Report

to

The Australian Fisheries Service

The Great Barrier Reef Marine Park Authority

and

The Fisheries Management Branch of the Queensland Department of Primary Industries

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THE DISTRIBUTION AND ABUNDANCE OF THE DUGONG IN THE TORRES STRAIT REGION.

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EXECUTIVE SUMMARY

In November 1987, dugongs were counted from the air at an overall sampling intensity of 7.4% over a total area of 30,533 km^2 in the Torres Strait region and adjacent waters of the Great Barrier Reef Marine Park. About half the survey was repeated in March 1988; persistently bad weather prevented its completion.

We corrected for perception bias (the proportion of animals visible in the transect which are missed by observers), and standardized for availability bias (the proportion of animals that are invisible due to water turbidity) with survey-specific correction factors. The resultant minimum population estimate in November 1987 was 12,522 $\pm$ S.E. 1,644 dugongs at an overall density of 0.41 $\pm$ S.E. 0.05 km^{-2}, a precision of 13%.

Although there were no significant differences between population and density estimates obtained from the repeat surveys of the same areas, relatively more dugongs were sighted close to the major western islands in the March survey.

Our data suggest that if the dugong population were increasing maximally, this region could support an unselective man-induced mortality of 700 dugongs per year at most. If the current rate of increase is similar to that estimated from the Daru dugong catch between 1978 and 1982, the maximum unselective harvest will be of the order of 300 dugongs. If significantly more females than males are being caught, these figures are overestimates.

In the absence of adequate catch statistics and current life history information, it is impossible to confirm whether the current dugong harvest in Torres Strait is likely to be below the sustainable yield. A high priority should therefore be placed on public education in an attempt to pre-empt any increase in catch.

The resultant maps of distribution and density suggest that, if the Torres Strait dugong sanctuary area is to be effective, its boundaries should be renegotiated or an additional protected area established around Buru (Turnagain) Island.

The low number of dugongs seen in the waters of the Great Barrier Reef Marine park adjacent to Torres Strait do not warrant special protection when the zoning plan for this area is revised. However, the Islanders need more information on the restrictions on their hunting within the Great Barrier Reef Marine Park.

RECOMMENDATIONS

1. That the collection of further dugong catch statistics from Torres Strait communities in both Australia and Papua New Guinea be given high priority. At the very least, the harvest of dugongs from Boigu Island should continue to be monitored as an index of hunting activity in the Western Islands. The Islanders should be encouraged to continue sending dugong tusks to James Cook University so that the age-sex composition of the catch can be verified.

2. That the dugong public education program be continued in the Australian communities and extended in collaboration with Papua New Guinea to the Papuan communities. The program should emphasize the vulnerability of the dugong to over-harvesting, the illegality of selling dugong meat and the current restrictions on dugong hunting in the sanctuary area and in the Great Barrier Reef Marine Park.

3. That negotiations be commenced with the Islanders to either extend the boundaries of the present dugong sanctuary to include some high density areas or to establish an additional protected area in the vicinity of Buru (Turnagain) Island. The concept of the Buru Island Sanctuary should be included in the public education program.

4. That the Papua new Guinea Government be encouraged to establish a similar sanctuary in a high density dugong area in Papuan waters.

5. That in order to monitor numbers, this survey be repeated in November 1992 and at five yearly intervals thereafter. (November is the month when favorable weather conditions are most likely and in view of the high cost of transporting a suitable aircraft and survey crew to Torres Strait, it is likely to be a waste of money to attempt a survey at another time of the year).

6. That a copy of this report be made available to each Community Council in Torres Strait. The report should be distributed in association with a personal presentation as part of the public education program and should be accompanied by a summary written for non-scientists.

Introduction

The dugong, Dugong dugon, listed as vulnerable to extinction by the International Union for the Conservation of Nature (IUCN, 1986), has traditionally been important in the culture and diet of the peoples of Torres Strait (see Johannes and MacFarlane, manuscript). In recent years, both some local people (see Johannes and MacFarlane, manuscript) and scientists (e.g. Hudson, 1986; Marsh, 1986) have been concerned by an apparent decline of dugong numbers in the area.

This concern was fueled by the decrease in the number of dugongs passing through the local market at Daru (9° 05'S, 143° 22'E) on the Papuan side of Torres Strait from 208 in 1979 to 81 in 1981, despite an increase in the availability of motorized craft, an extension of the hunting grounds, and an apparently sustained hunting effort (Marsh, 1986). The statistics of Johannes and MacFarlane (in press) suggest a parallel slump in the dugong catch of the Western Islanders; fewer than one fifth as many dugongs were caught in the Western Islands during their study in 1983-84 as were caught during the same months in 1976-78 (Nietschmann, 1982). In addition, a dugong hunter based on Thursday Island who kept records indicating that he had caught 41 dugongs between October 1975 and June 1976, claimed in November 1983 that he had not been able to catch a dugong for four to five years despite that fact that his catch effort remained the same and he continued to catch turtles (Marsh et al., 1984a).

A dedicated aerial survey of the major dugong hunting grounds in Torres Strait in November 1983 produced a minimum population estimate of 1,455 ± S.E. 276 dugongs (Marsh, 1986). It was appreciated that this was 'an underestimate, probably a gross underestimate of the Torres Strait dugong population' because the proportion of dugongs that were sighted under aerial survey conditions had not been calibrated. However, the difference between this estimate and the estimate of 22,000 required to support an annual unselective harvest of 500 dugongs, the lower limit of the estimated annual catch for at least some years between 1975 and 1982 (see Tables 1 and 2) was huge. In view of the decline in catch rates, this discrepancy led to serious doubts about there being enough dugongs in Torres Strait to sustain the level of hunting that had apparently taken place, especially as the estimate of a required population of 22,000 was based on population parameters obtained from the animals harvested by the hunters from Daru (Marsh, 1986).

Some Islanders claimed, however, that more dugongs would have been sighted if the 1983 survey had been carried out during (rather than immediately before) the wet season, and that a substantial proportion of animals occurred west of the 1983 survey area.

In view of recent improvements in aerial survey methodology, it was decided to conduct further surveys in 1987-88 to determine the distribution and abundance of dugongs in Torres Strait. These surveys were designed to take account of the Islanders' criticisms of the design of the previous survey.

Methods

The western and central waters of Torres Strait north of 11°S and the adjacent eastern coastal waters of Cape York south to Hunter Point (11°30'S., 142°50'E.) were surveyed between November 10 and 21 1987 (Fig. 1). About half this region was resurveyed between March 4 and 11 1988 (Fig. 2), before persistently rough weather forced this second survey to be terminated prematurely.

As far as possible, both 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 (sea state Beaufort 3 or less). The weather conditions encountered are summarized in Appendix Table 1; details of weather conditions for each transect for each survey are summarized in Appendix Table 2 (see Volume 4).

Survey Design

For estimation of regional densities of dugongs, the area was divided into 7 blocks (Fig. 1) on the basis of sampling intensity and placement of transects . Block areas (Table 3) were estimated from 1:250,000 maps using a planimeter or a digitizing 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 Partenavia 68B aircraft was flown at a groundspeed of 185 km h^{-1} (100 kn.) 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 survey altitude) was demarcated by fibre glass rods attached to artificial wing struts. The actual width of each transect was estimated by calculating the mean survey height for that transect (taking into account the altimeter correction at each landing using appropriate interpolations), assuming a combined transect width of 400 m at an altitude of 137 m.

The transect lines flown in November 1987 are shown in Fig. 1; those flown in March 1988 are shown in Fig. 2. In order to increase precision, all lines were aligned approximately across the ecological axes of the area i.e. east-west south of Buru (Turnagain) Island (9° 34'S, 142° 18'E,) and north-south along the Papua New Guinea coast. Lines were generally spaced at intervals of 5' latitude (9.3 km or 5 nm) in most of Block 3 and in Block 4; and at intervals of 2.5' latitude in the remaining blocks. Additional lines were flown in the Newcastle Bay area (Block 5). Some lines in the northern half of Block 3 were aligned so that their end points coincided with islands or reefs in order to aid navigation. The bias caused by this non-random placement is considered inconsequential in view of the very small size of these islands and reefs.

Counting Procedure

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 operational observers were available during the first day of each survey while the other observers were being trained. The observers reported their observations of dugongs, turtles (usually not identified to species), cetaceans, sharks, rays, sea snakes and surface plankton blooms in standard format into an intercom connected to a two track tape recorder. We 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 mid seat observers were visually screened from the rear 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 mid seat observers could hear the reports of the rear seat observers.

Data including aircraft height and position, locations of presumed seagrass beds, weather conditions, the starting and finishing times for each transect, and the sightings of the rear seat observers were recorded by the survey leader using a micro computer programmed as a data logger and timer.

More details on methodology are provided by Marsh and Sinclair (manuscripts a & b).

Post Survey Data Editing

The tape record of each transect was used to check and edit the computer records, so that each sighting could be classified as being made by one (specified) observer or both members of a tandem team. Records of the time of each observation and of the starting and finishing times for each transect enabled the position of each observation to be plotted on a map as a basis for the preparation of the smoothed density distribution maps.

Correction Factors

Correction factors were calculated for each survey 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 as outlined in Marsh and Sinclair (manuscript a). The corrections for perception bias were calculated on the basis of the proportion of sightings seen by one (specified) member or both members of each tandem team using the Petersen mark-recapture model; those for availability bias were based on the proportion of dugongs sighted during each survey that were on the surface in comparison to the proportion on the surface in a clear water area where all dugongs were potentially available.

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 (Table 3) (see Caughley and Grigg 1981). Input data were the estimated number of dugongs 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 4) following the method of Jolly and Watson (1979) (as outlined in Marsh and Sinclair, manuscript a).

The significance of the differences in density between surveys for the areas which were surveyed twice were tested using a two factor randomized block design with transect as the blocking factor. The analysis was carried out 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 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.

Results and Discussion

Dugong group size and composition

The distribution of dugong group sizes observed on the November 1987 survey did not differ significantly from that observed in March 1988 (Fig. 3) (G with William's Correction = 4.04, P> 0.25, 3 d.f.). The largest group (subjectively distinct clumping) seen in November was five, in March six. These results are comparable with the November 1983 survey where the largest group seen was six also (Marsh, 1986). In all three surveys, more than 75% of the dugongs sighted were alone or in a group of two animals (Fig. 3; Marsh 1986).

The proportion of calves seen was also similar in the three surveys: 14.3% in November 1983; 13.6% in November, 1987; 14.3% in March 1988. This is not surprising. Calving is diffusely seasonal in northern Australia and the calves stay with their mothers for at least 18 months (Marsh et al., 1984b) . On all three surveys (Fig. 3; Marsh, 1986) more than 70% of the cow-calf pairs identified were unaccompanied by any other dugongs.

Population and density estimates

The values of the mean group sizes and correction factors used in obtaining these estimates are summarized in Table 4. The raw data have been listed in the Appendix. Table 5 gives estimates of the density and numbers of dugongs per block for each survey together with the standard errors of these estimates.

The population estimates sum to 12,522 ± S.E. 1,644 dugongs for the whole region in November 1987 at an overall density of 0.41 ± S.E. 0.05 dugongs per km^2, a precision of 13%. This indicates that Torres Strait is a very important area for dugongs with a population comparable to that of the entire Great Barrier Reef Marine Park (Marsh and Saalfeld, unpublished data).

This estimate is, of course, substantially higher than the minimum estimates obtained for part of the same area by Marsh (1986). The difference is due to the improved survey methodology; Marsh's (1986) estimate was uncorrected for the biases inherent in the survey technique.

We consider that the present estimate is more likely to be an underestimate than an overestimate. The correction for availability bias for each survey (Table 4), is based on the ratio of the proportion of dugongs sighted that are at the surface during the survey to the proportion sighted in a clear water area when all dugongs present were potentially available, and assumes that the proportion of dugongs at the surface is the same for all habitats and at all times (Marsh and Sinclair, manuscript a). This assumption may not be valid in Torres Strait, where in contrast to the east coast of Australia where our other dugong surveys have been carried out, significant numbers of animals are seen in relatively deep water (see Fig. 7 and text below). Anderson's (manuscript) observations suggest a trend for dugongs to remain submerged longer in deeper water. A more accurate correction for availability bias in Torres Strait will require further investigation of dugong diving behaviour in this area.

Distribution of Dugongs

Figures 4 and 5 are smoothed density distribution maps based on the results of the November 1987 and March 1988 surveys respectively. Maps of actual sightings are provided in the Appendix. In November 1987, dugong density was highest on the seagrass beds (see Fig.6) around Badu and extending north across Orman Reef around Buru Island and east to Gabba Island (9°46'S, 142°37'E). The next highest density was observed over the Warrior Reef complex. Densities were very low along the coasts of Papua New Guinea and Cape York including the northernmost waters of the Great Barrier Reef Marine Park.

Differences between surveys

There was no significant difference in the number of dugongs observed in the areas covered by both surveys (Table 6). Addition of Beaufort sea state and/or cloud cover for each transect as covariates did not change this result and made little difference to the results.

Because the March survey was not completed, it is not possible to determine if there had been a major change in the distribution of dugongs in Torres Strait between the two surveys. However, a significantly higher proportion of the dugongs sighted in the areas surveyed both in November and March, was close (<10km) to the major western islands in March (47/160 or 29%) than in November (26/251 or 10%) (G with William's correction =23.46, d.f.= 1, $p<0.001$). This is consistent with the Islander's perceptions that dugongs are more abundant in the area from Cape

York to Mabuiag during the North-West monsoon (Johannes and MacFarlane, manuscript).

High densities of dugongs were observed in the Buru Island/ Orman Reef area in both November 1987 and March 1988. This was also the area supporting the highest densities of dugongs in November 1983 (Marsh, 1986). Large numbers of dugongs were also sighted in this area on a Coastwatch flight on June 17 1988 (M. McCarthy, pers. comm). It seems likely that the extensive seagrass beds in this area (Fig. 6) are consistently important dugong habitat, despite the essentially seasonal nature of the dugong catch from this area by Boigu Islanders (Johannes and MacFarlane, manuscript).

As much of the Orman Reef area is uncharted, we were able to estimate the depth of water in which only about 45% of dugongs were sighted in the November 1987 survey (Fig. 7). The figures from March 1988 are, of course, even less representative. The surveys indicate that significant numbers of animals are sighted in relatively deep water (>10m), in contrast to the northern waters of the Great Barrier Reef Marine park where 56% of dugongs are sighted in water less than 5m deep (Marsh and Saalfeld, manuscript). Significant numbers of dugongs are seen more than 10km from land in Torres Strait, in contrast to their essentially inshore distribution in most other areas. Dugong distribution in Torres Strait undoubtedly reflects the extensive beds of both intertidal and subtidal seagrass beds in this area (Fig. 6).

Sustainable annual catch

On the basis of experience in Torres Strait in the late 1970's, Nietschmann (1984), 'guesstimated' an average annual dugong catch in Torres Strait of about 750 animals. We do not know whether this estimate was restricted to the Australian Islands or whether it included dugongs caught by Islanders who operate crayboats. From the limited statistics available (see Tables 1 and 2), Marsh (1986) estimated that the total annual dugong catch for the Torres Strait area for at least some years between 1975 and 1982 was at least 500 to 1000 animals. She then estimated the minimum populations required to support an annual unselective harvest of 500 and 1000 dugongs assuming a population sex ratio of 1:1 on the basis of a simple population model which was constructed to determine the annual rate of increase of stable dugong populations with various combinations of life-history parameters in the range observed for several populations.

Marsh (1986) calculated that, even with the most optimistic combination of life history parameters, a dugong population was unlikely to increase at more than about 5% per year. If the parameters calculated from the dugongs passing through the Daru market in 1978-1982 are operable, the maximum rate of increase is likely to be only about 2%. It is likely, however, that the rate of increase of the Torres Strait dugong population is currently higher than this latter figure which was obtained soon after anecdotal evidence suggests there was a period of extensive seagrass dieback in Torres Strait (Johannes and MacFarlane, manuscript). The mean calving interval (the parameter to which the dugong population model is most sensitive) decreased significantly from nine years in 1978-79 to three years in 1981-82, coincident with the reported recovery of the Torres Strait seagrass beds (Marsh and Hudson, unpublished data).

Marsh's (1986) population model indicates that 12,500 dugongs are likely to be able to sustain an unselective harvest of only 700 animals per year when dugongs are breeding optimally. If the population parameters calculated on the basis of the dugong specimens obtained from the Daru harvest in 1978-82 are currently valid, the maximum sustainable harvest is of the order of 300 per year. Johannes and MacFarlane (in press) reported that adult females outnumbered adult males in the 'unselective' catch of the Boigu Islanders recorded by Mrs Pabai from Boigu by a ratio of 5:2. Dugong tusks are sexually dimorphic and the small sample which has been forwarded to us by Mrs Pabai indicate that her records are correct. Nonetheless, we find this sex ratio surprising, as the (much larger) catches from Mabuiag, Badu and Kubin (Nietschmann, 1984), and from Daru (Hudson, 1986) indicated a ratio close to parity. However, if the Torres Strait dugong catch as a whole is currently biased in favour of females, the sustainable harvest figures of between 300 and 700 dugongs are substantial overestimates.

It is impossible to evaluate whether the dugong is currently being over-exploited in Torres Strait without reliable catch figures from all the major hunting communities in the region, plus an estimate of the number of dugongs killed for illegal sale All the evidence available suggests that the number caught is now much lower than for the period between 1975 and 1983 as summarized in Tables 1 and 2. Johannes and MacFarlane (manuscript) estimate that the total legal harvest of dugongs by members of the Australian communities in Torres Strait in the mid 1980's was of the order of 120-140 animals per year. (In 1985-87, the annual average catch from Boigu, a major hunting community, averaged about 45 animals per year (Johannes and MacFarlane, manuscript)). Johannes and MacFarlane also consider that the illegal harvest of dugongs for cash in the course of crayfishing activities has declined substantially from the 1983 level (Table 2). We have no information about the current dugong catch by the people of the Western Province of Papua New Guinea except that it is believed to have declined substantially since the sale of dugong meat was banned in 1984 (Hudson, 1986).

We believe that there is no cause for complacency about the dugong situation in Torres Strait, despite the apparent decline in catches and the substantially higher population estimate resulting from the November 1987 survey. The situation has the potential to deteriorate rapidly if catches increase. It is clearly important to continue with the public education campaign in an attempt to pre-empt such an increase, and to encourage the Government of Papua New Guinea to do likewise. It would also be desirable to continue monitoring the legal catch by communities on both sides of the border. Given the logistical difficulties of doing this in the Australian communities (Johannes and MacFarlane, manuscript), we suggest that at the very least, the monitoring of the catch at Boigu should be continued as an index of hunting activity in the Western Islands.

Effectiveness of the present sanctuary area

The surveys indicate that dugong density in much of the present sanctuary area is very low (Fig. 4 and 5). We were unable to survey the remainder of the sanctuary because of our inability to hire a suitable survey aircraft with an Omega navigation system, however, the bathymetry of the unsurveyed area suggests that it is unlikely to be good dugong habitat. Our observations suggest that banning dugong hunting from this area (which was not heavily hunted) is likely to have a limited effect on dugong conservation in Torres Strait, except as a means of emphasising the danger of over-exploitation and the need for rational management.

If dugong management in Torres Strait is to be effective, it will be important to protect animals in at least some of the high density areas. To change the boundaries of the present sanctuary so soon after it has been established would be psychologically unsound. We suggest that it would be more appropriate to negotiate with the Islanders about establishing a second sanctuary area in the region of Buru Island, an area of seemingly consistently high dugong numbers. Such a sanctuary would probably meet most opposition from hunters from Boigu, Badu and Mabuiag. However, the records of Johannes and MacFarlane (manuscript) indicate that only about 10% of the catch from Boigu is obtained from the Buru area and that this catch is seasonally limited. The proportion of the catch of hunters from Badu and Mabuiag which is obtained from the vicinity of Buru is unknown; both communities are known to hunt at Orman Reef between their home islands and Buru (Johannes and MacFarlane, manuscript). Even if it is impossible to obtain agreement about such a sanctuary in the near future, we suggest that the idea should be canvassed as part of the public education programme. It would also be timely to suggest to the Papua New Guinea Government that a dugong sanctuary should be established in their waters, perhaps within the Maza Wildlife Management Area (Hudson, 1986).

Timing of future surveys

As discussed above, the dugong's rate of maximum annual population increase is limited by its biology to about 5% a year or less. A rate of decline would be determined by numerous factors including the harvest regime. Given the evidence of declining catches in Torres Strait, the annual rate of change of the population is 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 low 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 5. Thus future surveys for dugongs in Torres Strait should cover the whole area of important dugong habitat (Fig. 3)..

November is the time of year when weather conditions are most likely to be optimal for a period long enough to survey such a large area adequately, making it unrealistic to plan more than one survey 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 say 5% or 10% 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 13% (as for the November 1987 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 β error was set at 0.05.

It is estimated that if surveys were held every year, it would take 9 years i.e. ten surveys to be able to detect a 5% decline with 95% confidence; six years to detect a 10% decline. After nine years a dugong population declining at 5% per year would have been reduced to 63% of its size at the time of the first survey, whereas a population declining at 10% per year would have been reduced to 53% of its initial level after six years. A preliminary indication of such trends could be obtained more quickly by allowing α and/or β 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). For example, we have calculated that 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 five years, and we have recommended that dugong surveys be repeated in the Park at five-yearly intervals. 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 Torres Strait.

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TABLE 1: Dugong catch statistics from five Torres Strait communities 1975-82.

Collection period	Location	Number caught		Source
		Total	Average per month	
October 1975 - June 1976	Thursday Island	41	4.6	Personal records kept by one hunter for Dr G.E. Heinsohn
Sept 1976 - August 1978	Mabuiag	227	9.5	Records collected by Nietschmann during his stay on Mabuiag plus records kept for him by an Islander in Kubin and Badu - March (Nietschmann 1984)
January 1977 - December 1977	Kubin	50	4.2	
October 1976 - 1979	Badu	227	7.8	
July 1978 - March 1982	Daru	454	10.1	Records of dugongs sold in the Daru market collected by PNG Division of Wildlife (Hudson, 1986)

TABLE 2: Estimates of the dugong catch of Islanders on crayboats in 1983 on the basis of interviews conducted in late 1983 by Marsh et al., (1984) and MacFarlane (see Johannes and MacFarlane, manuscript).

Informant	Interviewer	Estimate	Basis of estimate
Island leader not involved with fishery	Marsh	>100	discussions with other Islanders
Islanders who owned and operated crayboats	Marsh	~500[a]	30 taken one week from several boats; maximum of 11 per day; last week (November 12-18 1984) four taken from one boat
Crayboat crews + personal involvement with cray industry 1980-81	MacFarlane	~240	Assumed 2 dugongs / per week per boat, 4 boats, 30 week season[b]

[a] Probably an overestimate; the Islanders wished to emphasise their prowess as hunters.

[b] This is probably an overestimate of the length of the crayfishing season and of the weekly catch. Peter Channells (pers. comm. 1988) reports that the average number of days per year worked by a freezer boat in 1981-86 was 109 and that vessels do not work continuously in areas where dugongs occur.

TABLE 3: Areas of survey blocks and sampling intensities.

Block	Area (km^2)	Sampling %
(a) November 1987		
0	2202.0	9.1
1	6420.0	9.5
2	7148.0	9.1
3	9287.0	4.2
4	3108.0	5.1
5	1221.0	12.2
6	1167.0	7.9
	30533.0	7.4
(b) March 1988		
2[a]	5477.0	9.5
3[a]	5904.0	4.9
4	3108.0	5.1
5[a]	829.0	10.0
6[a]	1070.0	8.5
	16388.0	7.0

[a] these blocks were incompletely sampled in the March 1988 survey (see Figure 2 for details of transects not flown).

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

Blocks : lines	Group size mean (C.V.)	Number of observers Port	Starboard	Perception Correction Factor estimate (C.V.) Port	Starboard	Availability Correction Factor estimate (C.V.)
(a) November 1987						
5: 9-13	1.3863(0.0470)	1[a]	1[b]	1.3538(0.0087)	1.3913(0.0188)	2.7203(0.1196)
2: 1-8; 3: 13-16	1.3863(0.0470)	2	1[b]	1.0425(0.0087)	1.3913(0.0188)	2.7203(0.1196)
0; 1; 2: 9-28; 3: 1-12; 4; 5: 1-8, 14-16; 6	1.3863(0.0470)	2	2	1.0425(0.0087)	1.0896(0.0188)	2.7203(0.1196)
(b) March 1988						
2: 1-5	1.4375(0.0505)	1[a]	1[b]	1.5238(0.0422)	1.5000(0.0568)	2.5714(0.1367)
2: 6-8	1.4375(0.0505)	2	1[b]	1.1513(0.0422)	1.5000(0.0568)	2.5714(0.1367)
2: 9-28; 3: 3-13; 4; 5: 1-4, 9-13; 6: 2-11	1.4375(0.0505)	2	2	1.1513(0.0422)	1.1538(0.0568)	2.5714(0.1367)

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

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

TABLE 5: Estimated densities and numbers of dugongs for the surveys. The values are ± standard error incorporating the errors resulting from sampling and in estimating mean group size and correction factors.

Block	Density per km^2	Numbers
(a) November 1987		
0	0.00 ± 0.00	0 ± 0
1	0.18 ± 0.04	1140 ± 280
2	1.11 ± 0.17	7925 ± 1204
3	0.29 ± 0.11	2673 ± 1041
4	0.23 ± 0.10	717 ± 300
5	0.06 ± 0.02	67 ± 27
6	0	0
Total	0.41 ± 0.05	12522 ± 1644
precision		0.13
(b) March 1988		
2[a]	0.84 ± 0.15	4596 ± 839
3[a]	0.31 ± 0.14	1832 ± 840
4	0.03 ± 0.03	84 ± 85
5[a]	0	0
6[a]	0	0
Total	0.40 ± 0.07	6511 ± 1190
precision		0.18

[a] these blocks incompletely surveyed due to bad weather preventing completion of survey.

TABLE 6: Summary of the analysis of variance comparing dugong density in Torres Strait in November 1987 and March 1988 using a randomized block design with transect line as the blocking factor. The analysis has been performed with and without Beaufort sea state and cloud cover as covariates.

Covariate	Factors			
	Lines (d.f. = 39)		Years (d.f. = 1)	
	F	p	F	p
none	1.90169	0.024	1.14217	0.292
Beaufort sea state	1.77641	0.040	1.03702	0.315
cloud cover	1.83974	0.031	1.00269	0.323
Beaufort sea state + cloud cover	1.72316	0.050	0.93619	0.340

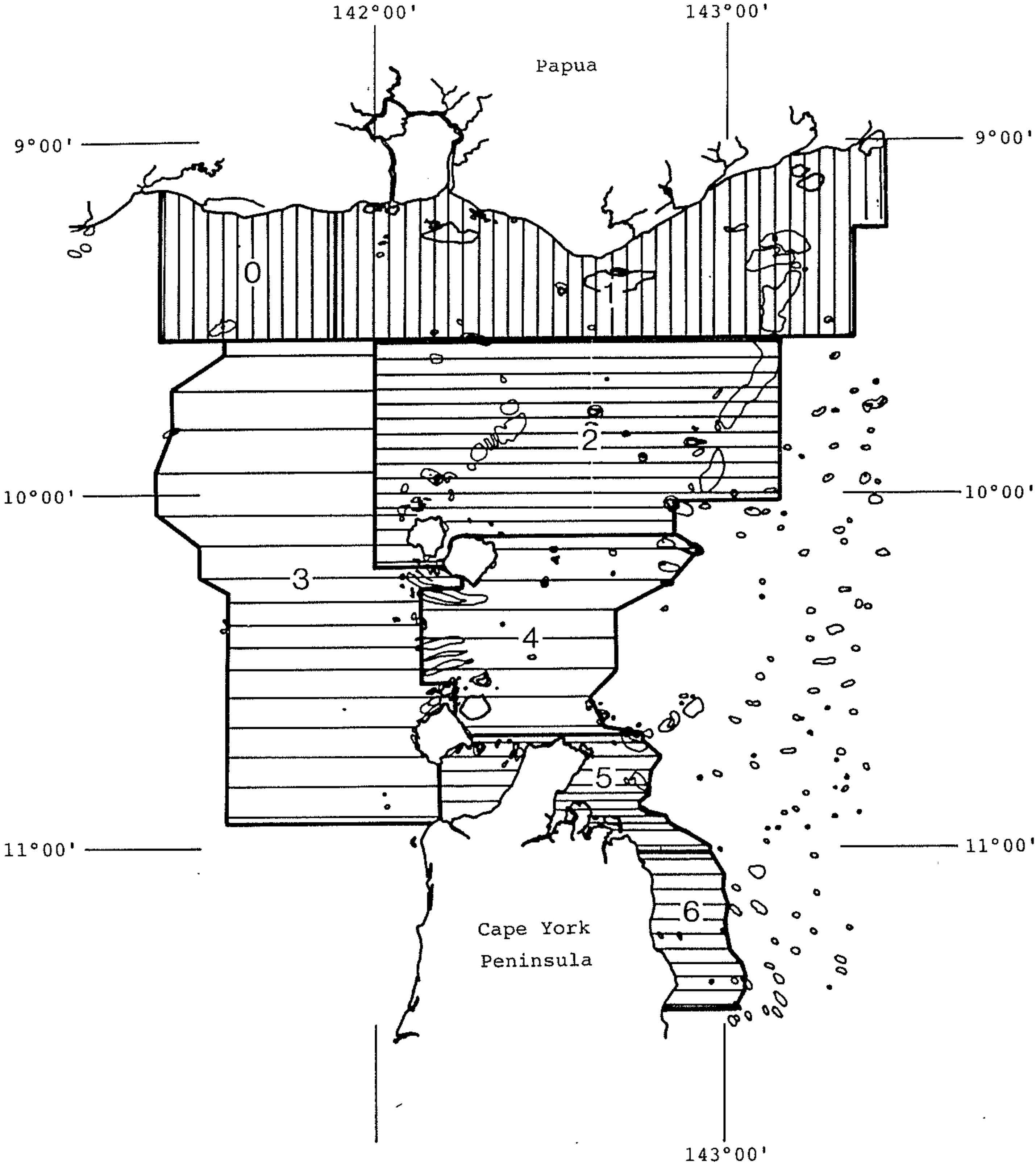

Figure 1: Survey area, showing the survey blocks (0-6) and transect lines for the November 1987 survey.

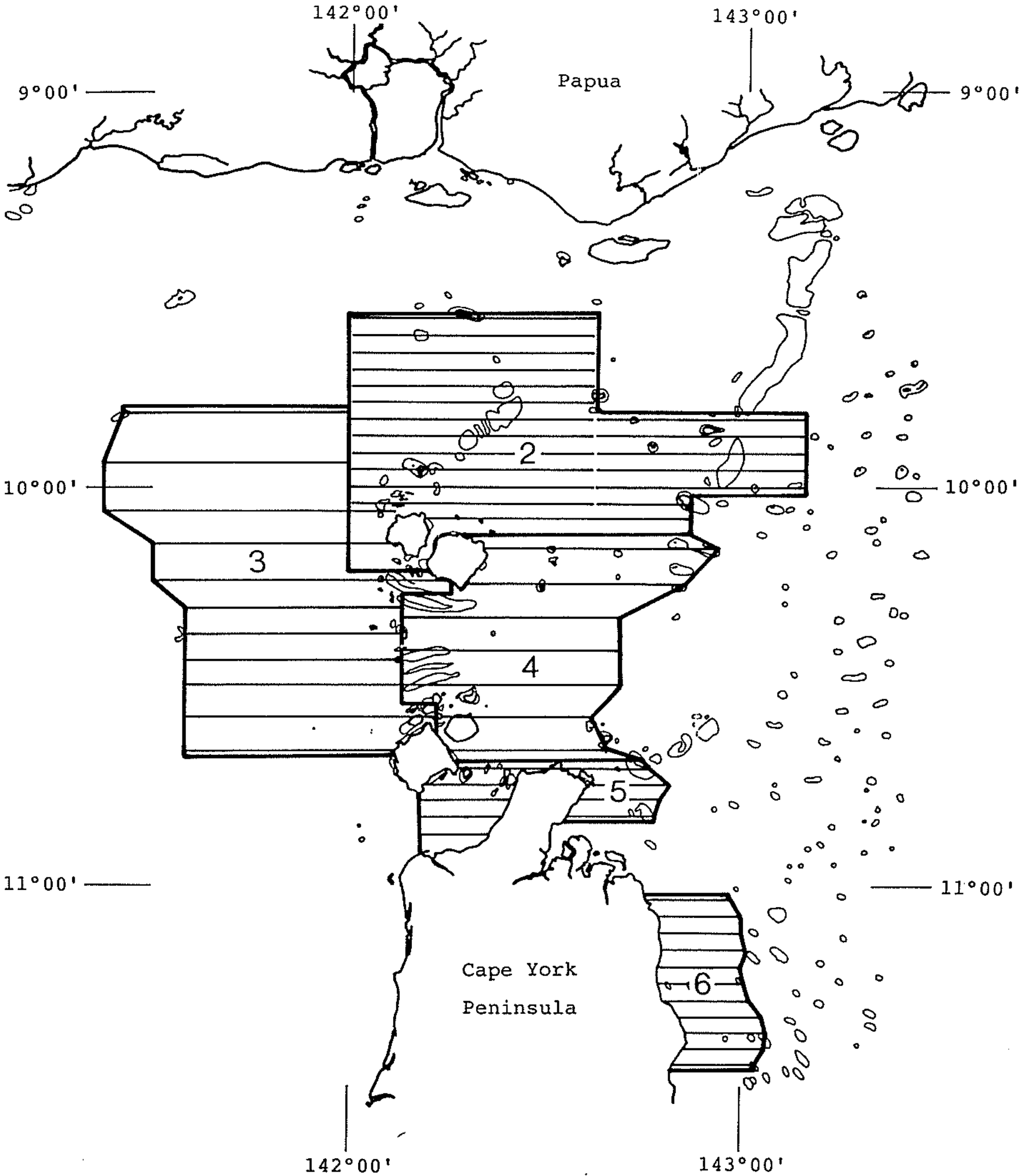

Figure 2: Survey area, showing the survey blocks (2-6) and transect lines for the March 1988 survey. Note that blocks 2, 3, 5 and 6 were incompletely surveyed with respect to the same blocks in the November 1987 survey, and that blocks 0 and 1 were not surveyed.

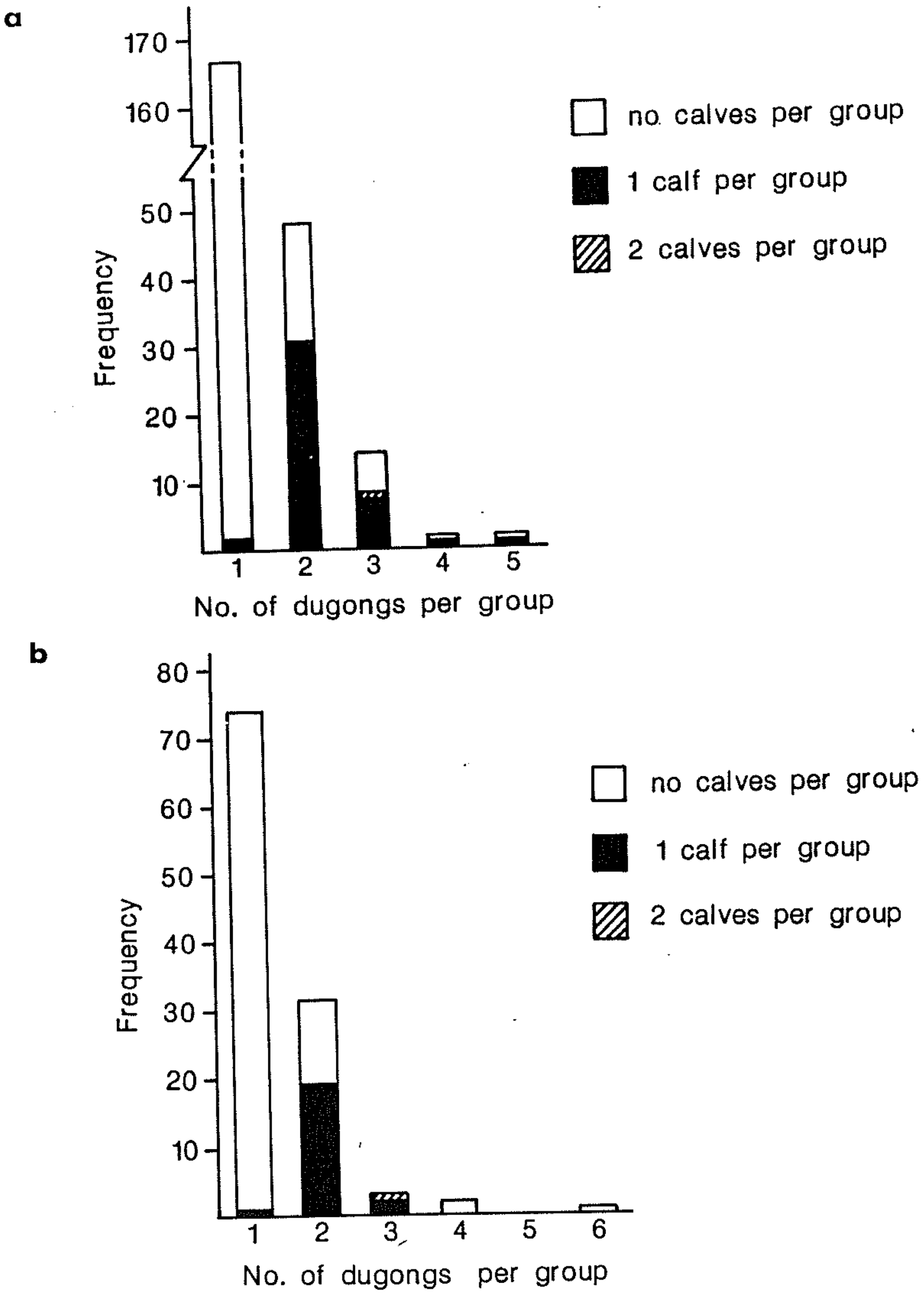

Figure 3: Frequency histograms showing details of dugong group size and composition for (a) November 1987 and (b) March 1988 surveys.

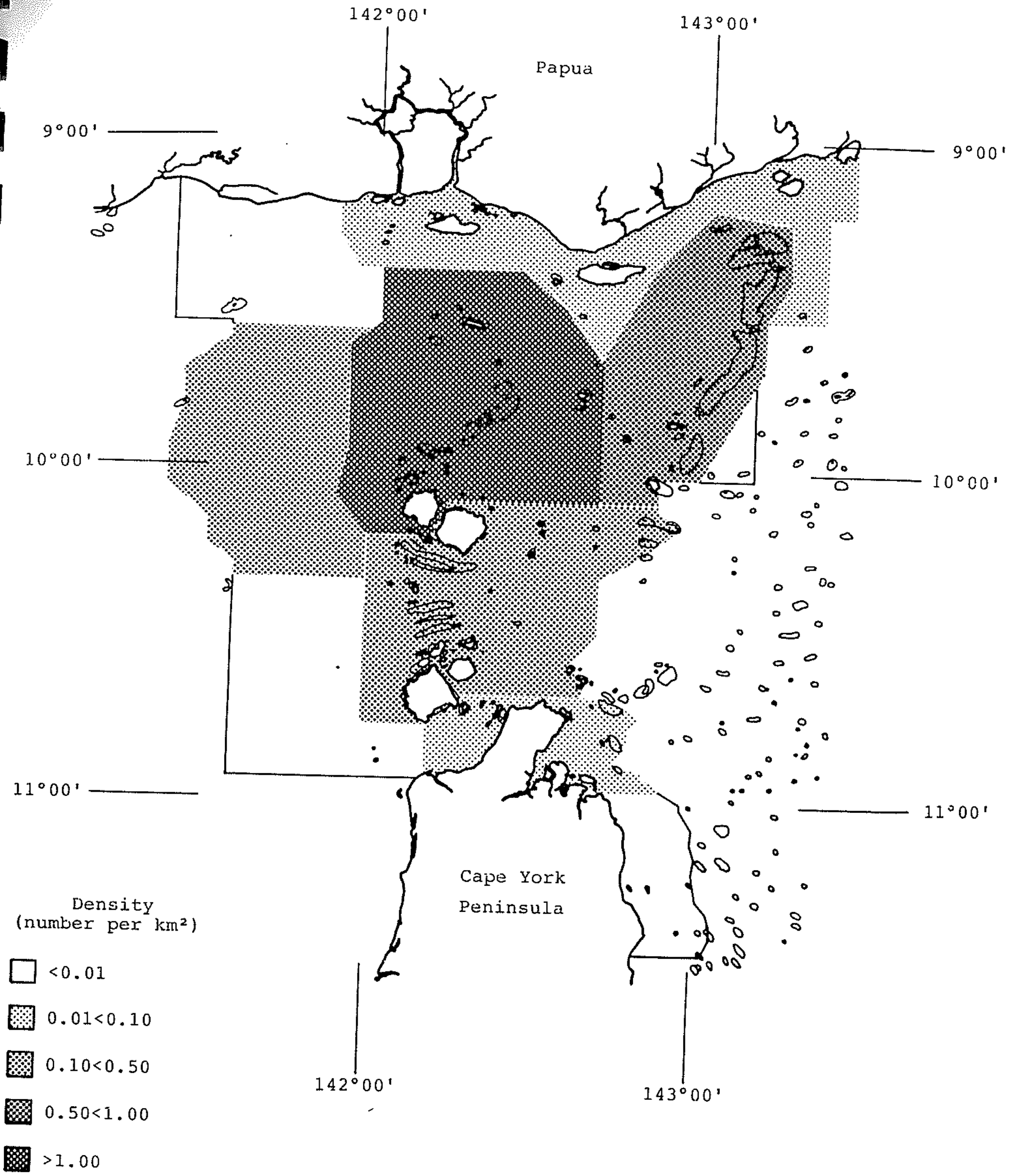

Figure 4: The distribution of dugong density in the survey area in November 1987. Overlay shows the boundaries of the Protected Zone Joint Authority Dugong Sanctuary Area.

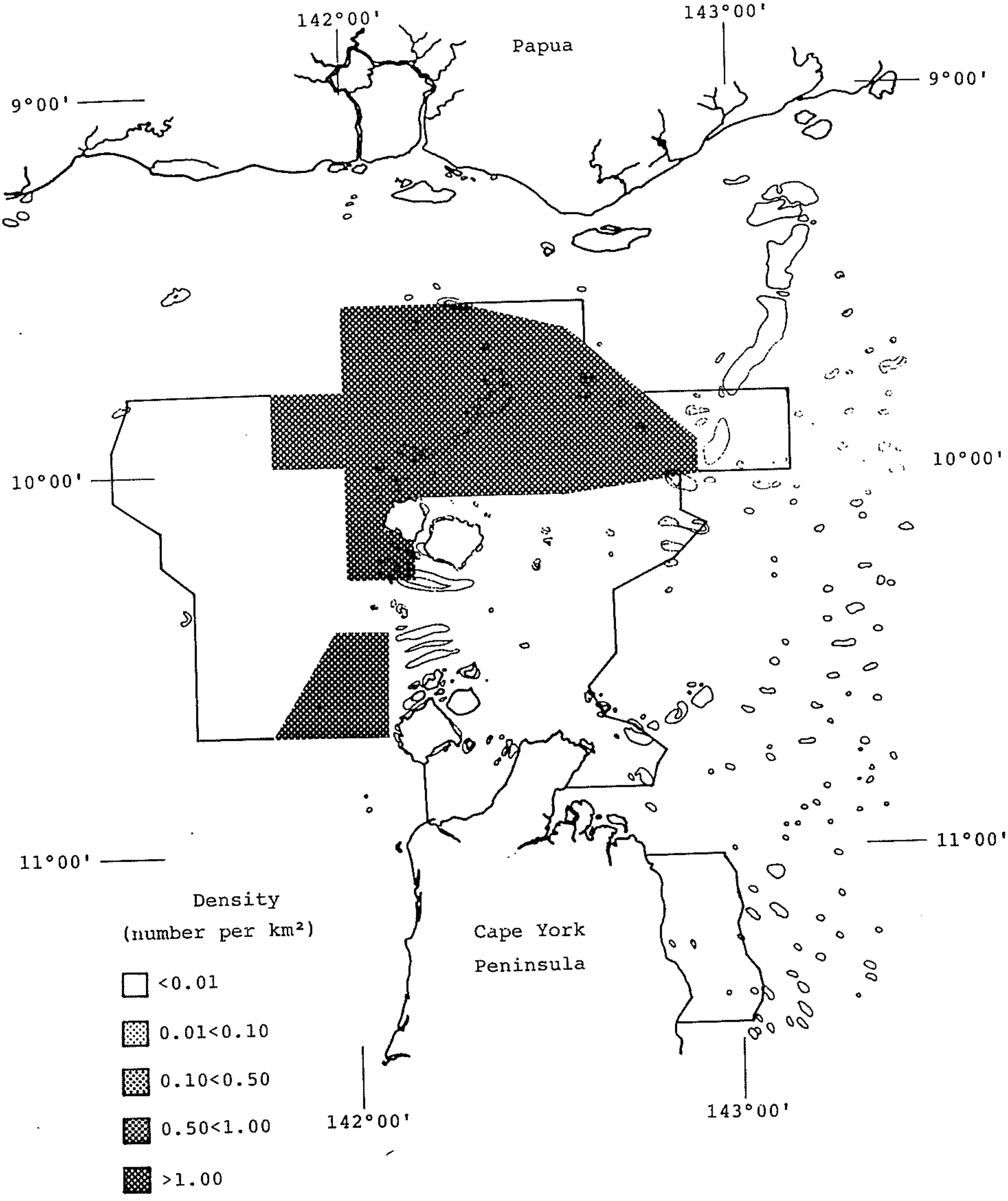

Figure 5: The distribution of dugong density in the survey area in March 1988. Overlay shows the boundaries of the Protected Zone Joint Authority Dugong Sanctuary Area.

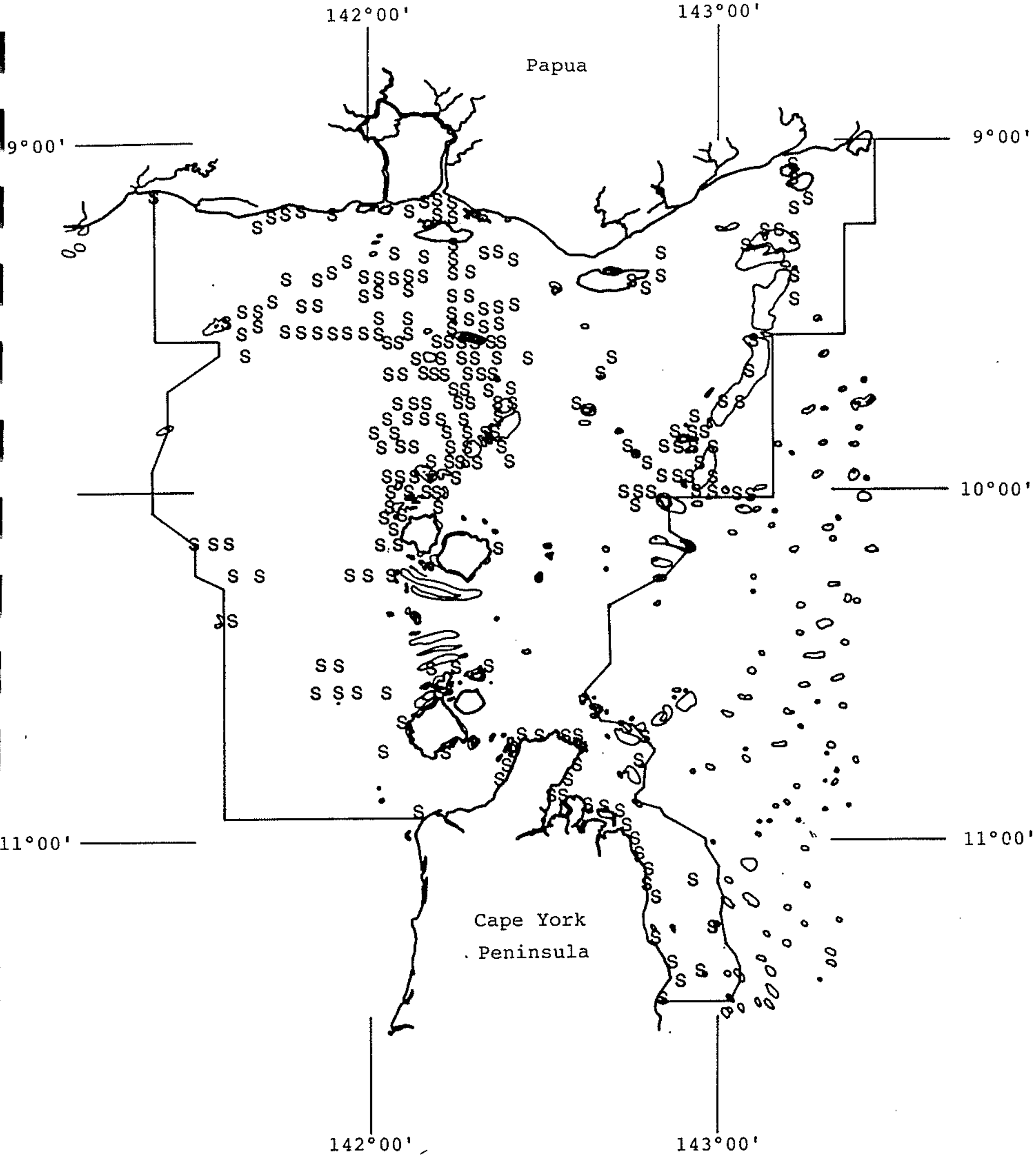

Figure 6: The distribution of presumed seagrass sightings from the air in the survey area. Sightings from the November 1987 and March 1988 surveys have been combined on a single map, with the boundaries of the survey area indicated.

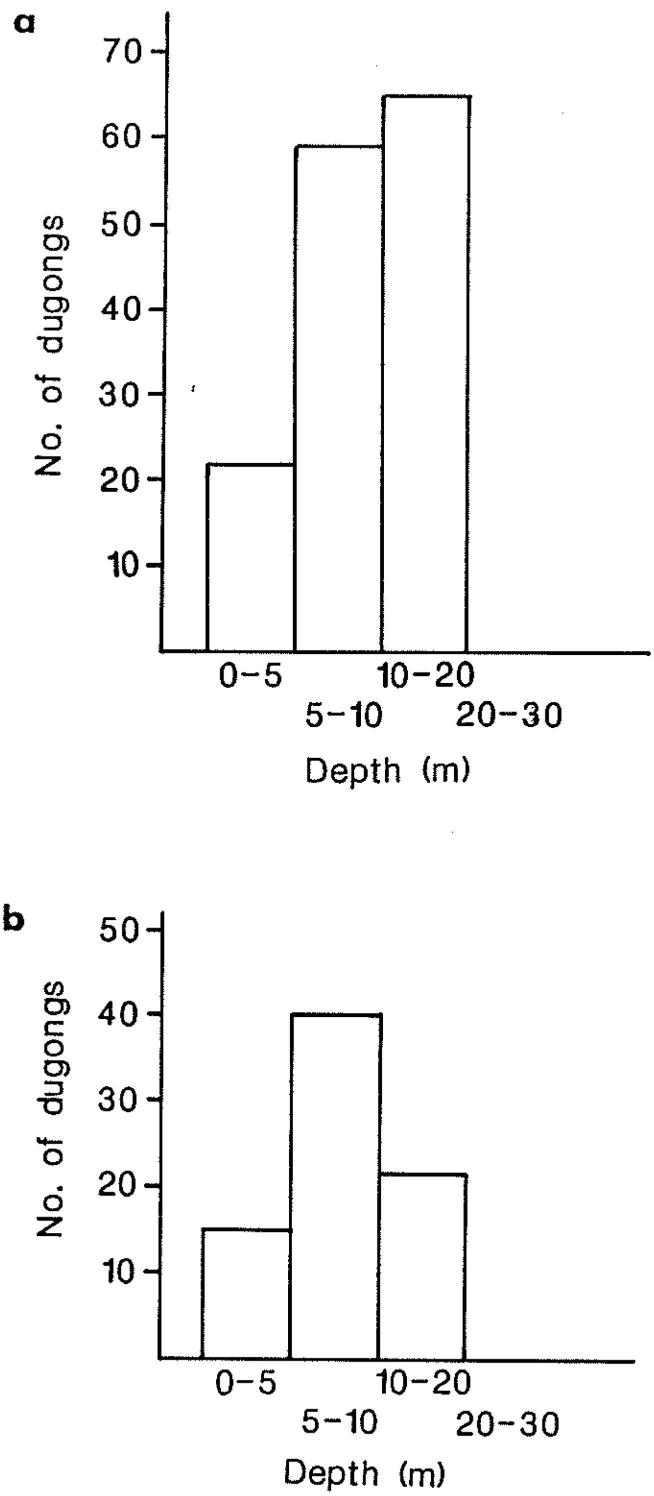

Figure 7: Frequency histograms showing the depths of water in which dugongs were sighted in (a) November 1987 and (b) March 1988. Estimates for depth of water are biased as they were made only for the less than 50% of sightings that occured in charted waters. Most of the uncharted waters are likely to be less than 10m deep.