The Distribution and Abundance of Dugongs in the Northern Great Barrier Reef Marine Park

Running Head: Dugong Aerial Surveys

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Abstract

In 1984 and 1985, dugongs were censused from the air at an overall sampling intensity of 9% over a total area of 31 288 km2 within the northern sections of the Great Barrier Reef Marine Park. Sightings were corrected for perception bias (the proportion of animals visible in the transect which are missed by observers), and availability bias (the proportion of animals that are invisible due to water turbidity) with survey-specific correction factors. There were no significant differences between population and density estimates obtained from repeat surveys of the same areas. The resultant population estimate (± s.e.) was 8 110 ± 1 073 dugongs at an overall density (± s.e.) of 0.26 ± 0.03 km^{-2}, a precision of 13%. Dugongs occurred up to 58 km offshore and in water up to 37 m deep. The highest density of animals was seen on coastal seagrass beds at depths of <5 m. Maps of density and distribution are given. The design and timing of future surveys is also discussed.

Introduction

This paper outlines the results of aerial censuses of dugongs, *Dugong dugon*, conducted over a total area of 31 288 km^2 in the northern sections of the Great Barrier Reef Marine Park in 1984 and 1985.

The aims were:

(1) to estimate the size of the population in order to assess the likely impact of indigenous hunting;

(2) to obtain a precise index of dugong density as a basis for monitoring population changes;

(3) to determine the pattern of regional variation in dugong density within the Great Barrier Reef lagoon and to compare this with the known distribution of seagrass beds;

(4) to investigate whether the pattern of dugong density is temporally constant;

(5) to determine the size of dugong groups and the incidence of calves;

(6) to evaluate and improve dugong aerial survey methodology.

Methods

The coastal zone of 7 952 km^2 between Cape Bedford (15°15'S., 145°21'E.), Cape Melville (14°10'S., 144°30'E.) and the outer Barrier Reef (Fig. 1) was surveyed between 13 and 15 November 1984 at an overall sampling intensity of 7.6%, and again between 1 and 5 November 1985 at an overall sampling intensity of 9.3%. The corresponding area (15 497 km^2) between Campbell Point (13°32'S., 143°35'E.) and Hunter Point (11°30'S., 142°50'E.) was surveyed between 21 and 26 April 1985 at a sampling intensity of 9.0%, and again between 7 and 8 November, and 17 and 21 November 1985. The intervening Princess Charlotte Bay area (7 839 km^2) was surveyed once between 31 October and 7 November 1985 at a sampling intensity of 8.5%. Overall, the sampling intensity for the entire region in the November 1985 survey was 9.0%.

All surveys were held during periods of neap tides to minimize water turbidity. Daily schedules were arranged to avoid severe glare associated with a low or mid-day sun. Repeatability was also increased by surveying only when weather conditions were good; the conditions encountered are summarized in Table 1.

Survey Design

For estimation of regional densities of dugongs, the area was divided into thirteen blocks (Fig. 1) on the basis of sampling intensity, depth contours, and/or Aboriginal hunting activity. Block areas were estimated from 1:250 000 maps using a planimeter or a digitising tablet. The areas of major islands were excluded from the block areas. The areas of small (<3 km^2) islands were included in the block areas.

The transect lines flown on the various surveys are shown in Fig. 1. In order to improve precision, all lines were aligned east-west i.e. approximately perpendicular to the depth contours so that both coastal and some offshore waters were included in each transect. For the 1984 survey of blocks 1 through 4, fourteen lines spaced at intervals of 5′ latitude (9.3 km or 5 nm) extended to the outer Barrier Reef. Each pair of these long lines was interspersed with two shorter lines 3.1 km (1.7 nm) apart and extending 21.6 km from the coast. (The latter is the distance flown in seven minutes at 185 km^{-1} [100 knots]). This survey design, which had a 13% sampling intensity inshore and 4.7% offshore, was developed on the assumption that almost all dugongs would be seen close to the coast. This assumption proved incorrect. As a result, in subsequent surveys lines were flown between the coast and the outer Barrier Reef at intervals of 2.5′ latitude to give a sampling intensity of approximately 8% for both inshore and offshore waters, an arrangement which also aided navigation by providing definite start and end points for each transect. Additional lines were flown in two areas of particular interest to the Great Barrier Reef Marine Park Authority: block 2 (sampling intensity 13.0% in 1984 and 16.3% in 1985) and block 11(sampling intensity 25.9% on both surveys).

Methodology

Survey methodology, data handling and analysis techniques were similar to those used in other surveys as outlined by Marsh and Saalfeld (1988) and Marsh and Sinclair (1989).

Correction Factors

Correction factors for perception bias (groups of dugongs visible on the transect line that were missed by observers) and availability bias (groups of dugongs that were unavailable to observers because of water turbidity) and their associated coefficients of variation were calculated as detailed in Marsh and Sinclair (1989). Mean group sizes and their associated coefficients of variation were calculated from the estimates of the size of groups with less than ten animals obtained during the various surveys.

Analysis

Because transects were variable in area, the Ratio Method (Jolly 1969; Caughley and Grigg 1981) was used to estimate density, population size and their associated standard errors for each block for each survey. Any statistical bias resulting from this method is considered inconsequential in view of the high sampling rate (see Caughley and Grigg 1981). Input data were the estimated number of dugongs (in groups of less than ten animals) for each tandem team per transect calculated using the corrections for perception and availability biases. 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 (Table 2) following the method of Jolly and Watson (1979) (see Marsh and Sinclair 1989). The number of dugongs in groups of greater than ten was added to the estimates of the population and density of the appropriate block at the end of the analysis as outlined in Norton-Griffiths (1978).

Differences in density between years and between blocks for the Cape Bedford - Cape Melville area (blocks 1 through 4), and between seasons and between the inshore and offshore zones for the Campbell Point - Hunter Point area (blocks 6 through 13), were tested separately using analysis of variance with and without measures of cloud cover (oktas) and/or sea state (Beaufort Scale) as covariates. Input data for both 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 within a block (or zone) contributing one density per survey (based on the combined corrected counts of both tandem teams). The densities were log-transformed for analysis to equalize the error variances.

There were two fixed factors (blocks and years) in the analysis of the survey results for blocks 2 through 4. (Block 1 was omitted because of the very low number of sightings in 1984 and the absence of sightings in 1985.) Lines within blocks could not be used as a factor because of the differences between years in the survey design (Fig. 1). An unweighted means analysis was used because the number of transects varied by block.

The same lines were flown during the two surveys of blocks 6 through 13 enabling line to be used as a (random) factor in the analysis. However, block was not used as a factor because dugongs were seen on both surveys in three of the eight blocks only. Accordingly, each line was divided into an inshore and an offshore zone at the 10 fathom (18 m) depth contour. Zone and season were treated as fixed factors. A split-plot design (Snedecor and Cochran 1967 p.369-372) was used for the analysis.

Results and Discussion

Reliability of Observers

A total of 128 groups of dugongs were categorized as being seen by both members of a tandem team. Observer reliability was investigated by comparing the reports of team members which were recorded into separate tracks of the two track tape recorder (Marsh and Sinclair 1989). Observers differed in their estimates of group size on six occasions. All of these groups contained six or fewer dugongs and the maximum difference in the count was two. In three instances, the discrepancy was due to one observer's failure to see a calf. The level of observer disagreement over dugong group sizes on these surveys (4.7%) was substantially lower than the 11% recorded by Marsh and Sinclair (in press) for their Moreton Bay experiment in which observers were required to estimate the size of all dugong groups including those with more than ten animals. The Moreton Bay experiment showed that observers found it difficult to count dugongs in large groups. The use of photographs to count dugongs in groups of ten or more during these surveys in Great Barrier Reef waters has clearly improved the accuracy of group size estimates.

During the Barrier Reef surveys, team members apparently differed over specific identity on six occasions (4.7%), compared with 3% in Moreton Bay. Three of the six discrepancies óccurred when one observer classified an animal as a dolphin while the other identified it as a dugong; twice one observer classified an animal as a dugong when the other was unsure; once apparently the same animal was called a dugong by one observer, a turtle by the other.

On eleven occasions during the Barrier Reef surveys, one team member described a dugong as being on the surface when his counterpart reported it as beneath the surface (8.6%). The categorization of the rear-seat observer was then used in the analyses. The corresponding discrepancy rate for the Moreton Bay experiment was 5% (Marsh and Sinclair in press). As dugongs are sometimes seen to surface and dive as the aircraft passes overhead, some of these differences are probably real.

Dugong Group Size and Composition

There was no significant difference between the distributions of group size frequency observed on the various surveys (Fig. 2) ($G = 7.5$; $P > 0.25$; 8 d.f.). The largest group (subjectively distinct clumping) seen on any of the surveys was twenty; about 68% of groups contained only a single dugong. The proportion of calves (Fig. 2) ranged from 10.4% to 16.3%. Differences between surveys were not significant ($G = 2.62$; $P > 0.50$; 4 d.f.). This is not surprising. Dugongs calve from August-September through December in this area and calves can stay with their mothers for at least 18 months (Marsh *et al.* 1984). The proportion of calves seen overall (14.7%) is similar to that seen during a survey of the Torres Strait area in November 1983 (14.3%) (Marsh 1986a).

Population and Density Estimates

The value of the mean group sizes and correction factors used in obtaining these estimates are summarized in Table 2. The raw data have been listed in Marsh (1986b). Table 3 gives estimates of density and numbers of dugongs per block on the various surveys, with their associated standard errors. Two standard errors have been listed for each estimate: (1) based on the difference in corrected dugong counts between transects, (2) incorporating the errors in estimating the appropriate correction factors and mean group sizes as well. The resultant increase in the standard error of (2) compared with (1) is relatively small and is mostly due to the availability correction factor which typically has the highest coefficient of variation of the three components of the error summarized in Table 2.

The population estimates sum ($\pm$ s.e.) to 8 110 $\pm$ 1 073 dugongs for the whole region in November 1985 at an overall density ($\pm$ s.e.) of 0.26 $\pm$ 0.03 dugongs per km^2, a precision (s.e./$\bar{x}$) of 13%.

Fig. 3 is a smoothed dugong density distribution map based on the results of the November 1985 surveys with an adjacent map showing the corresponding densities for the Cape Bedford to Cape Melville area based on the results of the November 1984 surveys. These maps should be useful when the zoning plans of the northern sections of the Great Barrier Reef Marine Park are revised. A map of the known seagrass beds in the region (Fig. 4) is provided for comparison. Overall 52% of dugong sightings were associated with known seagrass beds. Fifty-six percent of animals were sighted in depths of less than 5 m (Fig. 5). Coles *et al.* (1987) found that seagrass biomass is greatest in 2-6 m of water along this coast and recorded thirteen species of seagrass at sites less than 2 m deep. Most of the areas where the highest density (>1 per km^2) of dugongs were observed support extensive inshore beds of seagrass species such as *Halodule uninervis*, *Halophila ovalis* and *Halophila spinulosa*, and *Cymodocea serrulata* (Coles *et al.* 1987). These genera also tend to predominate in the stomachs of dugongs from north Queensland (Marsh *et al.* 1982).

Dugongs were sighted up to 58 km from the coast in water of depths ranging to 37 m (Fig. 5). The reasons for their venturing so far offshore is not understood as the distribution of offshore seagrass beds is poorly known. However, *Thallasia hemprichii* and *Cymodocea rotundata* have been recorded from reef platforms in this region (Coles *et al.* 1987), and dugongs were observed on offshore reefs especially in the Princess Charlotte Bay area (block 5). *Halophila decipens* is the only seagrass recorded at depths of greater than 11 m in the Great Barrier Reef lagoon (Coles *et al.* 1987) where it has been recorded from depths of up to 68 m (P. Arnold, in Lanyon 1986). All these genera are eaten by dugongs in this region (Marsh *et al.* 1982).

The results of the analysis of variance used to investigate the differences between the surveys of blocks 2, 3, and 4 held in November in both 1984 and 1985 (Table 4) indicated that densities differed significantly between blocks ($P < 0.001$) but not between years ($P = 0.18$). There was a significant interaction between years and blocks ($P < 0.05$) indicating that the dugongs were dispersed differently in different years. In particular, the results suggest movements of large numbers of dugongs between the high density inshore block 2 and the other blocks. Inclusion of Beaufort sea state as a covariate in the analysis increased the probability of there being no difference in dugong density between years to 0.54, indicating that the lower observed density in 1985 could be explained by the rougher seas (Table 1).

Comparison of the results of the April (post-wet season) and November (pre-wet season) surveys of blocks 6 through 13 in 1985 (Table 5) indicated that densities differed significantly between lines and particularly between zones, with the density significantly higher in the inshore zone than in the offshore zone. However, there was no significant difference in density between seasons, nor was there any significant season by zone interaction indicating that the pattern of dispersion was similar for both surveys. The inclusion of Beaufort sea state and cloud cover as covariates in the analyses made little difference to the result (Table 5) and did not alter any of the conclusions.

The 1984 and 1985 dugong population estimates obtained for blocks 1 through 4 were close, as were the April and November 1985 estimates of the population of blocks 6 through 9 (Table 3). Such agreement, despite the different weather conditions under which the surveys were conducted (Table 1), suggests that the use of survey-specific correction factors to correct for perception and availability biases was successful.

Design of Future Surveys

The population and density estimates obtained for the Cape Bedford - Cape Melville survey in 1984, in which inshore blocks 1, 2 and 3 were surveyed at an intensity of about 13% and the offshore block 4 at an intensity of about 5% (Fig. 1), had a precision based on the standard sampling theory estimates only of 15% (Table 3). This is a substantial improvement on the corresponding precision of 24% obtained for the same area in 1985 when blocks 1, 3 and 4 were surveyed at an intensity of about 8% and block 2 at an intensity of 16%. Future surveys of the areas from Cape Bedford to Cape Melville should be stratified along the lines of the November 1984 survey (see Fig. 1).

Significant numbers of dugongs were observed on the large offshore reefs in Princess Charlotte Bay in November 1985 (Fig. 3). The survey design used for this area (block 5) seems satisfactory as it returned a precision (based on standard sampling theory estimates only) of 16%. However, the corresponding values achieved for the surveys of the area between Campbell Point and Hunter Point (blocks 6-13) were 24%. Most dugongs were seen close to the coast in this region suggesting that precision could be improved by increasing the sampling fraction in the inshore area and reducing it in the offshore area along the lines used for the November 1984 survey of blocks 1 through 4 (Fig. 1).

It is estimated that if the survey designs were modified as outlined above, the precision of the population estimate for the whole area from Cape Melville to Hunter Point (based on standard sampling theory only) could be improved from the 12% obtained in 1985 to about 9% without increasing survey costs. Incorporating the errors in estimating the mean group size and correction factors would be expected to decrease the precision to about 11%.

Timing of future surveys

Dugongs are long-lived animals with a life-span of up to 70 years, a minimum pre-reproductive period of 9-10 years, and a mean calving interval which has been estimated as 3-7 years for various populations (Marsh *et al.* 1984; Marsh 1986a). Marsh (1986a) has calculated that even with the most optimistic combination of these parameters, a low schedule of natural mortality and no anthropogenic causes of mortality, the maximum rate of increase is likely to be of the order of 5% per year. Under the present zoning and management regulations, the level of man-induced mortality in the northern sections of the Great Barrier Reef Marine Park should be low. Thus, barring catastrophes, the annual rate of population change is also expected to be relatively low.

When designing a monitoring program for a vulnerable species such as the dugong, the consequences of failing to pick up a declining trend are more serious than the consequences of deciding that a declining trend is occurring when it is not. Thus it is particularly important to consider Type 2 statistical errors. If this expected slow rate of dugong population change is to be monitored within an acceptable range of statistical error, the precision of the population estimates will have to be high. Under a constant intensity of sampling, the precision of a population estimate improves as the size of the survey area is increased as evidenced by Table 3. Thus future surveys for cover large areas e.g. the whole region from Cape Bedford to Hunter Point. October-November is the only time of year when weather conditions are likely to be optimal for a period long enough to survey such large areas adequately, making it unrealistic to plan more than one survey of the area in any one year.

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 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) improvements in survey design would increase the precision to 11%; (2) the coefficient of variation is inversely related to the square root of abundance as predicted for strip transects by Seber (1982). The probabilities of both a Type 1 error α and a Type II error β were set at 0.05.

It is estimated that it would take 9 years of annual surveys i.e. ten surveys to be able to detect such a decline with 95% confidence. Meanwhile, a dugong population declining at 5% per year would have been reduced to 63% of its size at the time of the first survey. A preliminary indication of such a trend could be obtained more quickly by allowing α and/or β to assume larger values. Of course, a more rapid decline 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 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 1987, Table 2). For example, two dugong surveys 10 years apart could establish with 95% confidence that a population decreasing at 5% per year is declining. Such a low survey frequency would obviously provide substantially less information than annual surveys.

Any sampling strategy will be a compromise between information and cost. The Great Barrier Reef Marine Park Authority is required by law to revise zoning plans every 5 years. Given the expense, time and personnel needed to conduct large-scale surveys in remote areas, we suggest that this would also be an appropriate interval between dugong surveys in the northern sections of the Great Barrier Reef Marine Park.

Acknowledgments

We thank the Great Barrier Reef Marine Park Authority for funding this research; the observers: B. Barker-Hudson, D. Devine, W.J. Freeland, G.E. Heinsohn, N. Hedgecock, J. Lanyon, M. Simmons and A. Smith; the pilots: M. Ayrey and R. Videtta; Cape Flattery Mine, L. Goldman, P. Pini, the Queensland National Parks and Wildlife Service, and Sir Sidney Williams for their logistical support; L.M. Marsh for programming assistance; D.F. Sinclair for statistical advice, and T. Gerrodette for access to unpublished manuscripts. The manuscript benefitted from the criticisms of K. Radway Allen, Peter Bayliss, Graeme Caughley, Rhondda Jones and Dennis Sinclair.

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Legend to figures

Fig. 1 Survey areas, showing the survey blocks (1-13) and transect lines used in the 1985 surveys. The transects flown in November 1984 are shown in the adjacent map. The boundary between the inshore blocks 1, 2 and 3 and the offshore block 4 is 21.6 km from the coast (i.e. all transects in blocks 1, 2 and 3 are 21.6 km long). The 18 m (10 fathom) line forms the boundary between the inshore blocks 6, 8, 10, 11 and 12 and the offshore blocks 7, 9 and 13. (Adapted from Marsh and Saalfeld 1988.). The areas of the survey blocks (km^2) are as follows: Block 1: 1 004; 2: 665; 3: 1 050; 4: 5 233; 5: 7 839; 6: 451; 7: 1 561; 8: 1 194; 9: 4 600; 10: 259; 11: 396; 12: 452; 13: 6 584.

Fig. 2 Frequency histograms showing details of dugong group sizes on each survey and the proportion of dugongs seen in groups of various sizes over all surveys (a) all groups (b) groups containing calves □ groups with one calf; ■ groups with two calves; ◪ one group with one calf, one group with two calves.

Fig. 3 The distribution of dugong density in the survey area from Cape Bedford to Hunter Point in November 1985. The corresponding figure for the survey area from Cape Bedford to Cape Melville in November 1984 is also provided.

Fig. 4 The approximate distribution and density of inshore seagrass beds in the survey area provided for comparison with Fig. 3. The ground-truthed seagrass data are from Coles *et al*. (1985) and adapted from Marsh and Saalfeld (1988).

Fig. 5 Frequency histograms showing the number of dugongs seen in water of various depths on each survey and the proportion of dugongs seen in water of various depths over all surveys. These depths were obtained from marine charts and have not been corrected for tidal levels at the time of the survey. In view of the paucity of information for this area, these data must be regarded as very approximate.

Table 1 Weather conditions encountered on each survey.

	November 1984	April 1985	November 1985 Blocks 1-7	November 1985 Blocks 8-13
Wind speed ($km\ h^{-1}$)	$\leq$20	$\leq$30	$\leq$28	$\leq$19
Cloud cover (oktas)	0-2	2-7	0.5-5	0-4
Minimum cloud height (m)	650-1000	200-2500	460-1525	305-610
Beaufort Sea State mode (range)	1 (0-3)	2 (1-3.5)	2.5 (0-4)	1 (0-3)
Glare [a,b] mode (range)	1 (0-2)	2 (0-3)	1 (0-2.5)	1 (0-2.5)
Visibility (km)	>10	8->10	8->10	>20->50

a Worse side of aircraft

b Scale 0 = none, 1 = <25% of field of view affected by glare, 2 = 2.5 $\leq$ 50%, 3>50%.

Table 2: Details of group size estimates and correction factors used in the population estimates

Date of survey	Blocks: lines	Group size mean (s.e./$\bar{x}$)	Number of observers P[g]	Number of observers S[g]	Perceptual Correction Factor estimate (Cp^h) P[g]	Perceptual Correction Factor estimate (Cp^h) S[g]	Availability Correction Factor estimate (Ca^h)
November 1984	blocks 1-4	1.62 (0.04)	1[a]	1[a]	1.13 (0.01)	1.13 (0.01)	2.48 (0.14)
April 1985	blocks 6-13	1.57 (0.07)	1[b]	2	1.58 (0.07)	1.20 (0.07)	1.95 (0.19)
November 1985[e]	blocks 1-4; 5: 9-23; 6 & 7; 8 & 9: 10-12	1.47 (0.04)	2	2	1.10 (0.02)	1.15 (0.04)	2.62 (0.12)
November 1985[e]	block 5: 1-8	1.47 (0.04)	2	1[c]	1.10 (0.02)	1.53 (0.04)	2.62 (0.12)
November 1985[f]	blocks 8 & 9: 13-32; 10; 11: 39-42; 12: 43-48; 13: 33-48	1.53 (0.09)	2	2	1.06 (0.03)	1.02 (0.01)	1.44 (0.23)
November 1985[f]	blocks 11: 50-57; 12 & 13: 49	1.53 (0.09)	1[d]	2	1.42 (0.03)	1.02 (0.01)	1.44 (0.23)

[a] Based on correction factor for starboard rear seat observer on November 1985 survey blocks 8-13 (who saw a similar number of dugong groups to port observer on this survey), when weather conditions similar to this survey.

[b] Port correction factor based on starboard mid-seat observer this survey (who saw a similar number of dugong groups).

[c] Training transects for starboard mid-seat observer. Starboard correction factor based on correction factor starboard rear-seat observer for remainder of this survey.

[d] Training transects for port mid-seat observer. Port correction factor based on correction factor port rear-seat observer for remainder of this survey.

[e] Blocks flown October 31 - November 8, 1985.

[f] Blocks flown November 17 - 21, 1985.

[g] P = port; S = starboard.

[h] Coefficient of variation of associated correction factor

Table 3: Estimated densities and numbers of dugongs on the various surveys. The values are ± standard error incorporating the errors resulting from sampling, and in estimating mean group size and the correction factors. The numbers in brackets represent the standard errors resulting from sampling only.

Block	Initial Survey		November 1985 Survey	
	Density per km2	Numbers	Density per km2	Numbers
1	0.15 ± 0.06 (0.06)[a]	149 ± 61 (58)[a]	0	0
2	1.22 ± 0.45 (0.43)[a]	812 ± 299 (288)[a]	2.47 ± 0.87 (0.82)	1644 ± 570 (543)
3	0.93 ± 0.23 (0.21)[a]	974 ± 244 (223)[a]	0.26 ± 0.10 (0.10)	272 ± 110 (106)
4	0.18 ± 0.04 (0.04)[a]	964 ± 231 (208)[a]	0.12 ± 0.05 (0.05)	626 ± 256 (248)
sub - total				
blocks 1 - 4	0.36 ± 0.06 (0.06)[a]	2899 ± 454 (423)[a]	0.32 ± 0.08 (0.08)	2542 ± 634 (606)
precision[c]		0.16 (0.15)[a]		0.25 (0.24)
5	N/A	N/A	0.46 ± 0.09 (0.07)	3630 ± 714 (585)
precision[c]				0.20 (0.16)
6	2.07 ± 1.04 (0.99)b	934 ± 471 (448)[b]	1.76 ± 0.94 (0.92)	792 ± 423 (414)
7	0.10 ± 0.05 (0.04)b	151 ± 73 (68)[b]	0	0
8	0.74 ± 0.23 (0.19)[b]	878 ± 271 (226)[b]	0.51 ± 0.16 (0.11)	611 ± 192 (131)
9	0[b]	0[b]	0.03 ± 0.02 (0.02)	134 ± 104 (99)
10	0[b]	0[b]	0.09 ± 0.09 (0.09)	24 ± 23 (22)
11	0.53 ± 0.17 (0.15)[b]	209 ± 68 (59)[b]	0.56 ± 0.20 (0.18)	222 ± 81 (71)
12	0[b]	0[b]	0.06 ± 0.06 (0.06)	27 ± 26 (25)
13	0[b]	0[b]	0.02 ± 0.01 (0.01)	128 ± 83 (76)
sub - total				
blocks 6 - 13	0.13 ± 0.04 (0.03)[b]	2172 ± 552 (510)[b]	0.13 ± 0.03 (0.03)	1938 ± 491 (459)
precision[c]		0.25 (0.24)[b]		0.25 (0.24)
Total for November 1985 survey			0.26 ± 0.03 (0.03)	8110 ± 1073 (959)
precision[c]				0.13 (0.12)

[a] November 1984

[b] April 1985

[c] (s.e./$\bar{x}$)

N/A not available

Table 4: Summary of analysis of variance comparing observed dugong density in the Great Barrier Reef Marine Park between Cape Bedford and Cape Melville by blocks and by years (1) without covariates (roman print) and (2) with Beaufort sea state as a covariate[a] (*italics*).

Sources of variation	Sum of squares[b]		d.f		F		Significance of F	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Blocks	13.696	*14.176*	2	*2*	18.932	*19.694*	0.000	*0.000*
Years	0.827	*0.134*	1	*1*	2.228	*0.373*	0.134	*0.543*[c]
Blocks by years	2.753	*2.560*	2	*2*	3.806	*3.557*	0.026	*0.033*
Residual	30.383	*29.872*	84	*83*				
Regression		*0.510*		*1*		*1.418*		*0.237*

[a]. Assumption that regression slopes the same for all cells was not violated ($P = 0.612$).

[b]. Data transformed using *ln*(X + 0.33 smallest non-zero density).

[c]. The probability of no significant difference in dugong density between years was greatest ($P = 0.543$) when Beaufort sea state was used as the only covariate. The corresponding proability with cloud cover as a covariate was $P = 0.112$ and with Beaufort sea state and cloud cover as combined as covariates $P = 0.328$. The assumption that regression slopes are the same for each cell was not violated with cloud cover ($P = 0.283$) as a covariate, but was violated when Beaufort sea state and cloud cover were both used as covariates ($P = 0.044$).

Table 5: Summary of analysis of variance comparing observered dugong density in the Great Barrier Reef Marine Park between Campbell Point and Hunter Point by blocks and by season[a].

Source of variation	Sum of squares[b]	d.f.	*F*	Significance of *F*
Lines	22.053	48	1.532	0.039
Main plot comparisons				
Zones (inshore/offshore)	15.917	1	28.890	0.000
Main plot error	26.445	48		
Sub-plot comparisons				
Season	0.016	1	0.054	0.817
Season by zone	0.001	1	0.004	0.950
Sub-plot error	28.798	96		

[a]. The probability of there being no significant differences in dugong density between seasons was $P = 0.957$ with Beaufort sea state as a covariate, $P = 0.798$ with cloud cover as a covariate, and $P = 0.731$ with both Beaufort sea state and cloud cover as covariates.

[b]. Data transformed using ln(X + 0.33 smallest non-zero density).

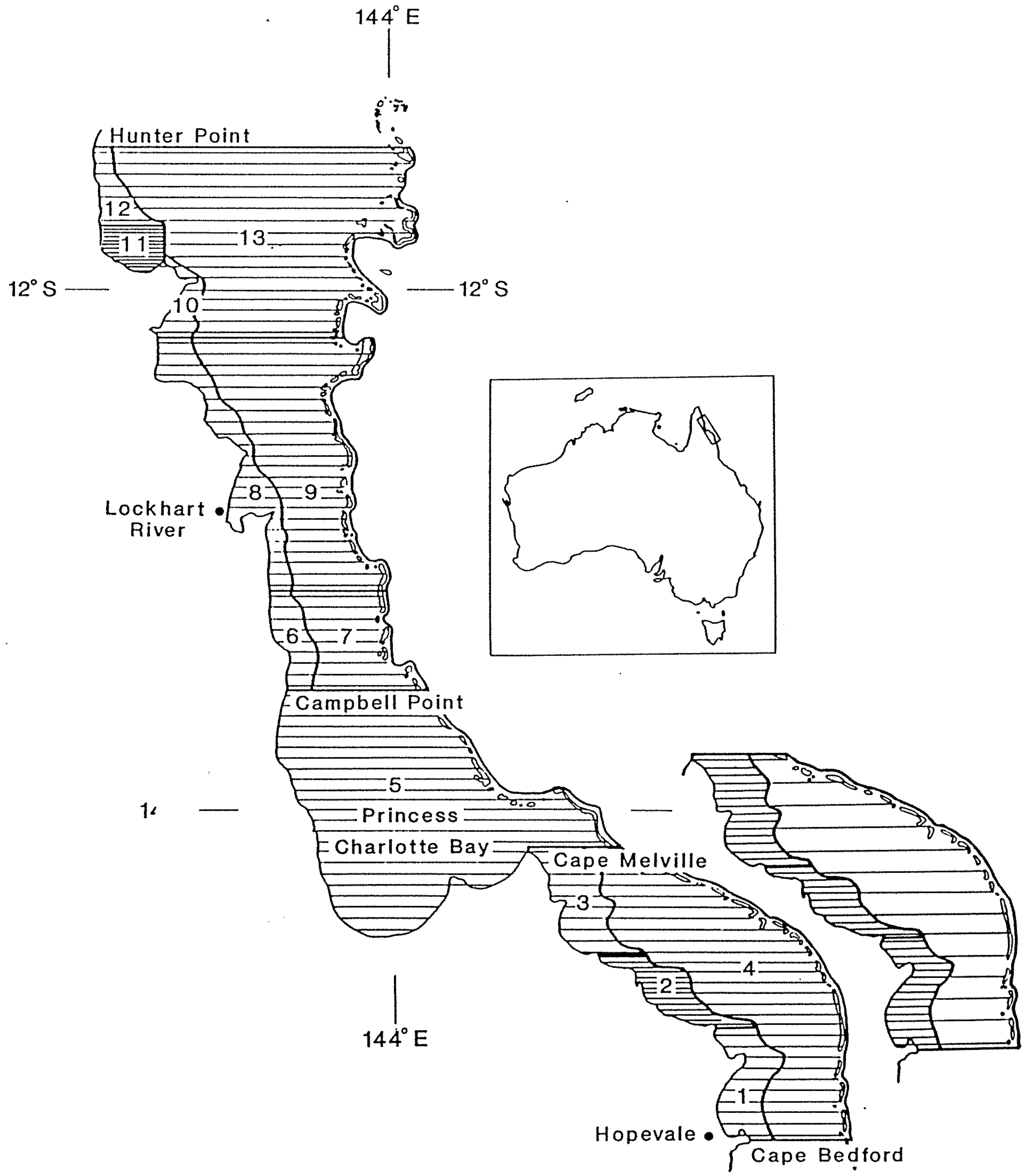

Fig. 1 Survey areas, showing the survey blocks (1-13) and transect lines used in the 1985 surveys. The transects flown in November 1984 are shown in the adjacent map. The boundary between the inshore blocks 1, 2 and 3 and the offshore block 4 is 21.6 km from the coast (i.e. all transects in blocks 1, 2 and 3 are 21.6 km long). The 18 m (10 fathom) line forms the boundary between the inshore blocks 6, 8, 10, 11 and 12 and the offshore blocks 7, 9 and 13. (Adapted from Marsh and Saalfeld 1988.). The areas of the survey blocks (km^2) are as follows: Block 1: 1 004; 2: 665; 3: 1 050; 4: 5 233; 5: 7 839; 6: 451; 7: 1 561; 8: 1 194; 9: 4 600; 10: 259; 11: 396; 12: 452; 13: 6 584.

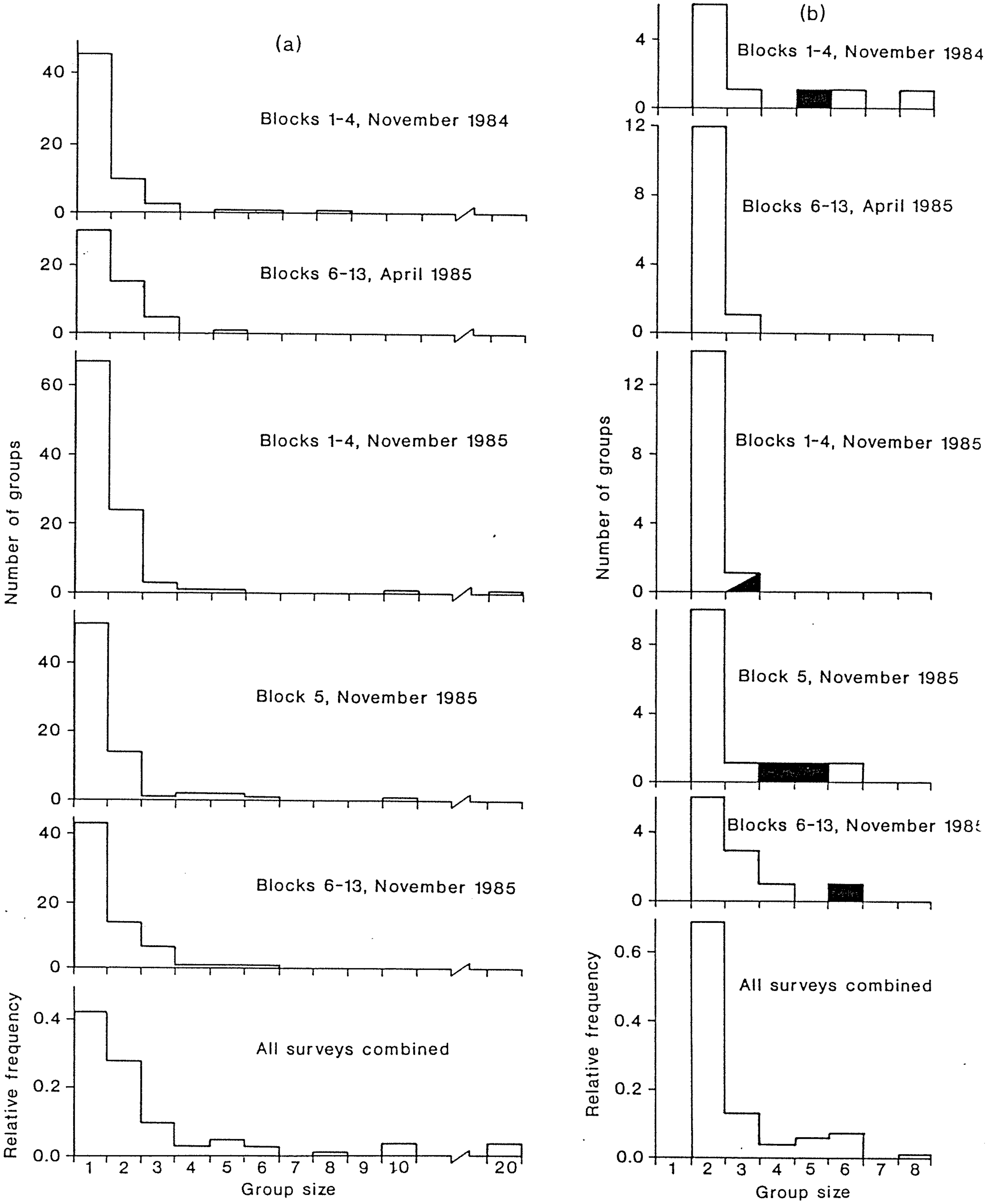

Fig. 2 Frequency histograms showing details of dugong group sizes on each survey and the proportion of dugongs seen in groups of various sizes over all surveys (a) all groups (b) groups containing calves ☐ groups with one calf; ■ groups with two calves; ◪ one group with one calf, one group with two calves.

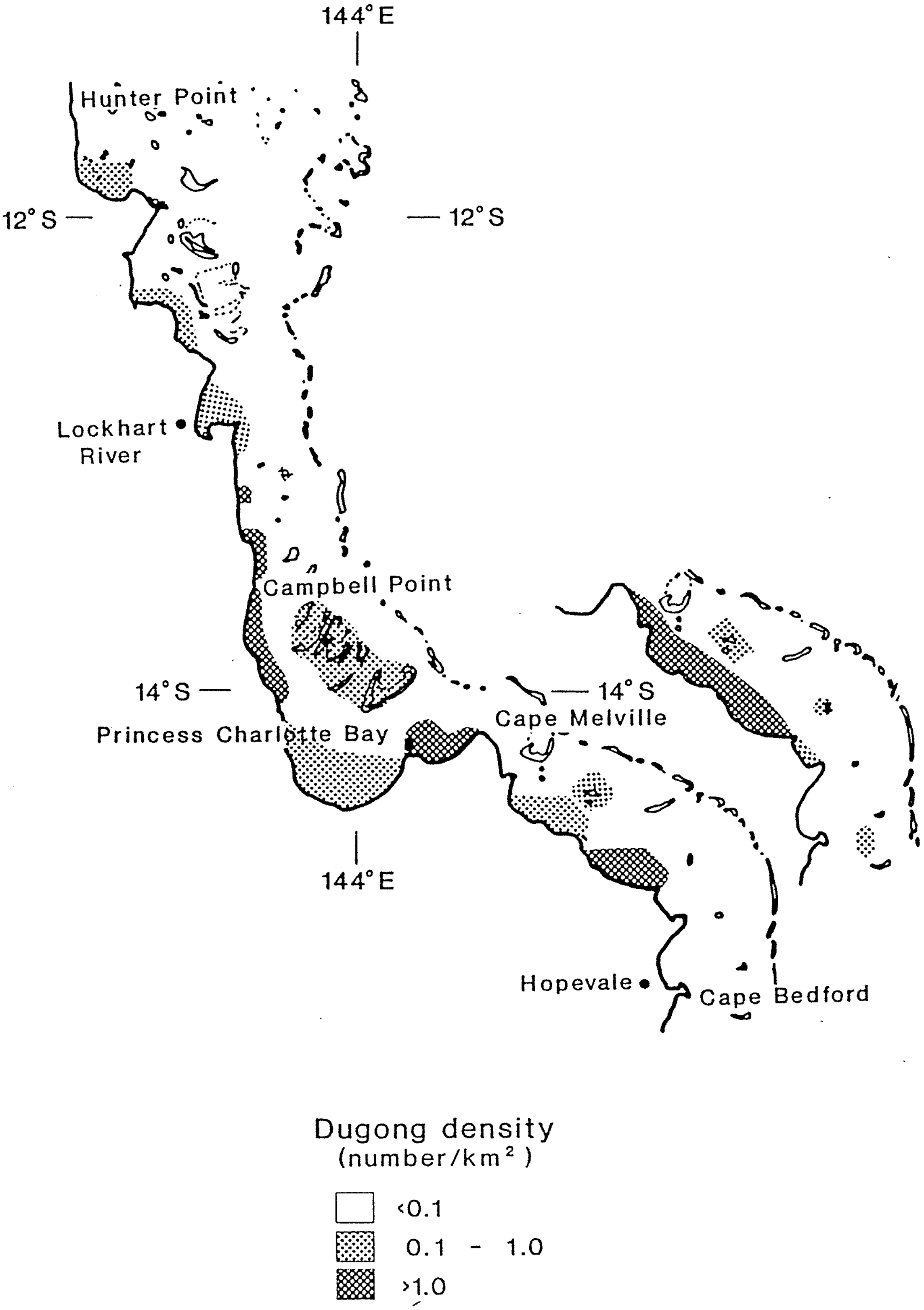

Fig. 3 The distribution of dugong density in the survey area from Cape Bedford to Hunter Point in November 1985. The corresponding figure for the survey area from Cape Bedford to Cape Melville in November 1984 is also provided.

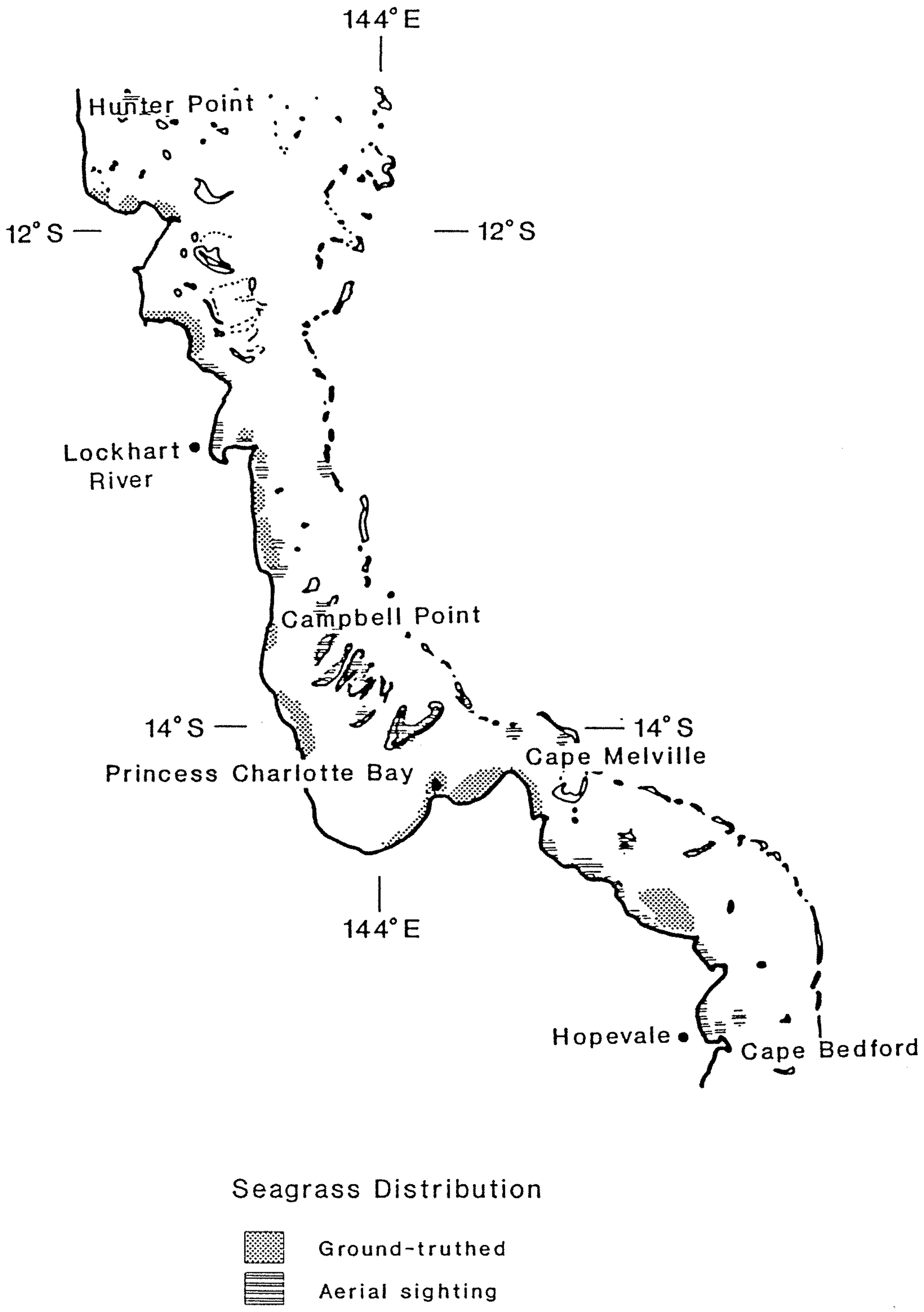

Fig. 4 The approximate distribution and density of inshore seagrass beds in the survey area provided for comparison with Fig. 3. The ground-truthed seagrass data are from Coles *et al.* (1985) and adapted from Marsh and Saalfeld (1988).

Biological basis for managing dugongs and other large vertebrates in the Great Barrier Reef Marine Park

Final Report
January 1989

VOLUME 4

Raw data tables and programmes used in the estimation of prevailing weather conditions and the calculation of population and density estimates

Note: The tables and programmes have also been supplied on a diskette in Word Perfect 4.2 format.

SECTION 1

Raw data tables for dugongs in the survey area from the tip of Cape York south to Cape Bedford

Section 1: Raw data tables for dugongs in the survey area from the tip of Cape York south to Cape Bedford.

Table 1: Details of weather conditions encountered during the surveys.

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

Table 3: Raw data for the surveys: dugong sightings.

Table 4: Logistics of flight time for each survey.

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

TABLE 1: Details of weather conditions encountered during the surveys.

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 - 4, November 1984										
13/11/84	1	7	E	1	3000	1.0	1.0(0.5-1.0)	1.0		Low 0425[a]
	2	10	ESE	0	-	3.0(2.0-3.0)	3.0(1.5-3.0)	1.0(0.0-2.0)		High 1201[a]
14/11/84	1	<5	NW	2	2000	1.0(0.0-1.0)	0.5-1.0	1.0(0.0-1.0)		Low 0521[a]
	2	7	ESE	0	-	2.5(1.5-3.0)		1.0(0.0-2.0)		High 1450[a]
15/11/84	1	13	ESE	1	2500	2.0(1.0-3.0)		1.0(1.0-2.0)		Low 0710[a]
	2	13	SE	0	-	2.5(0.0-3.0)		1.0(0.0-2.0)		High 1544[a]
Blocks 6 - 13, April 1985										
21/04/85	1	10	E	3,7	1500,3000	1.5(1.0-2.5)	2.0(1.0-2.5)	1.5(0.0-3.0)	0.0(0.0-1.0)	High 0943[b]
	2	10-15	E	5,5	1500,30000	2.0(1.0-2.0)	2.0(1.0-2.0)	1.0(0.0-2.0)	0.0(0.0-1.0)	Low 1558[b]
22/04/85	1	5	E	2,4	1500,2000	2.0(1.0-2.5)	2.0(1.0-2.5)	2.0(0.0-3.0)	0.0	High 0956[b]
	2	10	ENE	4	1000	2.0(1.5-2.5)	2.0(1.0-2.0)	1.0(0.0-2.0)	0.5(0.0-1.0)	Low 1617[b]
23/04/85	1	10	ESE	5,4	700,20000	1.5(1.0-2.0)	1.5(1.0-2.5)	2.0(1.0-3.0)	0.5(0.0-1.0)	High 1004[b]
24/04/85	1	10	SE	6	1000	2.0(1.5-2.0)	3.0(2.0-3.5)	2.0(0.0-3.5)	1.0(0.0-1.0)	High 0849[b]
	2	12	ESE	5	1400	2.5(2.0-3.0)	2.5(1.0-3.0)	2.0(1.0-3.0)	1.0(0.0-1.0)	Low 1649[b]
25/04/85	1	5	E	3	1000	1.5(1.0-2.5)	2.0(1.5-3.0)	2.0(1.0-3.0)	0.0(0.0-1.0)	High 0806[b]
	2	10	E	2	1000	3.0(2.0-3.0)	2.0(1.0-3.0)	2.0(2.0-3.0)	0.5(0.0-1.0)	Low 1551[b]
26/04/85	1	10	E	7	8000	2.0(2.0-2.5)	1.0(1.0-3.0)	2.0(1.0-3.0)	0.5(0.0-1.0)	High 0426[b]
	2	10	ESE	4	1500	1.5(1.0-2.0)	1.0(1.0-2.0)	2.0(1.0-3.0)	2.0(0.0-2.0)	Low 1519[b]
Blocks 1 - 7, November 1985										
31/10/85	1	10	SSE	3	1500	3.0(0.0-4.0)		1.0(0.0-2.0)	1.0(0.0-2.5)	High 0931[a]
	2	20	SSE	3	5000	3.0(1.0-4.0)		1.0	1.0(0.0-1.0)	Low 1605[a]
01/11/85	1	10	E	3-8	1500	3.0(1.0-3.0)	3.0(2.0-3.0)	2.0(0.0-2.0)	1.0(1.0-2.0)	High 1035[a]
02/11/85	1	10	E	5	1000	2.5(2.0-3.0)	3.0(2.0-3.0)	2.0(0.0-2.0)	1.0(0.0-2.0)	High 1120[a]
03/11/85	1	10	E	1-6	1500	2.5(1.0-3.0)	2.5(1.0-3.0)	2.0(0.0-2.5)	2.0(0.0-2.0)	Low 0416[a]
	2	10	E	3,5	1000,5000	2.5(2.0-3.0)	2.5(2.0-3.0)	2.0(0.0-2.0)	1.0(0.0-2.0)	High 1522[a]
05/11/85	1	10	E	2,2	1500,12000	2.0(1.0-2.5)	2.0(1.0-2.5)	0.0(0.0-2.5)	2.0(0.0-2.0)	Low 0846[a]
	2	15	E	1	1000	2.5(0.0-3.0)		1.0(0.0-2.0)	1.0(0.0-2.0)	High 1629[a]
06/11/85	1	10	E	5	1500	2.0(1.0-2.5)		1.0(0.0-2.0)	1.0(0.0-2.0)	Low 0957[a]
	2	15	E	1	1500	2.0(1.0-3.0)		2.0(0.0-2.5)	1.0(0.0-2.0)	High 1659[a]

TABLE 1: continued.

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, November 1985											
07/11/85	1	10	E	2-6	2000	1.0(0.0-2.5)		1.0(0.0-2.0)	0.0(0.0-2.0)	Low	1046[a]
	2	15	E	4,3	1500,9000	2.0(2.0-2.5)	2.0(1.0-2.5)	1.0(1.0-2.5)	1.0(0.0-2.0)	High	1729[a]
08/11/85	1	10	E	2-6	1000	2.5(1.0-2.5)	2.5(1.0-4.0)	1.0(0.0-2.0)	1.0(0.0-2.5)	Low	1133[a]
Blocks 8 - 13, November 1985											
17/11/85	1	5	NE	2	1500	0.5(0.0-1.0)	0.0(0.0-1.0)	1.0(0.0-2.5)	0.0(0.0-1.0)	Low	0700[b]
	2	10	E	1	1500	2.0	1.0(1.0-2.5)	2.0(0.0-2.0)	1.0(0.0-2.0)	High	1517[b]
18/11/85	1	0	-	2	2000	0.0(0.0-1.0)	0.0	1.0(-.0-1.0)	0.0(0.0-1.0)	Low	0900[b]
	2	0	-	1	1500	1.0(0.0-1.0)	0.0(0.0-1.0)	1.0(0.0-1.0)	0.0(0.0-1.0)	High	1625[b]
19/11/87	1	0	-	3	1000	1.0(0.0-1.5)	1.0(0.0-1.0)	1.0(0.0-2.0)	1.0(0.0-1.0)	Low	1025[b]
	2	10	ENE	-	-	2.0(1.0-2.5)	2.0(1.0-3.0)	2.0(0.0-2.0)	0.0(0.0-2.0)	High	1717[b]
20/11/85	1	5	E	1,4	1500,12000	1.0	1.0(0.0-1.0)	1.0(0.0-2.5)	1.0(0.0-2.0)	Low	1026[b]
	2	8	N	1,4	1500,12000	1.0(0.0-1.0)	1.0(0.0-1.0)	1.0(0.0-2.5)	0.5(0.0-1.0)	High	1800[b]
21/11/85	1	0	-	1	1500	0.5(0.0-1.0)	0.5(0.0-0.5)	1.0(0.0-2.0)	0.5(0.0-1.0)	Low	1219[b]

[a] Neap tides. Times are for Cape Flattery and equal Cairns -10 mins.

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

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)	Beaufort Sea State Offshore mode(range)	Glare North mode(range)	Glare South Mode(range)
Blocks 1 - 4, November 1984				
1	1.0	1.0	detailed glare data not recorded for this survey	
2	1.0	1.0(0.5-1.0)		
3	1.0	1.0		
4	-	1.0		
5	2.5(2.0-3.0)	2.5(2.0-2.5)		
6	-	1.5-3.0		
7	3.0	2.5-3.0		
8	3.0	3.0(2.0-3.0)		
9	-	3.0		
10	1.0	0.5(0.5-1.0)		
11	0.5	0.5(0.5-1.0)		
12	0.0-1.0	1.0		
13	0.5	1.0		
14	-	0.5		
15	2.0			
16	2.5(2.0-2.5)			
17	2.0(2.0-2.5)			
18	2.0(0.0-2.5)			
19	2.0(2.0-2.5)			
20	2.0			
21	2.5			
22	2.0(2.0-2.5)			
23	2.5			
24	2.5-3.0			
25	1.5(1.0-2.0)			
26	1.0-2.0			
27	1.0-2.0			
28	2.5(2.0-3.0)			
29	2.5			
30	2.5(2.0-3.0)			
31	3.0			
32	3.0			
33	2.5			
34	2.5			
35	2.5-3.0			
36	3.0			
37	2.0(2.0-2.5)			
38	1.5-2.0			
39	2.0			
40	2.0(2.0-2.5)			

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)
<u>Blocks 6 - 13, April 1985</u>				
1	2.0(2.0-2.5)	2.0(1.0-2.5)	2.0(1.0-2.0)	0.0
2	1.0(1.0-1.5)	1.0(1.0-2.0)	2.0(0.0-3.0)	0.0(0.0-1.0)
3	1.5(1.5-2.0)	1.5(1.0-2.0)	1.5(0.0-2.0)	0.0
4	1.5	1.0(1.0-2.0)	1.0(0.0-2.0)	0.0
5	1.5(1.5-2.0)	2.0(1.5-2.5)	1.0	0.0
6	1.5(1.0-2.0)	2.0(1.0-2.5)	1.5(1.0-2.0)	0.0
7	2.0	2.0(1.0-2.0)	1.0	0.0
8	1.0	1.5(1.0-2.0)	2.0(0.0-2.0)	0.0
9	2.0	2.0(1.5-2.0)	1.0	0.0
10	-	2.0	0.5(0.0-1.0)	0.0
11	1.5	1.5(1.5-2.0)	1.0	1.0
12	2.0	2.0	1.0	0.0
13	2.0(2.0-2.5)	2.0(2.0-2.5)	2.0	0.0
14	2.0(2.0-2.5)	2.0(2.0-2.5)	1.5(0.0-1.5)	0.0
15	2.5	2.5(2.0-2.5)	2.0(1.0-2.0)	0.0
16	2.0	2.0(2.0-2.5)	2.0	0.0
17	1.0(1.0-2.0)	2.0(1.5-2.5)	2.0	0.0
18	1.5(1.5-2.0)	1.5(1.0-2.0)	2.0(1.0-2.0)	0.0
19	2.0(1.0-2.0)	2.0(1.5-2.5)	2.0(1.0-2.0)	0.0
20	-	2.0(1.5-2.5)	3.0(2.0-3.0)	0.0
21	2.0	2.0(1.5-2.5)	2.5(2.0-3.0)	0.0
22	-	2.0(1.0-2.0)	2.0(1.0-3.0)	0.0
23	-	1.5(1.0-1.5)	2.5(2.0-3.0)	0.0
24	2.0	1.5(1.0-2.5)	2.0	0.0
25	2.5	2.0(2.0-2.5)	1.5(1.0-2.0)	1.0
26	2.5	2.0(1.0-2.5)	2.0	1.0
27	-	2.5(1.5-2.5)	2.0	1.0
28	2.5	2.5(1.0-3.0)	2.0	0.5(0.0-1.0)
29	2.0(2.0-2.5)	2.0(2.0-2.5)	3.0(1.0-3.0)	0.5(0.0-1.0)
30	3.0	2.5(1.0-2.5)	2.0	0.5(0.0-1.0)
31	3.0(2.5-3.0)	2.0(1.0-3.0)	2.0	0.0
32	2.5(2.0-3.0)	2.0(2.0-2.5)	2.0(2.0-3.0)	1.0(0.0-1.0)
33	2.0	1.0(1.0-2.0)	3.0(2.0-3.0)	0.0
34	2.5	2.0(1.0-2.5)	2.0	0.0
35	2.0	1.5(1.0-2.0)	2.0	1.0(0.0-1.0)
36	2.0	2.0(1.0-3.0)	2.0(1.0-2.0)	1.0
37	2.0(2.0-2.5)	1.5(1.5-2.5)	1.5(1.0-2.0)	1.0
38	-	2.5(2.0-3.0)	3.0(0.0-3.5)	1.0
39	2.0	3.0(2.0-3.0)	3.0(1.0-3.0)	0.0
40	1.0	1.0(1.0-2.0)	2.0	0.0
41	2.0	1.5(1.0-2.0)	2.0(2.0-3.0)	2.0(1.0-2.0)
42	2.0(1.5-2.5)	2.0(2.0-3.0)	2.0(2.0-3.0)	0.0
43	2.0	3.0(2.0-3.0)	2.0(1.0-2.0)	0.0(0.0-1.0)
44	2.0	2.5(2.5-3.5)	2.0(0.0-2.5)	1.0
45	2.0(1.5-2.5)	3.0(2.0-3.5)	2.0	0.5(0.0-1.0)
46	1.5	1.0(1.0-2.0)	2.0	1.0
47	1.0(1.0-1.5)	2.0(1.0-2.0)	2.0(1.0-2.0)	0.0(0.0-1.0)
48	1.5	2.0(1.0-2.0)	1.0(1.0-2.0)	1.0(0.0-1.0)
49	2.0	2.0(1.0-2.0)	2.0	0.0
50	1.0(1.0-1.5)		2.0	0.0
51	1.5(1.0-2.0)		2.0	0.0
52	2.0(1.0-2.0)		2.0(0.0-2.0)	0.0
53	1.0(1.0-2.5)		1.5(1.0-3.0)	0.0
54	2.5(2.0-2.5)		1.5(0.0-2.5)	0.0
55	2.0(1.5-2.5)		3.0	0.0
56	2.5(2.0-2.5)		3.0	0.0
57	1.5(1.0-2.0)		3.0	0.0

Table 2: continued.

Transect No.	Beaufort Sea State Inshore mode(range)	Offshore mode(range)	Glare North mode(range)	South Mode(range)
Blocks 1 - 4, November 1985				
1	2.5(1.0-3.0)	3.0	1.0-2.0	1.0
2	3.0	3.0	1.0	1.0-2.0
3	3.0	3.0(2.0-3.0)	1.0-2.0	1.0
4	3.0	3.0(2.0-3.0)	1.0	1.0-2.0
5	3.0	3.0(2.0-3.0)	1.0-2.0	2.0
6	3.0	3.0(2.0-3.0)	1.0-2.0	1.0-2.0
7	3.0(2.0-3.0)	2.0(2.0-3.0)	1.0-2.0	1.0
8	3.0	3.0	1.0-2.0	2.0
9	3.0	3.0(2.0-3.0)	2.0(0.0-2.0)	1.0(1.0-2.0)
10	3.0	2.5(2.0-3.0)	0.0-2.0	0.0-2.0
11	3.0	3.0(2.0-3.0)	2.0(1.0-2.0)	2.0(1.0-2.0)
12	2.0(2.0-3.0)	3.0(2.0-3.0)	1.0(0.0-1.0)	1.0(0.0-1.0)
13	2.5-3.0	3.0(2.0-3.0)	2.0(0.0-2.0)	1.0(0.0-2.0)
14	2.5	2.5(2.0-3.0)	2.0(1.0-2.0)	2.0(1.0-2.0)
15	3.0(2.5-3.0)	2.5(2.0-3.0)	1.0	2.0(1.0-2.0)
16	3.0(2.0-3.0)	3.0(2.0-3.0)	0.0(0.0-1.0)	2.0(0.0-2.0)
17	2.5(2.0-2.5)	2.5(2.0-3.0)	2.0(1.0-2.0)	2.0(1.0-2.0)
18	2.5(2.0-2.5)	3.0(2.0-3.0)	2.0(0.0-2.0)	1.0-2.0
19	2.5(2.0-3.0)	2.5(2.0-3.0)	1.0(0.0-2.0)	2.0(0.0-2.0)
20	2.5(2.0-2.5)	2.5(1.0-3.0)	2.0(0.0-2.0)	2.0(0.0-2.5)
21	3.0(2.5-3.0)	2.5(2.0-3.0)	0.0(0.0-1.5)	2.0(0.0-2.0)
22	3.0(1.0-3.0)	2.0(1.0-2.5)	1.0(0.0-2.0)	2.0(1.0-2.0)
23	2.5(2.0-3.0)	2.5(2.0-3.0)	1.0(0.0-2.0)	1.0(0.0-2.0)
24	2.0-2.5	2.0-2.5	0.0-2.0	2.0(1.0-2.0)
25	2.0(2.0-2.5)	2.0(1.0-2.5)	0.0(0.0-2.0)	0.0(0.0-2.0)
26	2.0(1.0-2.5)	2.5(1.0-2.5)	0.0-2.0	0.0(0.0-2.0)
27	2.5(2.0-2.5)	2.0(1.0-2.0)	1.0(0.0-2.0)	1.0(0.0-2.0)
28	2.5(2.5-3.0)		1.0	1.0
29	3.0(2.5-3.0)		2.0	2.0
30	3.0(2.5-3.0)		1.0	1.0-2.0
31	3.0(2.5-3.0)		2.0	2.0
32	3.0(2.5-3.0)		1.0	1.0-2.0
33	2.5(2.0-3.0)		1.0(1.0-2.0)	1.0(0.0-2.0)
34	2.5(2.5-3.0)		1.0	1.0-2.0

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 1985				
1	3.0(2.5-4.0)		1.0	1.0
2	3.0(1.0-4.0)		1.0	0.0
3	3.0(1.0-4.0)		1.0	1.0
4	3.5(2.0-4.0)		1.0	1.0
5	3.0(0.0-3.0)		1.0(0.0-2.0)	1.0(0.0-2.0)
6	3.0(0.5-3.0)		0.0-1.0	1.0(0.0-2.0)
7	3.0(1.0-4.0)		2.0(1.0-2.0)	2.5(1.0-2.5)
8	1.0(1.0-4.0)		0.0-1.0	1.0
9	2.5(0.0-3.0)		0.0-2.0	0.0-2.0
10	2.5(1.0-3.0)		1.0-2.0(0.0-2.5)	2.0(0.0-2.5)
11	2.5(2.0-3.0)		1.0(0.0-2.0)	1.0(1.0-2.0)
12	2.0(0.0-3.0)		1.0(0.0-2.0)	1.0(0.0-2.0)
13	2.5(1.0-4.0)		2.0(0.0-2.0)	2.0(0.0-2.5)
14	2.0(1.0-2.5)		1.0(0.0-2.0)	1.0(0.0-2.0)
15	1.0(1.0-2.5)		1.0(0.0-2.0)	1.0(0.0-2.0)
16	1.0(0.0-2.5)		1.0(0.0-2.0)	0.0(0.0-2.0)
17	2.0(1.0-2.5)		1.0(0.0-2.0)	0.0(0.0-2.0)
18	2.0(1.0-2.5)		0.0-1.0(0.0-2.0)	0.0-2.0
19	2.0(1.0-2.5)		1.0-2.0(0.0-2.0)	1.0-2.0
20	1.0(1.0-2.5)		1.0(0.0-1.0)	0.0-2.0
21	2.0(1.0-2.5)		1.0-2.0	0.0-2.0
22	2.5(1.0-2.5)		2.0(0.0-2.0)	1.0
23	2.0(1.0-2.5)		1.0(0.0-2.0)	1.0(0.0-2.0)

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 2 - 16, November 1985				
1	2.0	2.0(1.0-2.5)	0.0(0.0-2.0)	0.0-2.0
2	2.0	2.5(1.0-2.5)	1.0(0.0-1.0)	1.0(0.0-2.0)
3	2.0	1.0(1.0-2.0)	0.0(0.0-2.0)	0.0(0.0-2.0)
4	1.5(1.0-2.0)	2.0(1.0-2.5)	0.0-1.0	0.0(0.0-2.0)
5	2.0	2.0(1.0-2.5)	1.0(0.0-2.0)	1.0(0.0-2.0)
6	2.0-2.5	1.0(1.0-2.5)	1.0(0.0-1.0)	0.0-2.0
7	2.5(2.0-2.5)	2.0(1.0-3.0)	1.0(1.0-2.0)	1.0(0.0-2.0)
8	2.0(1.0-2.5)	2.0(1.0-3.0)	1.0(0.0-2.0)	1.0(0.0-2.0)
9	1.0(1.0-2.5)	2.5(1.0-3.0)	1.0(0.0-2.0)	1.0(0.0-2.0)
10	-	2.5(1.0-3.0)	1.0(0.0-2.0)	2.0(0.0-2.0)
11	2.0	2.5(1.0-4.0)	0.0-2.0	0.0-2.0(0.0-2.5)
12	1.0	2.0(1.0-3.0)	0.0-1.0	0.0-2.0
13	0.5(0.0-1.0)	0.0	0.0	0.0(0.0-1.0)
14	0.0(0.0-1.0)	0.0	0.0	0.0
15	0.0	0.0(0.0-1.0)	0.0	0.0-1.0
16	-	0.0(0.0-1.0)	0.0	0.0-1.0
17	1.0	0.0(0.0-1.0)	0.0(0.0-1.0)	0.0-1.0
18	1.0-1.5	0.5(0.0-1.0)	1.0	1.0-2.0
19	1.0	1.0(0.0-1.0)	0.0-1.0	0.0-1.0
20	2.0-2.5	1.5(1.0-2.0)	1.0(0.0-1.0)	0.0-1.0(0.0-2.0)
21	2.5	2.0(0.0-2.5)	0.0-1.0	1.0-2.0
22	-	2.0(1.0-2.5)	0.0(0.0-2.0)	0.0(0.0-1.0)
23	2.0(2.0-2.5)	1.0(0.0-2.0)	0.0-1.0	2.0
24	2.0	2.0(1.0-3.0)	0.0(1.0-2.0)	0.0(0.0-2.0)
25	1.5(1.0-2.0)	2.0(0.0-3.0)	0.0-1.0	2.0
26	-	1.0(0.0-1.0)	1.0(0.0-1.0)	1.0(1.0-2.0)
27	1.0	1.0(0.5-1.0)	1.0(0.0-1.0)	0.0(0.0-1.0)
28	-	1.0(0.5-1.0)	0.0	1.0
29	1.0(1.0-2.0)	1.0(0.0-1.0)	0.0-1.0	1.0(0.0-1.0)
30	0.0	1.0(0.0-0.5)	0.0(0.0-1.0)	1.0
31	0.5-1.0	0.5	1.0(0.0-1.0)	1.0(0.0-2.0)
32	1.0	1.0(0.0-1.0)	1.0(0.0-1.0)	1.0(0.0-1.0)
33	1.0	1.0(0.0-1.0)	1.0(0.0-1.0)	2.0(0.0-2.5)
34	-	1.0(0.0-1.0)	0.0(0.0-1.0)	1.0-2.0(0.0-2.0)
35	1.0	1.0(0.0-1.0)	1.0(0.0-2.0)	2.0(0.0-2.0)
36	-	1.0(0.0-1.0)	0.0(0.0-1.0)	1.0-2.0
37	1.0	1.0	0.0-1.0	1.0(0.0-2.0)
38	1.0	0.0(0.0-1.0)	0.0	0.0-1.0
39	-	1.0(0.0-1.0)	1.0(0.0-1.0)	1.0(0.0-2.0)
40	1.0(0.0-1.0)	0.0(0.0-1.0)	0.0	0.0-1.0
41	1.0(0.0-1.0)	1.0(0.0-1.0)	0.0	0.0-1.0
42	1.0	0.0(0.0-1.0)	0.0-1.0	0.0-1.0
43	0.5(0.0-1.0)	0.0	0.0(0.0-1.0)	1.0(0.0-1.0)
44	0.0	0.0	0.0	0.0-1.0
45	0.0	0.0	0.0	1.0
46	-	1.0(1.0-2.5)	1.0	2.0(0.0-2.0)
47	2.0	1.0(1.0-2.0)	1.0(0.0-1.0)	2.0(0.0-2.0)
48	-	0.0(0.0-1.0)	0.0-1.0	2.0(0.0-2.0)
49	0.5(0.0-1.0)	1.0(0.0-1.0)	1.0(0.0-1.0)	1.0(0.0-2.50
50	0.5(0.0-1.0)		0.0	1.0
51	0.0		0.0	1.0
52	0.0		0.0	1.0
53	0.0(0.0-1.0)		0.0	1.0
54	0.0		0.0	1.0-2.0
55	1.0		0.0	1.0
56	1.0		0.0(0.0-1.0)	1.0
57	1.0		1.0	1.0

TABLE 3: Raw data for the surveys: dugong sightings.

(a) Blocks 1 - 4, November 1984

Transect No.	No. of observers Port	No. of observers Starboard	No. of groups of turtles Port Rear	No. of groups of turtles Starboard Rear
001	1	1	0	1
002	1	1	1	1
003	1	1	0	1
004	1	1	0	0
005	1	1	0	0
006	1	1	0	0
007	1	1	0	1
008	1	1	0	2
009	1	1	4	1
010	1	1	3	5
011	1	1	6	0
012	1	1	1	2
013	1	1	1	1
014	1	1	0	0
015	1	1	0	0
016	1	1	0	0
017	1	1	0	0
018	1	1	0	0
019	1	1	0	0
020	1	1	0	0
021	1	1	0	0
022	1	1	0	0
023	1	1	0	1
024	1	1	0	1
025	1	1	0	1
026	1	1	6	4
027	1	1	0	1
028	1	1	0	2
029	1	1	0	0
030	1	1	1	1
031	1	1	1	2
032	1	1	2	3
033	1	1	0	1
034	1	1	1	0
035	1	1	1	0
036	1	1	0	0
037	1	1	0	0
038	1	1	0	0
039	1	1	0	1
040	1	1	0	1
			28	34

TABLE 3: continued.

(b) Blocks 6 - 13, April 1985

Transect No.	No. of observers Port	No. of observers Starboard	No. of groups of dugongs Port Rear	Starboard Mid	Starboard Rear	Starboard Tandem
001	1	2	2	0	0	0
002	1	2	1	0	1	0
003	1	2	0	0	0	0
004	1	2	1	0	0	0
005	1	2	1	6	0	5
006	1	2	1	1	0	0
007	1	2	0	0	0	0
008	1	2	1	1	0	0
009	1	2	0	0	0	1
010	1	2	0	0	0	0
011	1	2	0	0	0	0
012	1	2	2	0	0	0
013	1	2	0	0	0	0
014	1	2	2	0	0	0
015	1	2	1	0	0	0
016	1	2	0	0	0	0
017	1	2	0	1	0	0
018	1	2	0	0	0	0
019	1	2	0	0	0	0
020	1	2	0	0	0	0
021	1	2	0	0	0	0
022	1	2	0	0	0	0
023	1	2	0	0	0	0
024	1	2	0	0	0	0
025	1	2	1	0	0	0
026	1	2	0	0	0	0
027	1	2	1	0	0	1
028	1	2	2	0	2	0
029	1	2	0	0	1	0
030	1	2	1	0	0	0
031	1	2	0	0	0	0
032	1	2	0	0	0	0
033	1	2	0	0	0	0
034	1	2	0	0	0	0
035	1	2	0	0	0	0
036	1	2	0	0	0	0
037	1	2	0	0	0	0
038	1	2	0	0	0	0
039	1	2	0	0	0	0
040	1	2	0	0	0	0
041	1	2	0	0	0	1
042	1	2	0	0	0	1
043	1	2	0	0	0	0
044	1	2	0	0	0	0
045	1	2	0	0	0	0
046	1	2	0	0	0	0
047	1	2	0	0	0	0
048	1	2	0	0	0	0
049	1	2	0	0	0	0
050	1	2	0	0	0	0
051	1	2	0	1	0	0
052	1	2	0	0	0	0

TABLE 3: continued.

(b) Blocks 6 - 13, April 1985

Transect No.	No. of observers Port	Starboard	No. of groups of dugongs Port Rear	Starboard Mid	Rear	Tandem
053	1	2	2	0	1	1
054	1	2	2	0	1	0
055	1	2	0	0	0	1
056	1	2	0	0	0	0
057	1	2	0	0	1	1
			21	10	7	12

TABLE 3: continued.

(c) Blocks 1 - 4, November 1985

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	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	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	1	0	5	0	0	2
012	2	2	3	1	9	0	9	6
013	2	2	2	0	2	0	0	0
014	2	2	4	1	4	2	0	1
015	2	2	0	0	0	1	0	2
016	2	2	0	0	0	0	0	0
017	2	2	0	0	0	0	0	2
018	2	2	0	0	2	0	0	0
019	2	2	0	0	0	0	1	0
020	2	2	2	0	1	1	0	0
021	2	2	0	0	0	0	0	0
022	2	2	0	0	1	0	1	2
023	2	2	0	0	0	0	0	0
024	2	2	0	0	0	0	0	0
025	2	2	0	0	1	0	0	0
026	2	2	0	0	0	0	0	0
027	2	2	0	0	0	0	0	0
028	2	2	2	3	4	2	0	0
029	2	2	1	0	2	1	1	2
030	2	2	1	0	1	1	0	0
031	2	2	2	2	0	0	0	1
032	2	2	0	0	0	0	0	0
033	2	2	0	0	1	0	0	0
034	2	2	0	0	0	0	1	0
			18	7	33	8	13	17

TABLE 3: continued.

(d) Block 5, November 1985

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	1	0	1	0		1	
002	2	1	1	0	2		1	
003	2	1	0	0	0		0	
004	2	1	0	1	2		1	
005	2	1	2	1	0		2	
006	2	1	1	2	1		3	
007	2	1	1	3	2		2	
008	2	1	1	1	0		0	
009	2	2	0	1	0	0	0	0
010	2	2	0	0	0	0	0	1
011	2	2	1	0	2	0	1	1
012	2	2	1	0	3	1	0	1
013	2	2	1	1	1	0	1	3
014	2	2	1	0	1	2	1	0
015	2	2	0	0	3	0	0	1
016	2	2	0	0	0	1	0	0
017	2	2	0	0	1	0	0	0
018	2	2	0	0	2	1	0	1
019	2	2	0	0	0	1	0	0
020	2	2	1	0	0	1	0	0
021	2	2	0	0	0	0	1	0
022	2	2	0	0	0	0	1	0
023	2	2	0	0	0	0	0	0
			11	11	20	7	15	8

TABLE 3: continued.

(e) Blocks 6 - 13, April 1985

Transect No.	No. of observers Port	Starboard	No. of groups of dugongs	Port Rear		Starboard Mid	Rear	Tandem
001	2	2	1	0	2	0	0	1
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	3	0	2	0	0	4
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	1	0	0	0	0	0
010	2	2	1	0	0	0	0	0
011	2	2	1	0	0	1	0	0
012	2	2	0	0	0	0	0	0
013	2	2	0	1	0	0	0	0
014	2	2	0	1	0	0	0	1
015	2	2	0	0	0	0	0	1
016	2	2	0	0	0	0	0	0
017	2	2	0	0	1	0	0	0
018	2	2	1	0	1	0	0	0
019	2	2	0	0	0	0	0	1
020	2	2	0	0	0	1	1	0
021	2	2	0	0	0	0	0	0
022	2	2	0	0	0	0	0	0
023	2	2	0	0	0	0	0	0
024	2	2	0	0	0	0	0	1
025	2	2	0	0	0	0	0	0
026	2	2	1	0	0	0	0	0
027	2	2	0	0	1	0	0	0
028	2	2	0	0	0	0	0	0
029	2	2	1	0	1	0	0	0
030	2	2	0	0	4	0	0	1
031	2	2	0	0	0	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
035	2	2	0	0	0	0	0	0
036	2	2	0	0	1	0	0	0
037	2	2	0	0	0	0	0	0
038	2	2	0	0	0	0	0	1
039	2	2	0	0	1	0	0	0
040	2	2	0	0	2	0	0	2
041	2	2	0	0	0	1	0	0
042	2	2	0	0	0	0	0	0
043	2	2	0	0	0	0	0	0
044	2	2	0	0	0	0	0	0
045	2	2	0	0	0	0	0	0
046	2	2	0	0	0	0	0	0
047	2	2	1	0	0	0	0	0
048	2	2	0	0	0	0	1	0
049	1	2		0		0	0	0
050	1	2		1		0	1	0
051	1	2		0		0	0	0
052	1	2		0		0	0	0

TABLE 3: continued.

(e) Blocks 6 - 13, April 1985

Transect No.	No. of observers Port	Starboard		No. of groups of dugongs Port Rear		Starboard Mid	Rear	Tandem
053	1	2		3		0	2	2
054	1	2		5		0	2	2
055	1	2		0		0	0	0
056	1	2		0		0	0	1
057	1	2		0		0	1	2
			12	12	17	3	3	20

TABLE 4: Logistics of flight time for each survey

Survey	Transit Time (hrs)	Survey Time (hrs)	Dead Time (hrs)
Blocks 1 to 4, November 1984[a]	2.5	10.0	6.1
Blocks 6 to 13, April 1985	7.6	19.7	11.1
Blocks 1 to 7 and blocks 8 and 9 transects 10 to 12, November 1985	5.1	23.5	6.1
Blocks 8 and 9, transects 13 to 32 and blocks 10 to 13, November 1985	6.8	16.6	11.6

[a] Extra expenses: $286 for fuel relocation

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

(a) Correction for perception bias

Survey date	Blocks	Transects	No. of groups of dugongs Port mid-seat	 Port rear-seat	 tandem	 Starboard mid-seat	 Starboard rear-seat	 tandem
November 1984	1 to 4	1 to 40	correction factor based on starboard rear-seat observer, November 1985 survey, blocks 8 - 13, transects 13 - 57.					
April 1985	6 to 13	1 to 57		21		10	7	12
November 1985	1 to 4 5[a] 6 and 7 8 and 9	1 to 34 1 to 23 1 to 9 10 to 12	36	18	58	16	18	30
November 1985	8 and 9 10 to 13[b]	13 to 32 33 to 57	5	3	12	2	3	15

[a] starboard perception correction factor for transects 1 to 8, block 5 is based on starboard rear-seat observer correction factor for all transects excluding 1 to 8, block 5.

[b] port perception correction factor for transects 50 to 57, block 11 and transect 49, blocks 12 and 13 is based on port rear-seat observer correction factor for all transects excluding these.

(b) Correction for availability bias

Survey date	Blocks	Transects	No. of dugongs in groups ≤ 8 Surface	 Underwater	 Total
November 1984	1 to 4	1 to 40	71	101	172
April 1985	6 to 13	1 to 57	26	54	80
November 1985	1 to 4 5 6 and 7 8 and 9	1 to 34 1 to 23 1 to 9 10 to 12	78	192	270
November 1985	8 and 9 10 to 13	13 to 32 33 to 57	18	57	75