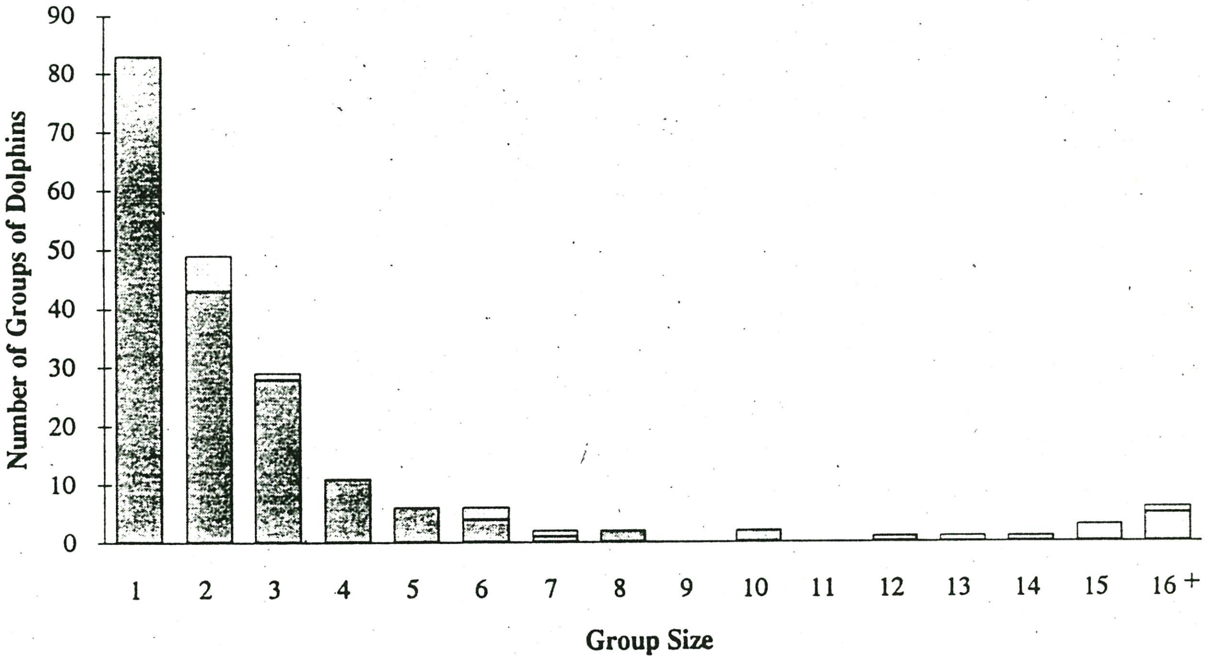

Figure 8. Frequency histogram showing dolphin group sizes and the proportion of groups of various sizes containing calves (light stippling).

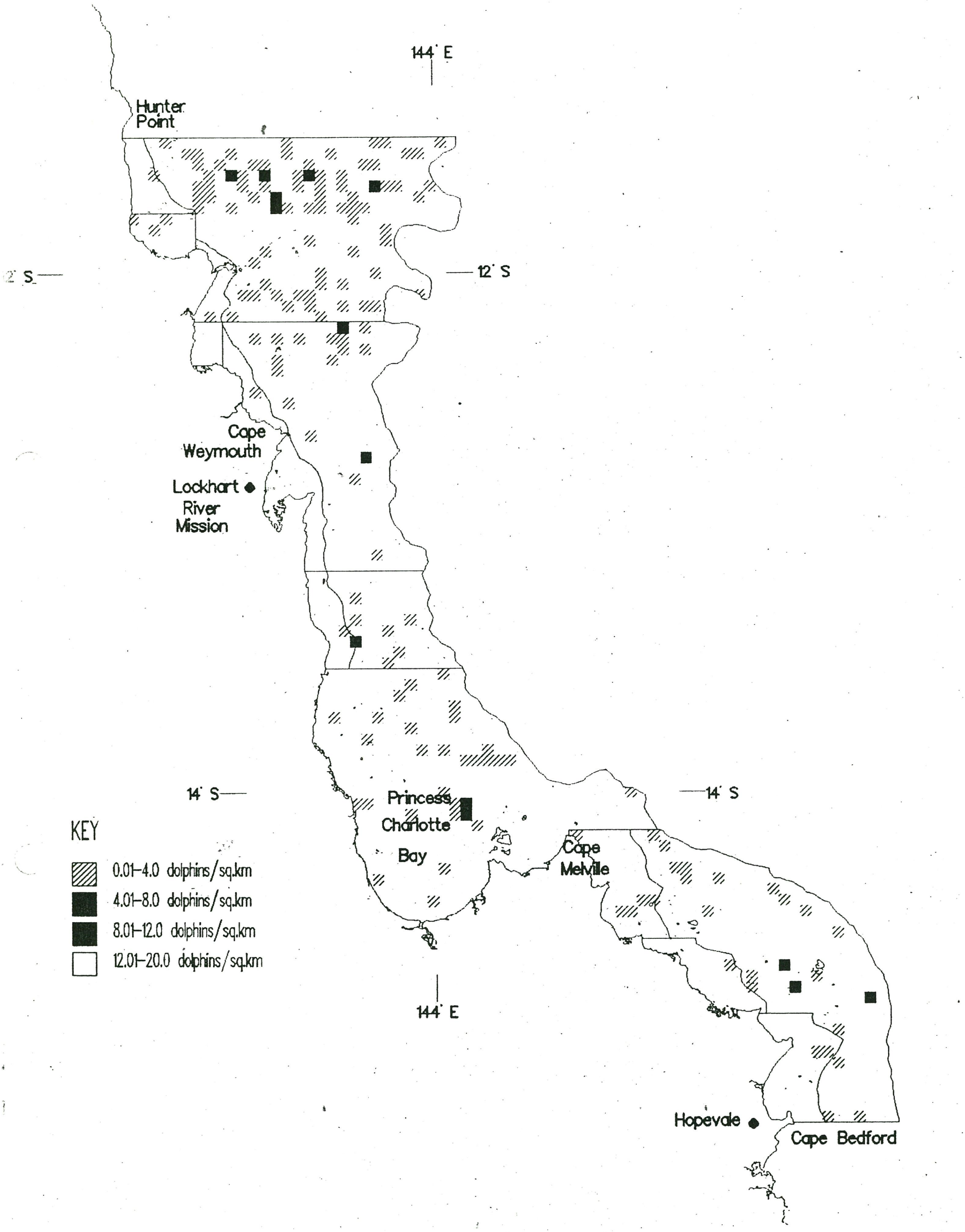

Figure 9. The survey area showing dolphin density based on the results of the 1990 survey, adjusted for sampling intensity, calculated on a 2.5 x 2.5 nm square grid.

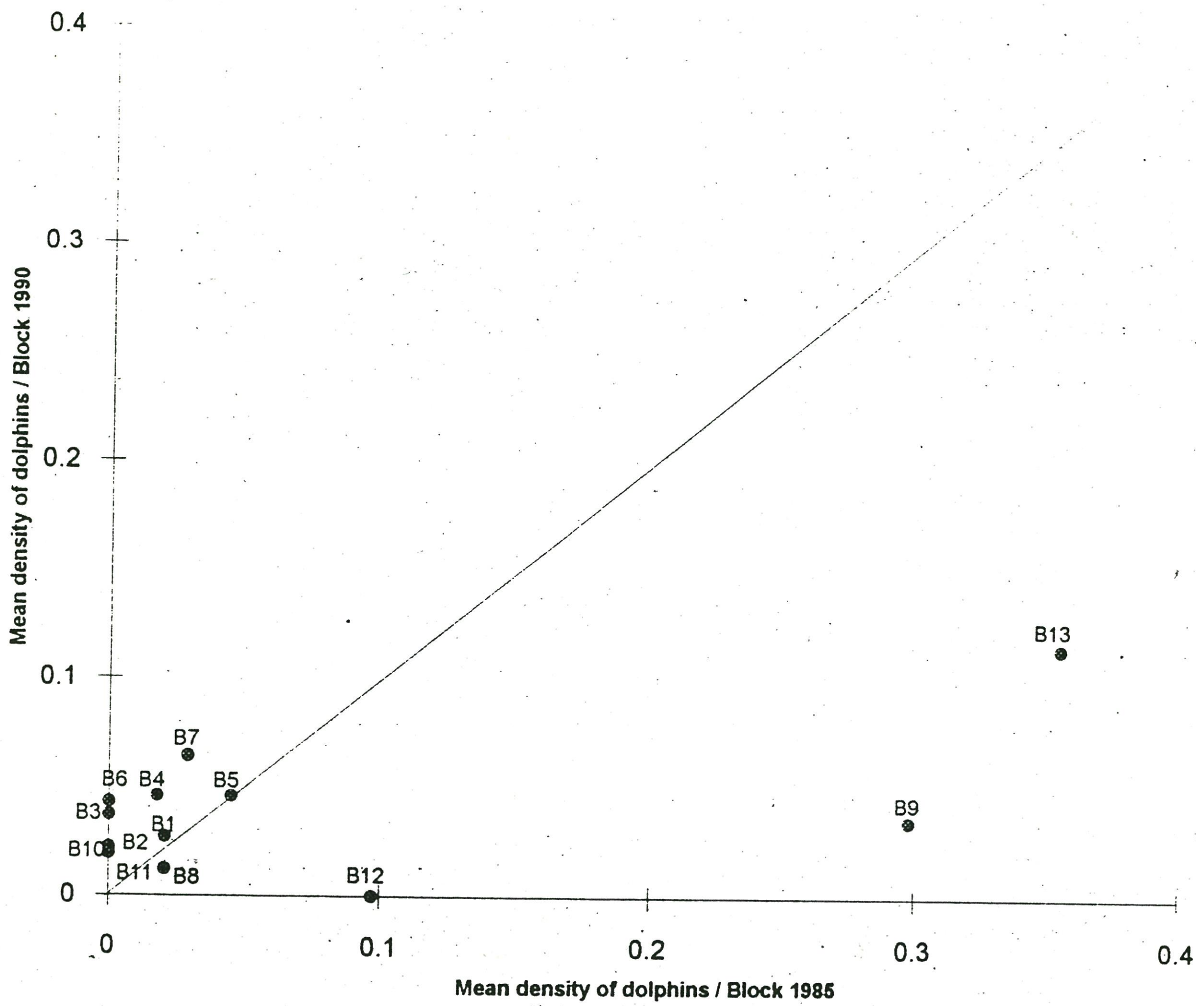

Figure 10. The mean [log (x+1)] density of dolphins in each block in 1985 and 1990. The line represents equal densities on the two surveys.

TABLE 1: Weather conditions encountered during the surveys in November 1985 and November-December 1990. 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 the field of view affected; 2, 25-50 %; 3 > 50 %.

	1985	1990
Wind speed (knots)	< 28	< 15
Cloud cover (oktas)	0-5	0-7
Minimum cloud height (m)	305-1,525	1,500-35,000
Beaufort sea state	1.5(0-4)	1.5(0-2.5)
Glare *	1(0-2.5)	2.2(1-3)
Visibility (km)	8- >50	N/A

* worse side of the aircraft

TABLE 2: Areas of survey blocks and sampling intensities for the 1990 survey.

Block	Area (km^2)	Sampling %
1	1004	8.7
2	665	16.9
3	1050	8.3
4	5233	9.3
5	7839	8.2
6	451	8.8
7	1561	8.6
8	1194	8.4
9	4600	8.6
10	259	9.8
11	396	26.5
12	452	8.4
13	6584	9.4
14*	243	24.9
TOTAL	31288	9.1

* Block 14 (Temple Bay) is part of Block 8 (sensu Marsh and Saalfeld, 1989a). Additional transects were flown in this area in 1990 due to the relevance of the area to the siting of the proposed Cape York Space Port. These additional transects were not used in the population estimate for the entire region (Table 7) or for comparisons with the 1985 survey. The area of Block 14 is not included in the total area.

TABLE 3: Details of group size estimates and correction factors used in the dugong population estimates

Blocks; lines	Group size mean (C.V.)	Number of observers		Perceptual Correction Factor estimate (C.V.)		Availability Correction Factor estimate (C.V.)
		Port	Starboard	Port	Starboard	
blocks 1-4: all lines	1.42 (0.04)	2	2	1.07 (0.01)	1.07 (0.01)	2.05 (0.12)
block 5: 1-19; 21-23	1.42 (0.04)	2	2	1.07 (0.01)	1.07 (0.01)	2.05 (0.12)
block 5: 20; 6: 33	1.42 (0.04)	1[a]	1[b]	1.30 (0.01)	1.24 (0.01)	2.05 (0.12)
blocks 6-14: 1-6; 17-20; 31-32; 34-35; 42-49	1.42 (0.04)	2	2	1.07 (0.01)	1.07 (0.01)	2.05 (0.12)
blocks 6-14: 36-37; 42-43	1.42 (0.04)	1[a]	2	1.30 (0.01)	1.07 (0.01)	2.05 (0.12)
blocks 6-14: 7-16; 21-28	1.42 (0.04)	1[a]	1[b]	1.75 (0.12)	1.60 (0.08)	2.05 (0.12)
blocks 6-14: 29-30; 38-41; 50-63	1.42 (0.04)	2	2	1.16 (0.06)	1.23 (0.10)	2.05 (0.12)

[a] Port correction factor based on port mid-seat observer.
[b] Starboard correction factor based on starboard mid-seat observer.

TABLE 4: Details of group size estimates and correction factors used in the turtle population estimates

Blocks: lines	Group size mean (C.V.)	Number of observers		Perceptual Correction Factor estimate (C.V.)		Availability Correction Factor estimate (C.V.)
		Port	Starboard	Port	Starboard	
blocks 1-4: all lines	1.18 (0.02)	2	2	1.10 (0.01)	1.11 (0.01)	1.61 (0.07)
block 5: 1-19; 21-23	1.18 (0.02)	2	2	1.10 (0.01)	1.11 (0.01)	1.61 (0.07)
block 5: 20; 6: 33	1.18 (0.02)	1[a]	1[b]	1.29 (0.01)	1.36 (0.01)	1.61 (0.07)
blocks 6-14: 1-6; 17-20; 31-32; 34-35; 42-49	1.18 (0.02)	2	2	1.10 (0.01)	1.11 (0.01)	1.61 (0.07)
blocks 6-14: 36-37; 42-43	1.18 (0.02)	1[a]	2	1.29 (0.01)	1.11 (0.01)	1.61 (0.07)
blocks 6-14: 7-16; 21-28	1.18 (0.02)	1[a]	1[b]	1.88 (0.05)	1.66 (0.06)	1.61 (0.07)
blocks 6-14: 29 & 30; 38-41; 50-63	1.18 (0.02)	2	2	1.43 (0.07)	1.25 (0.04)	1.61 (0.07)

[a] Port correction factor based on port mid-seat observer.
[b] Starboard correction factor based on starboard mid-seat observer.

TABLE 5: Details of group size estimates and correction factors used in the dolphin population estimates

Blocks: lines	Group size mean (C.V)	Number of observers		Perceptual Correction Factor estimate (C.V.)	
		Port	Starboard	Port	Starboard
blocks 1-4: all lines	2.07 (0.11)	2	2	1.02 (0.02)	1.16 (0.04)
block 5: 1-19; 21-23	2.07 (0.11)	2	2	1.02 (0.02)	1.16 (0.04)
block 5: 20; 6-14: 33	2.07 (0.11)	1[a]	1[b]	1.12 (0.01)	1.62 (0.02)
blocks 6-14: 1-6; 17-20; 31-32; 34-35; 42-49	2.07 (0.11)	2	2	1.02 (0.02)	1.16 (0.04)
blocks 6-14: 36-37; 42-43	2.07 (0.11)	1[a]	2	1.12 (0.01)	1.16 (0.02)
blocks 6-14: 7-16; 21-28	2.07 (0.11)	1[a]	1[b]	1.33 (0.14)	1.50 (0.09)
blocks 6-14: 29 & 30; 38-41; 50-63	2.07 (0.11)	2	2	1.05 (0.04)	1.11 (0.09)

[a] Port correction factor based on port mid-seat observer.
[b] Starboard correction factor based on starboard mid-seat observer.

TABLE 6: Numbers and densities of dugongs in the northern Great Barrier Reef region relative to other areas surveyed using the same technique.

Location	Date	Area (km²)	Population Estimate ± S.E.	Density km -¹ ± S.E.	% Calves	Reference
Shark Bay, WA	Jul-1989	14240	10146±1478	0.71±0.10	19	Marsh et al., 1991
Exmouth Gulf - Ningaloo, WA	Jul-1989	3387	1964±363	0.58±0.11	24	Marsh et al., unpub
Northern Coast Northern Territory	Dec-1983	28746	13800±2683	0.48±0.09	3	Bayliss 1986, Bayliss & Freeland 1989
Western Gulf of Carpentaria	Feb-1985	27216	16846±3259	0.62±0.12	12.5	Bayliss & Freeland
Mornington Island area	Dec-1991	8848	4067±723	0.46±0.08	6.5	Marsh & Lawler 1992b
Torres Strait	Nov-1987	30533	12522±1487	0.41±0.05	13.6	Marsh & Saalfeld 1991
	Nov-Dec 1991	30533	24225±3276	0.79±0.11	11.8	Marsh & Lawler 1992a
Northern Great Barrier Reef	Nov-1985	31288	8110±1073	0.26±0.03	10.4-16.3	Marsh & Saalfeld 1989a
	Nov-Dec 1990	31288	10471±1578	0.33 ±0.05	12.8	this study
Southern Great Barrier Reef	Nov 1986 Sept-Oct 1987	39396	3479±459	0.09±0.01	7.7-14.8	Marsh & Saalfeld 1990a
South-east Queensland	Jul-Aug 1988	9170	2479±365	0.26±0.04	20.4	Marsh Saalfeld & Preen 1990

TABLE 7: Comparison of the estimated densities and numbers of dugongs for the surveys conducted in 1985 and 1990. The values are ± standard error incorporating the errors resulting from sampling.

	Block	Density per km²		Numbers	
		1985	1990	1985	1990
Cape Bed	1	0	0.03±0.03	0	36±35
STARKE	2	2.47±0.87	2.35±0.73	1644±570	1564±488
Cape Melville → Murdoch Pt	3	0.26±0.10	0.86±0.62	272±110	903±650
Murdoch Pt → Hooker Pt	4	0.12±0.05	0.15±0.04	626±256	768±202
PCB	5	0.46±0.09	0.48±0.10	3630±714	3782±767
Point Stewart → (N)	6	1.76±0.94	3.71±2.30	792±423	1673±1037
	7	0	0.12±0.05	0	182±79
	8	0.51±0.16	0.69±0.26	611±192	829±305
	9	0.03±0.02	0.04±0.02	134±104	187±97
	10	0.09±0.09	0.13±0.13	24±23	35±34
	11	0.56±0.20	0.68±0.17	222±81	268±66
	12	0.06±0.06	0.08±0.07	27±26	37±32
	13	0.02±0.01	0.03±0.01	128±83	207±99
	Total	0.26±0.03	0.33±0.05	8110±1073	10471±1578
	Precision			0.13	0.15

TABLE 8: Summary of analysis of variance comparing observed dugong density in the Northern GBR in 1985 and 1990: (1) without covariates (2) with Beaufort sea state as a covariate. Data were transformed by log(x+1).

Sources of variation	DF 1	DF 2	F 1	F 2	Significance of F 1	Significance of F 2
Blocks**	12	12	18.29	2.57	0.0001	0.0038
Time*	1	1	0.06	2.68	0.1036	0.8013
Transect nested in Block*	178	178	1.5	1.37	0.0197	0.0037
Block by Time*	12	12	0.41	0.85	0.9575	0.6020
Transect nested in Block by Time	178	164***				
Regression*		1		0.19		0.6620

* Tested against Transect nested in Block by Time
** Tested against Transect nested in Block
***Beaufort sea state was not recorded for 13 transects.

TABLE 9: Comparison of the estimated densities and numbers of turtles in the surveys conducted in 1985 and 1990. The values are ± standard error incorporating the errors resulting from sampling.

Block	Density per km²		Numbers	
	1985	1990	1985	1990
1	0.39±0.11	0.31±0.12	390±104	315±117
2	1.21±0.23	2.54±0.30	803±156	1728±202
3	1.66±0.35	4.86±0.84	1742±369	5103±880
4	0.95±0.23	1.97±0.43	4983±1183	10283±2253
5	1.61±0.25	1.51±0.28	12605±1946	11810±2217
6	1.92±0.69	2.19±0.85	865±312	988±385
7	0.96±0.32	1.38±0.29	1495±496	2149±456
8	0.80±0.13	1.56±0.50	955±1959	1861±600
9	0.51±0.09	0.61±0.09	2361±405	2805±415
10	0.90±0.12	1.93±0.56	234±31	500±145
11	1.05±0.26	1.52±0.24	417±103	603±97
12	0.63±0.23	1.54±0.50	286±106	697±228
13	0.77±0.11	0.97±0.10	5151±705	6802±684
Total	1.03±0.08	1.46±0.11	32187±2532	45644±3501
Precision			0.08	0.08

TABLE 10: Densities of turtles in the northern Great Barrier Reef region relative to other areas surveyed using the same technique.

Location	Date	Area (km²)	Density km $^{-1}$ ± S.E.	Reference
Mornington Island area	Dec-1991	8848	0.95±0.15	Marsh & Lawler 1992b
Torres Strait	Nov-1987	30533	1.43±0.16	Marsh & Saalfeld 1991
	Nov-Dec 1991	30533	2.13±0.17	Marsh & Lawler 1992a
Northern Great Barrier Reef	Nov-1985	31288	1.03±0.08	Marsh & Saalfeld 1989a
	Nov-Dec 1990	31288	1.46±0.11	this study
South-east Queensland	Jul-Aug 1988	9170	0.32±0.04	Marsh & Saalfeld 1990b

TABLE 11: Summary of analysis of variance comparing observed turtle density in the Northern GBR in 1985 and 1990: (1) without covariates (2) with Beaufort sea state as a covariate. Data were transformed by log(x+1).

Sources of variation	DF 1	DF 2	F 1	F 2	Significance of F 1	Significance of F 2
Blocks**	12	12	12.32	3.36	0.0001	0.0002
Time*	1	1	48.06	1.1	0.0001	0.2939
Transect nested in Block*	178	178	2.48	2.44	0.0001	0.0001
Block by Time*	12	12	4.00	2.38	0.0001	0.0074
Transect nested in Block by Time	178	164***				
Regression*		1		1.29		0.2572

* Tested against Transect nested in Block by Time

** Tested against Transect nested in Block

***Beaufort sea state was not recorded for 13 transects.

TABLE 12: Comparison of the estimated densities and numbers of dolphins on the surveys conducted in 1985 and 1990. The values are ± standard error incorporating the errors resulting from sampling.

Block	Density per km²		Numbers	
	1985	1990	1985	1990
1	0.05± 0.03	0.08± 0.05	50± 34	76± 53
2	0.02±0.02	0.06± 0.03	13± 11	39± 17
3	0.04± 0.03	0.10± 0.05	37± 36	105± 53
4	0.03± 0.01	0.11± 0.03	135± 73	576± 144
5	0.05± 0.02	0.11± 0.02	379± 127	901± 174
6	0	0.12± 0.08	0	55± 36
7	0.02± 0.02	0.17± 0.06	36± 33	272± 96
8	0.18± 0.09	0.03± 0.03	219± 102	33± 31
9	0.41± 0.09	0.11± 0.03	1896± 396	490± 148
10	0.29± 0.18	0.09± 0.08	74± 47	24± 21
11	0.17± 0.08	0.06± 0.04	69± 31	25±15
12	0.29± 0.19	0	130± 846	0
13	0.54± 0.08	0.35± 0.96	3571± 492	2279± 399
Total	0.21± 0.08	0.16± 0.02	6609± 667	4875± 500
Precision			0.10	0.10

TABLE 13: Densities of dolphins in the northern Great Barrier Reef region relative to other areas surveyed using the same technique.

Location	Date	Area (km^2)	Density km^{-1} ± S.E.	Reference
Shark Bay, WA	Jul-1989	14240	0.19±0.02	Marsh et al., unpub.
Exmouth Gulf - Ningaloo, WA	Jul-1989	3387	0.16±0.04	Marsh et al., unpub
Mornington Island area	Dec-1991	8848	0.09±0.02	Marsh & Lawler 1992b
Torres Strait	Nov-Dec 1991	30533	0.07±0.02	Marsh & Lawler 1992a
Northern Great Barrier Reef	Nov-1985	31288	0.21±0.03	Marsh & Saalfeld 1989a
	Nov-Dec 1990	31288	0.16±0.02	this study
Inshore southern Cairns Section Great Barrier Reef	Oct-1987	11528	0.21±0.03	Marsh 1990
Inshore Central Great Barrier Reef	Sept-Oct 1987	11778	0.21±0.03	Marsh 1990
Inshore southern Great Barrier Reef	Nov-86	16090	0.11±0.00	Marsh 1990

TABLE 14: Summary of analysis of variance comparing observed dolphin density in the Northern GBR in 1985 and 1990: (1) without covariates (2) with 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**	12	12	14.53	3.41	0.0001	0.0002
Time*	1	1	6.51	0.01	0.0116	0.9896
Transect nested in Block*	178	178	0.9	0.8	0.7682	0.9315
Block by Time*	12	12	8.70	4.65	0.0001	0.0001
Transect nested in Block by Time	178	164***				
Regression*		1		0.08		0.7712

* Tested against Transect nested in Block by Time

** Tested against Transect nested in Block

***Beaufort sea state was not recorded for 13 transects.

APPENDIX

Tables of Raw Data and Maps of Sightings

TABLE 1 Weather conditions encountered during the surveys in November 1985 and November-December 1990. 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 the field of view affected; 2, 25-50 %; 3 > 50 %.

Date	Session	Wind Speed (knots)	Wind Direction	Cloud Cover (oktas)	Cloud Height (ft)	Beaufort Sea State Inshore mode(range)	Beaufort Sea State Offshore mode(range)	Glare North mode(range)	Glare South mode(range)	Tide Time
Blocks 1 - 7										
9/12/90	1	5	ESE	2,1	2000,35000	1.0(0.5-1.0)	1.5(0.5-2.0)	1.0(1.0-2.0)	2.0(1.0-3.0)	Low 0911
	2	8	ESE	2,1	2000,35000	2.0(2.0-2.5)	2.0(0.5-2.5)	1.0(1.0-2.0)	3.0(2.0-3.0)	High 1553
10/12/90	1	2	ESE	6	8000	0.0(0.0-0.5)	0.0(0.0-0.5)	1.0	1.0(1.0-2.0)	Low 1043
	2	8	ESE	0	-	2.5(0.5-3.0)	2.5(0.0-2.5)	1.0(1.0-2.0)	3.0(2.0-3.0)	High 1652
5/12/90	1	0	-	7	10000	1.0(0.0-1.0)		1.0	1.0(1.0-2.0)	High 1133
6/12/90	1	3	N	3,7	2000,5000	1.0(0.0-2.5)		1.0(1.0-2.0)	2.0(1.0-3.0)	Low 0533
	2	8	E	1	1500	1.5(1.5-3.0)		1.0-2.0	2.0(2.0-3.0)	High 1233
7/12/90	1	5	E	2,1	1500,30000	1.0(0.0-3.0)		1.0(1.0-2.0)	3.0(2.0-3.0)	Low 0637
Blocks 8 - 14										
4/12/90	1	0	-	1,2	2000,30000	0.0(0.0-1.5)	0.0(0.0-0.5)	1.0	2.0(1.0-3.0)	High 1128
	2	8	E	1	2000	1.0(1.0-3.0)	0.5(0.0-3.0)	2.0(1.0-3.0)	3.0(1.0-3.5)	Low 1619
3/12/90	1	5	E	5	1500	1.0(0.0-2.0)	1.0(0.0-1.0)	1.0(1.0-2.0)	3.0(1.0-3.0)	High 0916
	2	10	ENE	1,3	2000,30000	2.0(1.0-3.0)	1.0(0.0-2.5)	1.0(0.0-2.0)	1.0-3.0	Low 1519
25/12/90	1	-	-	2	2000	1.0(0.0-2.0)	1.5(1.0-2.0)	1.0(0.0-2.0)	2.0(1.0-3.0)	Low 0756
	2	10	ENE	4	2000	2.0(1.0-3.0)	2.0(1.0-2.5)	1.0(1.0-2.0)	2.0(1.0-3.0)	High 1453
24/12/90	1	0		1	2000	1.5(1.0-2.5)	1.0(0.0-2.0)	1.0(0.0-2.0)	2.0([illegible].0)	Low 0606
	2	5	ESE	6	4000	2.0(1.5-2.0)	1.0-2.0	1.0-2.0	3.0([illegible].0)	High 1334
21/12/90	1	10	ENE	1	3000	2.0(1.0-2.0)	2.0(1.0-2.5)	1.0(1.0-2.0)	2.0(1.0-3.0)	High 1045
	2	15	ENE	3	3000	2.0(1.0-2.0)	2.0(1.0-3.0)	1.0-2.0	2.0(1.0-3.0)	Low 1720

Times are for Cape Flattery and equal Cairns -10 mins.

Tide times are for Cape Grenville and equal Cairns +40 mins.

Lines 7-9 on block 6-7 also surveyed during this session.

TABLE 2: Beaufort Sea State and glare (for the north/east and south/west sides of the aircraft) for each transect.

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

Transect No.	Beaufort Sea State Inshore mode(range)	Offshore mode(range)	Glare North mode(range)	South Mode(range)
Blocks 1 - 4, November-December 1990				
1	1.0-2.5	2.5(1.0-2.5)	2.0	3.0
2	2.5(2.0-3.0)	1.0-2.5	1.0	2.0
3	2.5	1.0(0.0-2.0)	2.0	3.0
4	2.5(2.5-3.0)	1.0-2.5	1.0	3.0
5	-	0.0-2.5	1.0	3.0
6	2.0-2.5	1.0(0.0-2.0)	1.0	3.0
7	1.0-2.0	0.0-0.5	1.0	2.0
8	0.5(0.5-1.5)	0.0	2.0	3.0
9	0.5(0.0-0.5)	0.5-2.5	1.0	2.0
10	1.0-2.5	0.5(0.0-0.5)	1.0-2.0	2.0-3.0
11	1.0	1.5(1.0-2.0)	1.0	1.0
12	-	0.5-1.0	1.0	2.0
13	0.5-1.0	1.5(0.5-2.0)	1.0	1.0
14	1.0	1.0(0.5-1.0)	1.0	2.0
15	2.0-2.5	2.0(0.5-2.0)	2.0	3.0
16	2.0-2.5	1.5(0.5-1.5)	1.0	3.0
17	2.5(2.0-2.5)	2.0(0.5-2.0)	1.0	2.0-3.0
18	2.0-2.5	2.0(1.0-2.5)	1.0	3.0
19	2.0(1.0-2.5)	1.5(1.0-2.5)	1.0-2.0	3.0
20	0.5	0.0	1.0	1.0-2.0
21	0.0	0.0	1.0	2.0
22	0.0	0.0	1.0	1.0
23	0.0	-	1.0	2.0
24	-	0.0(0.0-0.5)	1.0	1.0
25	0.5	0.0	1.0	1.0-2.0
26	0.5	0.0	1.0	1.0
27	0.5	0.0	1.0	1.0
28	1.0		1.0	2.0
29	1.0		2.0	2.0
30	1.0(0.5-1.0)		1.0	2.0
31	1.0		1.0	2.0
32	1.0		1.0	2.0-3.0
33	1.0		1.0	1.0
34	1.0(0.5-1.0)		1.0	3.0

Table 2: continued.

Transect No.	Beaufort Sea State Inshore mode(range)	Beaufort Sea State Offshore mode(range)	Glare North mode(range)	Glare South Mode(range)
Blocks 5, November-December 1990				
1	1.0		1.0	1.0
2	1.0(1.0-2.0)		1.0	2.0
3	1.0(1.0-2.0)		2.0	3.0
4	1.0(1.0-3.0)		1.0	3.0
5	1.0(0.5-3.0)		1.0	3.0
6	1.0(0.5-3.0)		1.0	3.0
7	1.0(0.0-3.0)		1.0	2.0
8	2.0(0.5-3.0)		1.0	2.0-3.0
9	2.5(1.0-3.0)		1.0	3.0(2.0-3.0)
10	1.5(1.5-3.0)		1.0	2.0
11	2.0(1.0-3.0)		1.0	3.0(2.0-3.0)
12	2.0(1.5-3.0)		2.0	2.0-3.0
13	2.0(1.0-2.0)		1.0(1.0-2.0)	3.0(1.0-3.0)
14	1.0(0.0-2.0)		1.0	3.0
15	1.0(1.0-2.0)		1.0	2.0
16	1.0(1.0-2.0)		1.0	2.0
17	1.0(1.0-2.0)		1.0	1.0-2.0
18	2.0(1.0-2.5)		1.0	2.0
19	2.0(1.0-2.0)		1.0	1.0-2.0
20	1.0(0.0-1.0)		1.0	1.0-2.0
21	1.0(0.0-1.0)		1.0	1.0
22	1.0(0.0-1.0)		1.0	1.0-2.0
23	0.0(0.0-0.5)		1.0	1.0

Table 2: continued.

Transect No.	Beaufort Sea State Inshore mode(range)	Beaufort Sea State Offshore mode(range)	Glare North mode(range)	Glare South Mode(range)
Blocks 6 - 14, November-December 1990				
1	0.0	1.0(0.0-1.0)	1.0	2.0
2	-	1.0	1.0	1.0
3	0.5	1.0	1.0	2.0
4	-	1.0	1.0	1.0
5	1.0	1.0-0.0	1.0	1.0
6	1.0	1.0(0.5-1.0)	1.0	1.0
7	2.0	1.0(1.0-3.0)	2.0	3.0
8	2.0(1.0-2.0)	2.0-3.0	1.0	1.0-2.0
9	1.0-2.0	2.0(1.0-2.0)	2.0	2.0-3.0
10	2.0	1.0-2.5	1.0	1.0-2.0
11	-	2.0(1.0-2.5)	1.0-2.0	2.0-3.0
12	1.0	2.0(2.0-2.5)	2.0	2.0
13	2.0	2.0(1.0-2.5)	1.0	1.0-3.0
14	2.0	2.5(2.0-2.5)	2.0	2.0
15	-	2.5(1.0-2.5)	1.0	1.0-3.0
16	2.0	2.0(1.0-2.5)	1.0	1.0-2.0
17	2.0-2.5	2.0	1.0	2.0
18	1.0-2.5	1.0(1.0-1.5)	1.0	1.0-2.0
19	2.0(2.0-2.5)	1.0	1.0	2.0
20	2.0-2.5	1.0(0.5-2.0)	0.0	1.0
21	2.0	1.5(1.0-1.5)	2.0	3.0
22	2.0	2.0(1.0-2.0)	1.0	2.0-3.0
23	1.0	1.5(1.0-2.0)	1.0	2.0
24	1.0	2.0(1.0-2.0)	1.0	1.0-2.0
25	1.0	1.5-2.0	1.0-1.5	2.0
26	0.5(0.5-1.0)	2.0(1.0-2.0)	1.0	1.0
27	-	1.0(0.0-0.5)	1.0	2.0
28	1.0-2.0	1.0-1.5	0.0(0.0-1.0)	2.0(0.0-2.0)
29	2.0-2.5	1.0(1.0-2.0)	1.0	1.0-3.0
30	2.0(2.0-2.5)	2.0(1.0-2.5)	1.0	2.0(1.0-2.0)
31	1.0-1.5	0.0-0.5	1.0	1.0-2.0
32	2.5	1.5(1.0-2.5)	1.0(1.0-2.0)	3.0(2.0-3.0)
33	2.5-3.0	0.0-1.5	1.0	1.0
34	1.0-2.0	0.5(0.5-1.0)	1.0	3.0
35	1.0	0.5(0.5-1.0)	2.0	2.0-3.0
36	-	0.5(0.5-1.0)	1.0	2.0-3.0
37	1.0	0.5(0.5-1.0)	1.0	3.0
38	0.0-2.0	2.0(0.0-2.0)	1.0-2.0	2.0-3.0
39	0.0	1.5(1.0-.0)	0.0-2.0	2.0(2.0-3.0)
40	0.0-1.0	1.0(1.0-2.0)	1.0	2.0
41	1.0-2.0	1.0(0.5-2.0)	1.0(1.0-2.0)	2.0(2.0-3.0)
42	1.0	1.0(0.0-1.0)	1.0	1.0-3.0
43	0.0-0.5	1.0(0.5-1.0)	1.0	2.0-3.0
44	0.0	0.0	1.0	2.0-3.0
45	0.0	0.0(0.0-0.5)	1.0	1.0
46	0.0	0.0(0.0-0.5)	1.0	2.0
47	1.0-2.5	0.5(0.0-2.0)	2.0(1.0-3.0)	3.0(1.0-3.0)
48	2.0-3.0	0.0-3.0	1.0	3.0-3.5
49	3.0	1.0(0.0-3.0)	1.0-2.0	2.0
50	0.0-1.0		1.0	2.0
51	2.0(0.0-2.0)		1.0	1.0
52	1.0(1.0-1.5)		1.0	2.0
53	0.0-1.5		1.0	2.0
54	1.0-2.0		1.0	2.0
55	1.0-2.0		1.0	1.0
56	2.0(1.0-2.0)		1.0	2.0-3.0
57	-		1.0	1.0
58	2.0		2.0	3.0
59	2.5(1.0-2.5)		1.0	2.0
60	2.5		2.0	3.0
61	2.5		1.0	2.0
62	2.0-3.0		2.0	3.0
63	2.0-3.0		1.0-2.0	2.0

TABLE 3: Logistics of flight time for the survey

Block	Transit Time (hrs)	Survey Time (hrs)	Dead Time (hrs)
Blocks 1 to 4	6.91	20.34	4.48
Block 5	1.59	9.72	1.38
Blocks 6 to 14	2.17	10.88	1.58

TABLE 4: Raw data for the surveys used in calculating correction factors: dugong sightings. The transect numbers are marked on Figures 1 - 3 in this Appendix. These data do not distinguish between the inshore and offshore legs of a transect even though these may be in different blocks.

Blocks 1 - 4, November-December 1990

Transect No.	No. of observers Port	No. of observers Starboard	No. of groups of dugongs Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
001	2	2	0	0	0	0	0	0
002	2	2	0	0	0	0	0	0
003	2	2	0	0	0	0	0	0
004	2	2	0	0	1	0	0	0
005	2	2	0	0	0	0	0	0
006	2	2	0	0	0	0	0	0
007	2	2	0	0	0	0	0	0
008	2	2	0	0	0	0	0	0
009	2	2	0	0	0	0	0	0
010	2	2	0	0	0	0	0	0
011	2	2	0	0	1	0	0	0
012	2	2	0	0	0	1	0	2
013	2	2	1	0	5	1	2	6
014	2	2	2	0	0	0	0	0
015	2	2	0	1	0	0	0	0
016	2	2	0	0	2	1	0	1
017	2	2	5	0	10	4	1	4
018	2	2	0	3	7	2	3	4
019	2	2	0	0	1	0	1	3
020	2	2	0	0	2	0	0	0
021	2	2	0	0	1	0	0	1
022	2	2	0	0	3	1	0	0
023	2	2	0	0	0	0	0	2
024	2	2	0	0	0	0	0	0
025	2	2	0	0	0	0	0	1
026	2	2	0	0	1	0	0	0
027	2	2	0	0	0	0	0	0
028	2	2	1	0	0	1	0	0
029	2	2	1	0	3	1	0	4
030	2	2	2	3	10	3	3	6
031	2	2	2	0	1	0	0	2
032	2	2	0	0	0	0	0	0
033	2	2	0	0	1	0	0	0
034	2	2	1	0	1	0	0	1
			15	7	50	15	10	37

TABLE 4: continued.

Block 5, November-December 1990

Transect No.	No. of observers Port	No. of observers Starboard	No. of groups of dugongs Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
001	2	2	0	0	0	0	0	0
002	2	2	0	0	0	0	0	1
003	2	2	0	2	1	0	1	1
004	2	2	0	0	0	0	0	0
005	2	2	1	0	2	1	0	8
006	2	2	1	2	2	0	1	1
007	2	2	1	1	2	0	1	4
008	2	2	0	0	1	0	0	0
009	2	2	0	2	0	0	0	0
010	2	2	1	3	0	3	2	3
011	2	2	1	0	1	0	0	3
012	2	2	0	1	1	4	1	3
013	2	2	0	2	2	1	3	0
014	2	2	2	2	1	1	0	4
015	2	2	0	0	3	1	1	3
016	2	2	0	0	0	0	1	1
017	2	2	0	2	1	0	0	0
018	2	2	0	0	0	0	0	0
019	2	2	0	0	0	0	0	0
020	1	1	1	0	0	1	0	0
021	2	2	0	0	0	0	0	1
022	2	2	0	0	1	0	0	0
023	2	2	0	0	0	1	0	0
			8	17	18	13	11	33

TABLE 4: continued.

Blocks 6 - 14, November-December 1990

Transect No.	No. of observers Port	Starboard	No. of groups of dugongs Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
001	2	2	0	0	0	0	0	2
002	2	2	2	0	3	1	0	4
003	2	2	0	0	2	0	0	0
004	2	2	0	0	1	0	0	1
005	2	2	4	2	8	8	0	10
006	2	2	0	0	2	1	1	0
007	1	1	0	0	0	0	0	0
008	1	1	0	0	0	0	0	0
009	1	1	0	0	0	0	0	0
010	1	1	0	0	0	2	0	0
011	1	1	0	0	0	0	0	0
012	1	1	0	0	0	0	0	0
013	1	1	1	0	0	0	0	0
014	1	1	0	0	0	0	0	0
015	1	1	0	0	0	0	0	0
016	1	1	1	0	0	0	0	0
017	2	2	0	0	0	2	0	0
018	2	2	2	1	2	0	1	2
019	2	2	2	0	1	0	0	0
020	2	2	0	0	0	0	0	0
021	1	1	0	0	0	0	0	0
022	1	1	0	0	0	0	0	0
023	1	1	0	0	0	0	0	0
024	1	1	0	0	0	0	0	0
025	1	1	0	0	0	0	0	0
026	1	1	0	0	0	0	0	0
027	1	1	0	0	0	1	0	0
028	1	1	2	0	0	1	0	0
029	2	2	0	2	1	1	0	0
030	2	2	1	0	0	0	0	1
031	2	2	0	0	1	0	0	1
032	2	2	0	0	0	1	0	0
033	1	1	0	0	0	0	0	0
034	2	2	0	0	0	0	0	0
035	2	2	0	0	0	0	0	0
036	1	2	0	0	0	0	0	0
037	1	2	0	0	0	0	0	0
038	2	2	1	0	0	0	0	0
039	2	2	1	0	1	1	0	1
040	2	2	0	0	0	0	0	1
041	2	2	1	0	0	0	0	1
042	1	2	0	0	0	0	0	0
043	1	2	0	0	0	0	0	0
044	2	2	2	0	0	0	0	1
045	2	2	0	0	0	0	0	0
046	2	2	0	0	0	1	0	0
047	2	2	0	0	0	0	0	0
048	2	2	0	0	0	0	0	0
049	2	2	0	0	0	1	0	0
050	2	2	0	0	0	0	0	0

TABLE 4: continued.

Blocks 6 - 14, November-December 1990

Transect No.	No. of observers Port	No. of observers Starboard	No. of groups of dugongs Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
051	2	2	0	0	0	0	0	0
052	2	2	0	0	0	1	0	0
053	2	2	0	0	1	1	0	1
054	2	2	0	0	1	1	0	2
055	2	2	0	1	0	0	2	0
056	2	2	2	0	0	0	0	0
057	2	2	0	0	1	0	1	0
058	2	2	0	0	0	0	0	0
059	2	2	0	0	0	0	1	0
060	2	2	0	0	0	0	0	0
061	2	2	0	0	0	0	0	0
062	2	2	0	0	0	0	0	0
063	2	2	0	1	3	0	1	2
			22	7	28	24	7	30

TABLE 5: Raw data used to calculate correction factors for dugongs for each survey or sub-section of survey.

(a) Correction for perception bias

Blocks: lines	No. of groups of dugongs					
	Port			Starboard		
	mid-seat	rear-seat	tandem	mid-seat	rear-seat	tandem
1-4: all lines 5: 1-19; 21-23 **6-14:** 1-6; 17-20; 31-32, 34-35; 44-49	34	27	89	42	22	91
5: 20 **6-14:** 33; 36-37; 42-43*	35	27	89	43	22	91
6-14: 29-30; 38-41; 56-63	6	6	8	6	6	10
6-14: 7-16; 21-28*	10	6	8	10	6	10

* starboard and port perception correction based on mid seat observer correction factor.

(b) Correction for availability bias

Blocks	Transects	No. of dugongs in groups ≤ 10		
		Surface	Underwater	Total
all blocks and transects		172	331	503

TABLE 6: Raw data for analysis of variance and covariance: dugong sightings.

Block	Transect No.	Corrected density of dugongs 1985	Corrected density of dugongs 1990
1	1	0	0
1	2	0	0
1	3	0	0
1	4	0	0
1	5	0	0
1	6	0	0
1	7	0	0
1	8	0	0
1	9	0	0.36
1	10	0	0
2	1	3.98	0.36
2	2	13.45	0.36
2	3	1.48	3.63
2	4	3.44	0.36
2	5	1.01	0.36
2	6	0	1.43
2	7	1	7.8
2	8	0.51	1.07
2	9	0.48	0.36
2	10	0	0
2	11	1.99	1.81
2	12	0.51	9.79
2	13	3.05	3.27
3	1	0.49	6.88
3	2	0.5	1.06
3	3	0.99	0.36
3	4	0	0
3	5	0	0.36
3	6	0	0
3	7	0	0
3	8	0.48	0
3	9	0	0
3	10	0	0
4	1	0	0
4	2	0	0
4	3	0	0
4	4	0	0.25
4	5	0	0
4	6	0	0
4	7	0	0
4	8	0	0
4	9	0	0

TABLE 6: continued.

Block	Transect No.	Corrected density of dugongs 1985	Corrected density of dugongs 1990
4	10	0	0
4	11	0	0
4	12	0	0.28
4	13	0.19	0.69
4	14	0.69	0.13
4	15	0.2	0
4	16	0	0
4	17	0	0.21
4	18	0.13	0
4	19	0	0.19
4	20	0.28	0.1
4	21	0	0.26
4	22	0.72	0.39
4	23	0	0.28
4	24	0	0
4	25	0	0.22
4	26	0	0.33
4	27	0	0
5	1	1.01	0
5	2	1.3	0.22
5	3	0	0.87
5	4	0.95	0
5	5	0.88	1.34
5	6	1.09	0.69
5	7	1.13	0.85
5	8	0.24	0.09
5	9	0.08	0.13
5	10	0.09	0.77
5	11	0.45	0.33
5	12	1.16	1.41
5	13	1.36	1.12
5	14	0.91	1.3
5	15	0.76	1.11
5	16	0.19	0.13
5	17	0.14	0.32
5	18	0.54	0
5	19	0.14	0
5	20	0.15	0.25
5	21	0.19	0.13
5	22	0.18	0.13
5	23	0	0.14
6	1	3.89	1.41
6	2	0	5.66
6	3	0	0.7
6	4	1.02	0.76

TABLE 6: continued.

Block	Transect No.	Corrected density of dugongs 1985	Corrected density of dugongs 1990
6	5	7.05	18.13
6	6	0	1.72
6	7	0	0
6	8	0	0
6	9	1.35	0
7	1	0	0
7	2	0	0.38
7	3	0	0.24
7	4	0	0.24
7	5	0	0
7	6	0	0.22
7	7	0	0
7	8	0	0
7	9	0	0
8	1	0.73	2.85
8	2	0	0
8	3	0	0
8	4	0	0
8	5	1.25	0
8	6	0.81	0
8	7	0	3.19
8	8	0.25	0.67
8	9	0.54	2.86
8	10	0.32	1.36
8	11	1.1	0
8	12	0	0
8	13	0	0
8	14	0	0
8	15	0.56	0
8	16	0	0
8	17	0.74	0
8	18	1.35	2.76
8	19	0	2.83
8	20	0.52	0
8	21	1.78	0
8	22	0	0
8	23	0	0
9	1	0	0
9	2	0.3	0
9	3	0	0
9	4	0.19	0.42
9	5	0	0
9	6	0	0
9	7	0	0

TABLE 6: continued.

Block	Transect No.	Corrected density of dugongs 1985	Corrected density of dugongs 1990
9	8	0	0
9	9	0	0
9	10	0	0
9	11	0	0
9	12	0	0
9	13	0	0
9	14	0	0
9	15	0	0
9	16	0	0
9	17	0	0
9	18	0	0
9	19	0	0.23
9	20	0	0
9	21	0	0
9	22	0	0.21
9	23	0	0
10	1	0	0
10	2	0	0
10	3	0	0
10	4	0	0
10	5	0	0
10	6	0.59	0.92
10	7	0	0
10	8	0	0
11	1	0	1.52
11	2	1.11	0.43
11	3	0.21	0.65
11	4	0	0
11	5	0.44	0
11	6	0.21	0
11	7	0	0.35
11	8	2.03	1.08
11	9	1.51	1.57
11	10	0	1.34
11	11	0	1.1
11	12	0.9	1.2
12	1	0	0
12	2	0	0.46
12	3	0	0
12	4	0	0
12	5	0	0
12	6	0.51	0
12	7	0	0
13	1	0	0

TABLE 6: continued.

Block	Transect No.	Corrected density of dugongs 1985	Corrected density of dugongs 1990
13	4	0.07	0
13	5	0	0
13	6	0	0
13	7	0.08	0.25
13	8	0	0
13	9	0	0
13	10	0	0
13	11	0	0
13	12	0	0.14
13	13	0	0
13	14	0	0.06
13	15	0.14	0
13	16	0	0
13	17	0	0.06

TABLE 7: Raw data for the surveys used in calculating correction factors: turtle sightings. The transect numbers are marked on Figures 1 - 3 in this Appendix. These data do not distinguish between the inshore and offshore legs of a transect even though these may be in different blocks.

Blocks 1 - 4, November-December 1990

Transect No.	No. of observers Port	Starboard	No. of groups of turtles Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
001	2	2	1	0	0	1	0	1
002	2	2	2	0	0	1	0	0
003	2	2	1	1	1	1	0	0
004	2	2	0	0	1	0	0	0
005	2	2	1	0	2	2	3	2
006	2	2	2	0	1	2	0	1
007	2	2	0	0	0	0	1	0
008	2	2	1	0	0	1	1	1
009	2	2	1	2	0	2	0	2
010	2	2	1	2	0	1	1	1
011	2	2	4	4	5	1	1	5
012	2	2	4	1	5	3	3	5
013	2	2	3	3	4	3	4	5
014	2	2	4	2	12	2	3	8
015	2	2	1	2	7	2	2	4
016	2	2	3	2	2	1	6	10
017	2	2	2	4	10	2	3	2
018	2	2	5	0	5	3	0	3
019	2	2	4	8	11	3	1	5
020	2	2	12	2	33	9	4	25
021	2	2	4	8	23	13	7	23
022	2	2	10	1	26	5	9	28
023	2	2	13	4	23	8	4	27
024	2	2	2	2	21	1	2	23
025	2	2	9	4	6	6	5	10
026	2	2	9	3	11	5	5	6
027	2	2	4	5	6	5	8	10
028	2	2	3	0	3	4	0	4
029	2	2	4	1	0	7	0	5
030	2	2	2	1	3	0	4	1
031	2	2	3	1	7	1	2	7
032	2	2	1	1	0	0	0	2
033	2	2	3	0	4	2	2	2
034	2	2	3	3	1	0	3	2
			122	67	233	97	84	230

TABLE 7: continued.

Block 5, November-December 1990

Transect No.	No. of observers Port	Starboard	No. of groups of turtles Port Mid	Rear	Tandem	Starboard Mid	Rear	Tandem
001	2	2	1	0	1	1	0	1
002	2	2	0	0	0	1	0	2
003	2	2	3	1	2	1	1	2
004	2	2	4	0	0	1	0	0
005	2	2	2	0	1	2	1	1
006	2	2	1	2	1	5	1	5
007	2	2	1	2	0	0	0	1
008	2	2	6	2	3	3	0	2
009	2	2	5	1	2	6	1	1
010	2	2	6	4	2	4	3	6
011	2	2	6	0	5	5	2	1
012	2	2	14	4	14	11	4	3
013	2	2	12	5	13	13	2	15
014	2	2	5	2	17	14	0	15
015	2	2	1	2	10	2	3	5
016	2	2	3	5	2	4	4	5
017	2	2	10	9	2	9	6	7
018	2	2	7	5	10	7	5	14
019	2	2	3	0	2	2	1	0
020	1	1	2	0	0	3	0	0
021	2	2	0	0	3	0	0	1
022	2	2	0	0	0	0	0	0
023	2	2	3	0	3	2	1	9
			95	44	93	96	35	96

TABLE 7: continued.

Blocks 6 - 14, November-December 1990

Transect No.	No. of observers Port	No. of observers Starboard	No. of groups of turtles Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
001	2	2	3	2	4	3	0	1
002	2	2	10	0	3	4	0	2
003	2	2	2	2	6	0	4	5
004	2	2	3	0	5	3	3	8
005	2	2	3	2	13	2	1	6
006	2	2	1	2	3	2	1	2
007	1	1	0	0	0	0	0	0
008	1	1	5	0	0	1	0	0
009	1	1	1	0	0	4	0	0
010	1	1	2	0	0	1	0	0
011	1	1	0	0	0	1	0	0
012	1	1	6	0	0	3	0	0
013	1	1	2	0	0	4	0	0
014	1	1	2	0	0	1	0	0
015	1	1	1	0	0	1	0	0
016	1	1	1	0	0	0	0	0
017	2	2	4	0	1	0	0	0
018	2	2	1	0	0	0	0	1
019	2	2	3	0	4	1	2	0
020	2	2	0	0	1	0	0	1
021	1	1	2	0	0	3	0	0
022	1	1	2	0	0	0	0	0
023	1	1	0	0	0	2	0	0
024	1	1	1	0	0	1	0	0
025	1	1	2	0	0	1	0	0
026	1	1	0	0	0	1	0	0
027	1	1	3	0	0	6	0	0
028	1	1	13	0	0	8	0	0
029	2	2	4	2	2	5	4	2
030	2	2	5	3	2	1	0	3
031	2	2	1	1	3	2	2	7
032	2	2	5	1	1	1	1	4
033	1	1	16	0	0	3	0	0
034	2	2	4	1	3	1	2	6
035	2	2	2	3	7	2	2	0
036	1	2	6	0	0	2	3	11
037	1	2	5	0	0	1	0	2
038	2	2	1	1	1	2	5	1
039	2	2	2	5	1	1	1	4
040	2	2	6	4	3	2	1	3
041	2	2	2	0	2	9	2	5
042	1	2	9	0	0	0	1	3
043	1	2	6	0	0	1	1	6
044	2	2	10	0	2	4	1	0
045	2	2	2	1	9	2	0	8
046	2	2	2	0	12	4	3	8
047	2	2	10	0	10	1	6	9
048	2	2	12	1	6	10	1	7
049	2	2	8	1	11	8	2	11
050	2	2	1	1	2	3	5	0

TABLE 7: continued.

Blocks 6 - 14, November-December 1990

Transect No.	No. of observers Port	Starboard	No. of groups of turtles Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
051	2	2	1	1	1	1	1	3
052	2	2	1	2	1	0	0	0
053	2	2	0	0	1	0	1	1
054	2	2	2	0	3	0	1	1
055	2	2	1	0	0	1	0	0
056	2	2	1	0	1	3	1	1
057	2	2	1	1	1	0	0	3
058	2	2	0	0	0	0	0	0
059	2	2	0	0	0	1	0	0
060	2	2	0	0	0	0	0	0
061	2	2	0	1	0	0	0	0
062	2	2	0	0	1	0	0	0
063	2	2	0	0	0	0	0	0
			199	38	126	124	58	135

TABLE 8: Raw data used to calculate correction factors for turtles for the survey.

(a) Correction for perception bias

Blocks: lines	No. of groups of turtles					
	Port			Starboard		
	mid-seat	rear-seat	tandem	mid-seat	rear-seat	tandem
1-4: all lines 5: 1-19; 21-23 6-14: 1-6; 17-20; 31-32, 34-35; 44-49	301	128	440	240	150	412
5: 20 6-14: 33; 36-37; 42-43*	345	128	440	250	155	434
6-14: 29-30; 38-41; 56-63	36	32	28	41	27	41
6-14: 7-16; 21-28*	79	32	28	79	27	41

* starboard and port perception correction factor based on mid seat observer correction factor.

(b) Correction for availability bias

Blocks	Transects	No. of turtles in groups ≤ 10 Surface	Underwater	Total
all blocks and transects		890	1509	2399

TABLE 9: Raw data for analysis of variance and covariance: turtle sightings.

Block	Transect No.	Corrected density of turtles 1985	Corrected density of turtles 1990
1	1	0.3	0
1	2	0.3	0
1	3	0.28	0.48
1	4	0.87	0
1	5	0.57	0.73
1	6	0	0
1	7	0	0
1	8	0.87	0.72
1	9	0.56	0.97
1	10	0	0.24
2	1	1.41	4.4
2	2	2.86	3.87
2	3	0.58	2.2
2	4	1.16	1.69
2	5	0.86	0.72
2	6	1.41	3.87
2	7	0	3.59
2	8	1.16	2.43
2	9	0.3	2.43
2	10	0.87	0.48
2	11	0.58	1.71
2	12	0.58	2.45
2	13	3.45	3.19
3	1	1.47	2.44
3	2	1.43	0.72
3	3	0.88	3.19
3	4	0.58	1.95
3	5	3.46	4.85
3	6	3.93	7.65
3	7	0.3	7.98
3	8	1.67	6.23
3	9	0.28	4.83
3	10	0.86	8.7
4	1	0	0.5
4	2	0.57	0.47
4	3	0.54	0.31
4	4	0.4	0.17
4	5	0	1.26
4	6	0.23	1.2
4	7	0	0.25
4	8	0	0.29
4	9	0	0.52
4	10	0	0.74

TABLE 9: continued.

Block	Transect No.	Corrected density of turtles 1985	Corrected density of turtles 1990
4	11	0	0.25
4	12	0	0.48
4	13	0.99	1.22
4	14	1.02	2.07
4	15	0.32	1.4
4	16	0.32	0.72
4	17	0	0.58
4	18	0.39	0.4
4	19	1.65	1.92
4	20	2.74	5.01
4	21	3.16	6.22
4	22	2.28	5.11
4	23	1.13	5.5
4	24	0.28	2.03
4	25	2.49	2.07
4	26	1.33	4.21
4	27	0.77	1.94
5	1	0.24	0.84
5	2	0.94	0.44
5	3	1.91	1.17
5	4	0.66	0.54
5	5	2.25	0.53
5	6	1.49	0.99
5	7	0.33	0.25
5	8	0.52	0.97
5	9	0.91	0.68
5	10	0.98	1.08
5	11	1.2	0.84
5	12	3.51	4.76
5	13	5.44	5.63
5	14	5.15	4.65
5	15	3.74	2.15
5	16	5.74	2.06
5	17	2.46	3.1
5	18	1.09	3.13
5	19	0.64	0.54
5	20	0.75	0.42
5	21	0.75	0.36
5	22	0.82	0
5	23	1.47	1.73
6	1	0.55	0
6	2	1.14	4.3
6	3	1.7	0.95
6	4	1.27	2.56
6	5	0.44	6.51
6	6	0.44	0.78
6	7	1.44	0

TABLE 9: continued.

Block	Transect No.	Corrected density of turtles 1985	Corrected density of turtles 1990
6	8	3.22	0
6	9	8.9	4.19
7	1	1.04	1.61
7	2	0.23	1.29
7	3	3.55	2.82
7	4	0.88	2.75
7	5	1.31	1.47
7	6	0	1.33
7	7	0.51	0
7	8	0.23	1.29
7	9	0.71	0.21
8	1	0.88	1.06
8	2	0	1.14
8	3	1.03	2.97
8	4	0	1.19
8	5	2.75	0.97
8	6	0.93	1.3
8	7	0	0
8	8	0.27	0.23
8	9	0.28	0.24
8	10	0.54	1.83
8	11	0.61	0
8	12	1.67	3.27
8	13	0	1.46
8	14	0.48	0
8	15	1.9	1.72
8	16	0.49	0.69
8	17	0	0
8	18	2.88	3.94
8	19	0	11.69
8	20	1.23	5.32
8	21	0.57	5.65
8	22	1.5	5.81
8	23	0.48	5.48
9	1	0.08	0.4
9	2	0	0
9	3	0.11	1.65
9	4	0.51	1.37
9	5	0.11	0.64
9	6	0.56	0.3
9	7	0.69	0.33
9	8	0.61	0.69
9	9	0.1	0.18
9	10	0.31	0.71
9	11	0.09	0.3
9	12	0.07	0.41

TABLE 9: continued.

Block	Transect No.	Corrected density of turtles 1985	Corrected density of turtles 1990
9	15	0	0
9	16	0.71	0.38
9	17	0.07	0.19
9	18	0.81	1.24
9	19	0.49	1.45
9	20	0.6	0.62
9	21	1.11	0.74
9	22	1.2	0.78
9	23	0.76	0.68
10	1	0.73	0
10	2	1.24	1.29
10	3	1.19	2.71
10	4	0.89	4.5
10	5	0.83	2.1
10	6	1	2.65
10	7	0	3.38
10	8	0	0
11	1	0.8	1.11
11	2	1.48	0.29
11	3	1.38	2.03
11	4	0.35	0.59
11	5	3.45	2.93
11	6	0.53	1.88
11	7	0.41	1.02
11	8	1.89	0.76
11	9	0.48	2
11	10	0	0.64
11	11	0.26	2.79
11	12	0.54	2.59
12	1	1.48	1.37
12	2	0	0
12	3	0.41	4.34
12	4	0.27	0.47
12	5	0.86	1.47
12	6	0.28	1.47
12	7	0.35	1.85
13	1	0.99	1.8
13	2	1.18	1.18
13	3	0.98	0.77
13	4	0.57	1.03
13	5	0.44	0.38
13	6	0.95	0.7
13	7	1.23	0.9
13	8	2	1.53
13	9	1.15	0.82
13	10	0.59	0.63

TABLE 9: continued.

Block	Transect No.	Corrected density of turtles 1985	Corrected density of turtles 1990
13	11	0.82	0.47
13	12	0.41	0.8
13	13	0.11	0.47
13	14	0.21	1.23
13	15	0.94	1.08
13	16	0.59	1.22
13	17	0.51	1.42

TABLE 10: Raw data for the surveys used in calculating correction factors: dolphin sightings. The transect numbers are marked on Figures 1 - 3 in this Appendix. These data do not distiguish between inshore and offshore legs of a transect even though these may be in different blocks.

Blocks 1 - 4, November-December 1990

Transect No.	No. of observers Port	No. of observers Starboard	No. of groups of dolphins Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
001	2	2	0	0	1	2	0	0
002	2	2	0	0	0	0	0	0
003	2	2	0	0	0	0	0	0
004	2	2	0	0	0	0	0	0
005	2	2	0	0	0	0	0	0
006	2	2	0	0	0	1	0	0
007	2	2	1	0	0	1	0	0
008	2	2	0	0	0	0	0	0
009	2	2	0	0	0	0	0	1
010	2	2	0	0	0	0	0	0
011	2	2	0	0	0	0	0	0
012	2	2	1	0	0	0	1	0
013	2	2	0	0	1	0	0	1
014	2	2	0	0	1	0	0	0
015	2	2	0	0	1	0	0	0
016	2	2	0	0	0	0	0	0
017	2	2	0	0	0	0	0	0
018	2	2	0	0	0	0	0	1
019	2	2	0	0	0	0	0	0
020	2	2	1	1	1	0	0	1
021	2	2	0	0	1	0	1	1
022	2	2	0	0	1	0	0	0
023	2	2	0	0	1	0	0	1
024	2	2	0	0	4	0	1	0
025	2	2	0	0	0	0	0	0
026	2	2	0	0	1	0	0	0
027	2	2	0	0	0	0	1	1
028	2	2	0	0	0	0	0	0
029	2	2	0	0	0	0	0	0
030	2	2	0	0	0	0	0	0
031	2	2	1	0	1	0	0	0
032	2	2	0	0	0	0	0	0
033	2	2	0	0	0	0	0	0
034	2	2	0	0	0	0	0	0
			4	1	14	4	4	7

TABLE 10: continued.

Block 5, November-December 1990

Transect No.	No. of observers Port	Starboard	No. of groups of dolphins Port Mid	Rear	Tandem	Starboard Mid	Rear	Tandem
001	2	2	0	0	0	0	0	0
002	2	2	0	0	0	0	0	1
003	2	2	0	0	0	0	0	0
004	2	2	0	0	0	1	0	0
005	2	2	0	0	0	0	0	1
006	2	2	0	0	0	0	0	0
007	2	2	0	0	0	0	0	0
008	2	2	0	0	0	0	0	0
009	2	2	0	0	0	0	0	1
010	2	2	0	1	1	1	1	0
011	2	2	0	1	2	1	0	0
012	2	2	0	0	1	0	0	1
013	2	2	1	0	0	0	0	0
014	2	2	0	0	0	0	0	0
015	2	2	0	1	3	0	0	1
016	2	2	2	0	0	0	0	1
017	2	2	0	0	0	0	0	1
018	2	2	0	0	1	0	0	0
019	2	2	0	0	1	0	2	0
020	1	1	1	0	0	0	0	0
021	2	2	0	0	1	0	0	0
022	2	2	0	0	0	0	0	1
023	2	2	0	0	2	0	0	0
			2	3	12	3	3	8

TABLE 10: continued.

Blocks 6 - 14, November-December 1990

Transect No.	No. of observers Port	Starboard	No. of groups of dolphins Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
001	2	2	0	0	2	0	1	0
002	2	2	0	0	0	0	0	1
003	2	2	0	0	0	0	0	1
004	2	2	0	0	1	1	0	1
005	2	2	0	0	2	0	1	0
006	2	2	0	0	0	0	0	0
007	1	1	0	0	0	1	0	0
008	1	1	0	0	0	0	0	0
009	1	1	0	0	0	0	0	0
010	1	1	0	0	0	0	0	0
011	1	1	0	0	0	0	1	0
012	1	1	0	0	0	0	0	0
013	1	1	0	0	0	0	0	0
014	1	1	0	0	0	0	0	0
015	1	1	0	0	0	0	0	0
016	1	1	0	0	0	0	0	0
017	2	2	0	0	0	0	0	0
018	2	2	0	0	0	0	0	1
019	2	2	0	0	0	0	0	0
020	2	2	0	0	0	0	0	3
021	1	1	0	0	0	0	0	0
022	1	1	1	0	0	0	0	0
023	1	1	0	0	0	0	0	0
024	1	1	0	0	0	0	0	0
025	1	1	0	0	0	1	0	0
026	1	1	1	0	0	0	0	0
027	1	1	0	0	0	0	0	0
028	1	1	0	0	0	1	0	0
029	2	2	0	0	0	1	1	0
030	2	2	0	0	0	0	0	2
031	2	2	0	0	3	0	1	1
032	2	2	0	0	0	1	0	0
033	1	1	3	0	0	0	0	0
034	2	2	0	0	1	1	2	0
035	2	2	0	1	1	1	2	0
036	1	2	2	0	0	0	0	1
037	1	2	1	0	0	0	0	2
038	2	2	0	0	0	0	1	0
039	2	2	0	1	1	0	0	0
040	2	2	0	0	0	0	1	0
041	2	2	2	0	0	0	0	0
042	1	2	1	0	0	0	0	3
043	1	2	4	0	0	1	0	3
044	2	2	0	0	4	2	3	0
045	2	2	0	1	5	2	0	7
046	2	2	5	1	8	1	0	1
047	2	2	0	0	4	0	3	3
048	2	2	0	0	2	4	0	1
049	2	2	2	0	3	0	1	0
050	2	2	0	0	0	0	0	0

TABLE 10: continued.

Blocks 6 - 14, November-December 1990

Transect No.	No. of observers Port	No. of observers Starboard	No. of groups of dolphins Port Mid	Port Rear	Port Tandem	Starboard Mid	Starboard Rear	Starboard Tandem
051	2	2	0	0	0	0	0	0
052	2	2	0	0	0	0	0	0
053	2	2	0	0	0	0	0	0
054	2	2	0	0	0	0	0	0
055	2	2	0	0	0	0	0	0
056	2	2	0	0	0	0	0	0
057	2	2	0	0	0	0	0	0
058	2	2	0	0	0	0	0	0
059	2	2	0	0	0	0	0	0
060	2	2	0	0	0	0	0	0
061	2	2	0	0	0	0	0	0
062	2	2	0	0	0	0	0	0
063	2	2	0	0	0	0	0	0
			22	4	37	18	18	31

TABLE 11: Raw data used to calculate correction factors for dolphins for the survey.

(a) Correction for perception bias

Blocks: lines	No. of groups of cetaceans					
	Port			Starboard		
	mid-seat	rear-seat	tandem	mid-seat	rear-seat	tandem
1-4: all lines 5: 1-19; 21-23 **6-14:** 1-6; 17-20; 31-32, 34-35; 44-49	11	6	50	16	18	29
5: 20 **6-14:** 33; 36-37; 42-43[a]	23	6	50	17	18	38
6-14: 29-30; 38-41; 56-63	4	1	3	4	4	6
6-14: 7-16; 21-28[a]	2	1	3	1	3	6

[a] starboard and port perception correction factor based on mid seat observer correction factor.

TABLE 12: Raw data for analysis of variance and covariance: dolphin sightings.

Block	Transect No.	Corrected density of dolphins 1985	Corrected density of dolphins 1990
1	1	0	0.24
1	2	0	0
1	3	0	0
1	4	0	0
1	5	0.24	0
1	6	0	0
1	7	0.33	0.52
1	8	0	0
1	9	0	0
1	10	0	0
2	1	0	0
2	2	0	0
2	3	0	0.28
2	4	0	0.24
2	5	0	0
2	6	0	0
2	7	0	0
2	8	0	0
2	9	0	0
2	10	0	0
2	11	0	0.24
2	12	0	0
2	13	0	0
3	1	0	0
3	2	0	0
3	3	0	0.49
3	4	0	0.24
3	5	0	0
3	6	0	0
3	7	0	0
3	8	0	0
3	9	0	0
3	10	0	0.28
4	1	0	0.38
4	2	0.16	0
4	3	0	0
4	4	0	0
4	5	0	0
4	6	0	0.23
4	7	0.25	0
4	8	0	0
4	9	0	0.2

TABLE 12: continued.

Block	Transect No.	Corrected density of dolphins 1985	Corrected density of dolphins 1990
4	10	0	0
4	11	0	0
4	12	0	0.2
4	13	0	0.09
4	14	0.09	0.09
4	15	0	0.09
4	16	0	0
4	17	0	0
4	18	0	0.08
4	19	0	0
4	20	0.1	0.14
4	21	0	0.2
4	22	0.29	0.09
4	23	0.13	0.21
4	24	0	0.58
4	25	0	0
4	26	0.22	0.22
4	27	0	0.37
5	1	0	0
5	2	0	0.17
5	3	0	0
5	4	0	0.12
5	5	0	0.09
5	6	0.09	0
5	7	0.17	0
5	8	0.08	0
5	9	0	0.05
5	10	0.06	0.19
5	11	0.06	0.18
5	12	0.09	0.2
5	13	0	0.09
5	14	0	0
5	15	0	0.48
5	16	0	0.28
5	17	0.1	0.08
5	18	0.45	0.07
5	19	0.07	0.22
5	20	0.14	0.08
5	21	0	0.09
5	22	2.16	0.1
5	23	0	0.19
6	1	0	0
6	2	0	0
6	3	0	0.55
6	4	0	0.59

TABLE 12: continued.

Block	Transect No.	Corrected density of dolphins 1985	Corrected density of dolphins 1990
6	5	0	0
6	6	0	0
6	7	0	0
6	8	0	0
6	9	0	0
7	1	0	0.39
7	2	0	0.15
7	3	0	0
7	4	0	0.35
7	5	0.81	0.46
7	6	0	0
7	7	0	0.22
7	8	0	0
7	9	0	0
8	1	0	0
8	2	0	0
8	3	0	0
8	4	0	0
8	5	0	0
8	6	0	0
8	7	0	0
8	8	0	0
8	9	0	0
8	10	0	0
8	11	0	0
8	12	0	0
8	13	0	0
8	14	0	0
8	15	0	0
8	16	0	0
8	17	0	0.9
8	18	2.04	0
8	19	0	0
8	20	0	0
8	21	0	0
8	22	0	0
8	23	0	0
9	1	2.06	0
9	2	0	0.19
9	3	0	0
9	4	0	0
9	5	1.7	0
9	6	0	0
9	7	4.63	0
9	8	2.07	0

TABLE 12: continued.

Block	Transect No.	Corrected density of dolphins 1985	Corrected density of dolphins 1990
9	9	0	0.21
9	10	1.77	0
9	11	0	0.52
9	12	1.08	0
9	13	1.43	0.16
9	14	1.75	0
9	15	0	0
9	16	2.77	0.18
9	17	0.81	0
9	18	0.97	0
9	19	4.93	0.15
9	20	2.72	0.19
9	21	0.75	0.16
9	22	1.18	0.37
9	23	0.11	0
10	1	0	0.45
10	2	0	0
10	3	0	0
10	4	0	0
10	5	0	0
10	6	0	0
10	7	0	0
10	8	0	0
11	1	0	0
11	2	0	0
11	3	0	0.21
11	4	0	0.42
11	5	0	0
11	6	0	0
11	7	0	0
11	8	0	0
11	9	0	0
11	10	0	0
11	11	0	0
11	12	0	0
12	1	0.38	0
12	2	0	0
12	3	0	0
12	4	0	0
12	5	0	0
12	6	2.5	0
12	7	0	0
13	1	3.57	0.18
13	2	2.51	0.37
13	3	0.21	0.35

TABLE 12: continued.

Block	Transect No.	Corrected density of dolphins 1985	Corrected density of dolphins 1990
13	4	1.09	0.2
13	5	1.02	0.25
13	6	3.32	0.09
13	7	0.76	0.15
13	8	1.01	0.07
13	9	4.2	0.07
13	10	0.75	0.14
13	11	2.14	0.5
13	12	4.09	0.45
13	13	0	0.77
13	14	0	0.72
13	15	2.15	0.47
13	16	0.07	0.32
13	17	0.67	0.26

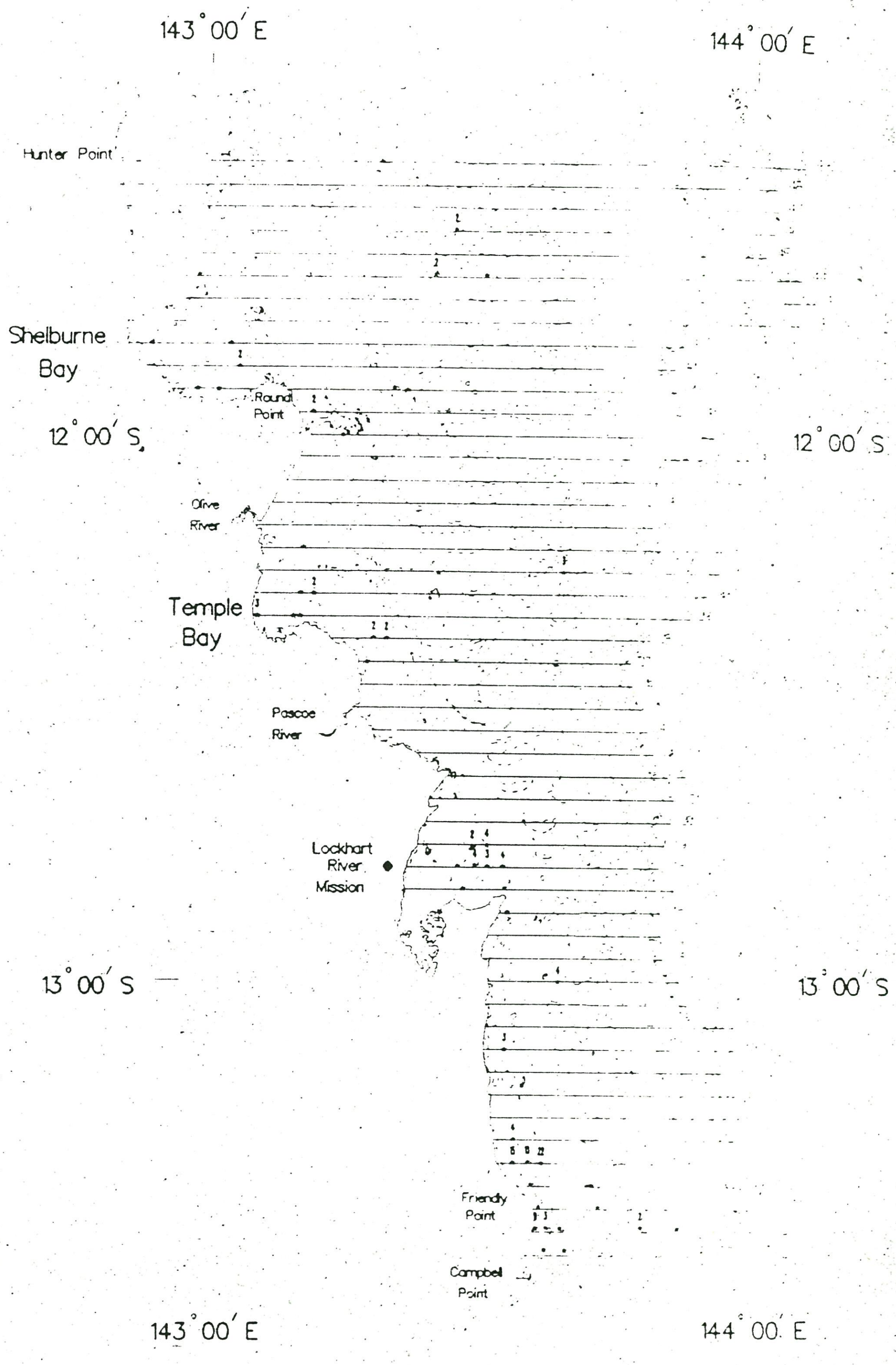

Figure 1. The survey area between Hunter Point and Campbell Point showing the positions of dugong sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. The transect numbers correspond with those in Appendix Tables 4, 7, 10.

Figure 2. The survey area between Campbell Point and Cape Melville showing the positions of dugong sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. The transect numbers correspond with those in Appendix Tables 4, 7, 10.

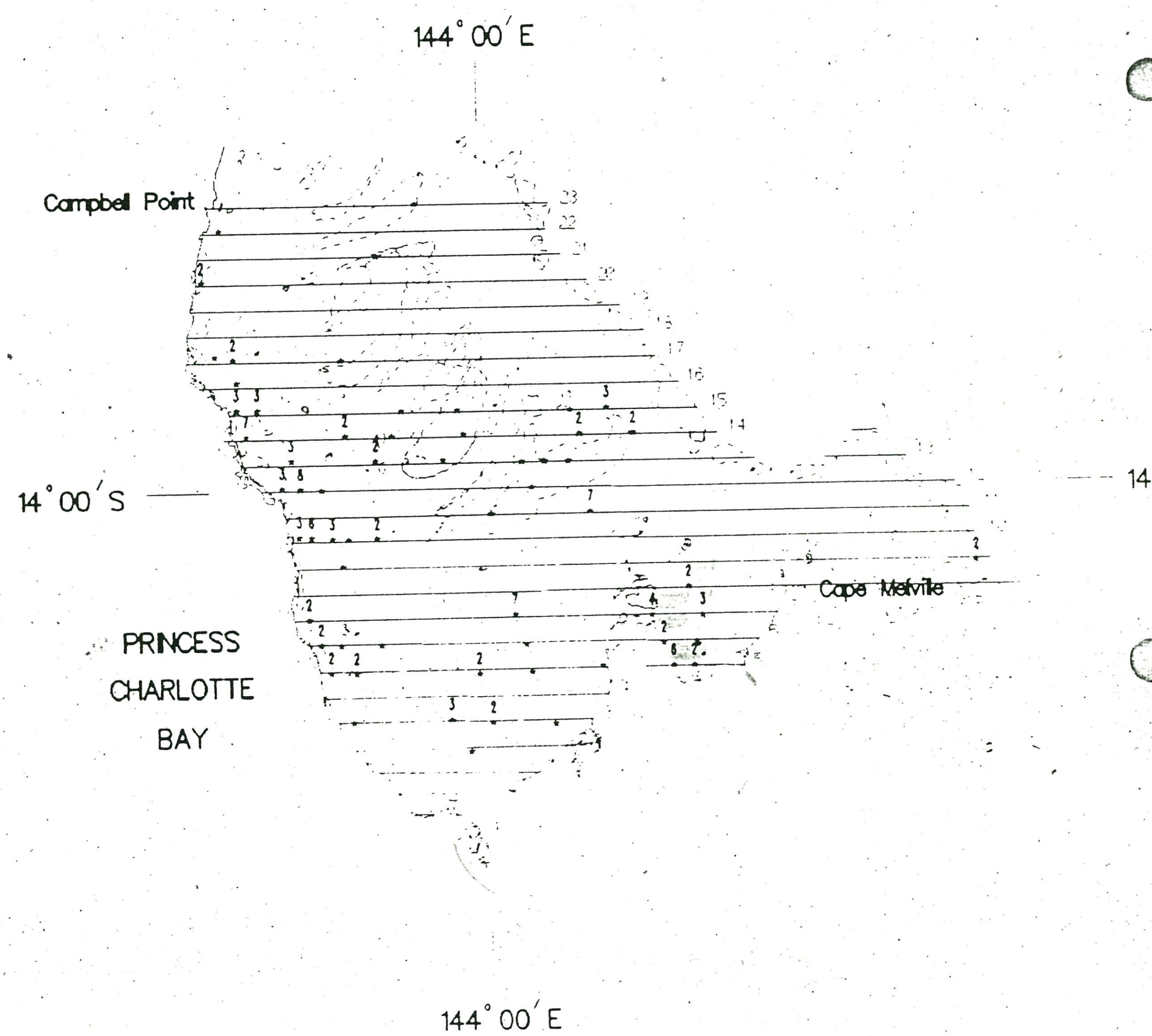

Figure 3. The survey area between Cape Melville and Cape Bedford showing the positions of dugong sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. The transect numbers correspond with those in Appendix Tables 4, 7, 10.

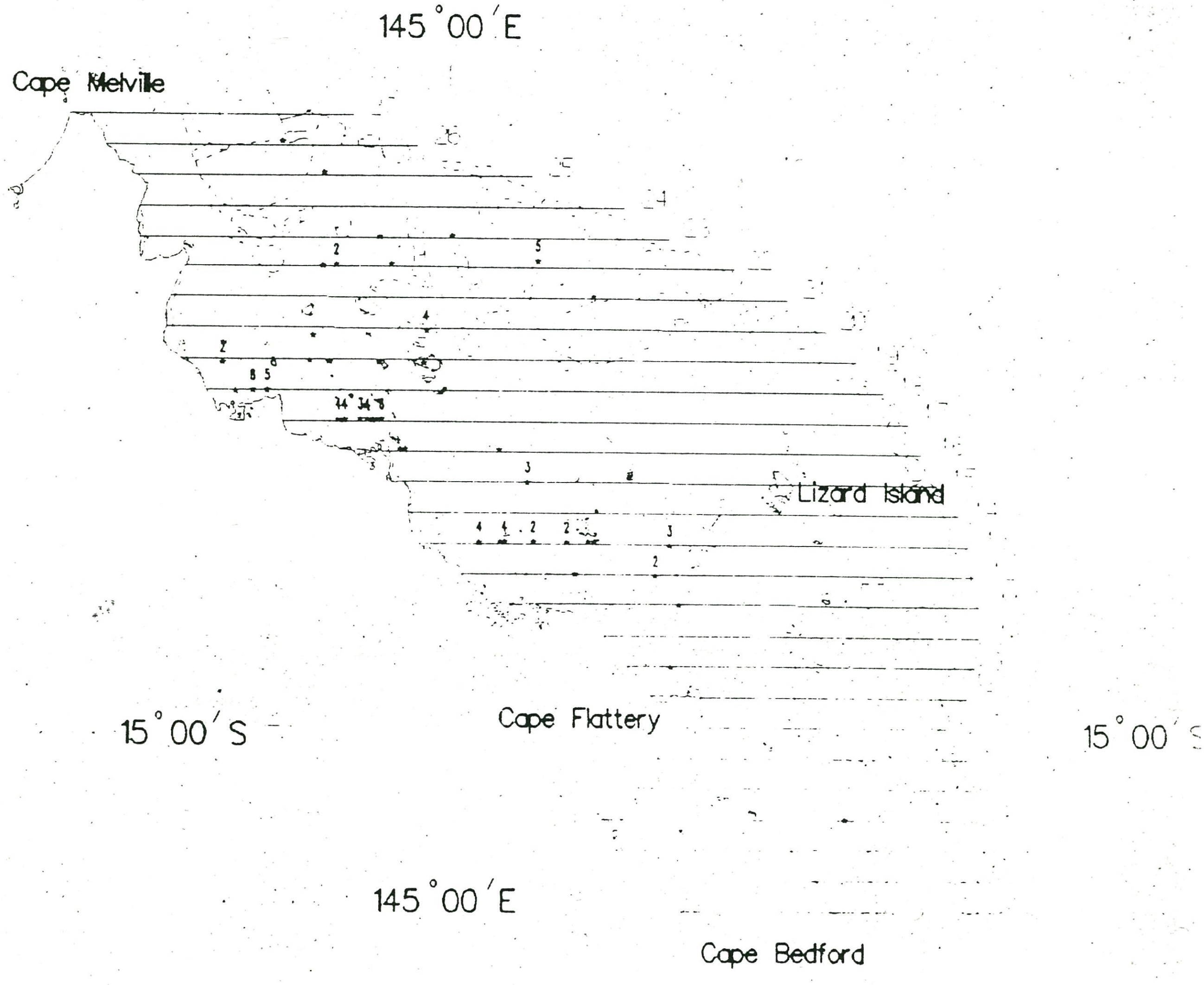

Figure 4. The survey area in Shelburne Bay showing the positions of dugong sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. (MNPB: Marine National Park B Zone; GUA= General Use A Zone; GUB: General Use B Zone).

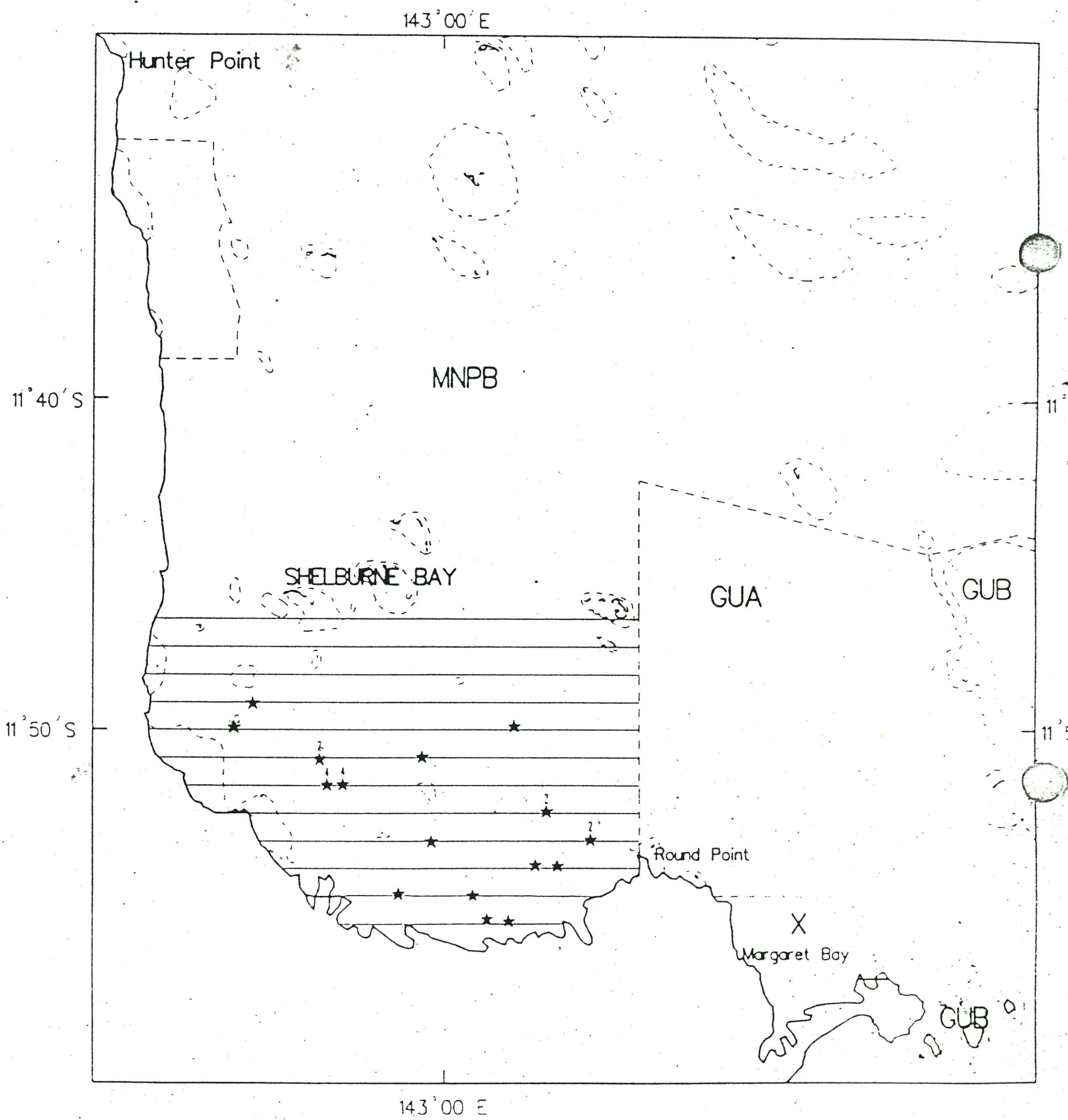

Figure 5. The survey area in Temple Bay showing the positions of dugong sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

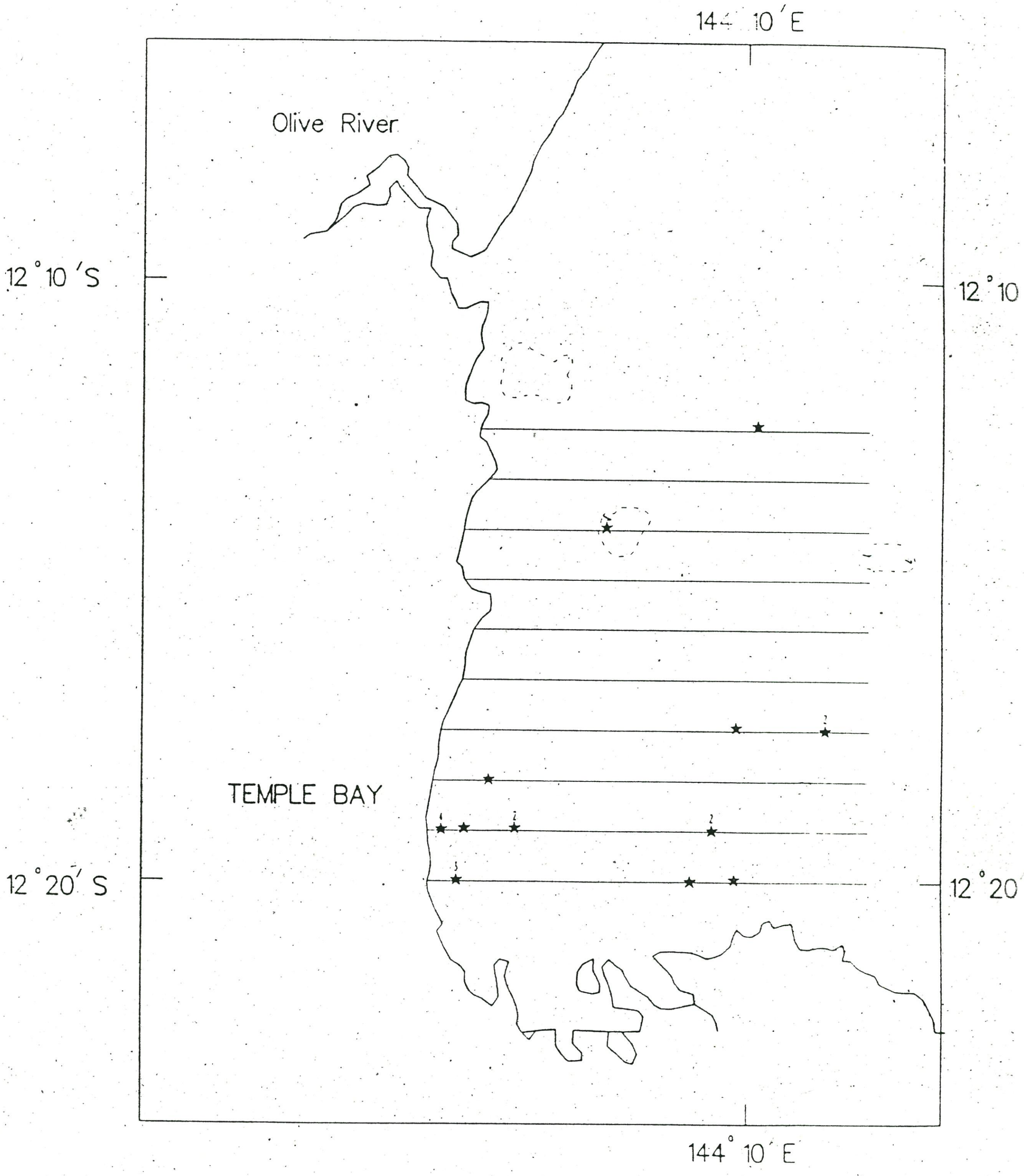

Figure 6. The survey area between Lookout Point and Red Point showing the positions of dugong sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

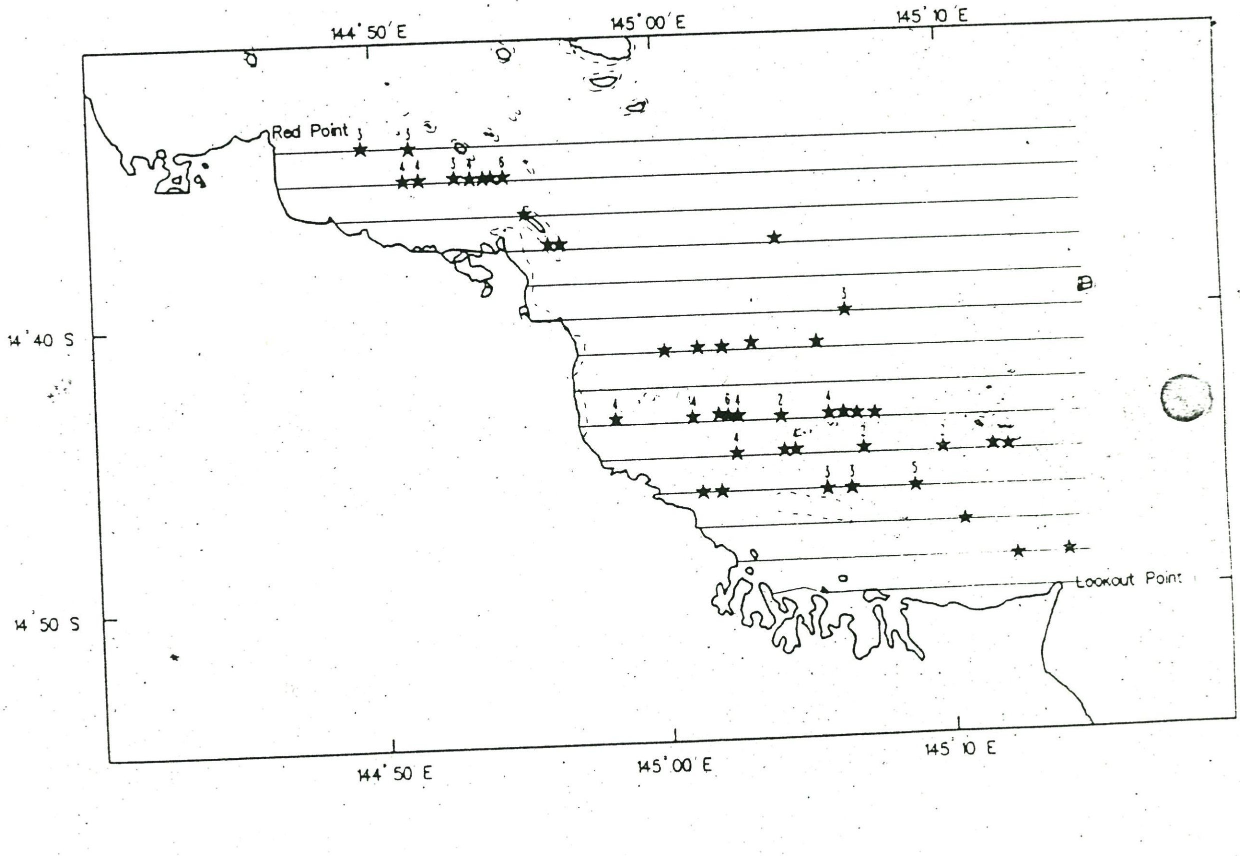

Figure 7. The survey area between Hunter Point and Campbell Point showing the positions of turtle sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

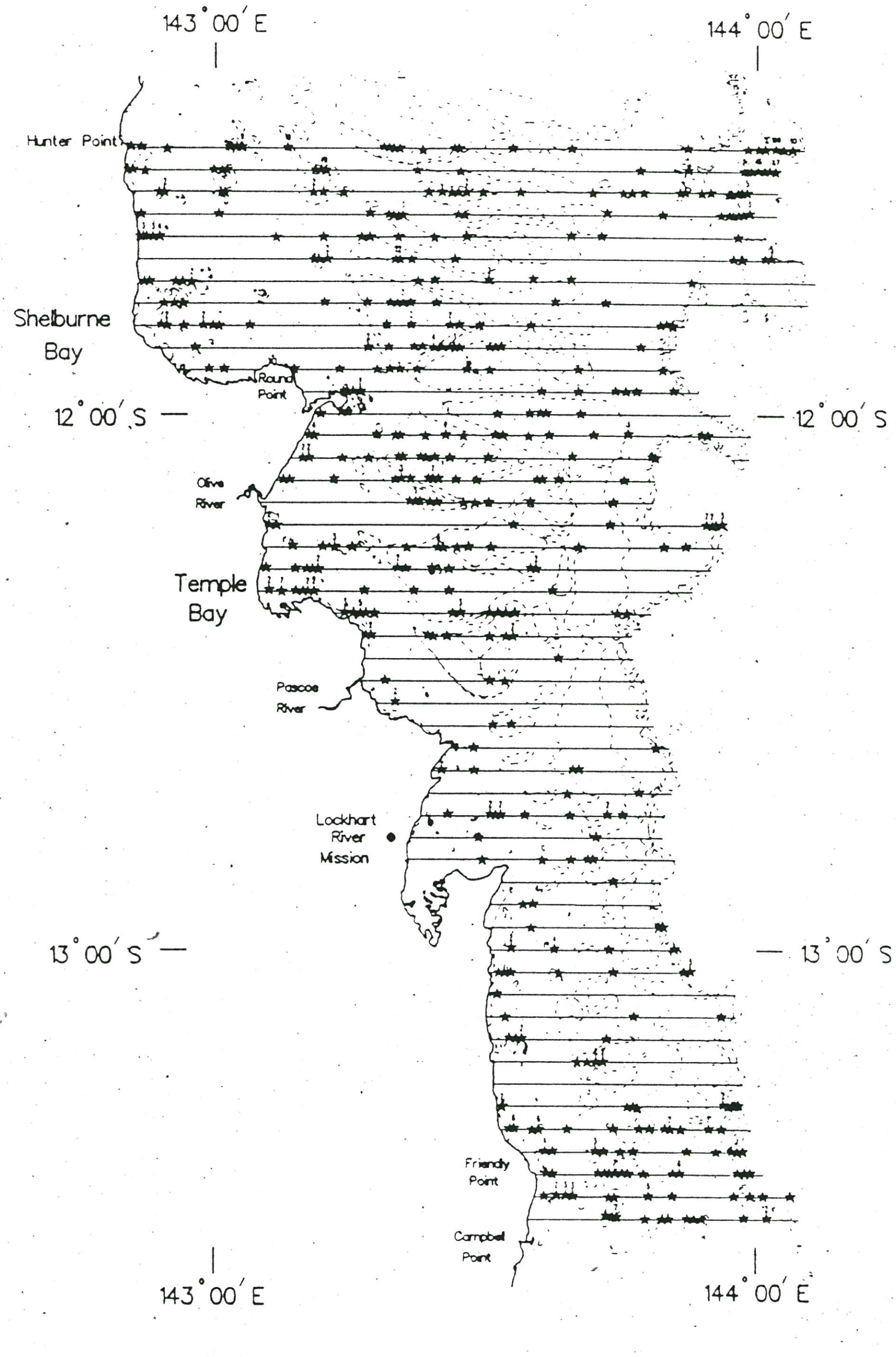

Figure 8. The survey area between Campbell Point and Cape Melville showing the positions of turtle sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

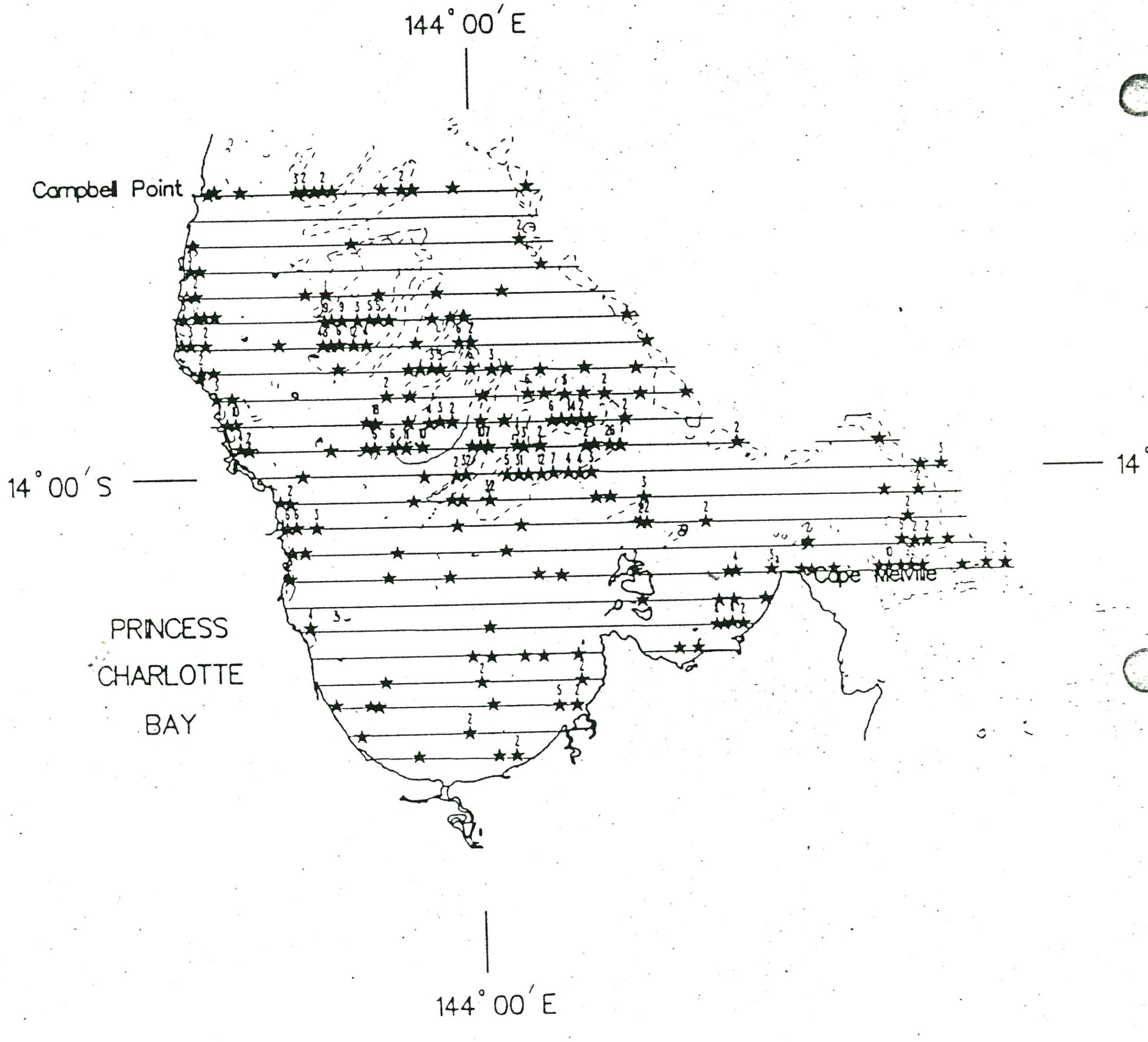

Figure 9. The survey area between Cape Melville and Cape Bedford showing the positions of turtle sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

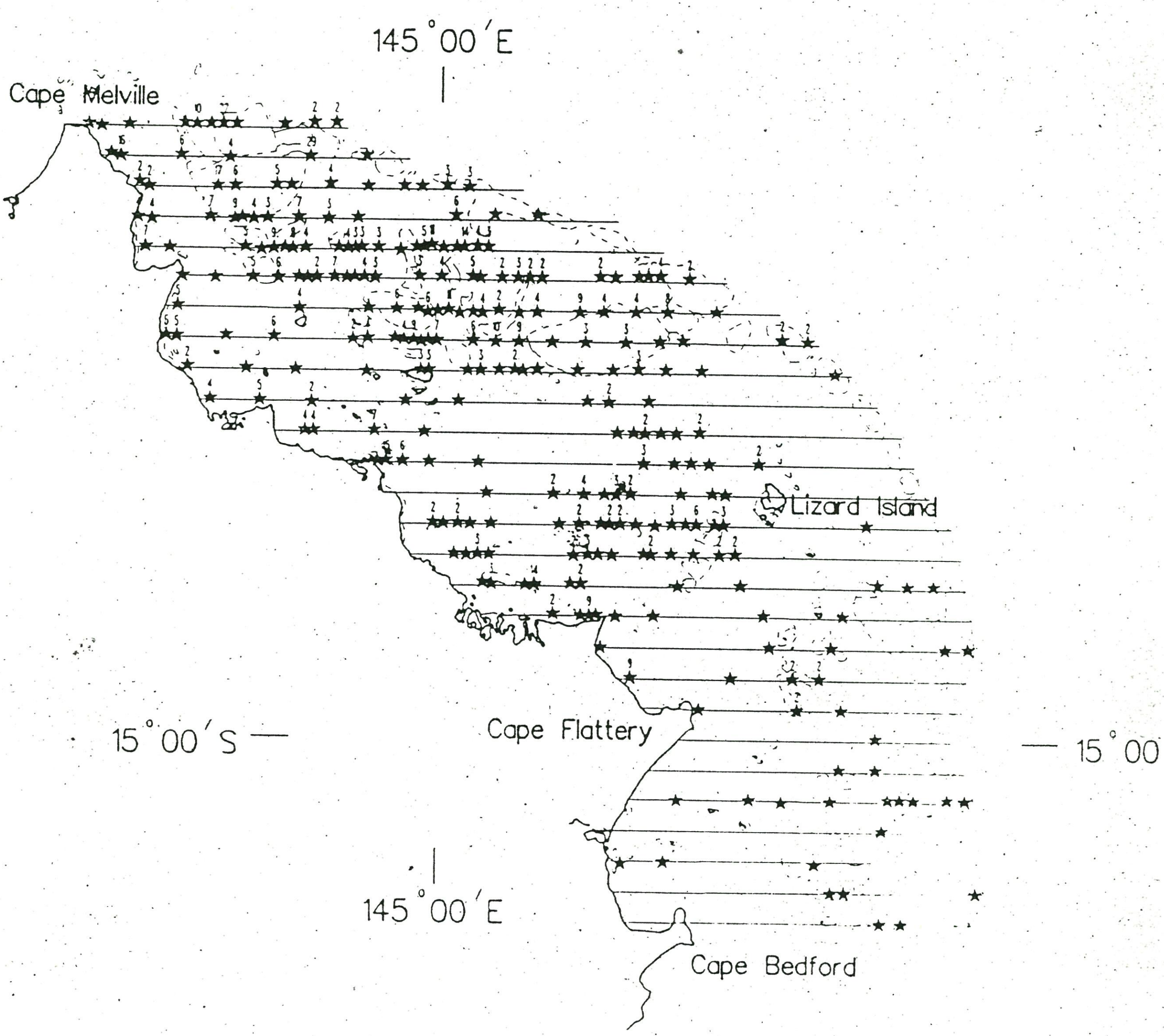

Figure 10. The survey area in Shelburne Bay showing the positions of turtle sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. (MNPB: Marine National Park B Zone; GUA= General Use A Zone; GUB: General Use B Zone).

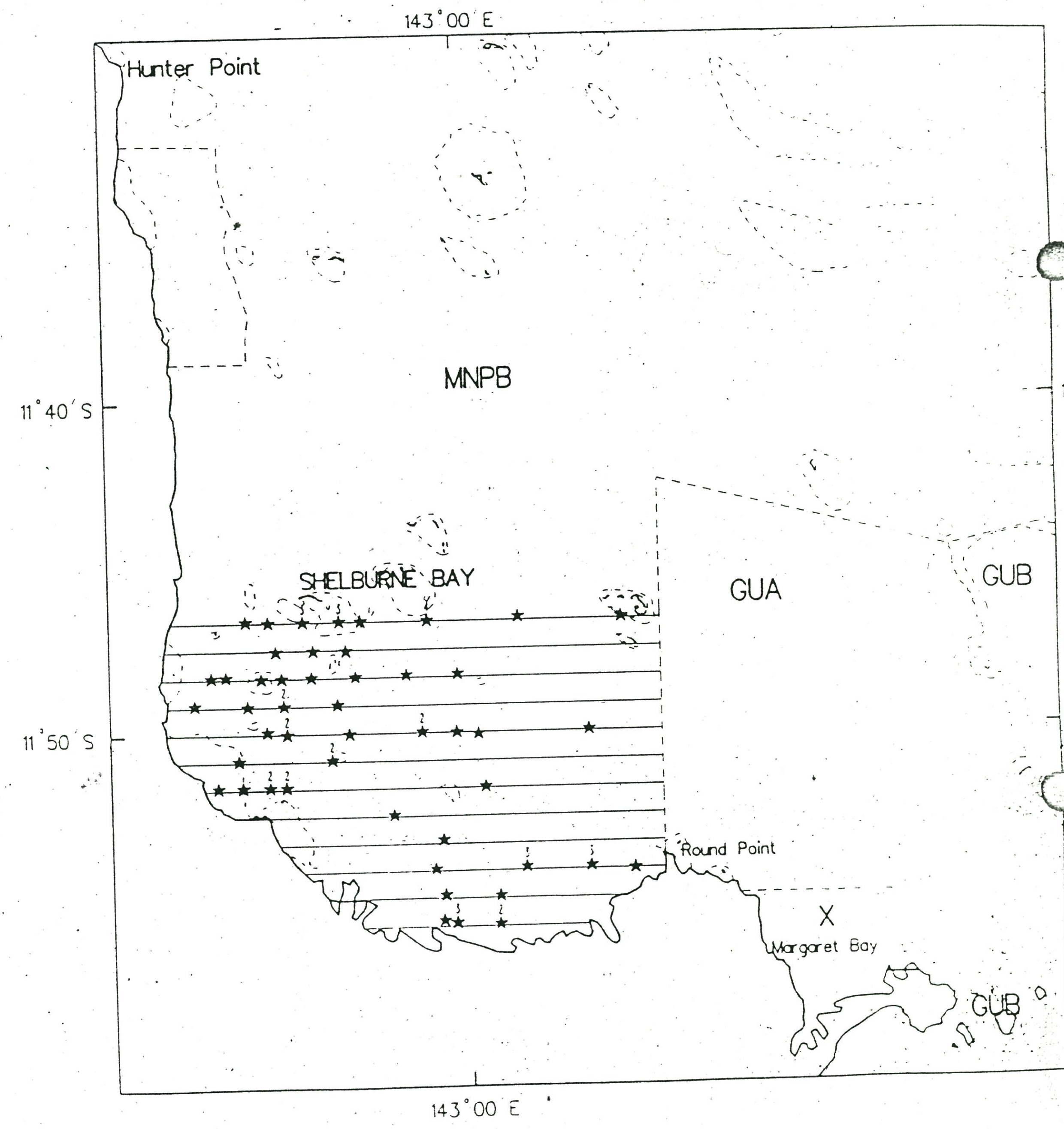

Figure 11. The survey area in Temple Bay showing the positions of turtle sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

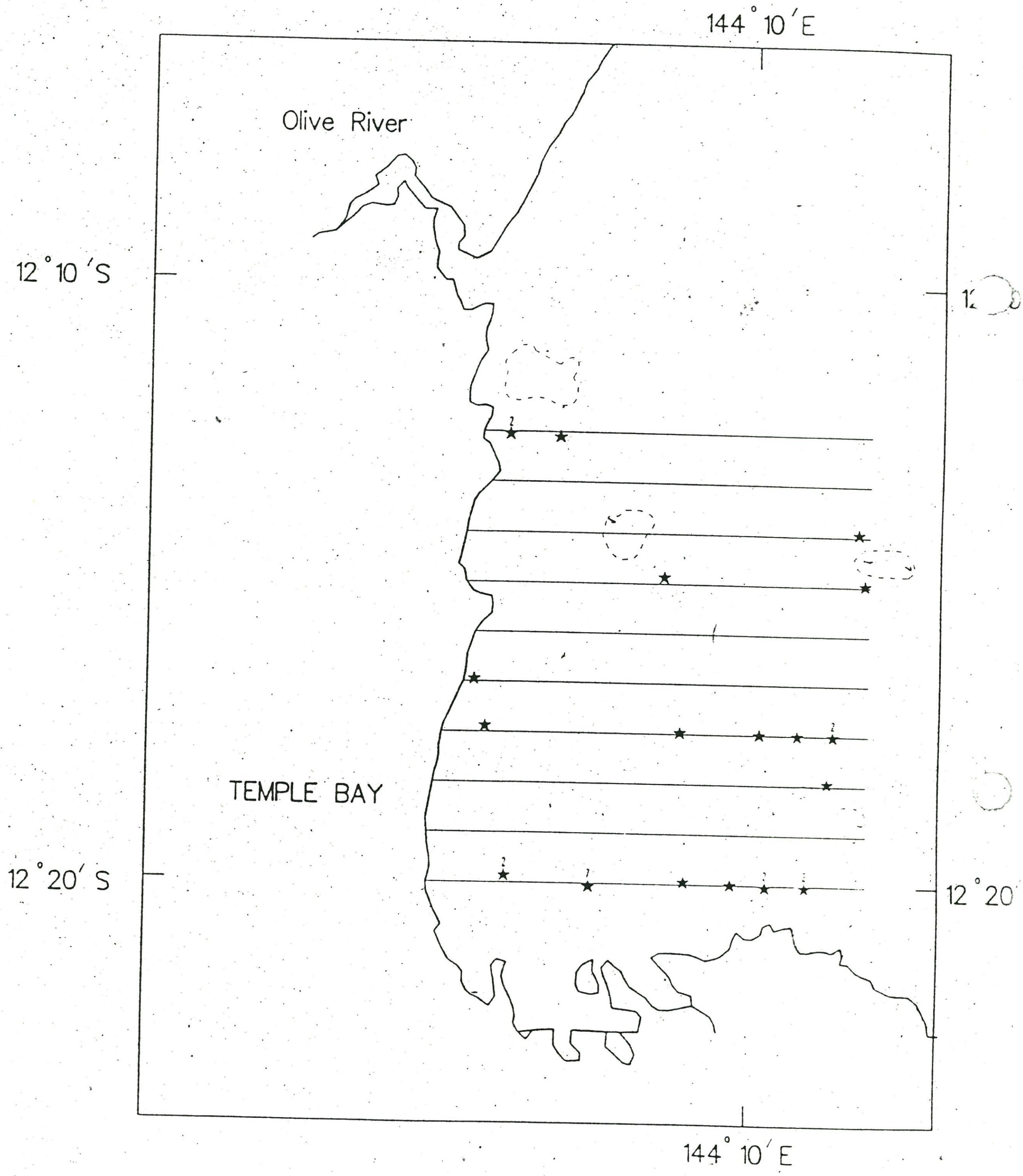

Figure 12. The survey area between Lookout Point and Red Point showing the positions of turtle sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

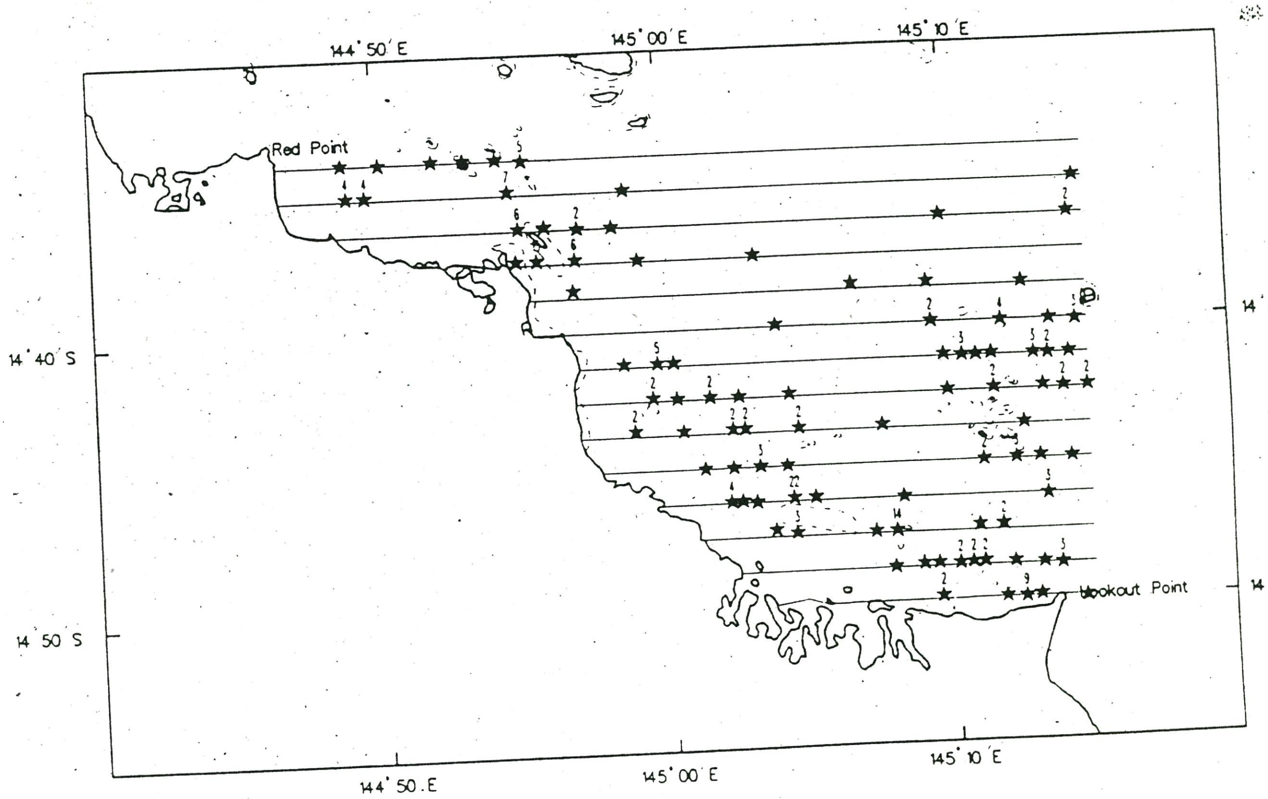

Figure 13. The survey area between Hunter Point and Campbell Point showing the positions of dolphin sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

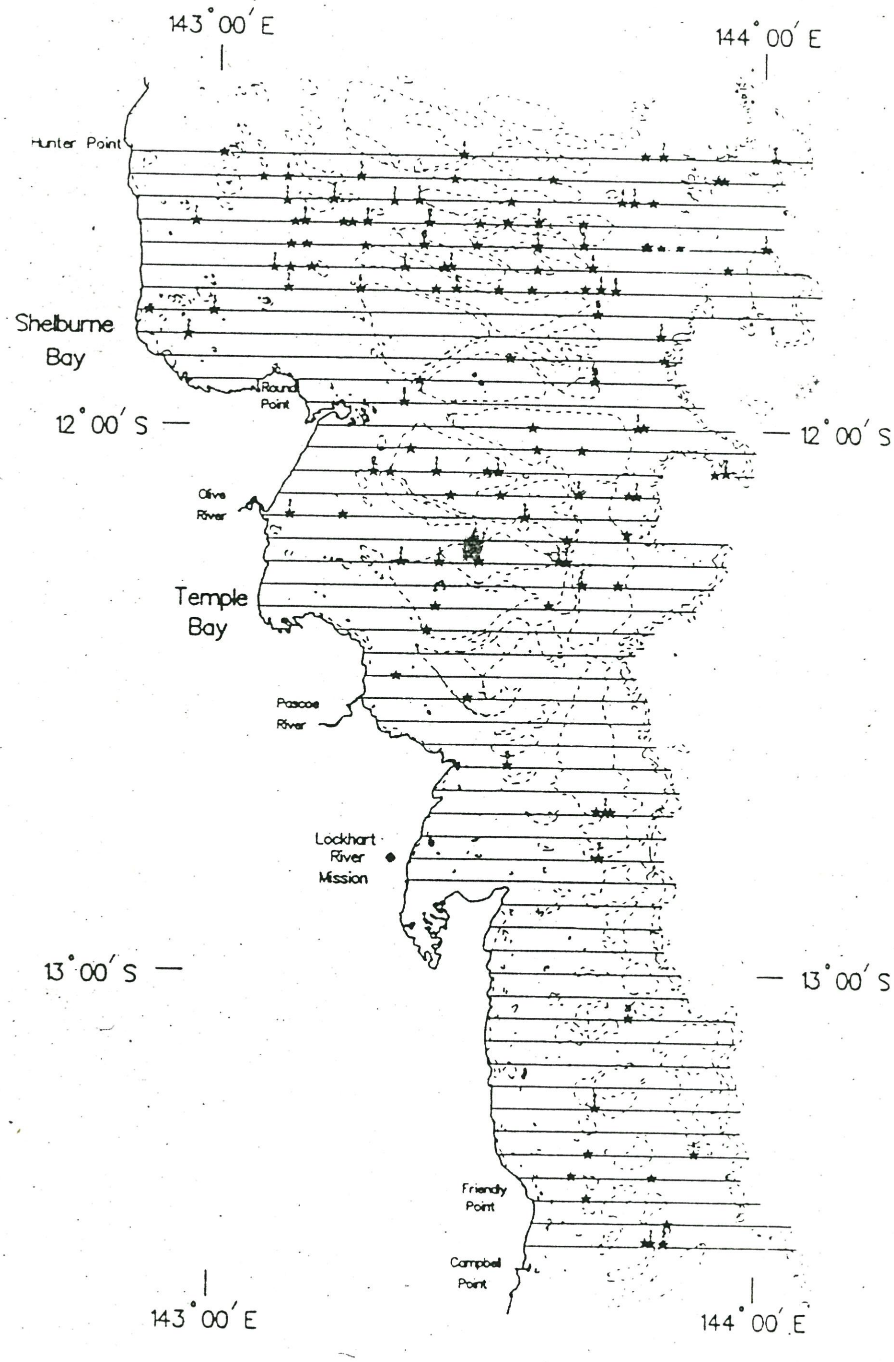

Figure 14. The survey area between Campbell Point and Cape Melville showing the positions of dolphin sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

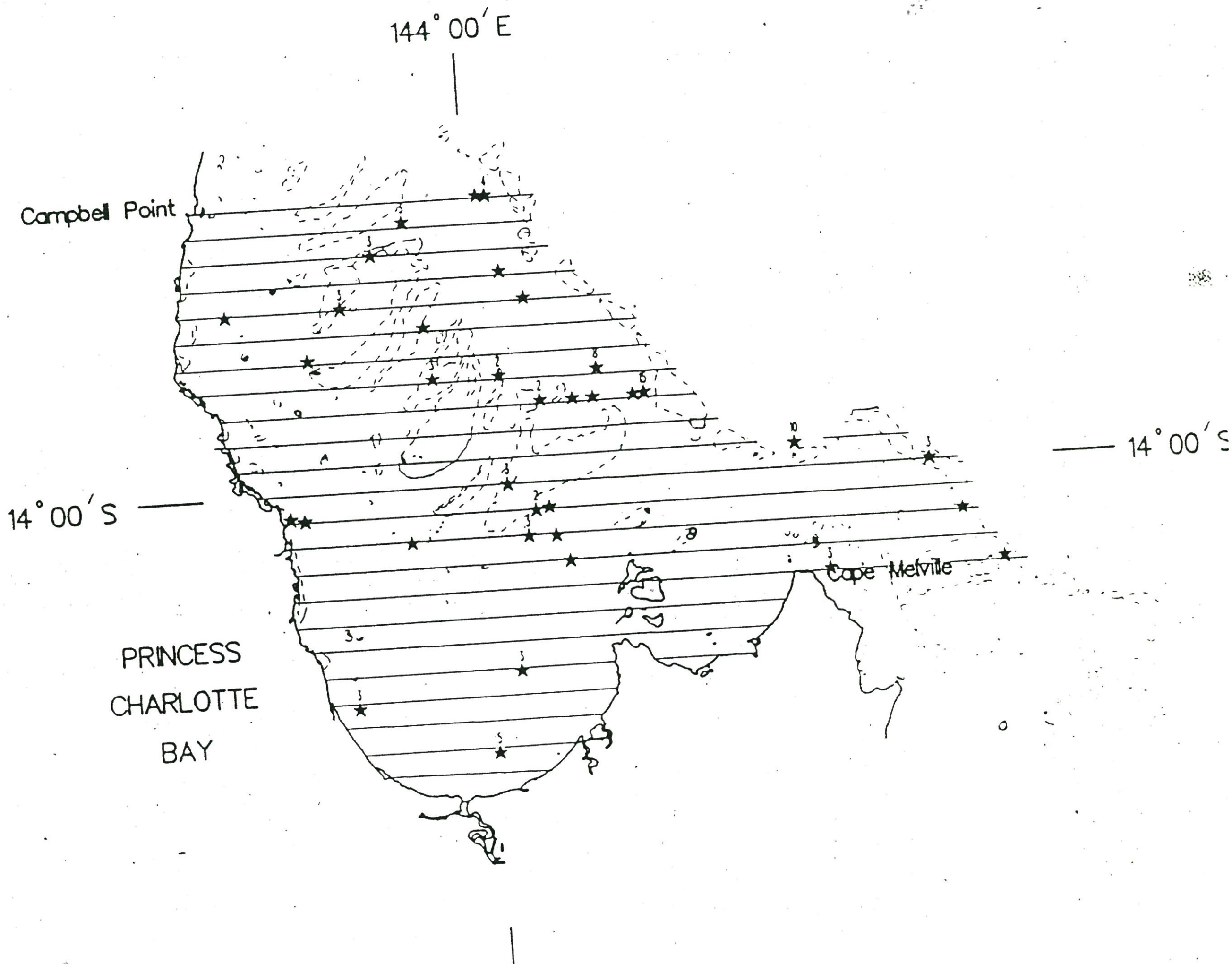

Figure 15. The survey area between Cape Melville and Cape Bedford showing the positions of dolphin sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed.

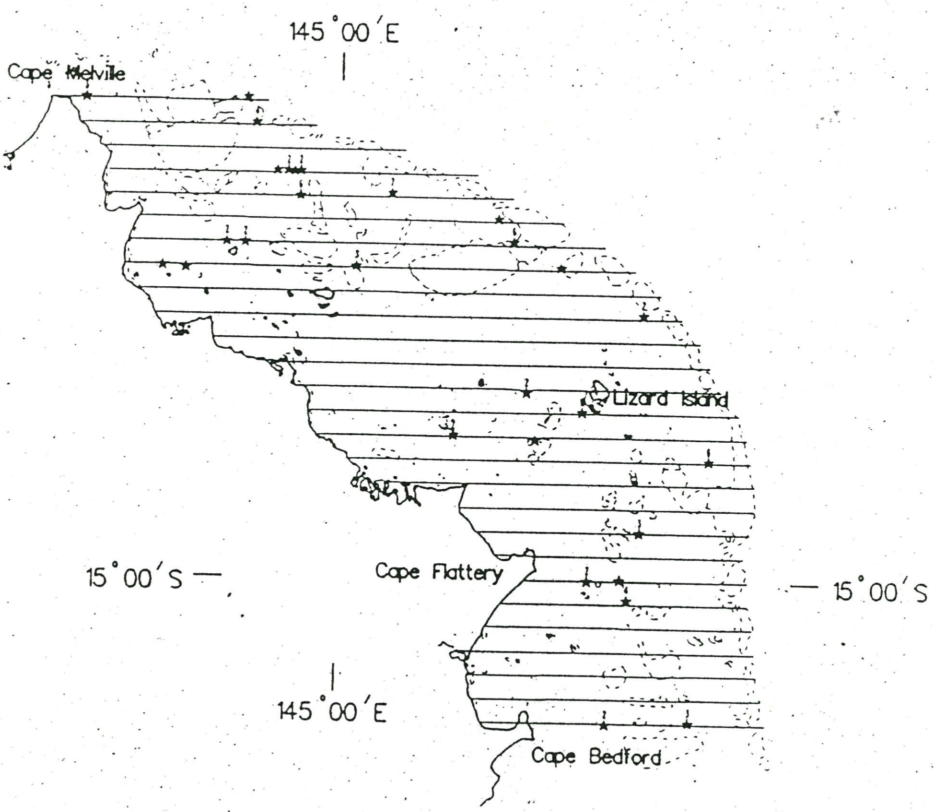

Figure 16. The survey area in Shelburne Bay showing the positions of dolphin sightings in November-December 1990. The numbers associated with the sightings do not necessarily reflect the sizes of the actual groupings observed. (MNPB: Marine National Park B Zone; GUA= General Use A Zone; GUB: General Use B Zone).

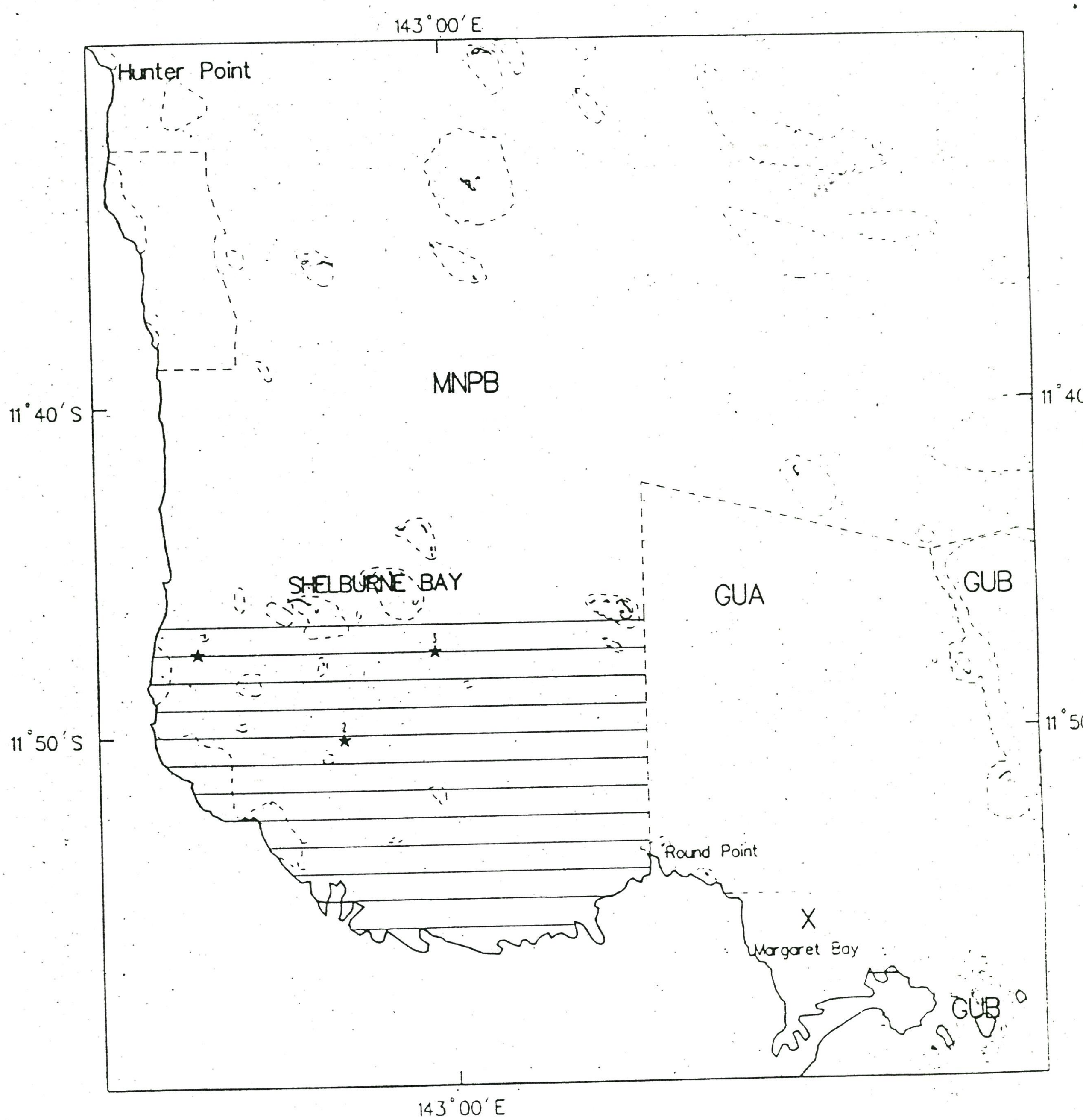

Figure 17. The surve[illegible] between Lookout Point and Red Point showing the positions of dolphin sightings [illegible]ovember-December 1990. The numbers associated with the sightings do not nece[illegible] reflect the sizes of the actual groupings observed.