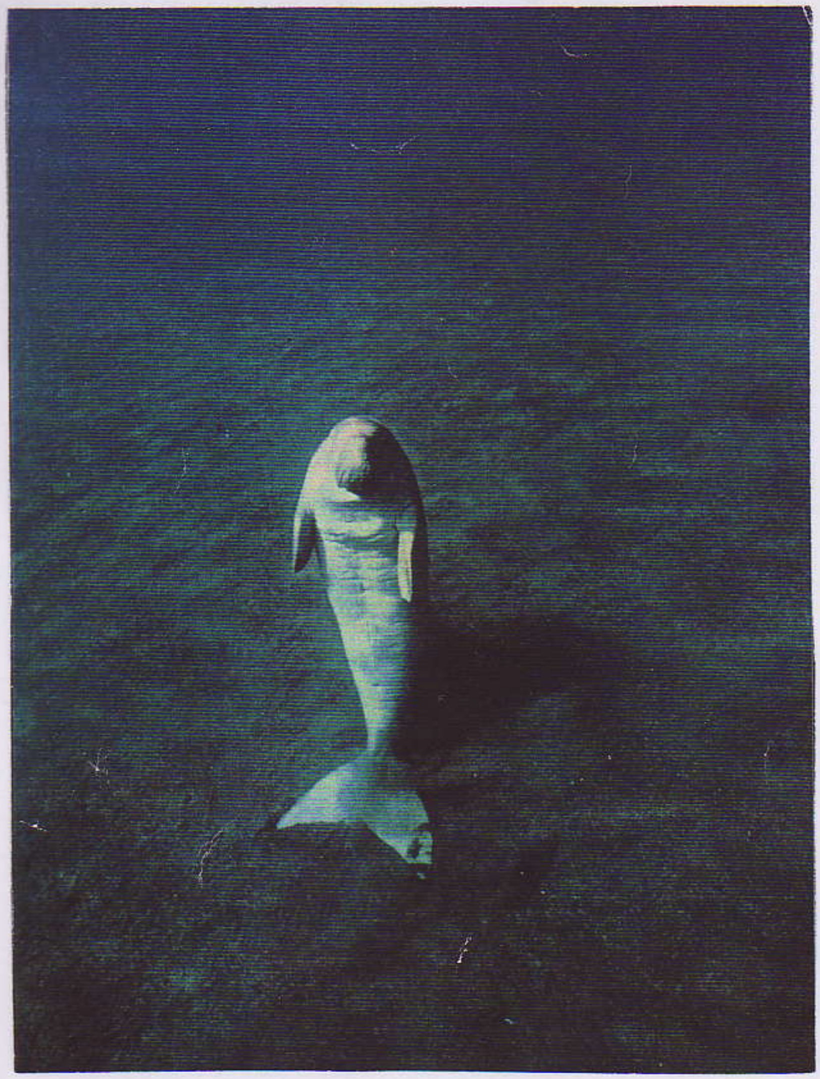
AERIAL SURVEY OF MARINE WILDLIFE IN GULF OF CARPENTARIA WATERS ADJACENT TO QUEENSLAND



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RESULTS OF AN AERIAL SURVEY OF THE MARINE WILDLIFE IN THE GULF OF CARPENTARIA WATERS ADJACENT TO QUEENSLAND IN DECEMBER 1997 AND CONSEQUENTIAL RECOMMENDATIONS FOR MANAGEMENT

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DISCLAIMER

EXECUTIVE SUMMARY

Background

- The Queensland waters of the Gulf of Carpentaria are a large and generally remote region that is well-known for its marine wildlife. The species present in this area include the dugong *(Dugong dugon)*; at least three species of coastal dolphins: the bottlenose dolphin (*Tursiops truncatus)*, the Irrawaddy River dolphin, *(Orcaella brevirostris)*, and the Indo-Pacific humpback dolphin (*Sousa chinensis)*; and six species of sea turtle: flatback (*Natator depressus*), green (*Chelonia mydas)*, hawksbill (*Eretmochelys imbricata),* leatherback (*Dermochelys coriacea)*, loggerhead (*Caretta caretta)*, and olive ridley (*Lepidochelys olivacea)*.

- This report describes the results of the first survey of the entire Queensland coastal waters of the Gulf of Carpentaria for marine wildlife using the quantitative aerial survey techniques, which are now standard for dugongs.

Objectives of project

1. Determine the distribution and relative abundance of dugongs, sea turtles and cetaceans (dolphins and small whales) in the survey area as a basis for conservation and fisheries management planning.
2. Compare the distribution and relative abundance of dugongs, sea turtles and dolphins in: (a) the Wellesley Island area, and (b) the Karumba area, with the results obtained from similar surveys of these areas in 1991 and 1994 respectively.
3. Compare the distribution and relative abundance of marine wildlife in the area with: (a) the spatial distribution of mesh netting effort as determined from the logbook data collected by the Queensland Fisheries Management Authority; and (b) the location of industrial developments along this coast.
4. Provide information of the spatial distribution of dugongs and green turtles as a basis for comparison with information on the spatial distribution of Indigenous hunting in the region when data on such hunting become available.
5. Provide advice on management actions required in the short, medium and long-term.
6. Provide recommendations on any further surveys for the area, including the survey interval.

Methodology

The survey used the strip transect aerial survey methodology routinely used for dugong surveys since the mid 1980s rather than the line transect methods now routinely used for dolphin surveys because:

1. Dugongs rather than dolphins or sea turtles were the main target species for the survey.
2. Consistent methodology is essential to a reliable time series.
3. The strip width is sufficiently narrow to preclude detectable variation in dugong sightability across the transect.
4. Dugongs are most often seen as solitary individuals or adult female-calf pairs in turbid water and exhibit cryptic surfacing behaviour. We therefore preferred to use a technique in which the observers do not have to take their eyes off the water to read an inclinometer.

We consider that this technique provides good information on the distribution and relative abundance of dugongs and reasonable information on the distribution and abundance of sea turtles and dolphins. However, the technique provides very limited information on the specific identification of dolphins or sea turtles.

Results of the aerial survey

- The coastal waters of the Gulf of Carpentaria adjacent to Queensland (33026 km^2) were surveyed between December 2 and 6 1997 using two survey crews each of six people in two aircraft. Two aircraft enabled the survey to be completed in five days and minimised the chance of the population estimates being confounded by local movements of dugongs within the survey period. The survey area was divided into the eight blocks on the basis of sampling intensity and transect placement. Transects were aligned in an east-west direction. Transect lines were spaced 2.5' apart in Blocks 1-5 and Block 8 and at intervals of 5' in Blocks 6 and 7 giving an overall sampling intensity of about 6%.

- Population estimates for dugongs and sea turtles were corrected for perception bias (the groups of animals visible on the transect line that were missed by observers). Estimates for these taxa were also standardised for availability bias (the groups of animals unavailable to the observers due to water turbidity) to facilitate comparisons with other surveys. Too few groups of dolphins were sighted for a reliable correction for perception bias to be calculated. A correction for availability bias was not attempted for dolphins because of the lack of a suitable standard.

- The total standardised population estimate for dugongs in the survey area was 4,266 $\pm$ s.e.657 at an overall density of 0.12 ± 0.02 dugongs per km^2. This is not an absolute population estimate. Sixty-two percent of the total were in the Wellesley Island area; 45% of the total were in the inshore waters of this region within the 3 m depth contour. These results confirm that the Wellesley Island region is the most important dugong habitat in Queensland apart from Torres Strait and Princess Charlotte Bay. A similar (but not identical) survey of the Wellesley Island region in 1991 resulted in a standardised population estimate of 4,066 $\pm$ s.e.723 dugongs. The number of dugongs sighted in both 1991 and 1997 was sufficient for statistical comparisons in only three survey blocks within this area. There was no significant difference between the estimated number of dugongs in these blocks in 1991 and 1997, however, the interaction between time and block was different between the two surveys due to a change in the distribution of dugongs within the Wellesley Island region.

The survey confirmed that the regions in the vicinity of the ports of Weipa and Karumba are not particularly important dugong habitat. The major difference between the results of this survey and the shoreline surveys conducted in the 1970s was that we only sighted one dugong between the mouth of the Staaten River and Cape Keer Weer (a distance of approximately 300 km) in 1997. This is the region where between 54 and 227 dugongs were sighted in various shoreline surveys in the 1970s. These figures are not strictly comparable due to differences in survey technique, but as explained in the text, they suggest that fewer dugongs occur in this region in late 1997 than 20 years ago.

Sea turtles were seen in all the survey blocks. Numbers were highest in offshore waters of the Wellesley Islands and along the west coast of the Cape York, north of the Holroyd River. The total standardised (not absolute) population estimate for the survey area was 15,728 $\pm$ s.e.1,225 turtles at an overall density of 0.48 $\pm$ s.e. 0.039 turtles per km^2. The only turtles, which were unambiguously recognised to species, were five leatherback turtles on the west coast of Cape York south of Kowanyama. Sets of possible nesting tracks formed by leatherback turtles were observed on the beach in this area during a low-level flight along the shoreline. The significance of the coastal waters in the region between the mouth of the Nassau and Mitchell Rivers to the leatherback turtles requires further investigation. Although the number of sightings in our survey was low, this may be a significant concentration of a fairly rare animal which is listed as 'endangered' under Queensland legislation and by the IUCN (1996), and as 'vulnerable' under Commonwealth legislation.

- Only 18 of the 64 groups (28%) of dolphins sighted were definitely identified to species. Of these, 14 groups (78%) were Bottlenose dolphins in groups of up to 23 animals. Two single Indo-Pacific humpback dolphins were sighted. A group of seven Irrawaddy River dolphins were sighted inshore west of the Wellesley Islands, another two in Port Musgrave. Two Irrawaddy River dolphins were also seen inshore of the Wellesley Islands. Densities were highest in the offshore blocks in the Wellesley Islands and along the coast of Cape York north of the Holroyd River, regions where most of the sightings were probably Bottlenose dolphins. The total relative (not absolute) population estimate of dolphins for the survey area was 3,415 $\pm$ s.e.684 at an overall density of 0.095 $\pm$ s.e.0.021 per km^2.

Options for Management

<u>Short-term options achievable under Queensland Fisheries Regulation</u>

These options have been discussed with the commercial fishing industry and the Queensland Fisheries Management Authority (QFMA).

Option 1.

Management actions outlined in the QFMA Gulf of Carpentaria Inshore Fisheries Management Plan (QFMA 1999).

Details of Option 1

Objective 3 of the Plan is 'to minimise the effects of fishing on protected wildlife'.

The Plan states that this objective is to be achieved by:
(a) the requirements under the Plan for attending certain types of net; and
(b) putting into effect closed water declarations under part 3 of the plan in areas identified by the Authority as being important for the species. The only such area identified in the Plan is the proposed closure at the mouth of the Norman River to protect dugong (QFMA 1999).
(c) the requirements under the Plan for minimum and maximum mesh sizes of nets.

The Plan states that the effects of fishing on protected wildlife is to be measured by:
(a) implementation by the Authority of the recording of the incidental catch of the species;
(b) compliance with net attendance requirements and closed water declarations under the Plan;
(c) compliance with the requirements under the Plan for minimum and maximum mesh sizes of nets.

The Plan further states that the provisions of the Plan for minimising the effects of fishing on protected wildlife are to be reviewed if there is significant:
(a) increase in the recorded incidental catch of the species; and
(b) decline in the level of compliance and closed water declarations under the Plan;
(c) decline in the level of compliance with the minimum and maximum mesh sizes for nets.

Assessment of Option 1

We consider that implementation of this option is unlikely to achieve the Plan's objective to minimise the effect of fishing on protected wildlife for the following reasons:
(1) The Plan does not specify the wildlife on which it plans to minimise the effects of fishing.
(2) The Plan does not include a mechanism to educate the fishermen about the need to minimise their impact on protected wildlife or to identify any wildlife caught. Due to the remoteness of the area, enforcement capacity is extremely limited and thus education is vital.

(3) Six species of sea turtles (green, loggerhead, flatback, leatherback, hawksbill, olive ridley), at least three species of dolphins (bottlenose, Irrawaddy and Indo-Pacific humpback) and one species of dugong occur in the Queensland waters of the Gulf of Carpentaria (Marsh *et al.* 1995). Thus the effect of fishing on individual species cannot be evaluated unless the fishers are trained to recognise the relevant species through an Endangered Species Awareness Course. These species of marine wildlife have different conservation status under the *Queensland Nature Conservation Act 1992* as follows:

Endangered:	loggerhead turtle, leatherback turtle, olive ridley turtle
Vulnerable:	dugong, green turtle, hawksbill turtle, flatback turtle
Rare:	Irrawaddy dolphin, Indo-Pacific humpback dolphin

(4) The Plan does not specify a penalty for failing to record incidental catch. We suggest that such failure should be a serious fisheries offence. Note: It is a legal requirement under the *Commonwealth Whale Protection Act 1980* to report the incidental death of a cetacean in Commonwealth waters in Australia. It will be a legal requirement under the *Commonwealth Environment Protection and Biodiversity Conservation Bill 1999* to report the taking of listed species of marine wildlife (including dugongs and sea turtles) as well as cetaceans in Commonwealth waters

(5) The Plan does not include an effective mechanism for the independent recording of incidental catches for the N3 fishery (operating to 8 nm offshore). Experience in New Zealand (Appendix 2) suggests that fishers fail to comply with compulsory incidental reporting programs for marine mammal by-catch. In New Zealand, such observer programs are funded by a Conservation Services Levy.

(6) The effectiveness of the net attendance rules proposed in the Plan for reducing the mortality of protected wildlife is unproven. Testing the effectiveness of these rules would be extremely expensive as outlined above.

(7) All closures nominated are river closures of limited use as protection for marine wildlife. The closure of the mouth of the Norman River, although welcome and important for maintaining the dugong's range in the Gulf, is unlikely to reduce the impact of fishing on protected wildlife in the Queensland waters of the Gulf of Carpentaria significantly because of the low numbers of dugongs, dolphins and sea turtles using the area.

(8) The proposed performance indicators do not measure the effects of fishing on protected wildlife.

Option 2.

Option suggested by Mr Gary Ward, commercial fisher and member of the Tropical Finfish Management Advisory Committee

Details of Option 2

General

The Management Plan for the Queensland Gulf of Carpentaria Inshore Finfish Fishery should:

(a) Recognise a Dugong Sensitive Area along the coast from the mouth of the Albert River to the mouth of Arthur's Creek (west of Bayley Point) and north to latitude 16 20's;

(b) Require all participants in the N3 and N9 fisheries to complete the QCFO's Endangered Species Awareness Course;

(c) Require all vessels operating in the Gulf of Carpentaria inshore finfish fishery to complete a dugong sighting log with returns to the QFMA with a view to developing a chart to inform fishers about dugong distribution in the Gulf;

(d) Include a chart detailing the distribution of seagrass beds to allow N3 entitlement holders to identify potential dugong areas;

(e) Introduce an observer program for the N3 fishery.

(f) Require that the situation regarding incidents involving protected species be formally reviewed each year at the October meeting of the Karumba Branch of QCFO;

(g) Require that offshore nets:
- be a maximum of 400 m long (drift nets) or 600 m long regardless of entitlements (set nets),
- have a maximum line strength of 35 gauge
- have at the net attendance,
- be no more than 100 m from the next set if multiple sets are used,
- not be used as a bottom set net;

(h) Require that for foreshore nets:
- the first net be not more than 1 km from primary vessel,
- be no more than 200 m per set (total maximum 600 m),
- have a maximum line strength of 50 gauge.

Assessment of Option 2

We consider that this option is a significant improvement over Option 1 for the following reasons:

(1) Option 2 includes mechanisms to educate the fishers about the need to minimise their impact on protected wildlife, to teach them to identify any wildlife caught, and to review the situation each year.

(2) Option 2 acknowledges the most important region along the Queensland coast of the Gulf of Carpentaria for dugongs and sea turtles as a Dugong Sensitive Area. This region contains an estimated 62% of the dugongs, 32% of the sea turtles and 28% of the dolphins in the Queensland waters of the Gulf of Carpentaria based on an aerial survey in December 1997.

(3) Option 2 includes additional measures designed to reduce the mortality of wildlife in both foreshore and offshore nets by a fisher with considerable local knowledge.

(4) Option 2 includes an observer program for the N3 fishery.

However, Option 2 may not be totally effective in minimising the effect of fishing on protected wildlife for the following reasons:

- It does not specify a penalty for failing to record incidental catch. Note: It is a legal requirement under the *Commonwealth Whale Protection Act 1980* to report the incidental death of a cetacean in Commonwealth waters in Australia. It will be a legal requirement under the *Commonwealth Environment Protection and Biodiversity Conservation Bill 1999* to report the taking of listed species of marine wildlife (including dugongs and sea turtles) as well as cetaceans in Commonwealth waters.
- The effectiveness of the proposed changes to the rules for offshore and foreshore nets in reducing the mortality of protected wildlife is unproven and will be very expensive to establish.

Option 3.

Details of Option 3

The initiative presented below is in addition to those included in Options 1 and 2 above.

(a) Ban foreshore and offshore netting in the Dugong Sensitive Area proposed in Option 2 above.

(b) Make a consequential reduction in the effort in the N3 fishery through a suitable adjustment package. (Based on QFMA logbook data for 1993-96, the required effort reduction is estimated to be about 7% of the total effort in the Gulf net fishery or 820 days per year).

(c) Make the use of Vessel Monitoring System compulsory for the N3 fishery as well as for the N9 fishery.

Assessment of Option 3

This option will go a long way towards meeting the objective of the Plan 'to minimise the effects of fishing on protected wildlife' by closing the most important area for marine wildlife to netting and by including options which may reduce catch in other areas. However, given the uncertainty of the effectiveness of these options in reducing bycatch, the effectiveness of Option 3 in minimising the effects of fishing outside the closure areas is unknown.

Longer-term management option

The Dugong Sensitive Area proposed in Option 2 above is under Native Title Claim and could be declared an Indigenous Protected Area by agreement between the traditional owners, the state of Queensland and the Commonwealth government. This would provide a structure for the community-based management of the dugong and green turtle catch. To be implemented effectively, such a management initiative should include training for community rangers in management and recording catch and supplying the community with the required infrastructure to monitor the catch e.g., boats.

If the seagrass surveys recommended below confirm significant seagrass resources in other areas, management arrangements should also be developed for these areas.

Suggestions for Future Surveys

Wildlife surveys

The optimum time interval between regional-scale quantitative aerial surveys for marine wildlife is a tradeoff between information and cost. Marsh and Saalfeld (1989b) recommended that regional surveys for dugong be conducted every five years. The disadvantage of this recommendation is that there is no replication within each survey interval, making unexpected changes difficult to interpret. Given that the 1997 estimate of the dugong population of the Wellesley Islands area was only 65% (but not significantly different from) the 1991 estimate, it would be desirable to resurvey the region in 1999 and at five year intervals thereafter, with the option of reducing the survey interval if a decline were confirmed.

It is impossible to interpret the differences between this survey and the shoreline surveys of the west cost of the Gulf of Carpentaria due to the differences in survey technique. A series of 3-5 shoreline surveys along this coast would be relatively cheap to execute, would eliminate the confounding effects of survey design, and would allow improved temporal comparisons.

A ground survey should be conducted along the western coast of Cape York in the turtle nesting season to establish whether or not leatherback turtles are nesting along the coast south of Mitchell River.

Seagrass

The most recent map of seagrass habitats of the Queensland coast of the Gulf of Carpentaria is 14 years old. An current map of potential dugong and sea turtle habitats would be a useful initiative in a package of measures to minimise the by-catch of protected wildlife. An organisation with expertise in the regional scale mapping of seagrass, such as The Queensland Department of Primary Industries, should be funded to conduct this work. Particular attention should be paid to the determining the presence/absence of seagrass in the estuaries along the coast of Cape York.

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INTRODUCTION

The Queensland coast of the Gulf of Carpentaria is a large and generally remote area (Figure 1), with little industrial activity except for two local developments: Weipa (site of the Comalco bauxite mine and the associated port) and Karumba (site of the loading facility for the Century Zinc and Lead Mine). The region supports a major component of the commercially important Northern Prawn Fishery and a limited entry inshore finfish fishery involving 109 licensed operators and with a total annual catch of about 1,100 tonnes worth $5.7 million (QFMA 1998). The area of the inshore finfish fishery comprises all tidal waters in the Gulf of Carpentaria and adjoining waterways between the 25 nautical mile line and the shore.

The region is well-known for its marine wildlife including the dugong, *Dugong dugon (*Marsh *et al.* 1980); three species of coastal dolphins: the bottlenose dolphin (*Tursiops truncatus)*, the Irrawaddy River dolphin, *(Orcaella brevirostris)*, and the Indo-Pacific humpback dolphin (*Sousa chinensis)* (Bannister *et al.* 1996); and six species of sea turtle: flatback (*Natator depressus*), green (*Chelonia mydas)*, hawksbill (*Eretmochelys imbricata),* leatherback (*Dermochelys coriacea)*, loggerhead (*Caretta caretta)*, and olive ridley (*Lepidochelys olivacea)* (Marsh *et al.* 1986; Poiner *et al.* 1990; Marsh *et al.* 1995).

Aerial surveys for dugongs were conducted along the Queensland coast of the Gulf of Carpentaria (Figure 1) in the 1970s using a shoreline survey technique described by Heinsohn *et al.* (1976). This technique identifies inshore dugong habitats and provides **uncorrected minimum counts** of the numbers of dugongs within one to two kilometres of the shore. These surveys consistently indicated that the area around the Wellesley Islands was important dugong habitat with 91 animals counted in April 1975 (Ligon 1976), 160 in April 1976, 271 in July 1976 (this survey did not include the South Wellesley Islands), 265 in November 1976 and 213 in April 1977 (Marsh *et al.* 1980). The surveys also suggested that there was a seasonal movement of dugongs within the Wellesley Islands area. In November, a higher proportion of the total number of dugongs sighted was closer to the southern Wellesley Islands (between Mornington Island and Point Parker) than in April (Marsh *et al.* 1980). This distribution agreed with the knowledge of traditional hunters (Marsh *et al.* 1980) suggesting that it was not an artefact of the shoreline survey design.

As a consultancy funded by Century Zinc (Marsh and Lawler 1993), the Wellesley Island region was re-surveyed for marine wildlife in December 1991 using the transect technique developed by Marsh and Sinclair (1989a) and Marsh and Saalfeld (1989a). The survey indicated that dugong numbers were high in shallow waters within the 3 m depth contour, a result consistent with the results of surveys by the CSIRO which found that most of the seagrass beds in this region occur at depths of less than 3.7 metres (Poiner *et al.* 1987). The estimated dugong population in the Wellesley Islands region in December 1991 was 4,067 $\pm$ s.e. 723 animals at an overall density of 0.46 $\pm$ s.e. 0.082 dugongs km^{-2}. When compared with surveys of other parts of the dugong's range in Australia using the same technique, this result indicated that this region supported Queensland's third largest population of dugongs and is among the six most important dugong habitats in Australia. The survey also indicated that the Wellesley Island area is important sea turtle habitat supporting an estimated minimum population of 8,391 ± 1,295 turtles. This estimate is a significant underestimate of the number of turtles present in the area because of the conservative availability correction factor and the invisibility of small turtles from the survey aircraft.

The status of the dugong along the eastern coastline of the Gulf of Carpentaria is less well known than around the Wellesley Islands. Bertram and Bertram (1973) reported anecdotal information that dugongs were fairly abundant in the estuaries of the Archer and Love Rivers but not during the Wet Season. Dugongs were also consistently sighted along the west coast of Cape York during the shoreline surveys conducted in the 1970s, as summarised below:

Date	Region	No. dugongs	Reference
April 1975	Staaten River mouth -Weipa	247	Ligon (1976)
April 1976	Staaten River mouth - Aurukun	174	Heinsohn (1976)
November 1976	Karumba - Mitchell River mouth	66	Heinsohn (1976)
November 1978	Karumba - Cape York (mostly Archer Bay - Holroyd River)	96	Heinsohn and Marsh (1978)

Quantitative aerial surveys were carried out in the local regions around Weipa (in November 1990) and Karumba (in December 1994) under consultancies funded by Comalco and Century Zinc (Marsh *et al.* 1994) respectively. The numbers of dugongs sighted were too low to estimate population size at either location. These surveys suggested that relative to the area around the Wellesley Islands, the vicinities of these ports were not currently important habitats for dugongs, dolphins or sea turtles. However, dugongs are seen in the vicinity of seagrass beds at the mouth of the Norman River. For example, Anthony Roelofs from the Queensland Department of Primary Industries seagrass ecology group reported at least two dugongs feeding in shallow water (1 metre) on the Alligator Bank on 25 May 1998). Roelof's group further reported seeing dugong feeding trails at this site on several other occasions between 1994 and 1997. (A. Roelofs *pers comm.* 1998).

The residents of Mornington Island (Marsh et al. 1980) and coastal communities in the Wellesley Island region hunt dugongs. Two respondents to the postal questionnaire distributed in 1974 by Anderson and Heinsohn (1978) variously reported an annual catch of 21-50 and 51-100. Marsh *et al.* (1980) estimated that Indigenous hunters at Mornington Island killed about 40 dugongs in the late 1970's on the basis of extensive periods of residence on the island by a biologist in 1976, 1977 and 1978. The residents of Sweers Island told Tony Preen in December 1997 that about 100 dugongs per year are killed by Indigenous hunters in the Wellesley Island (*pers. comm.* Tony Preen, December 1997). Given the lack of reliable quantitative data on the current harvest, it is impossible to evaluate its likely sustainability.

Dugongs were not hunted traditionally along the western coast of Cape York (Chase 1981) and Heinsohn (1976) noted that dugongs were not being hunted by the residents of Kowanyama and Edward River (now Pormpuraaw), although Bill Whiteman (now resident in Cardwell) reports hunting by the residents of Edward River in the 1980s (*pers comm.* to Tony Preen in 1997). However, there is anecdotal evidence that people resident in Weipa and Karumba hunted dugongs in the 1970s (Anderson and Heinsohn 1978 and Appendix 1) and that dugong meat was sold in Weipa South (Appendix 1). By the 1990s, people from Weipa were travelling across Cape York to hunt dugongs in the region around Lockhart River (Marsh 1996). Dugong meat was being traded illegally with non-Indigenous residents of the area (Deirings 1993). This information suggests that local Indigenous peoples consider that the likelihood of dugongs being hunted successfully in the Weipa region is now low, a result consistent with the 1991 aerial survey data.

Dugongs are also killed incidentally in gill nets. There are no contemporary quantitative data on the incidental take of dugongs along the Queensland coast of the Gulf of Carpentaria. However, anecdotal information supplied by various informants (Appendix 1) at that time suggests that incidental captures were not uncommon in the late 1970s and early 1980s when the number of gill-netters operating along the Queensland coast of the Gulf of Carpentaria (R. Garrett *pers comm.* 1998) and the fishing effort (Magro *et al.* 1996) were much higher than today. Public concern persists about the incidental by-catch of protected species as reflected in the Draft Management Plan for the Inshore Finfishery (QFMA 1998). More than 30 dugongs were reportedly drowned in a gill netting incident in the vicinity of the mouth of the MacArthur River along the Northern Territory coast of the southern Gulf of Carpentaria in 1995 (see *Northern Territory News* July 11, 12, 13, 14, 17, 23, and 26 1995). In addition, there has been community concern about the by-catch of marine wildlife in nets set by boats fitted with power-assisted hauling devices (*Sunday Mail* November 30 1997).

In 1977, in recognition of the cultural and social needs of other resource users, 16 of the Gulf's 27 rivers in Queensland were partially closed to mesh netting and recently additional closures in the region were announced to protect fish stocks (QFMA 1999). One of the reasons for the closure of an area at the mouth of the Norman River to netting is to protect dugongs (QFMA 1998). The inshore finfish fishery is also closed from October through January each year to protect barramundi stocks. Although there are no marine parks in the Queensland waters of the Gulf of Carpentaria, the benthos is protected by the following Fisheries Habitat Areas: Eight Mile Creek, Morning Inlet-Bynoe River, Staaten-Gilbert and Nassau River.

This report describes the results of the first survey of the entire Queensland coastal waters of the Gulf of Carpentaria using the quantitative aerial survey techniques which are now standard for dugongs (Marsh and Saafeld 1989a, Marsh and Sinclair 1989a). The survey confirmed that, although dugongs, dolphins and sea turtles were distributed throughout the region, their densities were generally low except in the Wellesley Island area, which is a habitat of national importance for dugongs and sea turtles.

OBJECTIVES OF THIS PROJECT

The objectives outlined in the original contract with Environment Australia were as follows:

1. Determine the distribution and relative abundance of dugongs, sea turtles and cetaceans (dolphins and small whales) in the survey area as a basis for conservation and fisheries management planning.
2. Compare the distribution and relative abundance of dugongs, sea turtles and dolphins in: (a) the Wellesley Island area, and (b) the Karumba area, with the results obtained from similar surveys of these areas in 1991 and 1994, respectively.
3. Compare the distribution and relative abundance of marine wildlife in the area with: (a) the spatial distribution of mesh netting effort as determined from the logbook data collected by the Queensland Fisheries Management Authority; and (b) the location of industrial developments along this coast.
4. Provide information of the spatial distribution of dugongs and green turtles as a basis for comparison with information on the spatial distribution of Indigenous hunting in the region when data on such hunting become available.
5. Provide advice on management actions required in the short, medium and long-term.
6. Provide recommendations on any further surveys for the area, including the survey interval.

METHODS

Aerial survey

Survey design

The coastal waters of the Gulf of Carpentaria adjacent to Queensland (Figure 2) were surveyed between December 2 and 6 1997 using two survey crews each of six people in two Partenavia 68B aircraft. Aircraft 1 surveyed most of Block 6 and Block 7; Aircraft 2 Blocks 1-5, the southernmost four transects of Block 6 and Block 8. Two aircraft were used to minimise the chance of the population estimates being confounded by local movements of dugongs within the survey period. The survey area was divided into the eight blocks (Figure 2) on the basis of sampling intensity and transect placement. Transects were aligned in an east-west direction. Transect lines were spaced 2.5' apart in Blocks 1-5 and Block 8 and at intervals of 5' in Blocks 6 and 7 giving an overall sampling intensity of about 6% (Table 1). Block nomenclature was arranged to facilitate comparison with the 1991 survey of the Wellesley Islands (Marsh and Lawler 1993).

Table 1. Areas of survey blocks and sampling intensities sampled during the December 1997 survey of the Gulf of Carpentaria.

Block	Area in km^2	Sampling %
8[1]	1869.18	8.24
1	1506.2	9.17
2	2622.1	9.3
3	611.5	9.26
4	3611.59	9.06
5	2504.74	8.48
6	10165.96	4.2
7	10133.08	4.31
TOTAL	**33026.35**	**6.04**

[1] Block 8 listed first due to its position as the westernmost Block

The survey design was determined by:

1. the known distribution of suitable seagrass habitat,
2. the endurance of the aircraft,
3. the aircraft time available for the survey, and
4. the design of the previous surveys of the local regions around the Wellesley Islands (in December 1991), Weipa (in November 1990) and Karumba (in December 1994).

A total of 33026 km^2 was surveyed. A global positioning system mounted in each aircraft facilitated precise and accurate navigation. Aircraft 2 was fitted with a radar altimeter for accurate height control. Although aircraft 1 had a pressure altimeter only, it was calibrated regularly.

In order to increase repeatability, the survey was conducted only when the weather conditions were good (usually Beaufort Sea State ≤ 3; Table 2 and Appendix Table 1). Whenever possible, daily schedules were arranged to avoid severe glare associated with a low or midday sun.

Table 2. Summary of weather conditions encountered during the December 1997 survey of the Gulf of Carpentaria.

Parameter	Aircraft 1 (Blocks 6,7)	Aircraft 2 (Blocks 1-5,8)
wind speed (km h^{-1})	0 – 18	9 - 13
cloud cover (oktas)	0 – 8	0 - 2
minimum cloud height (m)	600	2000-7000
Beaufort sea state[1]	2.3 (0.0 - 4.0)	1.8 (0.0 - 3.5)
Glare N[1,2]	1.1 (0.0 - 2.0)	1.1 (0.0 - 3.0)
Glare S[1,2]	1.9 (0.0 - 3.0)	1.3 (0.0 - 3.0)
Visibility (km)	>20	>20

[1] mean of modes for each transect with total range in parentheses
[2]0=0, 1:0<25% field of view affected, 2: 25-50%, 3:>50%.

Block areas (Table 1) were estimated from 1:100,000 digitised topographic coverage (AUSLIG) using the ArcInfo GIS package. The areas of all islands were excluded from the block areas. The length of each transect was also estimated from these digitised maps.

Survey methodology

We used the strip transect aerial survey methodology as detailed by Marsh and Sinclair (1989a) and Marsh and Saalfeld (1989a). We chose to continue using this methodology rather than the line transect methods now routinely used for dolphin surveys (e.g. Barlow *et al.* 1997) because:

1. Dugongs rather than dolphins or sea turtles were the main target species for the survey.
2. Consistent methodology is essential to a reliable time series.
3. Marsh and Saalfeld (1990) verified that the strip width used is sufficiently narrow to preclude detectable variation in dugong sightability across the transect.
4. Dugongs are most often seen as solitary individuals or adult female-calf pairs in turbid water and exhibit cryptic surfacing behaviour. We therefore preferred to use a technique in which the observers do not have to take their eyes off the water to read an inclinometer.
5. The use of this methodology had been endorsed at a dugong aerial survey workshop sponsored by the Australian Fisheries Management Authority and attended by statisticians and biologists experienced in aerial surveys in November 1997.

The transect width (200 m on either side of the aircraft at the survey altitude of 137 m) was demarcated with calibrated fibreglass rods attached to artificial wing struts on either side of each aircraft. Each sighting was recorded as being made in a specified quarter of the transect to facilitate deciphering whether simultaneous sightings by tandem observers were the same group of animals. Dolphins and sea turtles were generally not identified to species.

Correction factors

Population estimates for dugongs and sea turtles were corrected for perception bias (the groups of animals visible on the transect line that were missed by observers). Estimates for these taxa were also corrected for availability bias (the groups of animals unavailable to the observers due to water turbidity). Too few groups of dolphins were sighted for a reliable correction for perception bias to be calculated. A correction for availability bias was not attempted for dolphins because of the lack of a suitable standard.

There was a tandem team of observers on either side of each aircraft (Marsh and Sinclair 1989a). Each team of observers was visually and acoustically isolated from the other team in the same aircraft and reported their sightings in standard format in separate tracks of a two-track tape recorder. After each flight, the tape record of each transect was used to verify and edit the computer records of the flight, so that each sighting could be coded as made by one specific member or both members of a tandem observing team (Marsh and Sinclair 1989a). The corrections for perception bias for dugongs and sea turtles (Table 3) were calculated using the Peterson Mark Recapture Model on the basis of the proportion of sightings of the relevant taxon seen by the tandem teams in Aircraft 2 as the number of sightings seen by the observers in Aircraft 1 was too low to estimate the corrections for perception bias reliably. The perception correction factor requires that all groups of animals of the same taxon to be equally sightable. Marsh and Sinclair (1989b) showed that this is a reasonable assumption for the small groups of dugongs usually observed.

We corrected for availability bias for dugongs by standardising the proportion of dugongs sighted by each team during the survey to the number seen on the surface in clear water where all dugongs were potentially available (Marsh and Sinclair, 1989a). As in other turtle surveys, the correction for availability bias (Table 3) was calculated by standardising the proportion of turtles sighted against the

November 1985 survey of turtles in the northern waters of the Great Barrier Reef Marine Park (Marsh and Saalfeld 1989b). The corrections for availability bias for both dugongs and sea turtles make the untested assumption that a constant proportion of the target species is at the surface. We used the corrections for availability bias developed for the region in 1991 to facilitate comparisons between surveys. At the suggestion of a statistician at the AFMA sponsored Aerial Survey Workshop in 1997 (Ken Pollock 1997 *pers comm.*), we changed the criteria for an animal being sighted at the surface (from being seen 'at the surface' 'to break the surface') for this survey as part of new research to improve the absolute estimates of dugong abundance. This change made it inappropriate to use the new correction factor for comparing across surveys in this report. Accordingly we used the 1991 estimates of availability bias for dugongs and turtles (Table 3). The new criteria will be used in conjunction with data on dugong diving and surfacing behaviour to estimate the absolute abundance of dugongs in future research (Marsh , unpublished data).

Table 3. Correction factors used to provide standardised estimates of population size and density for dugongs and sea turtles sampled during the December 1997 survey of the Gulf of Carpentaria.

Taxon	Availability Correction Factor[1] ± s.e.	Perception Correction Factor2[2]: port ± s.e.	Perception Correction Factor[2]: starboard ± s.e.
Dugong	2.49 ± 0.15	1.01 ± 0.01	1.02 ± 0.01
Sea turtle	1.75 ± 0.09	1.10 ± 0.02	1.10 ± 0.02

[1]Based on correction factor developed for 1991 survey
[2]Based on sightings of Aircraft 2, too few animals sighted by Aircraft 1 to calculate

Analysis

As the transects were variable in area, the Ratio Method (Jolly 1969, Caughley and Grigg 1981) was used to estimate the density, population size and associated standard errors for each taxon for each block. Any statistical bias resulting from this method is considered inconsequential due to the relatively high sampling intensity (Table 1, see also Caughley and Grigg 1981). As in dugong previous surveys and following the recommendation of Norton-Griffiths (1978), input data were the estimated number of dugongs (in groups of fewer than 10 animals), turtles or dolphins for each tandem team per transect calculated with the corrections for perception and availability biases. The resultant standard errors of the population estimates were adjusted to incorporate the errors associated with the various correction factors as outlined in Marsh and Sinclair (1989a). The only group of more than 10 dugongs was a group of 200 in Block 4. Accordingly, 200 was added to the estimates of the populations and density of Block 4 at the end of the analysis, as outlined in Norton-Griffiths (1978). The population estimates for the whole survey area was obtained by summing the estimates for each block for each taxon. The standard errors of the population estimates for the entire region were calculated as the square root of the sum of the variances of the population estimates of each block. This method assumes that the population estimates for each block are independent. Marsh *et al.* (1996a) showed that this is a reasonable assumption as any spatial auto-correlation in dugong distribution occurs at a much smaller spatial scale than the survey blocks.

Differences between this survey and the 1991 survey of the Wellesley Island area (Marsh and Lawler 1993) with regard to the estimated numbers of dugongs were tested using analysis of variance. Input data were the ln (x+1) corrected counts of dugongs per transect. Adjustments were made for any inter-survey changes in survey design. Fixed factors in the model were time and block. Transect was treated as a random factor nested within block. Input data for all analyses were the corrected counts of dugongs per transect based on mean group sizes and the estimates of the correction factors for perception and availability bias, each transect contributing one corrected count per survey based on combined corrected counts of both tandem teams. All significance tests were two tailed. Similar comparisons could not be made with the 1991 survey data for sea turtles and dolphins in the Wellesley Island area (Marsh and Lawler 1993) due to the lack of suitable availability correction factors. Too few animals of any taxon have been sighted in any of the surveys of the Weipa and Karumba areas for inter-survey comparisons.

Density diagrams, adjusted for sampling intensity, were produced using the ARCINFO GIS package (ESRI Australia). A coverage of 5 x 5 nm square grids overlaying the survey area was used to calculate the densities of each taxon.

Density in each cell was calculated as:

Density km^2 = Corrected number of animals sighted in each cell / Area surveyed in each cell
where, Area surveyed in cell = Transect length in km * Transect width (i.e. 0.4 km).

The large group for which a total count was obtained was included in the density estimate for the appropriate cell.

Spatial analysis of gill-netting effort

The data on gill netting for the survey area for 1993-1996 were obtained from the C-fish logbook database maintained by the Queensland Fisheries Management Authority. Fishers are required to record the location of their fishing activity on a daily basis on a 30' grid (Figure 3). Recording on a 6' grid is voluntary, but the compliance is high. For example in 1996, 79 of the 90 fishers who operated in the survey area reported catch with 6' precision, 28 reported with 30' precision, with an overlap of 17 fishers. To convert all the effort to 6' precision, we divided the content of each 30' cell evenly across the content of the (non-zero) 6' cells that fell within the 30' cell using the ARCINFO GIS package (ESRI Australia). A check on the accuracy of this procedure at the scale of the entire state for 1996 suggested that it was 98% accurate. (The total effort of the Queensland net fisheries for 1996 was 34,709 days. After spreading the 30 minute effort and catch over all non-zero 6 minute grid cells, the total effort was 34,659 days). The fishing effort for each aerial survey block in the Gulf of Carpentaria was measured for each year (1993-1996) as the sum of the number of fishing days calculated over all the 6' cells in that block. When a grid cell spanned more than one survey block, effort was assigned using a 'largest area of overlap rule'.

RESULTS

Dugongs

1997 survey

As is usual in strip transect surveys of dugongs, most sightings (77/96 or 80%) were of solitary animals (Figure 4). The largest group of dugongs sighted was a diffuse aggregation of an estimated 200 dugongs in Block 4 (Figure 5). Excluding this large aggregation, the mean group size was 1.359 $\pm$ s.e. 0.067.

Dugong density was highest in Block 4 (Table 4), the coastal region within the 3-m depth contour in the Wellesley Islands area. The numbers of dugongs sighted in Blocks 1, 3 and 6 were too low to calculate population estimates for these blocks. The total population estimate for the survey area was 4,266 $\pm$ 657, an overall density of 0.12 $\pm$ 0.02 dugongs per km^2 (Table 4), of which 62% were in the Wellesley Island area (Blocks 1-5) and 45 % in Block 4.

Table 4: Estimated numbers and densities of dugongs for the December 1997 survey of the Gulf of Carpentaria.

Block	Density per km^2 ± s.e.	Estimated population size ± s.e.
8[1]	0.18 ± 0.10	336.5 ± 180.8
1	0[2]	0[2]
2	0.19 ± 0.06	503.5 ± 156.5
3	0[2]	0[2]
4	0.47 ± 0.34	1906.5 ± 482[3]
5	0.10 ± 0.05	238 ± 134.1
6	0[2,2]	0[2]
7	0.13 ± 0.03	1281.8 ± 352.1
Total	0.12 ± 0.02	4266.2 ± 656.9

[1] Block 8 listed first due to its position as the westernmost Block
[2]Too few sightings to estimate population size
[3] Includes large herd of 200 dugongs which was not included in density estimate for Block 4

Comparison with previous surveys

The 1997 survey supported the results of previous surveys by confirming that:

- the Wellesley Island area supports significant numbers of dugongs
- the regions in the vicinity of the ports of Weipa and Karumba were not particularly important dugong habitat (although the Weipa area was the most important area on the west coast of Cape York).

The estimated dugong population of the Wellesley Islands area in 1997 was 2,648 ± s.e.524 compared with 4,066 ± s.e.723 (see Appendix Figure 3) for a similar (but not identical see Appendix Figure 2) survey region in 1991. The number of dugongs sighted was sufficient for statistical comparisons of the areas flown in both Blocks 2, 4 and 5 only in 1991 and 1997 (Table 5). There was no significant overall difference between the estimated number of dugongs in these areas in 1991 and 1997. However, it should be noted that the 1997 estimate was only 65% of the 1991 estimate and that the mean estimate for Block 4 was only half that in 1991. The interaction between time and block was different between the two surveys due to a change in the distribution of dugongs within these three blocks as illustrated below:

	% in 1991	% in 1997
Block 2	4	19
Block 4	93	72
Block 5	3	9
Total	100	100

In 1991, the high tides were at night and evidence of dugongs using the inshore intertidal seagrass beds in Block 4 came from dugong feeding trails observed at low tide (Marsh and Lawler 1993). In 1997, the large diffuse group of 200 dugongs was sighted close to the coast at the western end of transect 97 in Block 4 (Figure 5).

The major difference between the results of this survey and the surveys conducted in the 1970s was that we only sighted one dugong between the mouth of the Staaten River and Cape Keer Weer (Figure 5), a region where between 54 and 227 dugongs were sighted in various shoreline surveys in the 1970s (Ligon 1976, Heinsohn 1976, Heinsohn and Marsh 1978). Unfortunately, comparisons between these surveys are of dubious reliability due to differences in survey techniques. Shoreline surveys attempt a total count of dugongs in the strip of sea approximately 1 km wide adjacent to the shore. The resultant data are uncorrected counts. Strip surveys sample the dugong habitat across the depth gradient perpendicular to the shore and use statistical corrections to convert these counts to population estimates as outlined above. Although the population estimates from strip transect surveys are greater than that for shoreline surveys, the uncorrected number of dugongs sighted may be greater for shoreline surveys. If between 54 and 227 dugongs were visible close to the coast between the mouth of the Staaten River and Cape Keer Weer as suggested by the surveys conducted in the 1970s, we would expect to sight between 2 and 9 dugongs in a strip transect survey at a sampling intensity of about 4% as in December 1997, rather than the one sighted. Given the error in counting, the low number counted in this region in 1997 is likely not to be significantly different from the low end of the range of estimates from the shoreline surveys in the 1970s, but is likely to be different from the higher end of this range .

Table 5. Results of analysis of variance comparing the estimated numbers of dugongs sighted in the areas of Blocks 2, 4, 5 surveyed in 1991 and 1997.

Source of variation	SS	DF	MS	F	Significance of F
Within + residual	4.99	41	0.12		
Transect within block (Error 1)	16.66	41	0.41	3.34	**0.000 P<0.0001**
Year	0.11	1	0.11	0.92	0.342
Year*Block	1.36	2	0.68	5.58	**0.007**
Error 1	16.66	41	0.41		
Block	5.95	2	2.98	7.32	**0.002**

Calves made up 6.6% of sightings in 1991, 8.1% in 1997.

Sea Turtles

1997 survey

Virtually all sightings were of solitary turtles. The mean group size for Aircraft 1 was 1.0089 ± s.e. 0.0062, for Aircraft 2 was 1.0678 ± s.e. 0.0203. The only turtles which were unambiguously recognised to species were five leatherback turtles (Figure 6) in Block 6 between transects 55 and 74 inclusive (Appendix Figure 1). Several sets of possible nesting tracks formed by leatherback turtles were observed on the beach between transects 55 and 59 during a low level flight along this shoreline between transects 64 and 53 on December 6 1997. Given the distinctive size and shape of Leatherback turtles its is very unlikely that any of the other turtles sighted were leatherbacks.

Sea turtles were seen in all the survey blocks (7). Densities were highest in Blocks 2 and 7 (Table 6). The total population estimate for the survey area was 15,728 ± s.e.1, 225 turtles at an overall density of 0.48 ± s.e.0.03 turtles per km^2 (Table 6).

Table 6: Estimated numbers and densities of sea turtles for the December 1997 survey of the Gulf of Carpentaria.

Block	Density per km^2 $\pm$ s.e.	Estimated population size $\pm$ s.e.
8[1]	0.28 ± 0.06	517.8 ± 112.7
1	0.44 ± 0.13	1980.1 ± 74.2
2	0.76 ± 0.14	658.2 ± 196.9
3	0.11 ± 0.10	69.4 ± 61.9
4	0.46 ± 0.14	1657.7 ± 489.8
5	0.28 ± 0.10	688.8 ± 245.9
6	0.22 ± 0.05	2277.2 ± 489.3
7	0.78 ± 0.09	7878.5 ± 948.5
Total	0.48 ± 0.04	15728.5 ± 1224.8

[1] Block 8 listed first due to its position as westernmost Block

Comparison with previous surveys

The survey supported the limited results of previous surveys by confirming that:

- the region in the vicinity of the ports of Karumba is not particularly important sea turtle habitat (Marsh *et al.* 1994).
- the Wellesley Islands, with 32% of the sea turtles in the survey area, are an important sea turtle habitat (see Appendix Figure 4).

The estimated sea turtle population of the Wellesley Islands area in 1997 was 5,055 ± s.e.695 compared with 8,391 ± s.e.1,295 for a similar (but not identical see Appendix Figure 2) survey region in 1991. The data for 1991 were not in a format suitable for statistical comparisons. Given the large sampling errors associated with surveys for sea turtles, the results suggest reasonable overall temporal consistency in the spatial distribution of sea turtles in the survey area.

	% in 1991	% in 1997
Block 1	10.6	13.0
Block 2	25.5	39.2
Block 3	1.3	1.4
Block 4	53.5	32.8
Block 5	9.1	13.6
Total	100	100

Dolphins

1997 survey

Only three of our aerial survey team members have the expertise to identify dolphins from the air. Two of these people were team leaders. As a result, only 18 of the 64 groups (28%) of dolphins sighted were definitely identified to species. Of these, 14 groups (78%) were Bottlenose dolphins in groups of up to 23 animals. Two single Indo-Pacific humpback dolphins were sighted, one on transect 19, the other on transect 54 (Figure 8 and Appendix Figure 1). A group of seven Irrawaddy River dolphins were sighted on the inshore end of transect 125 in Block 8, another two in Port Musgrave on transect 12. Two Irrawaddy River dolphins were also seen inshore on transect 103 in the Wellesley Island area but outside the strip. The mean group size was 2.98 ± s.e.0.83. Dolphins were seen in all the survey blocks except Block 3 (Figure 8). The numbers sighted in Blocks 3,4, and 5 were too small to calculate population estimates. Densities were highest in Blocks 1,2, and 7 (Table 7) where most of the sightings were probably of Bottlenose dolphins. The total population estimate for the survey area was 3,415 ± s.e.684 at an overall density of 0.10 ± s.e.0.02 dolphins per km^2 (Table 7).

Table 7: Estimated numbers and densities of dolphins for the December 1997 survey of the Gulf of Carpentaria.

Block	Density per km^2 ± s.e.	Estimated population size ± s.e.
8[1]	0.09 ± 0.04	161.7 ± 81.1
1	0.14 ± 0.07	206.4 ± 103.8
2	0.26 ±0.09	672.6 ± 241.8
3	0[2]	0[2]
4	0[2]	0[2]
5	0[2]	0[2]
6	0.06 ± 0.03	615 ± 280.3
7	0.15 ± 0.06	1489.6 ± 560
Total	0.10 ± 0.02	3145.2 ± 684

[1] Block 8 listed first due to its position as the westernmost Block
[2]Too few sightings to estimate population size

Comparison with previous surveys

The survey supported the limited results of previous surveys conducted by confirming that:

- the region in the vicinity of the port of Karumba is not important dolphin habitat (Marsh *et al.* 1994).
- the Wellesley Islands with 28% of the dolphins in the entire survey area are important habitat.

The estimated dolphin population of the Wellesley Islands area in 1997 was 879 ± 263 and very similar to the results of 836 ± 199 for a similar (but not identical see Appendix Figure 2) survey region in 1991. Although the data for 1991 were not in a format suitable for statistical comparisons, the results of both surveys suggest that the offshore blocks are more important for dolphins than the inshore blocks.

	% in 1991	% in 1997
Block 1	40.6	23.4
Block 2	14.7	76.6
Block 3	7.5	0[2]
Block 4	19.2	0[2]
Block 5	18.0	0[2]
Total	100	100

[2]To few sightings to estimate population size

Gill-netting effort

Data from the QFMA C-Fish Logbook Program indicate that about 84% of netting effort (days fished) in the Queensland waters of the Gulf of Carpentaria to 25 nm offshore occurred in the survey area in 1996 (Figure 9). About 90% of the effort *in the survey area* was in Blocks 6 and 7. An average of 8.6% of the effort *in the survey area* occurred in the Wellesley Island area (Blocks 1-5) with 7.7% occurring in Block 4, the region which supports the greatest numbers and highest densities of dugongs (Table 4).

Table 8: Details of netting effort in the aerial survey blocks (from QFMA logbook data).

Block	Days fished 1993	Days fished 1994	Days fished 1995	Days fished 1996	Mean days fished 1993-1996	% catch survey area 93-96	% catch Gulf 1996	No. fishers[2] 1996	% 1996 catch
8[1]	126	126	125	103	120	1.30	0.91	8	1.90
1	7	11	10	5	8	0.08	0.04	2	0.13
2	13	0	14	2	7	0.07	0.02	1	0.01
3	2	6	0	0	2	0.02	0.00	0	0.00
4	907	754	572	687	730	7.70	6.04	15	8.43
5	53	36	155	46	73	0.77	0.40	6	0.49
6	5911	5829	6665	6146	6138	64.40	54.04	66	57.03
7	2153	2726	2377	2518	2444	25.70	22.14	33	32.00
Total	9172	9488	9918	9509	9522	100.00	100.00	90	100.00

[1] Block 8 listed first due to its position as the westernmost Block
[2] an operator may record catch from more than one area

Ninety operators reported catch in the survey area in 1996, 18 of these in Blocks 1-5.

DISCUSSION

Significance of the Queensland Coast of the Gulf of Carpentaria for Marine Wildlife

The estimated dugong population of the Queensland coast of the Gulf of Carpentaria is compared with other areas surveyed in Australia using the same technique (Table 9). There were far more dugongs in the waters of the Gulf of Carpentaria adjacent to the Northern Territory (16,846 $\pm$ s.e.3, 259) in the 1980s than in the waters adjacent to Queensland in 1997 (4,266 $\pm$ s.e.657 or 20% of the Gulf of Carpentaria population), presumably at least partially reflecting the much greater area of seagrass along the Northern Territory coast (751 km^2 compared with 155.3 km^2 (17% of total) in Queensland, Poiner *et al.* 1987). Table 9 also indicates that the Wellesely Island area is the second most important dugong habitat in Queensland outside of Torres Strait.

There are far fewer comparable data published for dolphins and sea turtles than for dugongs. In addition, the turtle data published for the northern Great Barrier Reef are not strictly comparable with the Gulf of Carpentaria because of the abundance of reef habitats in the former. The most valid comparison is probably with Shark Bay in Western Australia (Preen *et al.* 1997), a World Heritage area, which is famous for dolphins:

	Dolphin Density km^2	Sea Turtle Density km^2
Shark Bay 1994	0.09 $\pm$ s.e. 0.03	1.02 $\pm$ s.e 0.22
Qld water of Gulf of Carpentaria	0.10 $\pm$ s.e.0.02	0.48 $\pm$ s.e.0.04

The significance of the coastal waters in the region between the mouth of the Nassau and Mitchell Rivers to the leatherback turtles requires further investigation. Although the number of sightings in our survey was low, this may be a significant concentration of a fairly rare animal which is listed as 'endangered' under both Queensland legislation and by the IUCN (1996) and as 'vulnerable' under Commonwealth legislation.

Table 9. Comparison of the estimate of the dugong population of the Gulf of Carpentaria obtained by this survey with other regions surveyed by similar techniques.

Survey region	Major habitats within survey region	Area km^2	Date last survey	Estimated dugong population $\pm$ s.e.	Reference
Shark-Bay WA		14906	July 1994	10529 ± 1464	Preen *et al.* 1997
Exmouth Gulf - Ningaloo W.A.		4049	July 1994	1974 ± 588	Preen *et al.* 1997
Northern coast Northern Territory		28746	Dec. 1983	13800 ± 2683	Bayliss 1986 modified by Bayliss and Freeland 1989
Gulf coast Northern Territory		27216	Feb. 1985	16846 ± 3259	Bayliss and Freeland 1989
	Limmen Bight - Sir Edward Pellew Islands	6160		9635 ± 2632	
Gulf coast Qld		33026	Dec. 1997	4266 ± 657	this report
	Wellesley Island area	10856		2648 ± 524	
Torres Strait		30568	Nov. 1996	27881 ± 3126	Marsh *et al.* 1997a
	Orman Reef-Turnagain Island area	4340		10869 ± 100	
	Torres Strait west of main western islands	9657		8623 ± 2411	
Northern Great Barrier Reef (Hunter Point - Cape Bedford)		25800	Nov.-Dec. 1995	8190 ± 1172	Marsh and Corkeron 1996
	Princess Charlotte Bay	7985		4396 ± 1052	
Southern Great Barrier Reef (Cape Bedford - southern boundary)		28564	Nov. 1994	1682 ± 236	Marsh *et al.* 1996b
Hervey Bay - Great Sandy Strait		4992	1994	807 ± 151	Marsh *et al.* 1996b

Gill-Netting Effort along the Queensland Coast of the Gulf of Carpentaria

In 1996, one third of the gill-netting effort (days) in Queensland occurred in Gulf of Carpentaria waters (Pantus unpublished data), 2% of the total for Queensland occurred in the Wellesley Island area.

Strategies for Management of Dugongs along the Queensland Coast of the Gulf of Carpentaria

In discussing strategies for managing human impacts on marine wildlife in the survey region (Figure 2), we have concentrated on dugongs because this is the only taxon, (apart from Leatherback turtles and a low proportion of dolphins), for which specific identification was attempted. Strategies to regulate traditional hunting must consider green turtles as well as dugongs as the two species are hunted together using the same techniques (Marsh 1996). Strategies to minimise incidental capture in gill nets and to conserve habitat from pollution will benefit dugongs, dolphins and sea turtles alike.

Given Australia's international responsibilities to protect the dugong (Bertram 1981), it important to maintain numbers throughout its range in Australia, especially as it appears that the Australian dugong population does not occur as a single large interbreeding population. Molecular techniques have been used to investigate the stock structure of dugongs (Tikel 1998). Preliminary results suggest that the geographical range of the South East Asian haplotypes does not overlap with that of Australian haplotypes suggesting that there is no genetic exchange between Australia and Asia. The genetic structure of dugong populations around the Australian coast appears to have been influenced by the former Torres Strait land bridge that once connected Australia to Papua New Guinea even though this could not have acted as a barrier to dugong movements for 6,000 years (Tikel 1998). This breeding pattern conforms with an 'isolation by distance model' which means that any individual is more likely to breed with others in a neighboring bay than with dugongs some distance away. This conclusion is supported by morphometric analysis, which shows that the skull shape of dugongs from the Wellesley Islands area is significantly different from that of dugongs from Townsville (Spain and Marsh 1981). These studies suggest that if dugongs disappear from an area it is unlikely to be recolonised quickly. Thus, it is important to maintain dugong numbers throughout its range in Australia, including along those regions of the Gulf of Carpentaria coast where densities are low (Figure 5).

Impacts on dugongs along the coast of the Gulf of Carpentaria include Indigenous hunting (Marsh *et al.* 1980), incidental drowning in gill nets (Marsh 1984, unpublished data see Appendix 1), direct mortality (Limpus and Reed 1985, Marsh 1989) and habitat loss (Poiner and Peterkin 1995) due to tropical cyclones and floods. All of these impacts must be considered in the context of the dugong's life history. Population simulations (Marsh 1995b, Marsh 1999) indicate that dugong numbers are unlikely to increase at more than about 5% per year, even if all the females in a population are breeding maximally. The rate of increase is likely to be lower in areas such as the Gulf of Carpentaria coast where there is mortality due to incidental drowning in mesh nets and Indigenous hunting.

Given the difficulty in detecting trends in dugong abundance, particularly at low densities (Marsh 1995a), it is often potentially easier to detect the circumstances that are likely to lead to a decline in abundance than it is to detect a decline *per se* (Wade 1998). In the United States, management actions related to human-caused mortality of marine mammals no longer rely on detecting depletion but rather on detecting a mortality rate that will lead to depletion. Wade (1998) describes methodology for identifying populations of cetaceans and pinnipeds with levels of human-caused mortality that could lead to depletion, taking account of the uncertainty of available information.

Mortality limits for a stock are calculated for a specified conservation goal as the product of:

- the minimum population estimate for that stock N_{min} (an estimate which accounts for the imprecision of the abundance estimate),
- one-half the maximum net productivity rate R_{max} (the maximum theoretical or estimated net productivity rate of the stock at a small population size), and

- a recovery factor F_r between 0.1 and 1, which can be regarded both as an additional factor to hasten the recovery of a depleted population and as a safety factor to account for uncertainties other than the precision of the abundance estimate.

The U.S. *Marine Mammal Protection Act 1972* now stipulates the use of this approach and defines the mortality limit for the conservation goal specified under the Act for each stock as the Potential Biological Removal or PBR. Unfortunately, we are unable to use this technique to assess the status of the dugong in the Gulf of Carpentaria. We do not have the data required to calculate a PBR. Nor is the time series of aerial surveys adequate to detect a trend. Thus the only option available is to use the Precautionary Principle and attempt to minimise the known impacts. Ways in which this might be done are discussed below.

Indigenous hunting

Regional-scale aerial surveys suggest that dugong numbers have been stable over the last decade in several remote, northern regions of northern Australia where Indigenous hunting by a few isolated communities is the major impact (Marsh 1997). However, it is recognised that the power of such surveys to detect trends in abundance is limited (Gerrodette 1987, Marsh 1995a) especially at a local scale, because the precision of abundance estimates decreases as abundance decreases (Taylor and Gerrodette 1993). Although the information on dugongs in the Gulf of Carpentaria is inadequate to assess their status in this region, the potential for undetected local depletion within the hunting grounds of Indigenous communities such as Mornington Island is considerable.

Despite this difficulty of detecting trends in abundance, a time series of aerial surveys indicates that dugong numbers significantly declined (by approximately 50% between the mid 1980s and early 1990s) along the urbanised coast of the Great Barrier Reef (Marsh *et al.* 1996b and Marsh 1997). As a result of this decline, some Indigenous groups have decided not to hunt dugongs in this region and there is now no permitted hunting south of Cooktown. The Great Barrier Reef Ministerial Council recently established a two-tiered system of Dugong Protection Areas (DPAs) in the Great Barrier Reef Region in which gill netting is greatly restricted or banned (seven DPA Zones A totalling 2,407 km^2) or subject to lesser modifications designed to reduce the probability of a dugong drowning after entangling in a commercial gill net (eight DPA Zones B totalling 2,243 km^2). Thirty-eight, non-Indigenous commercial fishers surrendered their licences as a result of these initiatives. The resultant controversy has drawn attention to the sustainability of dugong hunting by Indigenous peoples in remote communities including those in the Gulf of Carpentaria. Such hunting is currently mostly unregulated, despite calls from some Indigenous leaders for cooperative management arrangements.

The social reasons for traditional hunting are complex. In Cape York communities, hunting often occurs to provide meat for the families or households of the hunter (Roberts *et al.* 1996). It is likely that the situation is the same in dugong hunting communities in the Gulf of Carpentaria such as Mornington Island, however, this has not been documented. Although meat is available in community stores, it is expensive and often of medium quality. Anecdotal evidence suggests that fresh fish and meat are preferred sources of protein (Roberts *et al.* 1996). However, the importance of bush protein such as dugong meat to the diet of the Indigenous inhabitants of the Gulf of Carpentaria has not been quantified as it has in Arnhem land (Altman 1984) and Torres Strait (Harris *et al.* 1994, Marsh *et al.* 1997b). Indigenous communities are being encouraged to increase their consumption of bush protein as parts of programs to improve their health (CYRAG 1996). Such programs do not acknowledge the legitimacy of conservation concerns about some of the food species promoted.

There are no quantitative data on the number of dugongs hunted in this region since Marsh *et al.* (1980) published limited figures for the Mornington Island community. (The limited data on Indigenous hunting of dugongs in this region are summarised at Appendix 1). It is not possible to assess the sustainability of the present dugong catch without the following information:

(1) absolute estimates of the dugong population size (rather than the minimum estimates presented here),
(2) estimates of the dugong catch,
(3) current estimates of life history parameters,
(4) information on the sex ratio of the catch. (Marsh *et al.* (1980) presented evidence that the Mornington Island hunters were avoiding pregnant females.)

Theoretically hunting is unlikely to drive a species to extinction because hunting pressure declines with the density of the prey species since it takes longer to find an animal when densities are low. However, this safeguard does not necessarily apply when:
(1) the technology available to the hunters improves with consequential decreases in the search time, and/or
(2) hunting is targeted towards more than one species (Bomford and Caughley 1996).

In addition, the ethos of taking only enough for one's family may not ensure sustainability if settlements grow rapidly and taboos formerly regulating wildlife use are weakened (Collins *et al.* 1996). All these conditions are relevant to the Indigenous hunting of dugongs in the Queensland waters of the Gulf of Carpentaria as exemplified by improvements in technology, the change in the size of settlements and the weakening of taboos. In addition, dugongs and turtles are hunted together. Thus dugong hunting will cease only when the combined density of dugongs and green turtles is so low that hunting is not worthwhile. As our aerial surveys indicate that turtles are much more abundant than dugongs in this region (Marsh and Lawler 1993, Tables 4 and 6, Figures 5 and 6), we consider that there is a danger of dugongs being seriously impacted by hunting unless it is regulated in some way.

Communities like Lockhart River complain of people from the west coast of Cape York Peninsula culling animals from what they see as their traditional fisheries. Roberts *et al.* (1996) document sea voyages by hunters from Injinoo and New Mapoon (immediately north of the survey area) to Shelburne Bay on hunting trips. People also travel by road from Weipa to Lockhart River to hunt dugongs (see Deirings 1993). At present, such forays are limited by the small size of boats used, the cost of fuel and road access. Extensive travel to many hunting grounds in the region is currently constrained by weather, especially during periods of rough seas (sea travel) and during the wet season (land travel). This can change rapidly as infrastructure improves.

The establishment of outstations which is being encouraged (CYRAG 1996) is probably also changing the spatial pattern of hunting. Although this is likely to diminish the refugial value of areas where hunting does not currently occur, there may be benefits such as additional local control of hunting and a reduction in the number of dugongs hunted near established communities.

Indigenous peoples living on reserves were exempt from the restrictions on dugong or sea turtle hunting under the *Fisheries Act 1976* Qld. The *Fisheries Act 1994* Qld is silent on the issue of Indigenous hunting but the *Nature Conservation Act 1992* Qld provides for the traditional use of natural resources by Aborigines and Torres Strait Islanders provided that such use is in accordance with the provisions in conservation plans. However, this section of the *Nature Conservation Act 1992 Qld* has not been proclaimed as yet and so there is no release in the present legislation from its ban on taking protected wildlife. Hunting is allowed under permit by the Queensland Marine Parks under the *Marine Parks Act 1982* Qld. However, this Queensland legislation is of limited relevance to Gulf of Carpentaria communities as there are no marine parks in the Gulf. Thus the entitlement to traditional hunting by Indigenous peoples in the Gulf of Carpentaria is not currently addressed in Queensland law. This situation is in marked contrast to that in nearby Torres Strait where the traditional way of life of the Indigenous inhabitants is specifically protected under the Torres Strait Treaty Article 10. The implications for Indigenous hunting of dugongs and sea turtles of the *Native Title Act 1993* Cth and its 1998 amendments are uncertain, especially as no determination has yet been made in favour of Native Title claimants in the Gulf of Carpentaria. The area of high dugong and sea turtle abundance in the

Wellesley Island region is currently under Native Title claim.

Thus the present legal status of most Indigenous hunting by Gulf of Carpentaria communities does not satisfy the findings of the Law Reform Commission (1986), because it does not `bring legislation into line with current practice'. Administrative policy has been tested on this issue and has proved ineffective as demonstrated by a series of cases in which attempts have been made to prosecute Indigenous peoples for taking wildlife (see Roberts *et al.* 1996). All cases have received wide media publicity. Most have resulted in charges being dropped or no penalties enforced.

Rapid and effective implementation of a comprehensive community-based management regime (perhaps along the lines developed by other communities is the only viable option to manage dugong and sea turtle hunting by communities along the Queensland coast of the Gulf of Carpentaria. Useful models include the Aboriginal Land and Natural Resource Management Office at Kowanyama (Sinnamon 1998); the Turtle and Dugong Hunting Management Plan developed by Hope Vale Community on Cape York (Hope Vale 1999) in conjunction with the Great Barrier Reef Marine Park Authority (Hope Vale 1999), the Bawinanga Aboriginal corporation at Maningrida and the Dhimurru Land/Sea Management Corporation at Nhulinbuy (see Davies *et al.* 1999).

As the then Executive Director of the Cape York Land Council (Pearson 1995) wrote:

> *In talking about conservation regimes, Peninsula Aboriginal people will be most resistant to outsiders, particularly governments, unilaterally telling them how they should manage their land,* and
>
> *The development of land management capacity at the community level will take time.*

It is reasonable to assume that "land" could be replaced with "wildlife" when issues of dugongs and sea turtles conservation are considered, a view reinforced by the wishes expressed in documents such as the Draft Cape York Land Use Strategy (CYRAG 1996) and Sinnamon (1998).

Mechanisms need to be developed to ensure that special significance of the dugong and green turtle to Aboriginal peoples living in Gulf communities, especially major dugong and turtle hunting communities such as Mornington Island, is formally recognised. Mechanisms need to be put in place to empower these peoples to take a significant strategic and operational role in the development of all dugong and sea turtle management and research initiatives including the development of legislation and threat abatement plans. Effective co-operative management will require the development of a long-term strategy for the training, career structure and resourcing of Indigenous community rangers. Such a strategy is needed so that they can participate effectively in dugong and sea turtle management and research programs and play an increasingly important role in managing their lands (CYRAG 1996). At a workshop in June 1998, Torres Strait community leaders stressed that the survival of dugong and turtle populations relies on establishing a team of accredited community rangers to manage these traditionally significant animals. This approach is consistent with the Oceans Policy (Commonwealth of Australia 1998).

Incidental captures in gill nets

Although the impact of incidental capture in gill nets has not been quantified along the Queensland coast of the Gulf of Carpentaria, it is recognised as a major source of mortality of coastal marine mammals throughout the world (IWC 1994). The anecdotal information in Appendix 1 suggests that dugong mortality in gill nets was high in the 1970s-1980s. Various initiatives have been implemented with a view to reducing this impact including: spatial closures to gill netting (Dawson and Slooten 1993), acoustic alarms designed to scare porpoises from the vicinity of nets (Reeves *et al.* 1996, Dawson *et al.* 1998), fishing gear modifications and net attendance rules.

There are social, economic, and political costs to all such initiatives and ecological, economic and political costs to ignoring the problem. The challenge is to devise the optimum package of measures which minimises these costs while reducing the mortality to levels which will allow the recovery of the marine mammal stock, i.e. below the potential biological removal (PBR) level (Wade 1998).

Spatial closures to gill netting and acoustic alarms are measures designed to reduce the probability of an individual encountering a gill net, an effective spatial closure reducing the probability to zero. Modifications to fishing gear and to net attendance rules are designed to enhance the capacity of a marine mammal, which encounters a net to escape (although their effectiveness is unknown). Net attendance rules may enhance the ability of the fisher to detect and release the animal in a relatively unharmed and unstressed condition.

The overall effect of reducing the probability of a dugong encountering a net to zero will be greatest in areas in which the probability of an individual encountering a net is highest and which support the greatest numbers of the marine mammal species throughout the time period under consideration. Similar criteria would apply to choosing areas in which to deploy acoustic alarms but as they have not been tested for any of the marine mammal species occurring in the Gulf of Carpentaria (Dawson *et al.* 1998) they are not considered further in this report.

If the probability of a dugong encountering a net is spatially heterogeneous, areas in which it is high are clearly important targets for closure. These are typically areas where the overlap of habitat use by gill netters and marine mammals is greatest. Causes of high overlap include high net density and the physical nature of the site, e.g. narrow movement corridors. Our information is generally insufficient to identify such locations in the Gulf of Carpentaria although it is likely that estuaries with seagrass are regions of overlap between fishers and dugongs.

Priority should also be given to breeding and feeding areas, which consistently support the largest number of individuals. In the Gulf of Carpentaria, this is now clearly the Wellesley Island region (from the mouth of the Albert River to the mouth of Arthur's Creek (west of Bayley Point) and north to latitude 16 20's), which at the time of the 1997 survey supported an estimated 62% of the dugongs, 32% of the sea turtles and 28% of the dolphins in the entire survey area (Table 10).

Table 10. Comparison of the wildlife values of, and fishing effort in, various parts of the survey area.

Area	% dugongs 1997	% turtles 1997	% dolphins 1997	% fishing effort Gulf fishery 1996[1]
coast west of Wellesley Is (Block 8)	8	3	5	1
Wellesley Is region (Blocks 1-5)	**62**	**32**	**28**	**7**
Leichhardt-Holroyd Block 6	0	15	20	54
Holroyd-Crab Is Block 8	30	50	47	22

[1] 16% of the effort is outside the survey area

The closure of the entire Wellesley Island region should go a long way to meeting the objective of the QFMA Gulf of Carpentaria Inshore Finfish Management Plan (QFMA 1999) 'to minimise the effects of fishing on protected wildlife' by closing the most important area for marine wildlife to netting. As this area consistently supports high numbers of dugongs (Ligon, 1976, Marsh *et al.* 1980, Marsh and Lawler

1993, Table 4), such a closure should reduce fishing mortality even if individual animals spend only some of their time in the area.

The closure to commercial netting at the mouth of the Norman River (QFMA 1999) is welcome. This closure will be an important initiative to maintain the range of the dugong in the Gulf of Carpentaria. The draft seagrass maps produced by the Queensland Department of Primary Industries based on a survey in 1986 suggest that there was no seagrass between the mouths of the Kirke and Norman Rivers. However, this closure will be of much less significance to dugongs in the Gulf of Carpentaria than a closure of Block 4 to gill netting would be for two reasons:

(1) Although dugongs occur in the area (A. Roelofs QDPI *pers comm. 1998*), it is of limited importance as dugong habitat with an estimated 14 km^2 of seagrass (QDPI unpublished data) compared with 108 km^2 in the Wellesley Islands area and adjacent coast (Poiner *et al.* 1987).

(2) As the Karumba area is targeted for industrial development, it will be more difficult to maintain habitat quality than elsewhere in the survey region (with the likely exception of the Weipa area).

If seagrass is subsequently found in the estuaries along the west coast of Cape York, consideration should be given to additional closures in the vicinity of seagrass beds.

Choosing when and where to modify fishing practices

The effectiveness of modifications to fishing practices can only be measured by controlled experiment. Such experiments are expensive. Very large scale trials are required if the probability of entanglement in unmodified nets is low as is likely in the Gulf of Carpentaria. For example, if the bycatch occurs in 1% of sets, almost 2,700 sets each of unmodified and modified gear would be required to show a 50% reduction in bycatch with 80% power at α =0.10 (Dawson *et al.* 1998). This means that such studies cannot be carried out cost-effectively in areas of low entanglement rate. This is an important constraint since the low reproductive rates of dugongs, dolphins and sea turtles make small populations (such as occur throughout most of the survey area, Figures 5-8) vulnerable even at low rates of entanglement.

Modifications to fishing practices are also harder to enforce than closures *per se*. Hence they are most appropriate in areas in which the probability of an individual encountering a net is low, which support lower numbers of marine mammals than the areas targeted for closure and where it is possible to provide effective enforcement. Effective enforcement will be difficult to achieve in a remote area such as the Queensland coast of the Gulf of Carpentaria, except in the vicinities of the patrol bases at Weipa and Karumba. Nonetheless, we suggest that fishing practices be modified throughout the Queensland waters of the Gulf of Carpentaria with the aim of reducing the incidence of marine wildlife drowning in gill nets in accordance with the objective of the QFMA Gulf of Carpentaria Inshore Finfish Management Plan (QFMA 1999). Such modifications should be developed in close consultation with local fishers who need to be educated through an extension program, about the need for such changes. The rate of by-catch will then need to be measured using an observer program and the program reviewed regularly.

Natural mortality of dugongs and sea turtles

Dugongs and sea turtles are killed as a result of extreme climatic events in the Gulf of Carpentaria. A respondent to Anderson and Heinsohn's (1978) postal survey reported that between 11 and 20 dugong carcasses had washed up on the beaches at Mornington Island after the unusually heavy Wet Season in 1973-74. Cyclone Ted (< biblio >) stranded at least two dugongs at Mornington Island in 1977. In 1984, the storm surge associated with Cyclone Kathy stranded at least 27 dugongs (Marsh 1989) and an estimated 1,000 green turtles (Limpus and Reed 1985) on the supratidal mudflats at the mouth of the MacArthur River.

Distribution and loss of seagrass habitats along the Queensland coast of the Gulf of Carpentaria

Along the Queensland coast of the Gulf of Carpentaria, both dugongs and green turtles depend on seagrass meadows which are largely restricted to shallow intertidal and subtidal regions to 3.7 m (Poiner *et al.* 1987). According to Poiner *et al.* (1987), the seagrass is distributed as follows:

Crab Is	2.3km^2	1.5%
Port Musgrave	4.8km^2	3.1%
Albatross Bay	6.8km^2	4.4%
Archer Bay	4.8km^2	3.1%
Wellesley Islands	108.4km^2	69.8%
Wellesley Islands-N.T border[1]	28.2km^2	18.1%

[1] assuming 50% of seagrass between Wellesley Is and Sir Edward Pellow Is occurs in Queensland.

This result is generally consistent with the pattern of dugong distribution we observed in November 1997 (Figure 5), but does not explain the large numbers of dugongs sighted between the mouth of the Staaten River and Cape Keer Weer during the shoreline surveys conducted for dugongs in the 1970s (Heinsohn 1976, Ligon 1976, Heinsohn and Marsh 1978) or the anecdotal reports of incidental drownings of dugongs in fishing nets at this time (Appendix 1).

The seagrass beds along the western coast of Cape York are poorly known and have been mapped at low resolution. Poiner *et al.* (1987) conducted their mapping in 1982 (Crab Island to Karumba) and 1984 (Karumba to Queensland border) along transects aligned perpendicular to the coast at intervals of 3-5 nautical miles (1 nautical mile = 1.852 km). The Queensland Department of Primary Industries mapped the region in 1986 along transects running perpendicular to the shore at intervals of 7 nm with spot dives every 1 mn (Warren Lee Long *pers comm.* 1998). This survey detected several additional small seagrass beds along the west coast of Cape York. However, neither of these mapping exercises suggests that there were significant areas of seagrass between Cape Keer Weer and Karumba. This finding is inconsistent with the number of dugongs sighted in this region in the 1970s (Heinsohn 1976, Ligon 1976, Heinsohn and Marsh 1978) and the anecdotal accounts of incidental dugong deaths in this region (Appendix 1). Tropical seagrass beds can be ephemeral (Poiner and Peterkin 1995), but the reasons for this are poorly understood. We suggest that the seagrass beds along the Queensland coast of the Gulf of Carpentaria be remapped at a more detailed scale to ascertain whether or not the absence of habitat is a plausible explanation for the low number of dugongs we sighted in the region between Cape Keer Weer and Karumba in November 1978. The estuaries in the region should be targeted during this survey as they are likely to be the regions of maximum overlap between dugongs and fishers.

Alternatively, there may have been a decline in dugong numbers in the area due to unsustainable levels of dugong mortality (Appendix 1). Repeating the shoreline surveys of the 1970s along the west coast of Cape York would allow improved temporal comparisons than are possible at present because of the confounding of changes in survey technique with time.

Sparse population and a lack of development except in the immediate vicinity of Weipa and Karumba, should mean that there has not been any major anthropogenic induced loss of seagrass along the Queensland coast of the Gulf of Carpentaria. (The shallow coastal habitat where seagrasses occur is protected from trawling by closures (Warren Lee Long *pers. comm.*1998)). However, natural events such as floods and cyclones can cause widespread loss of seagrasses in both shallow and deep water (Poiner and Peterkin 1995, Preen *et al.* 1995, Preen and Marsh 1995). Since 1984, the Gulf of Carpentaria has been the site of a CSIRO study of the effects of cyclones on seagrasses. Cyclone Sandy in 1985 caused the loss of 70% of the 183 km^2 of seagrass between the Sir Edward Pellew Group and Limmen Bight along the Northern Territory coast of the Gulf of Carpentaria, equivalent to 20% of the seagrasses in the entire Gulf of Carpentaria (Poiner and Peterkin 1995). Although recolonisation of the area was slow, much of the area had recovered to pre-cyclone Sandy conditions by 1994 (Poiner and Peterkin 1995). Several dugongs were rejected by Mornington Islanders upon butchering in 1976-1977 because of their watery fat (Marsh 1984), a symptom of starvation also seen in Hervey Bay dugongs after the loss of 1000 km^2 of seagrass in 1992 (Preen and Marsh 1995, unpublished data). This observation suggests that flooding in the lower Gulf of Carpentaria associated with the record 1973-74 Wet Season may have caused significant and prolonged loss of seagrass in the Wellesley Islands region. Dugong movement in response to this loss is a possible explanation of the large number of animals sighted along the West Coast of Cape York, especially by Ligon (1976).

Current land use practices may exacerbate the effects of natural catastrophes such as cyclones (Preen and Marsh 1995), and integrated catchment management programs are seen as an important part of good management for the seagrasses in the GBR (Lee Long and Coles 1996). A Landcare Program has been established in the Mitchell River catchment, but to our knowledge similar large-scale programs have not been established in the other catchments draining into the Gulf of Carpentaria. The draft Cape York Land Use Strategy emphasises the need for sustainable land use but has as its objective a more than threefold increase in cattle numbers. We suggest that the issue of the impact of terrestrial runoff on the coastal waters of the Gulf of Carpentaria warrants further study.

The available evidence suggests that the vicinities of the ports of Karumba and Weipa are not important habitats for dugongs, dolphins or sea turtles. Both the Weipa and Karumba loading facilities require maintenance dredging (Patterson and Ford 1988, Century Zinc 1994). Dredging may generate plumes of sediment which could affect the nearby seagrass beds. Spills of ore from ship loading operations provide a risk of heavy metal accumulation in sediments, however, the loading operations will be some 5 km from the seagrass beds at the mouth of the Norman River where dugong feeding trails have been observed (Century Zinc 1994). Given the low numbers of dugongs along this coast, the impacts of any habitat loss associated with the port of Weipa is almost certainly low. The seagrass bed near Karumba is more significant given the apparent scarcity of seagrass between Cape Keer Weer and Karumba.

Options for Management (these options are also included in the Executive Summary)

Short-term options achievable under Queensland Fisheries Regulation

Variations of these options have been discussed with the commercial fishing industry and the Queensland Fisheries Management Authority (QFMA) as follows:

- Tropical Finfish Management Committee of the QFMA, April 1998
- Dr Joe Baker, Chair Tropical Finfish Management Committee, January 1998 and September 1998
- Mr Gary Ward, Member Tropical Finfish Management Committee and President Gulf Branch of Queensland Commercial Fisheries Organisation August -September 1998
- Mr Bill Kehoe, former Board Member QFMA and Secretary Gulf Branch of Queensland Commercial Fisheries Organisation August -September 1998
- Mr Ted Loveday, President Queensland Commercial Fisheries Organisation August -September 1998

Helene Marsh also reported the results of the survey to the October 2, 1998 meeting of the Gulf Branch of the Queensland Commercial Fisheries Organisation by sending a video to the Branch and discussed the options outlined below.

Option 1.

Management actions outlined in the QFMA Gulf of Carpentaria Inshore Fisheries Management Plan (QFMA 1999).

Details of Option 1

Objective 3 of the Plan is 'to minimise the effects of fishing on protected wildlife'.

The Plan states that this objective is to be achieved by:
(d) the requirements under the Plan for attending certain types of net; and
(e) putting into effect closed water declarations under part 3 of the plan in areas identified by the Authority as being important for the species. The only such area identified in the Plan is the proposed closure at the mouth of the Norman River to protect dugong (QFMA 1999).
(f) the requirements under the Plan for minimum and maximum mesh sizes of nets.

The Plan states that the effects of fishing on protected wildlife is to be measured by:
(d) implementation by the Authority of the recording of the incidental catch of the species;
(e) compliance with net attendance requirements and closed water declarations under the Plan;
(f) compliance with the requirements under the Plan for minimum and maximum mesh sizes of nets.

The Plan further states that the provisions of the Plan for minimising the effects of fishing on protected wildlife are to be reviewed if there is significant:
(d) increase in the recorded incidental catch of the species; and
(e) decline in the level of compliance and closed water declarations under the Plan;
(f) decline in the level of compliance with the minimum and maximum mesh sizes for nets.

Assessment of Option 1
We consider that implementation of this option is unlikely to achieve the Plan's objective to minimise the effect of fishing on protected wildlife for the following reasons:
(4) The Plan does not specify the wildlife on which it plans to minimise the effects of fishing.
(5) The Plan does not include a mechanism to educate the fishermen about the need to minimise their impact on protected wildlife or to identify any wildlife caught. Due to the remoteness of the area, enforcement capacity is extremely limited and thus education is vital.
(6) As six species of sea turtles (green, loggerhead, flatback, leatherback, hawksbill, olive ridley), at least three species of dolphins (bottlenose, Irrawaddy and Indo-Pacific humpback) and one species of dugong occur in the Queensland waters of the Gulf of Carpentaria (Marsh *et al.* 1995), the effect of fishing on individual species cannot be evaluated unless the fishers are trained to recognise the relevant species through an Endangered Species Awareness Course. These species of marine wildlife have different conservation status under the *Queensland Nature Conservation Act 1992* as follows:
Endangered: loggerhead turtle, leatherback turtle, olive ridley turtle
Vulnerable: dugong, green turtle, hawksbill turtle, flatback turtle
Rare: Irrawaddy dolphin, Indo-Pacific humpback dolphin
(9) The Plan does not specify a penalty for failing to record incidental catch. We suggest that such failure should be a serious fisheries offence. Note: It is a legal requirement under the *Commonwealth Whale Protection Act 1980* to report the incidental death of a cetacean in Commonwealth waters in Australia. It will be a legal requirement under the *Commonwealth Environment Protection and Biodiversity Conservation Bill 1999* to report the taking of listed species of marine wildlife (including dugongs and sea turtles) as well as cetaceans in Commonwealth waters
(10) The Plan does not include an effective mechanism for the independent recording of incidental

catches for the N3 fishery (operating to 8 nm offshore). Experience in New Zealand (Appendix 2) suggests that fishers fail to comply with compulsory incidental reporting programs for marine mammal by-catch. In New Zealand, such observer programs are funded by a Conservation Services Levy.

(11) The effectiveness of the net attendance rules proposed in the Plan for reducing the mortality of protected wildlife is unproven. Testing the effectiveness of these rules would be extremely expensive as outlined above.

(12) All closures nominated are river closures of limited use as protection for marine wildlife. The closure of the mouth of the Norman River, although welcome and important for maintaining the dugong's range in the Gulf, is unlikely to reduce the impact of fishing on protected wildlife in the Queensland waters of the Gulf of Carpentaria significantly because of the low numbers of dugongs, dolphins and sea turtles using the area.

(13) The proposed performance indicators do not measure the effects of fishing on protected wildlife.

Option 2.

Option suggested by Mr Gary Ward, commercial fisher and member of the Tropical Finfish Management Advisory Committee

Details of Option 2

General

The Management Plan for the Queensland Gulf of Carpentaria Inshore Finfish Fishery should:

(a) Recognise a Dugong Sensitive Area along the coast from the mouth of the Albert River to the mouth of Arthur's Creek (west of Bayley Point) and north to latitude 16 20's;

(b) Require all participants in the N3 and N9 fisheries to complete the QCFO's Endangered Species Awareness Course;

(c) Require all vessels operating in the Gulf of Carpentaria inshore finfish fishery to complete a dugong sighting log with returns to the QFMA with a view to developing a chart to inform fishers about dugong distribution in the Gulf;

(d) Include a chart detailing the distribution of seagrass beds to allow N3 entitlement holders to identify potential dugong areas;

(e) Introduce an observer program for the N3 fishery.

(f) Require that the situation regarding incidents involving protected species be formally reviewed each year at the October meeting of the Karumba Branch of QCFO;

(g) Require that offshore nets:
- be a maximum of 400 m long (drift nets) or 600 m long regardless of entitlements (set nets),
- have a maximum line strength of 35 gauge
- have at the net attendance,
- be no more than 100m from the next set if multiple sets are used,
- not be used as a bottom set net;

(h) Require that for foreshore nets:
- the first net be not more than 1 km from primary vessel,
- be no more than 200m per set (total maximum 600m),
- have a maximum line strength of 50 gauge.

Assessment of Option 2

We consider that this option is a significant improvement over Option 1 for the following reasons:

(1) Option 2 includes mechanisms to educate the fishers about the need to minimise their impact on protected wildlife, to teach them to identify any wildlife caught, and to review the situation each year.

(2) Option 2 acknowledges the most important region along the Queensland coast of the Gulf of Carpentaria for dugongs and sea turtles as a Dugong Sensitive Area. This region contains an estimated 62% of the dugongs, 32% of the sea turtles and 28% of the dolphins in the Queensland waters of the Gulf of Carpentaria based on an aerial survey in November 1997.

(3) Option 2 includes additional measures designed to reduce the mortality of wildlife in both foreshore and offshore nets by a fisher with considerable local knowledge.

(4) Option 2 includes an observer program for the N3 fishery.

However, Option 2 may not be totally effective in minimising the effect of fishing on protected wildlife for the following reasons:

(4) It does not specify a penalty for failing to record incidental catch. Note: It is a legal requirement under the *Commonwealth Whale Protection Act 1980* to report the incidental death of a cetacean in Commonwealth waters in Australia. It will be a legal requirement under the *Commonwealth Environment Protection and Biodiversity Conservation Bill 1999* to report the taking of listed species of marine wildlife (including dugongs and sea turtles) as well as cetaceans in Commonwealth waters.

(5) The effectiveness of the proposed changes to the rules for offshore and foreshore nets in reducing the mortality of protected wildlife is unproven and will be very expensive to establish.

Option 3.

Details of Option 3

The initiative presented below is in addition to those included in Options 1 and 2 above.

(a) Ban foreshore and offshore netting in the Dugong Sensitive Area proposed in Option 2 above.

(b) Make a consequential reduction in the effort in the N3 fishery through an extension of the adjustment package outlined in the Plan. (Based on QFMA logbook data for 1993-96, the required effort reduction is estimated to be about 7% of the total effort in the Gulf net fishery or 820 days per year).

(c) Make the use of Vessel Monitoring System compulsory for the N3 fishery.

Assessment of Option 3

This option will go a long way towards meeting the objective of the QFMA Gulf of Carpentaria Inshore Finfish Management Plan (QFMA 1999) 'to minimise the effects of fishing on protected wildlife' by closing the most important area for marine wildlife to netting and by including options which may reduce catch in other areas. However, given the uncertainty of the effectiveness of these options in reducing bycatch, the effectiveness of Option 3 in minimising the effects of fishing outside the closure areas is unknown.

<u>Longer-term management option</u>

The Dugong Sensitive Area proposed in Option 2 above is under Native Title Claim and could be declared an Indigenous Protected Area by agreement between the traditional owners and the state of Queensland and the Commonwealth. This would provide a structure for the community-based management of the dugong and green turtle catch.

If the seagrass surveys recommended below, confirm significant seagrass resources in other areas, management arrangements should also be developed for these areas.

Suggestions for Future Surveys

Wildlife surveys

The optimum time interval between regional-scale quantitative aerial surveys for marine wildlife is a tradeoff between information and cost. Marsh and Saalfeld (1989b) recommended that regional surveys for dugong be conducted every five years. The disadvantage of this recommendation is that there is no replication within each survey interval, making unexpected changes difficult to interpret. Given that the 1997 estimate of the dugong population of the Wellesley Islands area was only 65% (but not significantly different) from the 1991 estimate, it would be desirable to resurvey the region in 1999 and at five year intervals thereafter, with the option of reducing the survey interval if a decline were confirmed.

It is impossible to interpret the differences between this survey and the shoreline surveys of the west cost of the Gulf of Carpentaria due to the differences in survey technique. A series of 3-5 shoreline surveys along this coast would be relatively cheap to execute, would eliminate the confounding effects of survey design, and would allow more robust temporal comparisons.

A ground survey should be conducted along the western coast of Cape York in the turtle-nesting season to establish whether or not leatherback turtles are nesting along the coast south of the mouth of the Mitchell River.

Seagrass

The most recent map of seagrass habitats of the Queensland coast of the Gulf of Carpentaria is 12 years old. An current map of potential dugong and sea turtle habitats would be a useful initiative in a package of measures to minimise the by-catch of protected wildlife. An organisation with expertise in the regional scale mapping of seagrass, such as the Queensland Department of Primary Industries, should be funded to conduct this work. Particular attention should be paid to checking for the presence of seagrass in the estuaries along the coast of Cape York.

ACKNOWLEDGMENTS

Environment Australia and the Queensland Department of Environment and Heritage jointly funded this survey. We thank our skilled and co-operative pilots Rodney Battle, and Stephen Shannon; our observers Rose Barracliffe, Peter Boosi, Aynsley Callidane, Dawn Couchman, Stephanie Lemm, Liz Macedo and Robert Vedetta; Graham Hammond for assistance with the spatial analysis; Adella Edwards for assistance with Figure 1; and Carole Eros for general assistance in the compilation of this report. Peter Bayliss and Tim Clancy made useful comments on the draft report which have greatly improved the final product.

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APPENDIX 1: ANECDOTAL INFORMATION ON DUGONG MORTALITY (reproduced from Marsh 1984)

West Coast of the Gulf of Carpentaria (Karumba-Cape York)

DATE	DETAILS	SOURCE
Traditional		
1974	Questionnaire suggests that 1 to 20 dugongs killed annually in Weipa area.	Anderson & Heinsohn (1978)
Incidental captures in gill nets		
1978	During an aerial survey on November 23 and 24 between Cape York and Karumba 24 gill nets checked. A dead dugong was seen in a net near Cape Keer-weer.	Heinsohn and Marsh (1979)
1980	A researcher who interviewed 17 professional fishermen (4 at Archer River; 5 at Mitchell River; 4 at Nassau River; 4 at Rocky Creek) reported that the fishermen were each catching five to ten dugongs per year. One operator at Archer River allegedly caught 23 in one week in June 1979. Two other fishermen moved from this area at this time to avoid catching dugongs. The proportion of these animals that were released alive is unknown.	Marsh and Heinsohn (1982)
Commercial		
1952	Dugong meat frequently served at barbeques at Karumba Golf and Country Club.	Article in Pix November 1952 stimulated letter to Queensland Minister of Agriculture and Stock from A.H. Chisholm Editor-in-Chief of Australian Encyclopaedia on November 4, 1952.
1983	Dugong meat is frequently sold in Weipa south.	P. Reeders (*pers comm.* to H. Marsh 1983)

Wellesley Islands area

DATE	DETAILS	SOURCE
Traditional hunting		
1974	One respondent to postal questionnaire indicates an annual catch of between 51 and 100; another respondent suggests annual catch	Anderson and Heinsohn (1978) and unpublished data

	of between 21 and 50.	
1976-78	On the basis of the experience of biologist Blair Gardner who spent several weeks on Mornington Island during the 1976 and 1977 hunting seasons plus all of 1978, the annual take was estimated at 40 per year.	Marsh *et al*., (1980)
<u>Incidental catch in gill nets</u>		
1984	A barramundi fisherman interviewed by biologist estimated that when fishing in the Forsythe Island area he averaged catching a dugong per day in his nets. The proportion released alive is not known.	Information given to H. Marsh by non-government biologist in 1984 (Name withheld on request)
<u>Other mortality</u>		
1974	Respondent to questionnaire indicated that 11-20 dugong carcasses had washed up on the beaches on Mornington Island in 1974. This may have been associated with the unusually heavy wet season.	Anderson & Heinsohn (1978)
1976	At least two dugongs were stranded at Mornington Island by Cyclone Ted.	Heinsohn & Marsh (1977)
1976-77	A number of dugongs were rejected by the Mornington Islanders upone butchering as being sick because of their "watery fat".	H. Marsh (unpublished data 1976-77)

<u>Gulf of Caprentaria - Northern Territory border to Karumba</u>

DATE	**DETAILS**	**SOURCE**
<u>Fishery</u>		
1930-1937	Doomadgee Mission located on coast. Supplied dugong oil to Chemist Rousch.	Chemist Rousch *pers comm.* to F.G. Fisher (1979)
<u>Incidental catch in gill nets</u>		
1982	In first 19 days of barramundi season 5 of 40 Karumba-based fishermen had each caught a dugong. Three were released alive; two rolled up in the net and drowned. Two were caught in the Burketown area and one at each of the Flinders, Bynoe and Norman Rivers in nets set on the coastal foreshore flats outside the river estuaries.	B. Keogh *pers comm.* to R. Garrett (1982)

1982	4 dead dugongs sighted by Coastal Surveillance Aircraft on beach at Point Parker close to barramundi boat.	Dr S. Garnett *pers comm.* (1982)
1984	One dugong drowned off Tarrock Point during one month's barramundi netting between Morning Inlet and Parker Point.	Barramundi fisherman *pers comm.* to H. Marsh (1984)

APPENDIX 2

PRESS RELEASE FROM NEW ZEALAND ON HECTOR'S DOLPHINS DROWNING IN GILL NETS

DOLPHIN CARNAGE MUST END

Conservation Minister, Nick Smith, said today that the number of deaths of New Zealand's Hector's dolphins from fishing activities along the Canterbury coast must end. He challenged fishermen to work with the Department of Conservation, the Ministry of Fisheries and conservation interests to prevent the ongoing carnage.

"Seeing so many dead Hector's dolphins is a gut wrenching experience. Fishermen have for years denied the problem. It is now time to take this threat seriously or we risk denying future generations of New Zealanders the chance to enjoy these magnificent creatures," Mr Smith said.

The Minister today visited the Cetacean Investigation Centre at Massey University to observe the autopsies of Hector's dolphins retrieved from fishing nets off the Canterbury coast during last summer. Three of the dolphins were retrieved from recreational fishing nets, six were caught in commercial gillnets, and one by a trawler.

Hector's dolphins are only found in New Zealand, principally around the coast of the South Island. The total population for the species is estimated to be less than 4000.

"What makes me particularly angry about this issue is that fishermen have for years failed to report fatalities and denied there was a problem. It has taken years to negotiate an observer programme. The initial results from this first year observer coverage has confirmed our worst fears. Despite observer coverage on only 89 of 351 fishing days, six fatalities were observed. I remain cynical of the fact that fishermen claim there were no deaths during the 252 days of fishing when observers were not present. I am advised by statisticians that the probability of the fatalities occurring only on the days when observers were present is less than 1 in 10 billion. Were this true, I'd be advising every Canterbury fishermen to be buying a Lotto ticket, such is their luck. It is a legal requirement under the Marine Mammals Protection Act to report deaths of dolphins."

"These results confirmed the validity of creating New Zealand's first marine mammal sanctuary around Banks Peninsula, in 1988. The fact that significant numbers of the Hector's dolphins are still being killed beyond the sanctuary shows there are further steps that we need to consider to protect this special species," said Mr Smith.

The Minister also announced the new Conservation Services Levy for the fishing industry to deal with the issue of by-catch of both marine mammals and seabirds.

The new levies involve an increase from $782,000 to $1,062,255. Mr Smith said it was fair that the fishing industry met the cost of attempts to minimise the impacts the industry had on our native species.

"The greatest frustration I have about the Conservation Services Levies is that we spend nearly $300,000 a year on observers when I would much rather spend the money on preventative measures. Sadly, I have no confidence that fishermen will be honest about their impacts on marine mammals and seabirds and, until I am convinced otherwise, we need to continue the observer programme."

Among the projects the Minister has just approved for funding through Conservation Services Levies for 1998/99 will be an investigation of the use of acoustic devices, known as pingers, to warn dolphins of the presence of a fishing net. A further project to estimate the population of Hector's dolphins off the Canterbury Coast has been approved alongside a decision to develop a population management plan for the species. These three new projects commit an additional $175,000 to protect the Hector's dolphins.

"While I am frustrated with the fishing industry's track record, there are signs the industry is recognising that it cannot ignore these issues. I welcome their suggestion of a joint working party between industry, conservationists and the Department to try and find a solution to this problem. The level of dolphin deaths is not acceptable and, if we can't find a way to reduce the fatalities, we shall have to consider the option of closing off areas beyond Banks Peninsula to some types of fishing," he said.

For further information from the Minister of Conservation contact Tina Nixon, Press Secretary Ph: 04 471 9132 or 025 2232 789.

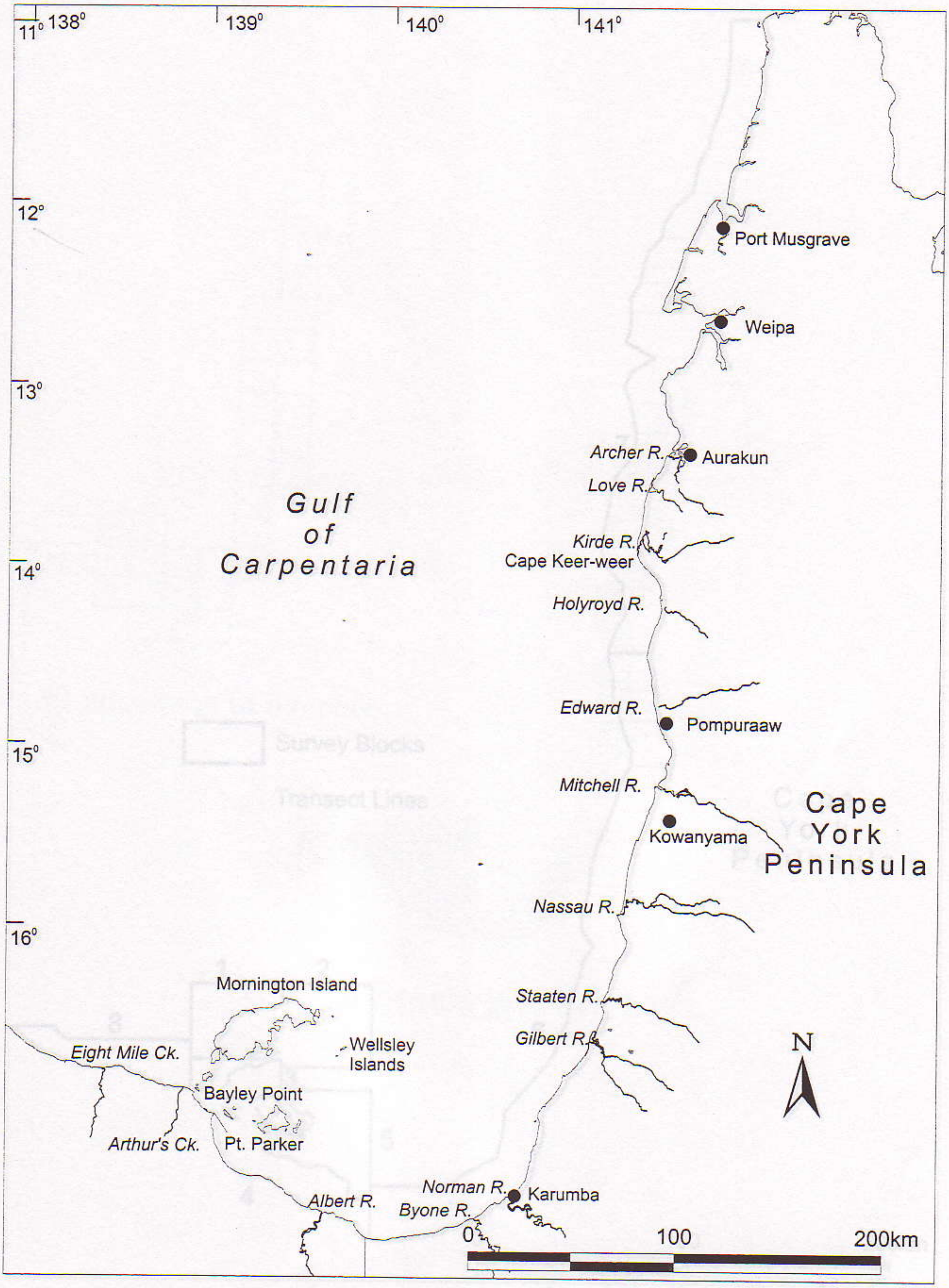


Figure 1: Map of Queensland coast of the Gulf of Carpentaria showing place names mentioned in the text.

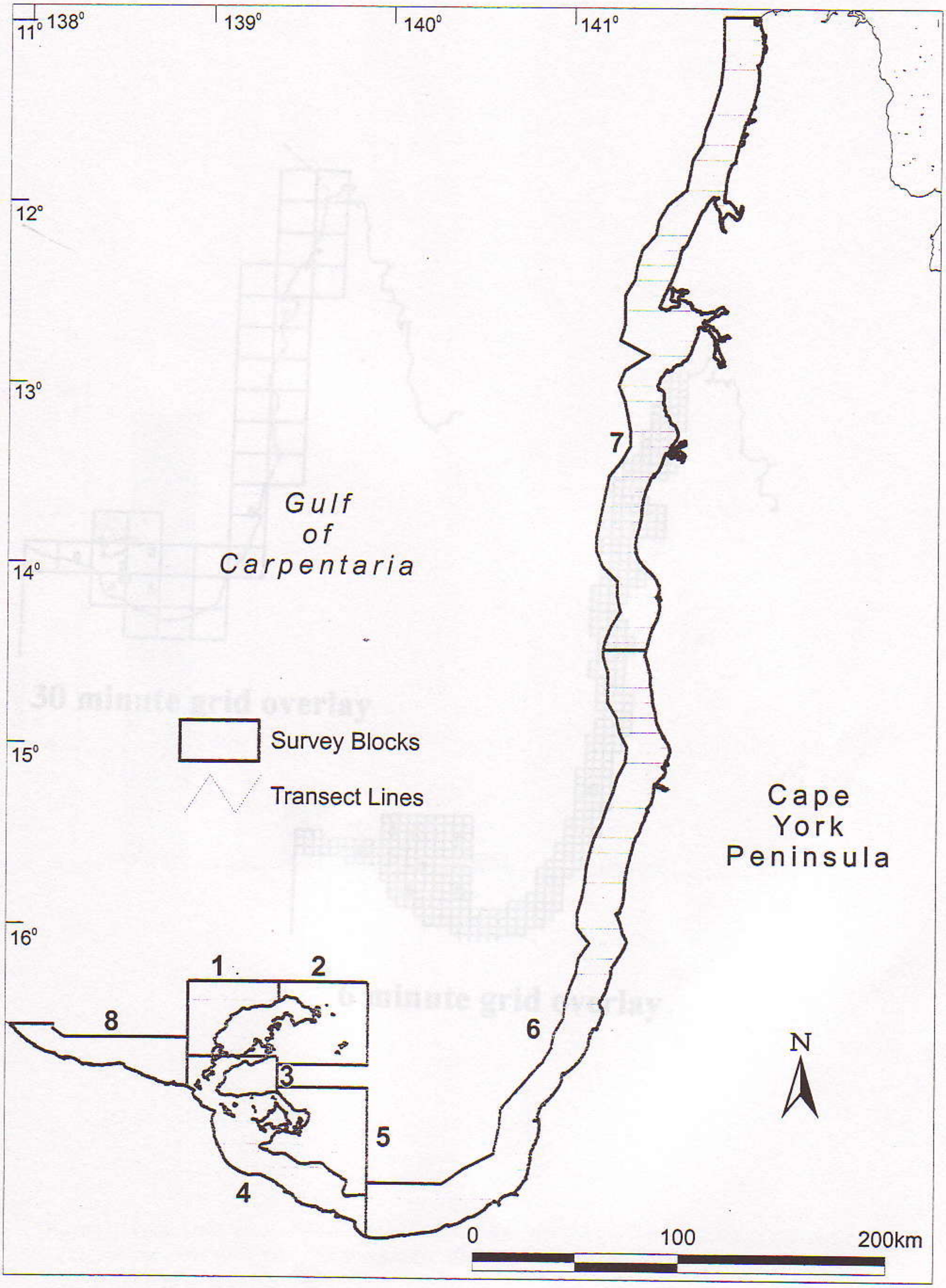


Figure 2: Map of survey area showing blocks and transect lines for the December 1997 survey. The western boundary of Block 3 in the 3 m depth contour line.

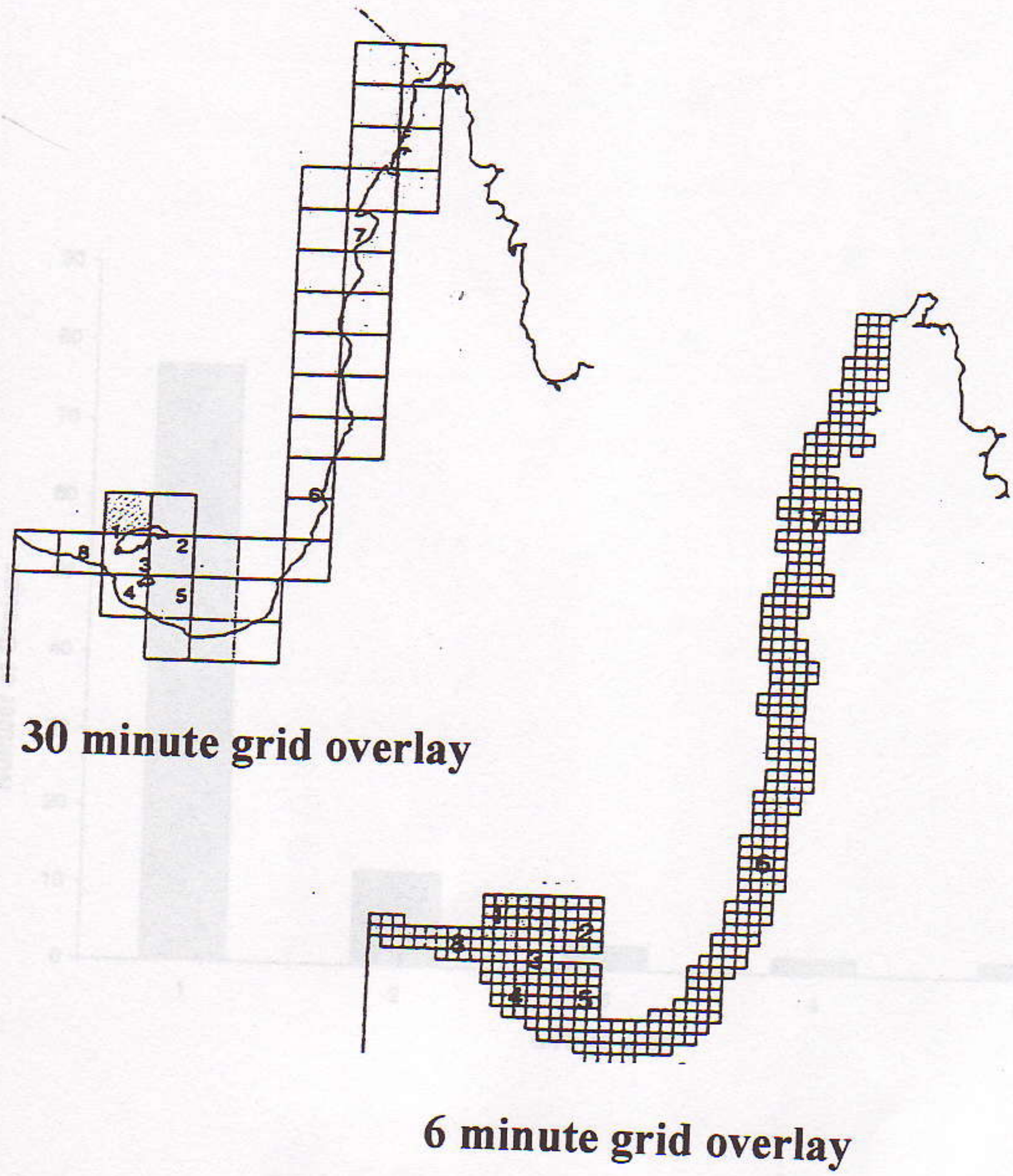


Figure 3: Gulf of Carpentaria showing boundaries of the aerial survey blocks and 6' and 30' reporting grids for the commercial inshore finfish fishery.

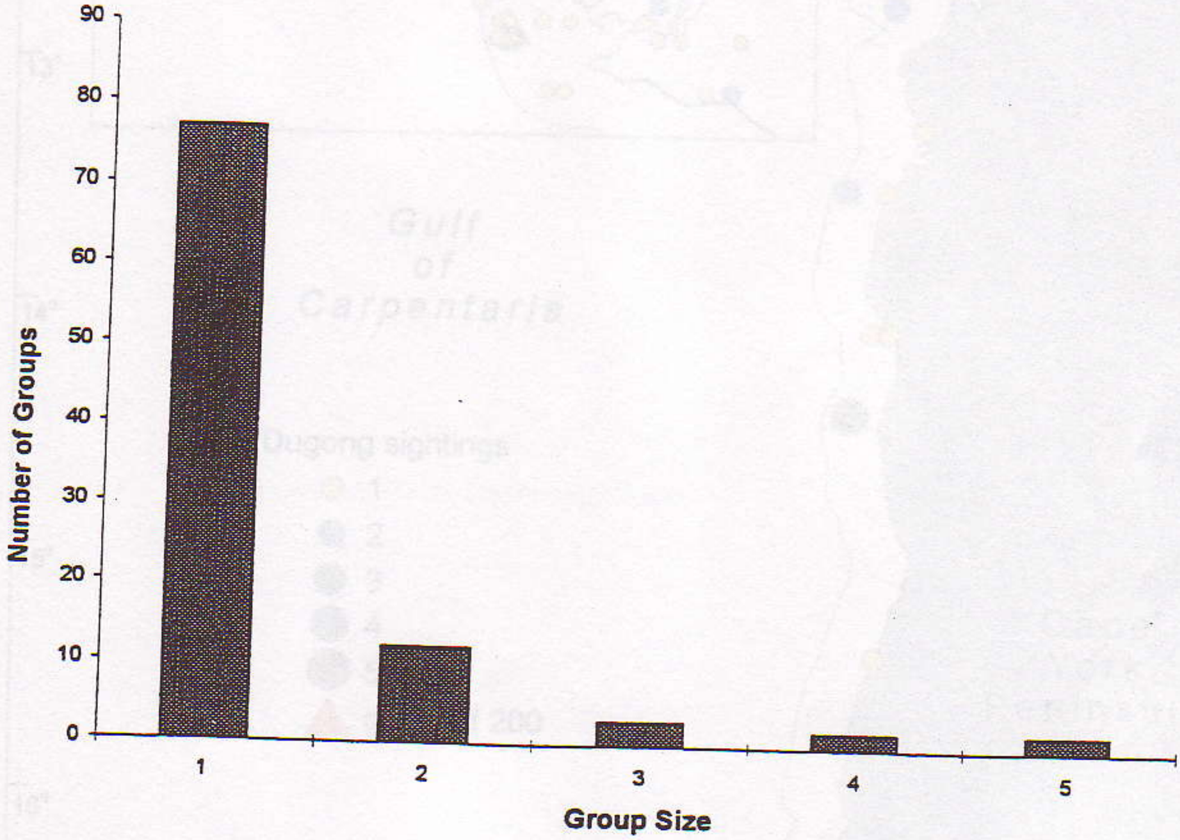


Figure 4: Histogram of the size of groups of dugongs sighted on transects during the survey in December 1997 (excludes the loose aggregation of 200 dugongs in Block 4 for which a total count was attempted).

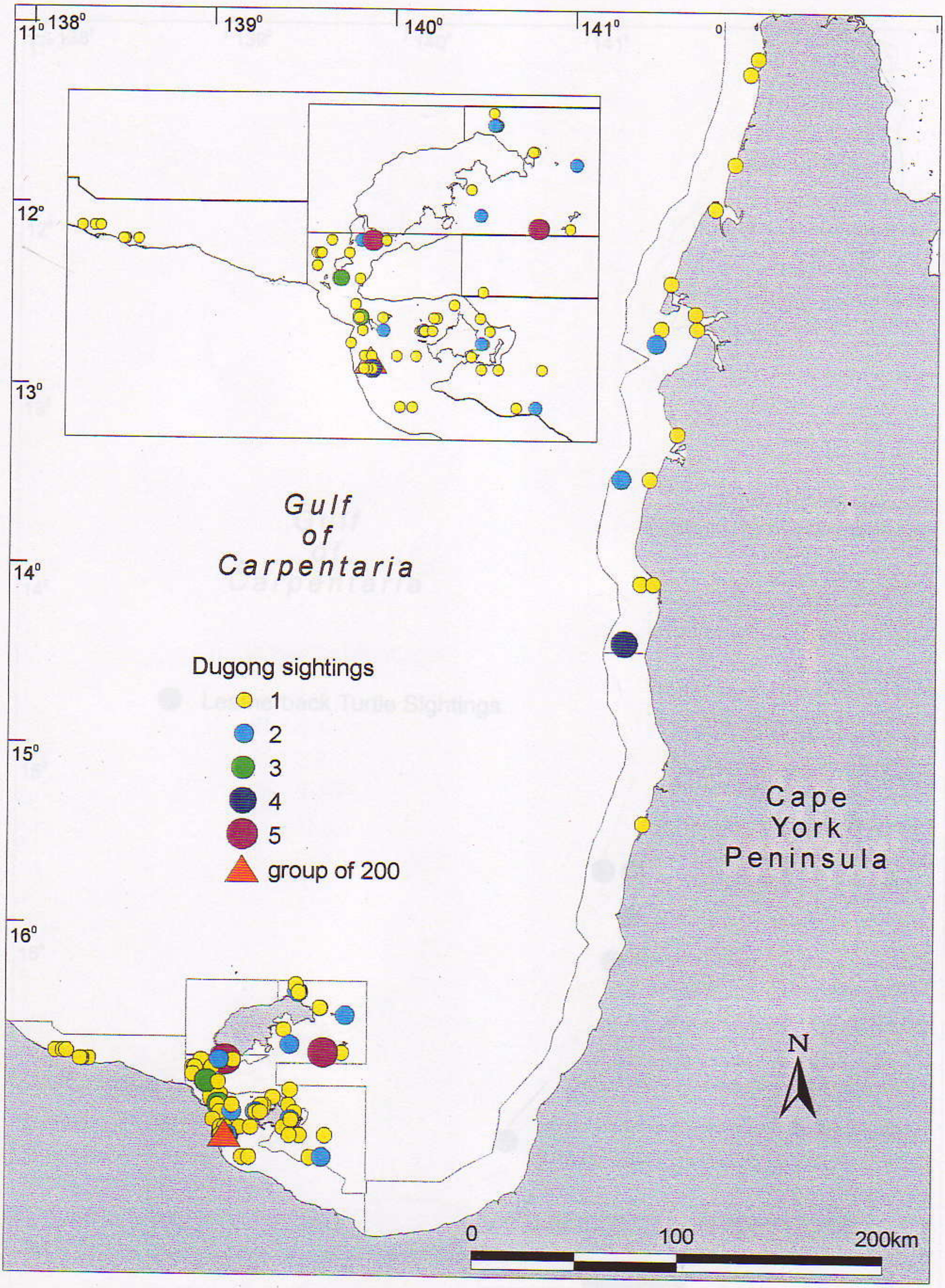


Figure 5: Map of the survey area showing the sightings of dugong groups in December 1997.

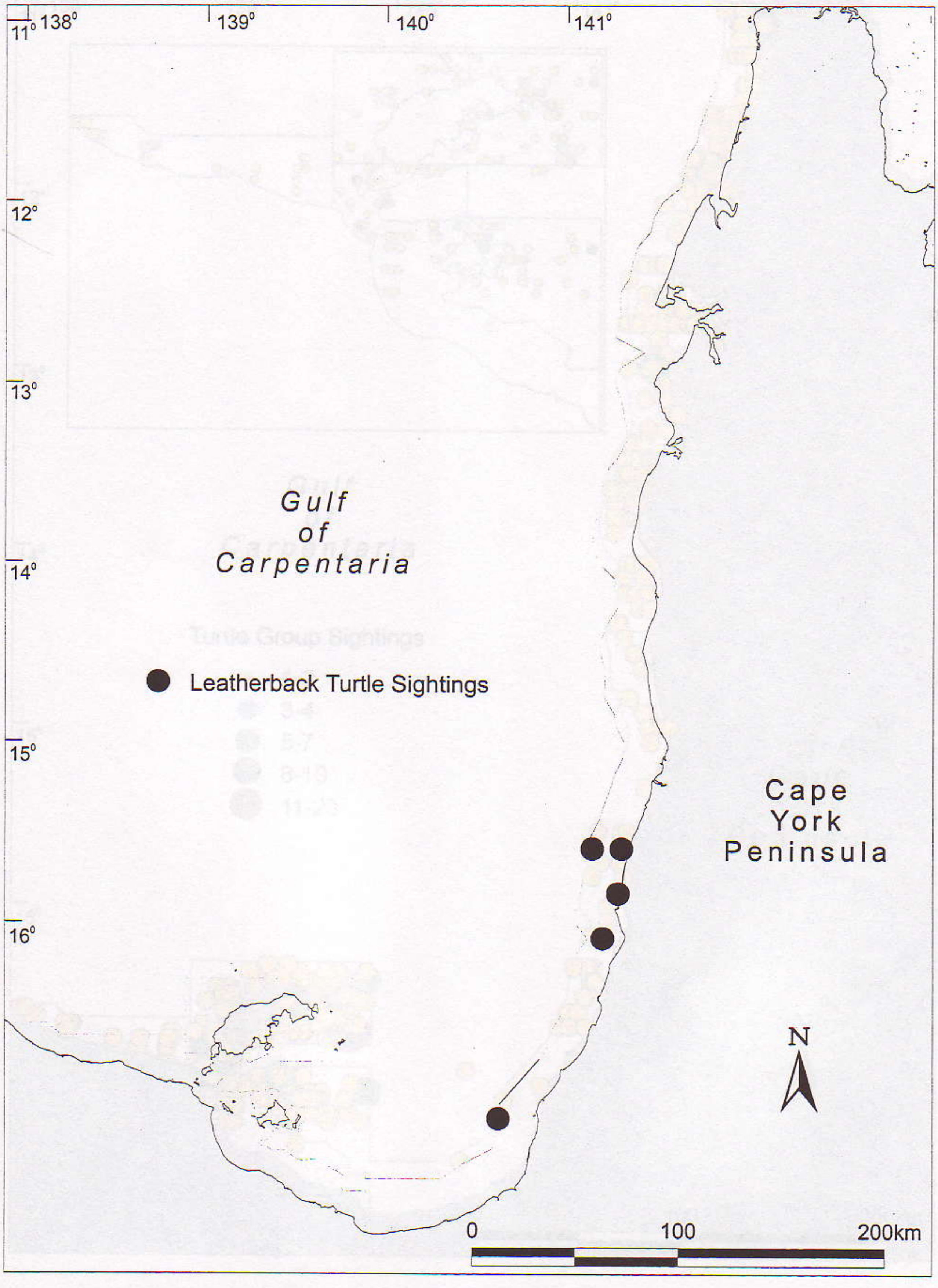


Figure 6: Map of the survey area showing sightings of leatherback turtles in December 1997

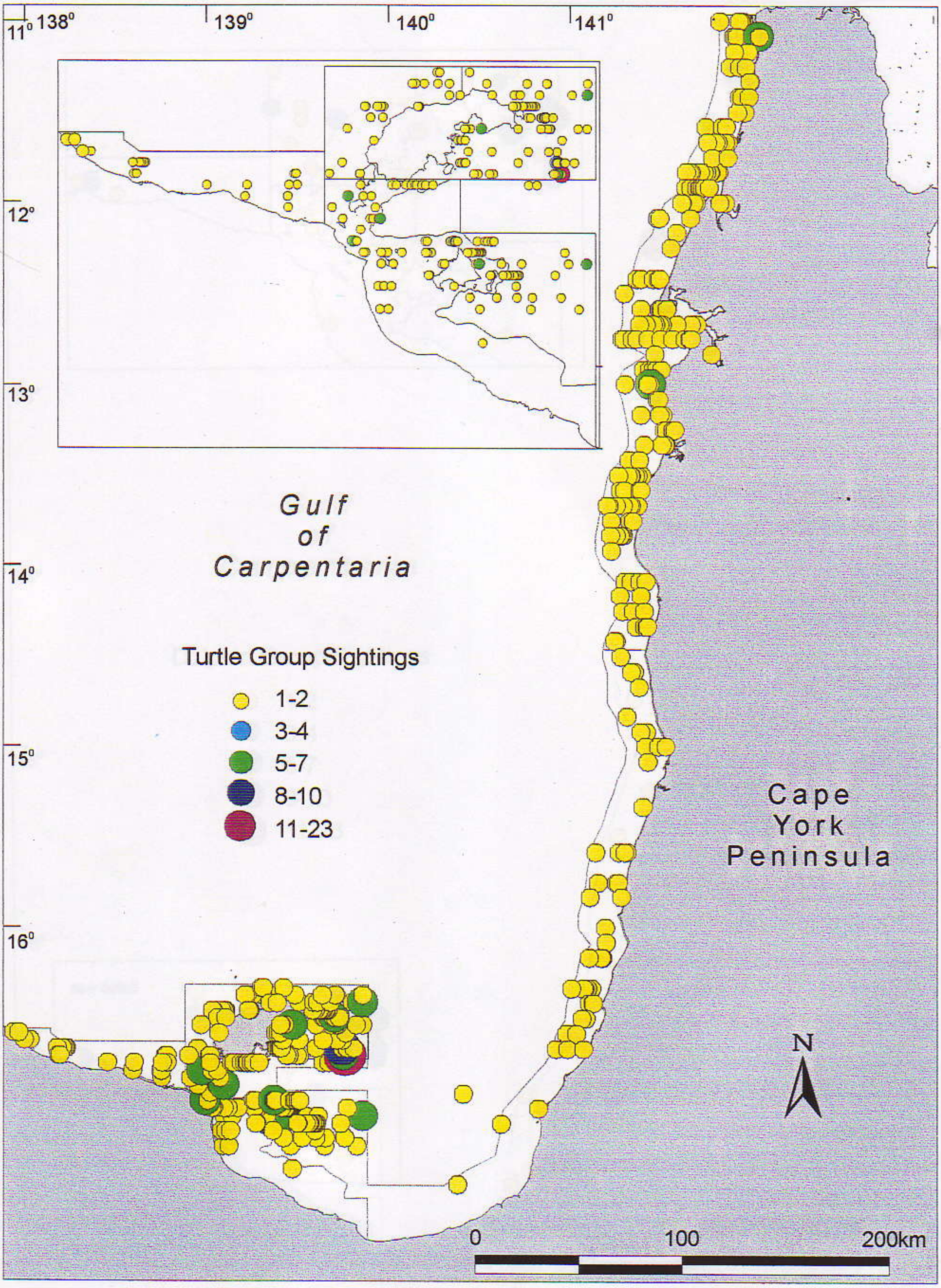


Figure 7: Map of the survey area showing the sightings of all turtles in December 1997.

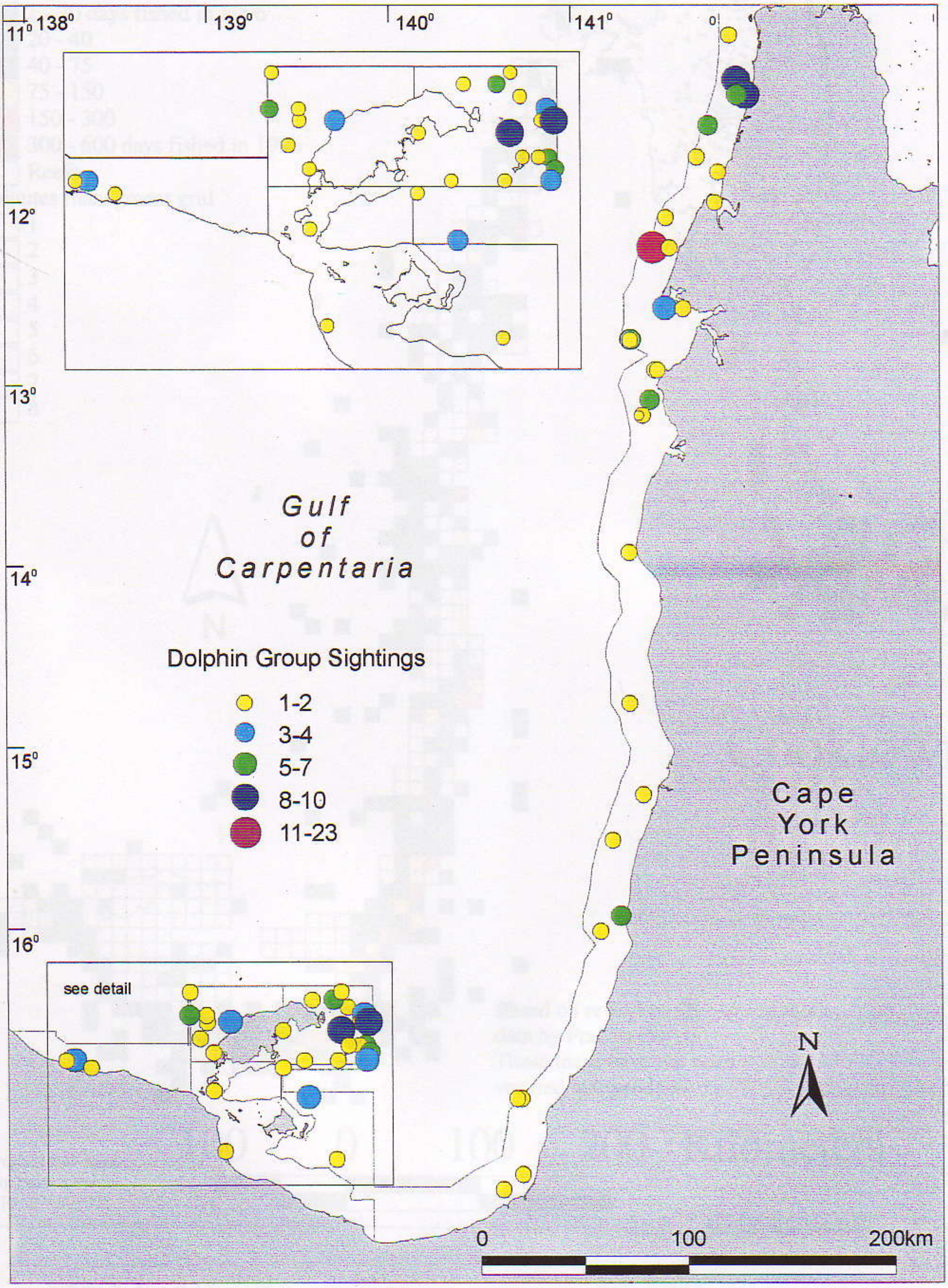


Figure 8: Map of the survey area showing the sightings of dolphin groups in December 1997.

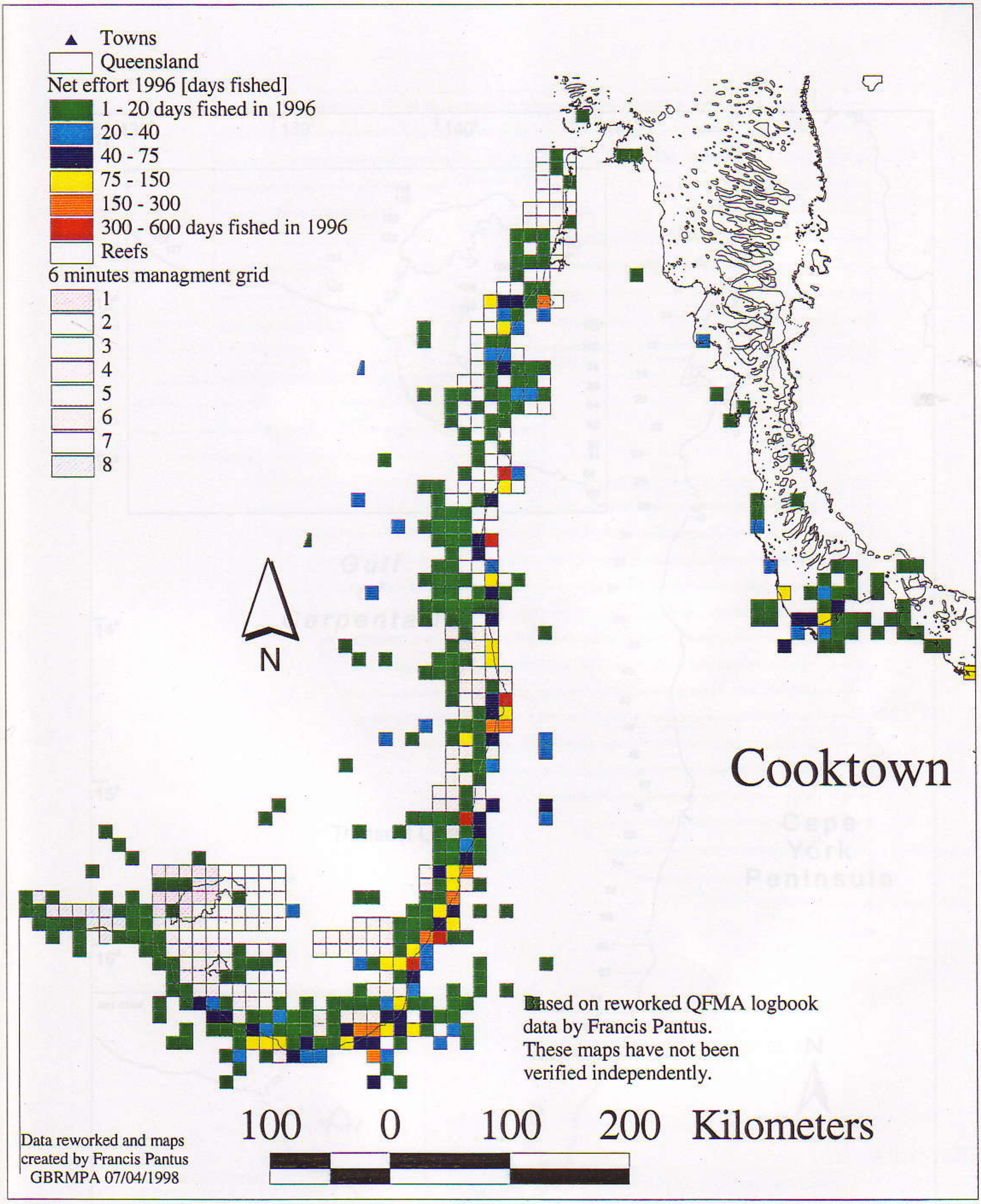
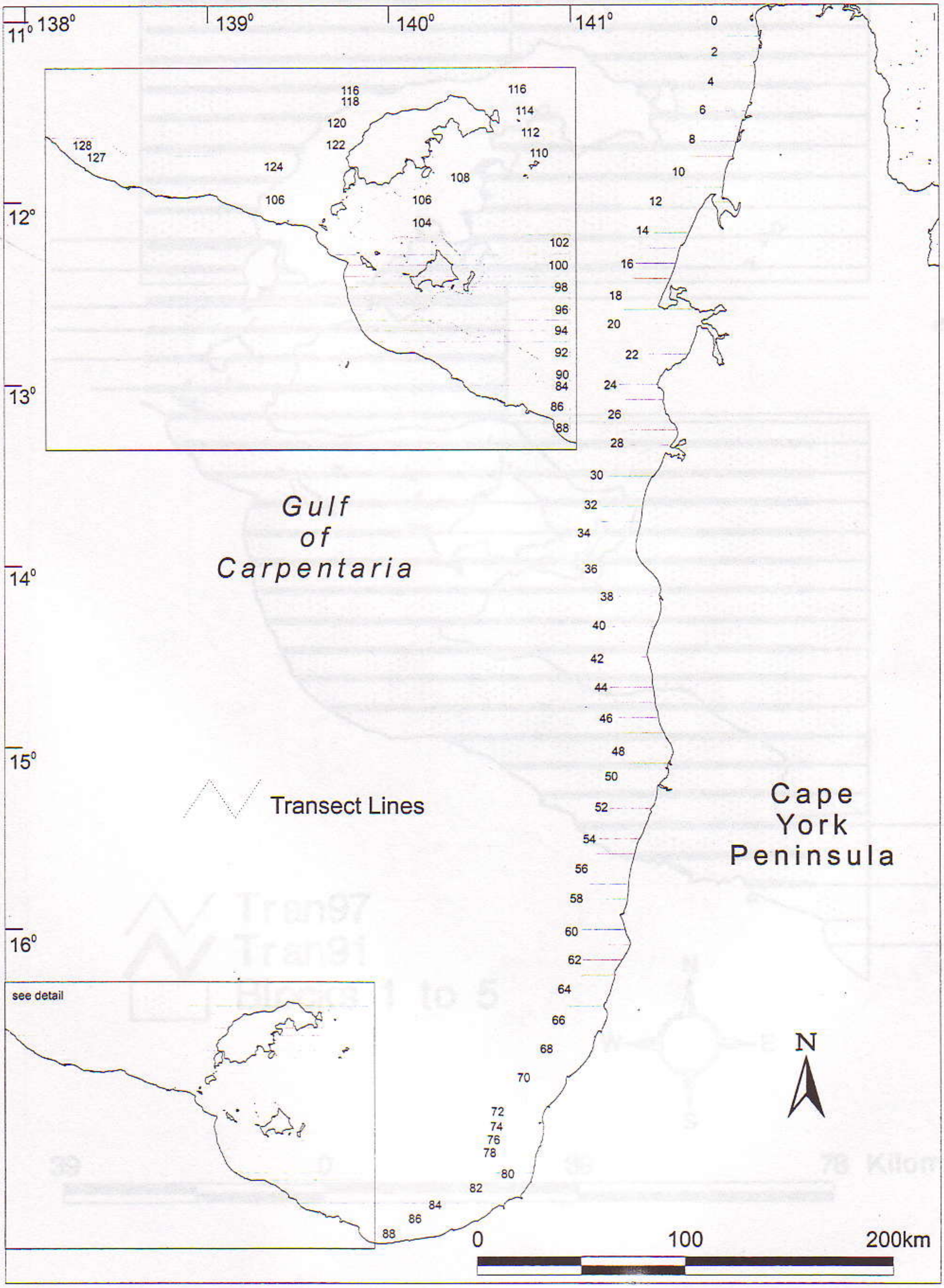
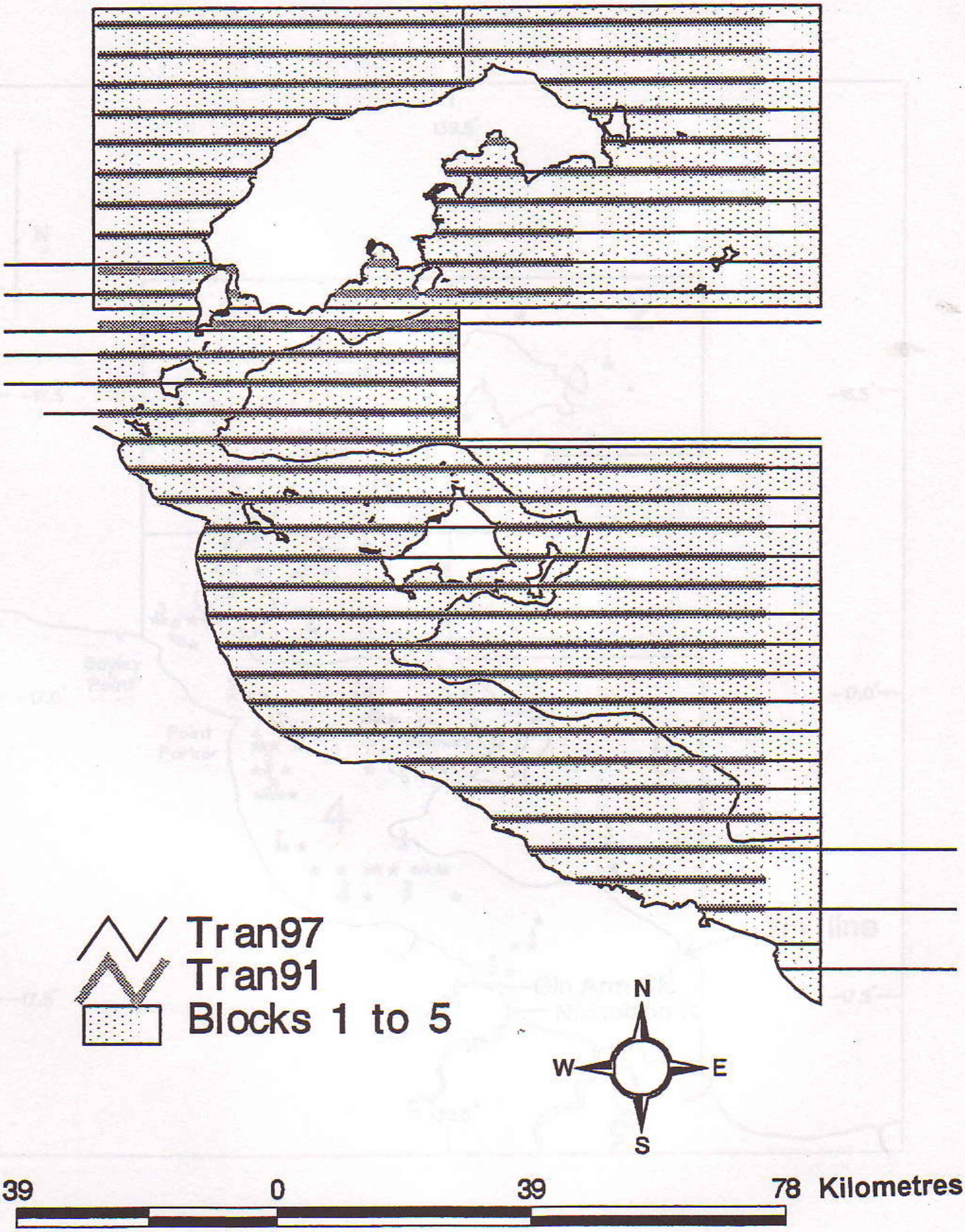


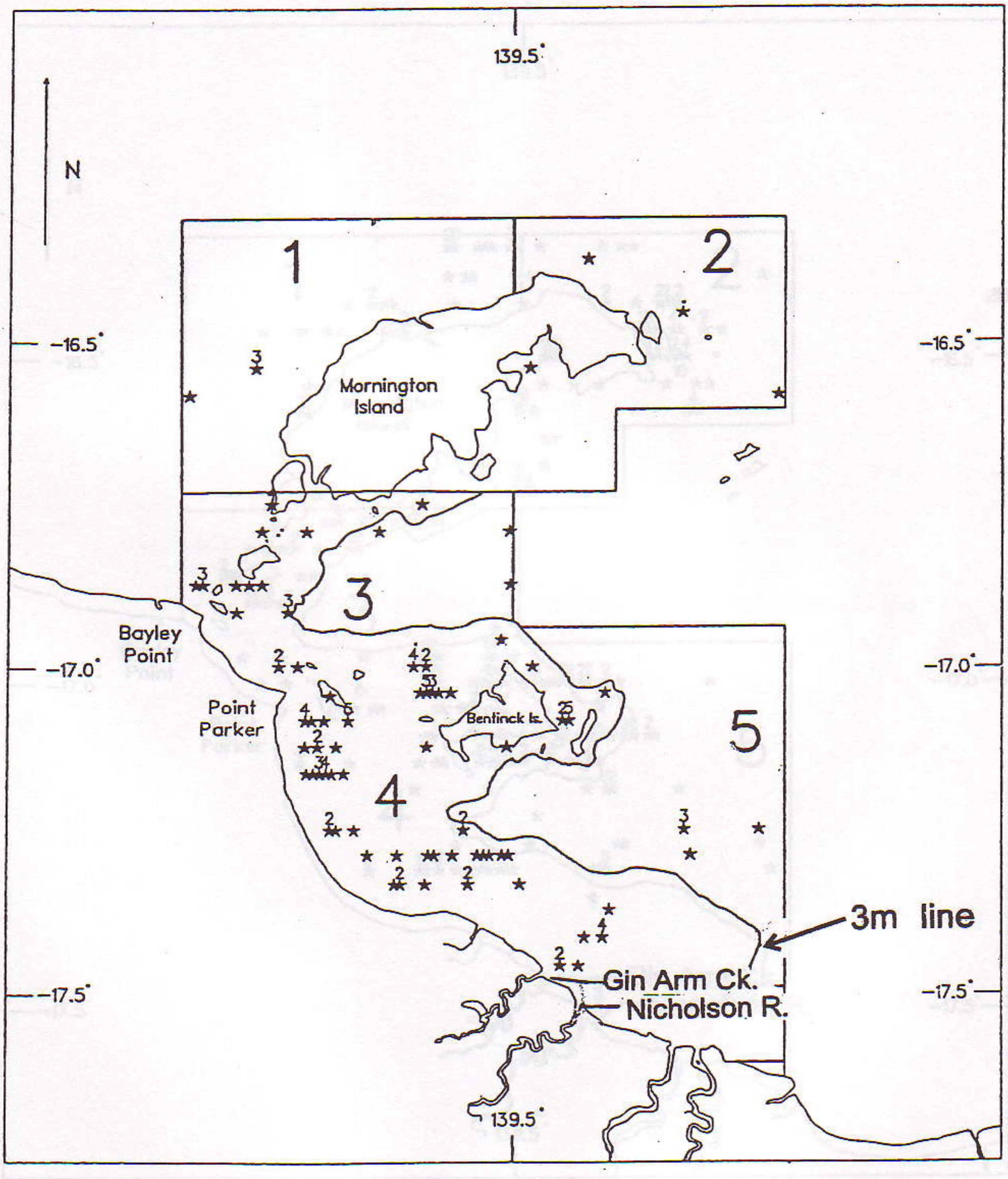
Figure 9: Net fishing effort (days) in the Gulf of Carpentaria and the northern Great Barrier Reef in 1996.



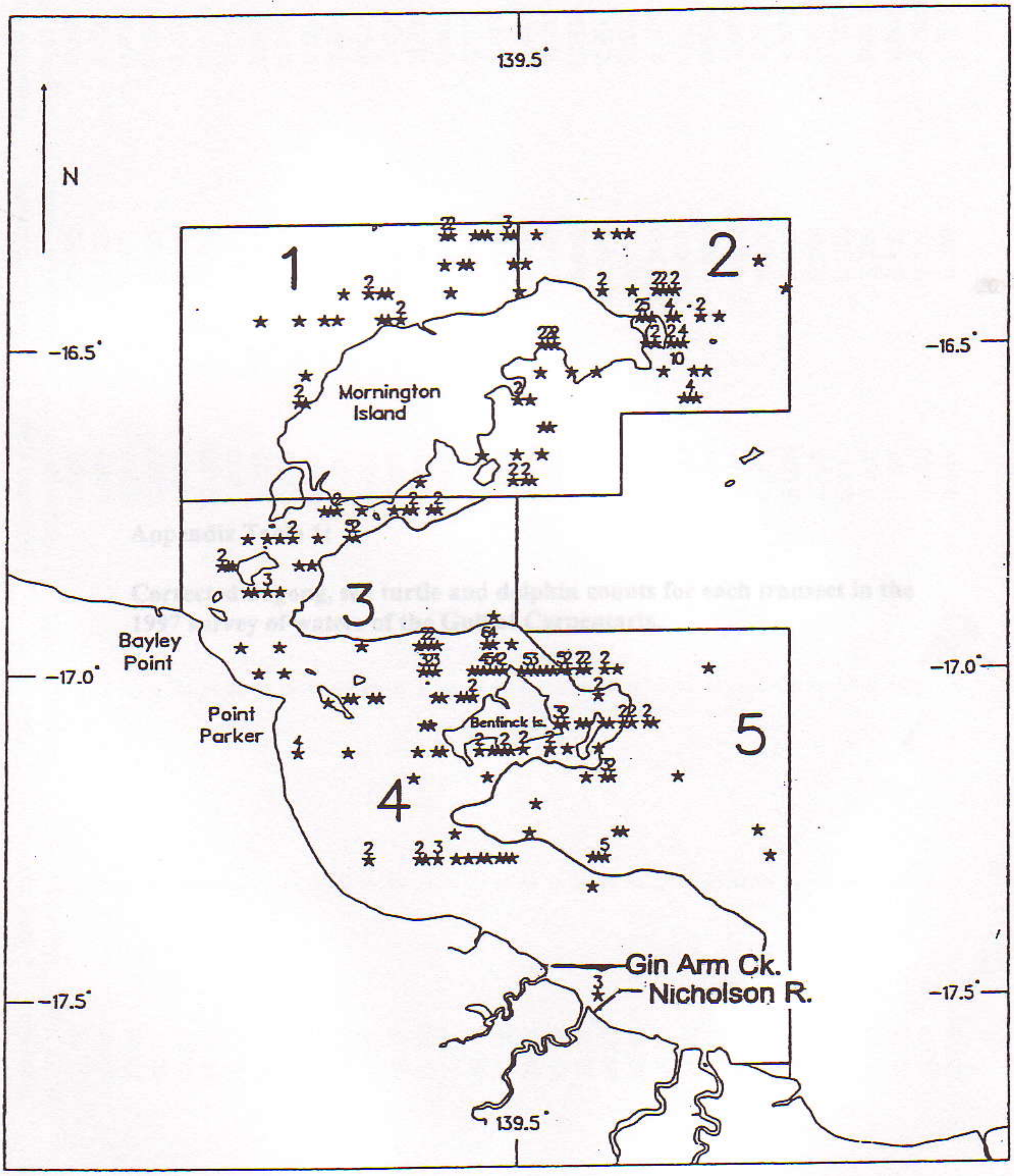
Appendix Figure 1: Numbered transects flown in December 1997



Appendix Figure 2: Transect match between the 1991 and 1997 surveys of the Wellesley Islands.



Appendix Figure 3:Dugong sightings in the Wellesley Islands during the aerial survey conducted in 1991 (Marsh and Lawler1993).



Appendix Figure 4: Sea turtles sightings in the Wellesley Islands during the aerial survey conducted in 1991 (Marsh and Lawler 1993).

Appendix Table 1:

Corrected dugong, sea turtle and dolphin counts for each transect in the 1997 survey of waters of the Gulf of Carpentaria.

Transect number	Block	Transect Length (km)	Raw count dugongs - stbd	Raw count dugongs - port	Adjusted count dugongs - port	Adjusted count dugongs - stbd	Adjusted count dugongs - total
0	7	21.72	0	0	0.000	0.000	0.000
1	7	23.87	0	0	0.000	0.000	0.000
10	7	22.65	0	0	0.000	0.000	0.000
100	4	42.79	4	6	20.527	13.727	34.254
100	5	34.04	0	0	0.000	0.000	0.000
101	4	49.65	3	3	10.263	10.295	20.558
101	5	44.46	0	0	0.000	0.000	0.000
102	4	51.46	2	0	0.000	6.863	6.863
102	5	48.97	0	0	0.000	0.000	0.000
103	3	35.42	0	0	0.000	0.000	0.000
103	4	13.47	0	0	0.000	0.000	0.000
103	5	52.80	0	1	3.421	0.000	3.421
104	3	32.02	0	0	0.000	0.000	0.000
104	4	20.20	2	1	3.421	6.863	10.284
104	8	7.05	0	0	0.000	0.000	0.000
105	3	30.77	0	0	0.000	0.000	0.000
105	4	18.58	0	1	3.421	0.000	3.421
105	8	24.67	0	0	0.000	0.000	0.000
106	3	26.48	0	0	0.000	0.000	0.000
106	4	26.28	1	3	10.263	3.432	13.695
106	8	35.25	0	0	0.000	0.000	0.000
107	2	52.85	0	0	0.000	0.000	0.000
107	3	8.86	0	0	0.000	0.000	0.000
107	4	27.06	1	2	6.842	3.432	10.274
108	2	52.91	2	0	0.000	6.863	6.863
109	2	55.80	0	1	3.421	0.000	3.421
11	7	23.09	0	0	0.000	0.000	0.000
110	2	56.46	0	0	0.000	0.000	0.000
111	2	56.35	0	1	3.421	0.000	3.421
112	2	51.87	0	0	0.000	0.000	0.000
113	2	31.42	1	0	0.000	3.432	3.432
114	2	32.06	2	0	0.000	6.863	6.863
115	2	41.12	0	0	0.000	0.000	0.000
116	1	53.00	0	0	0.000	0.000	0.000
			18	19			

Transect number	Block	Transect Length (km)	Raw count dugongs - stbd	Raw count dugongs - port	Adjusted count dugongs - port	Adjusted count dugongs - stbd	Adjusted count dugongs - total
116	2	52.36	2	2	6.842	6.863	13.705
117	1	53.65	0	0	0.000	0.000	0.000
117	2	52.38	0	1	3.421	0.000	3.421
118	1	53.62	0	0	0.000	0.000	0.000
118	2	1.54	0	0	0.000	0.000	0.000
119	1	37.37	0	0	0.000	0.000	0.000
✓ 12	7	33.46	1	1	3.421	3.432	6.853
120	1	26.01	0	0	0.000	0.000	0.000
121	1	23.25	0	0	0.000	0.000	0.000
122	1	20.45	0	0	0.000	0.000	0.000
123	1	16.68	0	0	0.000	0.000	0.000
124	1	17.01	0	0	0.000	0.000	0.000
124	8	90.50	0	0	0.000	0.000	0.000
125	1	14.64	0	0	0.000	0.000	0.000
125	8	82.60	1	2	6.842	3.432	10.274
126	4	14.68	0	1	3.421	0.000	3.421
126	8	65.59	4	0	0.000	13.727	13.727
127	8	24.07	0	0	0.000	0.000	0.000
128		22.29	0	0	0.000	0.000	0.000
13	7	23.11	0	0	0.000	0.000	0.000
14	7	20.86	0	0	0.000	0.000	0.000
15	7	23.64	0	0	0.000	0.000	0.000
16	7	23.82	0	0	0.000	0.000	0.000
✓ 17	7	22.25	1	0	0.000	3.432	3.432
18	7	27.86	0	0	0.000	0.000	0.000
✓ 19	7	41.96	0	1	3.421	0.000	3.421
✓ 2	7	23.05	1	0	0.000	3.432	3.432
✓ 20	7	47.27	2	0	0.000	6.863	6.863
× 21	7	45.88	0	1	3.421	0.000	3.421
22	7	28.00	0	0	0.000	0.000	0.000
23	7	24.79	0	0	0.000	0.000	0.000
24	7	23.14	0	0	0.000	0.000	0.000
25	7	23.34	0	0	0.000	0.000	0.000
26	7	24.16	0	0	0.000	0.000	0.000
			12	9			

Transect number	Block	Transect Length (km)	Raw count dugongs - stbd	Raw count dugongs - port	Adjusted count dugongs - port	Adjusted count dugongs - stbd	Adjusted count dugongs - total
27	7	27.97	1	0	0.000	3.432	3.432
28	7	24.27	0	0	0.000	0.000	0.000
29	7	24.57	0	0	0.000	0.000	0.000
3	7	21.63	0	1	3.421	0.000	3.421
30	7	25.78	0	2	6.842	0.000	6.842
31	7	23.65	0	0	0.000	0.000	0.000
32	7	23.49	0	0	0.000	0.000	0.000
33	7	24.24	0	0	0.000	0.000	0.000
34	7	23.84	0	0	0.000	0.000	0.000
35	7	23.54	0	0	0.000	0.000	0.000
36	7	24.82	0	0	0.000	0.000	0.000
37	7	23.52	0	2	6.842	0.000	6.842
38	7	24.86	0	0	0.000	0.000	0.000
39	7	23.09	0	0	0.000	0.000	0.000
4	7	22.28	0	0	0.000	0.000	0.000
40	7	24.99	0	0	0.000	0.000	0.000
41	7	25.69	0	1	3.421	0.000	3.421
42	6	25.34	0	0	0.000	0.000	0.000
43	6	24.97	0	0	0.000	0.000	0.000
44	6	25.69	0	0	0.000	0.000	0.000
45	6	26.77	0	0	0.000	0.000	0.000
46	6	23.44	0	0	0.000	0.000	0.000
47	6	24.84	0	0	0.000	0.000	0.000
48	6	25.23	0	0	0.000	0.000	0.000
49	6	23.68	0	0	0.000	0.000	0.000
5	7	23.21	0	0	0.000	0.000	0.000
50	6	26.18	0	0	0.000	0.000	0.000
51	6	24.22	0	0	0.000	0.000	0.000
52	6	24.39	0	0	0.000	0.000	0.000
53	6	24.30	0	1	3.421	0.000	3.421
54	6	24.95	0	0	0.000	0.000	0.000
55	6	24.43	0	0	0.000	0.000	0.000
56	6	24.03	0	0	0.000	0.000	0.000
57	6	23.53	0	0	0.000	0.000	0.000
			1	7			

Transect number	Block	Transect Length (km)	Raw count dugongs - stbd	Raw count dugongs - port	Adjusted count dugongs - port	Adjusted count dugongs - stbd	Adjusted count dugongs - total
58	6	24.59	0	0	0.000	0.000	0.000
59	6	24.06	0	0	0.000	0.000	0.000
6	7	22.80	0	0	0.000	0.000	0.000
60	6	25.86	0	0	0.000	0.000	0.000
61	6	21.76	0	0	0.000	0.000	0.000
62	6	23.09	0	0	0.000	0.000	0.000
63	6	20.82	0	0	0.000	0.000	0.000
64	6	21.75	0	0	0.000	0.000	0.000
65	6	20.58	0	0	0.000	0.000	0.000
66	6	22.31	0	0	0.000	0.000	0.000
67	6	21.56	0	0	0.000	0.000	0.000
68	6	21.25	0	0	0.000	0.000	0.000
69	6	20.48	0	0	0.000	0.000	0.000
7	7	22.98	0	0	0.000	0.000	0.000
70	6	19.77	0	0	0.000	0.000	0.000
71	6	22.92	0	0	0.000	0.000	0.000
72	6	22.77	0	0	0.000	0.000	0.000
74	6	23.37	0	0	0.000	0.000	0.000
76	6	23.76	0	0	0.000	0.000	0.000
78	6	22.00	0	0	0.000	0.000	0.000
8	7	23.26	0	0	0.000	0.000	0.000
80	6	38.17	0	0	0.000	0.000	0.000
82	6	46.46	0	0	0.000	0.000	0.000
84	4	42.14	0	0	0.000	0.000	0.000
84	6	78.26	0	0	0.000	0.000	0.000
85	4	27.49	0	0	0.000	0.000	0.000
86	4	17.91	0	0	0.000	0.000	0.000
86	6	64.89	0	0	0.000	0.000	0.000
87	4	6.65	0	0	0.000	0.000	0.000
88	4	6.09	0	0	0.000	0.000	0.000
88	6	43.30	0	0	0.000	0.000	0.000
✓ 9	7	25.41	1	0	0.000	3.432	3.432
90	4	34.20	0	0	0.000	0.000	0.000
90	5	13.56	0	0	0.000	0.000	0.000
			1	0			

Transect number	Block	Transect Length (km)	Raw count dugongs - stbd	Raw count dugongs - port	Adjusted count dugongs - port	Adjusted count dugongs - stbd	Adjusted count dugongs - total
91	4	41.47	0	0	0.000	0.000	0.000
91	5	12.05	0	0	0.000	0.000	0.000
92	4	45.22	0	0	0.000	0.000	0.000
92	5	16.76	0	0	0.000	0.000	0.000
93	4	55.09	0	0	0.000	0.000	0.000
93	5	23.63	0	0	0.000	0.000	0.000
94	4	40.03	2	0	0.000	6.863	6.863
94	5	43.23	1	1	3.421	3.432	6.853
95	4	28.58	0	0	0.000	0.000	0.000
95	5	56.85	0	0	0.000	0.000	0.000
96	4	26.34	0	0	0.000	0.000	0.000
96	5	61.22	0	0	0.000	0.000	0.000
97	4	34.25	0	0	0.000	0.000	0.000
97	5	55.03	1	2	6.842	3.432	10.274
98	4	47.09	3	2	6.842	10.295	17.137
98	5	38.93	0	0	0.000	0.000	0.000
99	4	37.53	3	0	0.000	10.295	10.295
99	5	35.05	0	0	0.000	0.000	0.000

10	5
18	19
12	9
1	7
1	0
10	5
42	40

82.

Transect number	Block	Transect Length (km)	Raw count turtles - stbd	Raw count turtles - port	Adjusted count turtles - port	Adjusted count turtles - stbd	Adjusted count turtles - total
0	7	21.72	3	2	3.874	5.809	9.683
1	7	23.87	1	4	7.749	1.936	9.685
2	7	23.05	2	0	0.000	3.873	3.873
3	7	21.63	1	2	3.874	1.936	5.810
4	7	22.28	2	0	0.000	3.873	3.873
5	7	23.21	2	1	1.937	3.873	5.810
6	7	22.80	2	0	0.000	3.873	3.873
7	7	22.98	1	2	3.874	1.936	5.810
8	7	23.26	4	1	1.937	7.745	9.682
9	7	25.41	1	1	1.937	1.936	3.873
10	7	22.65	2	8	15.498	3.873	19.371
11	7	23.09	1	7	13.560	1.936	15.496
12	7	33.46	2	4	7.749	3.873	11.622
13	7	23.11	3	3	5.812	5.809	11.621
14	7	20.86	1	0	0.000	1.936	1.936
15	7	23.64	0	1	1.937	0.000	1.937
16	7	23.82	0	0	0.000	0.000	0.000
17	7	22.25	0	6	11.623	0.000	11.623
18	7	27.86	0	1	1.937	0.000	1.937
19	7	41.96	0	5	9.686	0.000	9.686
20	7	47.27	4	5	9.686	7.745	17.431
21	7	45.88	2	9	17.435	3.873	21.308
22	7	28.00	1	2	3.874	1.936	5.810
23	7	24.79	1	5	9.686	1.936	11.622
24	7	23.14	2	6	11.623	3.873	15.496
25	7	23.34	1	1	1.937	1.936	3.873
26	7	24.16	1	2	3.874	1.936	5.810
27	7	27.97	0	6	11.623	0.000	11.623
28	7	24.27	2	2	3.874	3.873	7.747
29	7	24.57	1	1	1.937	1.936	3.873
30	7	25.78	4	3	5.812	7.745	13.557
31	7	23.65	2	2	3.874	3.873	7.747
32	7	23.49	1	6	11.623	1.936	13.559
33	7	24.24	0	3	5.812	0.000	5.812

Transect number	Block	Transect Length (km)	Raw count turtles - stbd	Raw count turtles - port	Adjusted count turtles - port	Adjusted count turtles - stbd	Adjusted count turtles - total
34	7	23.84	0	7	13.560	0.000	13.560
35	7	23.54	0	1	1.937	0.000	1.937
36	7	24.82	0	0	0.000	0.000	0.000
37	7	23.52	1	3	5.812	1.936	7.748
38	7	24.86	0	2	3.874	0.000	3.874
39	7	23.09	3	0	0.000	5.809	5.809
40	7	24.99	2	2	3.874	3.873	7.747
41	7	25.69	2	0	0.000	3.873	3.873
42	6	25.34	1	0	0.000	1.936	1.936
43	6	24.97	1	1	1.937	1.936	3.873
44	6	25.69	0	1	1.937	0.000	1.937
45	6	26.77	0	0	0.000	0.000	0.000
46	6	23.44	1	0	0.000	1.936	1.936
47	6	24.84	1	1	1.937	1.936	3.873
48	6	25.23	1	2	3.874	1.936	5.810
49	6	23.68	1	0	0.000	1.936	1.936
50	6	26.18	0	0	0.000	0.000	0.000
51	6	24.22	0	0	0.000	0.000	0.000
52	6	24.39	0	1	1.937	0.000	1.937
53	6	24.30	0	1	1.937	0.000	1.937
54	6	24.95	0	0	0.000	0.000	0.000
55	6	24.43	0	3	5.812	0.000	5.812
56	6	24.03	0	0	0.000	0.000	0.000
57	6	23.53	1	2	3.874	1.936	5.810
58	6	24.59	1	1	1.937	1.936	3.873
59	6	24.06	0	0	0.000	0.000	0.000
60	6	25.86	1	0	0.000	1.936	1.936
61	6	21.76	0	1	1.937	0.000	1.937
62	6	23.09	3	2	3.874	5.809	9.683
63	6	20.82	0	0	0.000	0.000	0.000
64	6	21.75	3	4	7.749	5.809	13.558
65	6	20.58	1	3	5.812	1.936	7.748
66	6	22.31	1	1	1.937	1.936	3.873
67	6	21.56	1	1	1.937	1.936	3.873

Transect number	Block	Transect Length (km)	Raw count turtles - stbd	Raw count turtles - port	Adjusted count turtles - port	Adjusted count turtles - stbd	Adjusted count turtles - total
68	6	21.25	2	1	1.937	3.873	5.810
69	6	20.48	0	0	0.000	0.000	0.000
70	6	19.77	0	0	0.000	0.000	0.000
71	6	22.92	1	0	0.000	1.936	1.936
72	6	22.77	0	1	1.937	0.000	1.937
74	6	23.37	0	1	1.937	0.000	1.937
76	6	23.76	0	0	0.000	0.000	0.000
78	6	22.00	0	0	0.000	0.000	0.000
80	6	38.17	0	0	0.000	0.000	0.000
82	6	46.46	0	1	1.937	0.000	1.937
84	4	42.14	0	0	0.000	0.000	0.000
84	6	78.26	0	0	0.000	0.000	0.000
85	4	27.49	0	0	0.000	0.000	0.000
86	4	17.91	0	0	0.000	0.000	0.000
86	6	64.89	0	0	0.000	0.000	0.000
87	4	6.65	0	0	0.000	0.000	0.000
88	4	6.09	0	0	0.000	0.000	0.000
88	6	43.30	0	0	0.000	0.000	0.000
90	4	34.20	0	0	0.000	0.000	0.000
90	5	13.56	0	0	0.000	0.000	0.000
91	4	41.47	0	0	0.000	0.000	0.000
91	5	12.05	0	0	0.000	0.000	0.000
92	4	45.22	0	0	0.000	0.000	0.000
92	5	16.76	0	0	0.000	0.000	0.000
93	4	55.09	0	1	2.050	0.000	2.050
93	5	23.63	0	0	0.000	0.000	0.000
94	4	40.03	0	0	0.000	0.000	0.000
94	5	43.23	0	0	0.000	0.000	0.000
95	4	28.58	0	0	0.000	0.000	0.000
95	5	56.85	0	0	0.000	0.000	0.000
96	4	26.34	1	1	2.050	2.049	4.099
96	5	61.22	1	2	4.101	2.049	6.150
97	4	34.25	0	0	0.000	0.000	0.000
97	5	55.03	4	2	4.101	8.197	12.298

Transect number	Block	Transect Length (km)	Raw count turtles - stbd	Raw count turtles - port	Adjusted count turtles - port	Adjusted count turtles - stbd	Adjusted count turtles - total
98	4	47.09	2	2	4.101	4.099	8.200
98	5	38.93	0	1	2.050	0.000	2.050
99	4	37.53	3	5	10.251	6.148	16.399
99	5	35.05	5	4	8.201	10.247	18.448
100	4	42.79	8	2	4.101	16.395	20.496
100	5	34.04	2	1	2.050	4.099	6.149
101	4	49.65	13	5	10.251	26.642	36.893
101	5	44.46	1	1	2.050	2.049	4.099
102	4	51.46	6	5	10.251	12.296	22.547
102	5	48.97	3	2	4.101	6.148	10.249
103	3	35.42	0	0	0.000	0.000	0.000
103	4	13.47	1	0	0.000	2.049	2.049
103	5	52.80	0	0	0.000	0.000	0.000
104	3	32.02	2	1	2.050	4.099	6.149
104	4	20.20	1	2	4.101	2.049	6.150
104	8	7.05	0	0	0.000	0.000	0.000
105	3	30.77	0	0	0.000	0.000	0.000
105	4	18.58	2	0	0.000	4.099	4.099
105	8	24.67	1	0	0.000	2.049	2.049
106	3	26.48	0	0	0.000	0.000	0.000
106	4	26.28	3	0	0.000	6.148	6.148
106	8	35.25	2	1	2.050	4.099	6.149
107	2	52.85	0	0	0.000	0.000	0.000
107	3	8.86	0	0	0.000	0.000	0.000
107	4	27.06	0	0	0.000	0.000	0.000
108	2	52.91	5	6	12.302	10.247	22.549
109	2	55.80	6	6	12.302	12.296	24.598
110	2	56.46	4	1	2.050	8.197	10.247
111	2	56.35	1	4	8.201	2.049	10.250
112	2	51.87	6	5	10.251	12.296	22.547
113	2	31.42	4	5	10.251	8.197	18.448
114	2	32.06	8	6	12.302	16.395	28.697
115	2	41.12	3	3	6.151	6.148	12.299
116	1	53.00	1	4	8.201	2.049	10.250

Transect number	Block	Transect Length (km)	Raw count turtles - stbd	Raw count turtles - port	Adjusted count turtles - port	Adjusted count turtles - stbd	Adjusted count turtles - total
116	2	52.36	3	2	4.101	6.148	10.249
117	1	53.65	1	1	2.050	2.049	4.099
117	2	52.38	1	0	0.000	2.049	2.049
118	1	53.62	1	1	2.050	2.049	4.099
118	2	1.54	0	0	0.000	0.000	0.000
119	1	37.37	3	7	14.352	6.148	20.500
120	1	26.01	0	2	4.101	0.000	4.101
121	1	23.25	0	1	2.050	0.000	2.050
122	1	20.45	0	1	2.050	0.000	2.050
123	1	16.68	0	0	0.000	0.000	0.000
124	1	17.01	1	0	0.000	2.049	2.049
124	8	90.50	3	2	4.101	6.148	10.249
125	1	14.64	2	1	2.050	4.099	6.149
125	8	82.60	1	4	8.201	2.049	10.250
126	4	14.68	2	0	0.000	4.099	4.099
126	8	65.59	2	0	0.000	4.099	4.099
127	8	24.07	0	2	4.101	0.000	4.101
128	8	22.29	0	0	0.000	0.000	0.000

Transect number	Block	Transect Length (km)	Raw count dolphins - stbd	Raw count dolphins - port	Adjusted count dolphins - port	Adjusted count dolphins - stbd	Adjusted count dolphins - total
0	7	21.72	0	0	0.000	0.000	0.000
1	7	23.87	0	1	2.891	0.000	2.891
2	7	23.05	0	0	0.000	0.000	0.000
3	7	21.63	0	0	0.000	0.000	0.000
4	7	22.28	0	1	2.891	0.000	2.891
5	7	23.21	2	0	0.000	5.781	5.781
6	7	22.80	0	0	0.000	0.000	0.000
7	7	22.98	0	1	2.891	0.000	2.891
8	7	23.26	0	0	0.000	0.000	0.000
9	7	25.41	0	1	2.891	0.000	2.891
10	7	22.65	1	0	0.000	2.891	2.891
11	7	23.09	0	0	0.000	0.000	0.000
12	7	33.46	0	1	2.891	0.000	2.891
13	7	23.11	1	0	0.000	2.891	2.891
14	7	20.86	0	0	0.000	0.000	0.000
15	7	23.64	1	1	2.891	2.891	5.782
16	7	23.82	0	0	0.000	0.000	0.000
17	7	22.25	0	0	0.000	0.000	0.000
18	7	27.86	0	0	0.000	0.000	0.000
19	7	41.96	1	1	2.891	2.891	5.782
20	7	47.27	0	0	0.000	0.000	0.000
21	7	45.88	3	0	0.000	8.672	8.672
22	7	28.00	0	0	0.000	0.000	0.000
23	7	24.79	0	2	5.781	0.000	5.781
24	7	23.14	0	0	0.000	0.000	0.000
25	7	23.34	0	1	2.891	0.000	2.891
26	7	24.16	2	0	0.000	5.781	5.781
27	7	27.97	0	0	0.000	0.000	0.000
28	7	24.27	0	0	0.000	0.000	0.000
29	7	24.57	0	0	0.000	0.000	0.000
30	7	25.78	0	0	0.000	0.000	0.000
31	7	23.65	0	0	0.000	0.000	0.000
32	7	23.49	0	0	0.000	0.000	0.000
33	7	24.24	0	0	0.000	0.000	0.000

Transect number	Block	Transect Length (km)	Raw count dolphins - stbd	Raw count dolphins - port	Adjusted count dolphins - port	Adjusted count dolphins - stbd	Adjusted count dolphins - total
34	7	23.84	0	0	0.000	0.000	0.000
35	7	23.54	0	1	2.891	0.000	2.891
36	7	24.82	0	0	0.000	0.000	0.000
37	7	23.52	0	0	0.000	0.000	0.000
38	7	24.86	0	0	0.000	0.000	0.000
39	7	23.09	0	0	0.000	0.000	0.000
40	7	24.99	0	0	0.000	0.000	0.000
41	7	25.69	0	0	0.000	0.000	0.000
42	6	25.34	0	0	0.000	0.000	0.000
43	6	24.97	0	0	0.000	0.000	0.000
44	6	25.69	0	0	0.000	0.000	0.000
45	6	26.77	1	0	0.000	2.891	2.891
46	6	23.44	0	0	0.000	0.000	0.000
47	6	24.84	0	0	0.000	0.000	0.000
48	6	25.23	0	0	0.000	0.000	0.000
49	6	23.68	0	0	0.000	0.000	0.000
50	6	26.18	0	0	0.000	0.000	0.000
51	6	24.22	0	1	2.891	0.000	2.891
52	6	24.39	0	0	0.000	0.000	0.000
53	6	24.30	0	0	0.000	0.000	0.000
54	6	24.95	0	1	2.891	0.000	2.891
55	6	24,43	0	0	0.000	0.000	0.000
56	6	24.03	0	0	0.000	0.000	0.000
57	6	23.53	0	0	0.000	0.000	0.000
58	6	24.59	0	0	0.000	0.000	0.000
59	6	24.06	1	0	0.000	2.891	2.891
60	6	25.86	0	1	2.891	0.000	2.891
61	6	21.76	0	0	0.000	0.000	0.000
62	6	23.09	0	0	0.000	0.000	0.000
63	6	20.82	0	0	0.000	0.000	0.000
64	6	21.75	0	0	0.000	0.000	0.000
65	6	20.58	0	0	0.000	0.000	0.000
66	6	22.31	0	0	0.000	0.000	0.000
67	6	21.56	0	0	0.000	0.000	0.000

Transect number	Block	Transect Length (km)	Raw count dolphins - stbd	Raw count dolphins - port	Adjusted count dolphins - port	Adjusted count dolphins - stbd	Adjusted count dolphins - total
68	6	21.25	0	0	0.000	0.000	0.000
69	6	20.48	0	0	0.000	0.000	0.000
70	6	19.77	0	0	0.000	0.000	0.000
71	6	22.92	2	0	0.000	5.781	5.781
72	6	22.77	0	0	0.000	0.000	0.000
74	6	23.37	0	0	0.000	0.000	0.000
76	6	23.76	0	0	0.000	0.000	0.000
78	6	22.00	0	0	0.000	0.000	0.000
80	6	38.17	1	0	0.000	2.891	2.891
82	6	46.46	0	1	2.891	0.000	2.891
84	4	42.14	0	0	0.000	0.000	0.000
84	6	78.26	0	0	0.000	0.000	0.000
85	4	27.49	0	0	0.000	0.000	0.000
86	4	17.91	0	0	0.000	0.000	0.000
86	6	64.89	0	0	0.000	0.000	0.000
87	4	6.65	0	0	0.000	0.000	0.000
88	4	6.09	0	0	0.000	0.000	0.000
88	6	43.30	0	0	0.000	0.000	0.000
90	4	34.20	0	0	0.000	0.000	0.000
90	5	13.56	0	0	0.000	0.000	0.000
91	4	41.47	0	0	0.000	0.000	0.000
91	5	12.05	0	0	0.000	0.000	0.000
92	4	45.22	0	0	0.000	0.000	0.000
92	5	16.76	0	0	0.000	0.000	0.000
93	4	55.09	0	0	0.000	0.000	0.000
93	5	23.63	0	0	0.000	0.000	0.000
94	4	40.03	0	0	0.000	0.000	0.000
94	5	43.23	0	0	0.000	0.000	0.000
95	4	28.58	0	0	0.000	0.000	0.000
95	5	56.85	0	1	2.891	0.000	2.891
96	4	26.34	0	1	2.891	0.000	2.891
96	5	61.22	0	0	0.000	0.000	0.000
97	4	34.25	0	0	0.000	0.000	0.000
97	5	55.03	0	0	0.000	0.000	0.000

Transect number	Block	Transect Length (km)	Raw count dolphins - stbd	Raw count dolphins - port	Adjusted count dolphins - port	Adjusted count dolphins - stbd	Adjusted count dolphins - total
98	4	47.09	0	0	0.000	0.000	0.000
98	5	38.93	0	0	0.000	0.000	0.000
99	4	37.53	0	0	0.000	0.000	0.000
99	5	35.05	0	0	0.000	0.000	0.000
100	4	42.79	0	0	0.000	0.000	0.000
100	5	34.04	0	0	0.000	0.000	0.000
101	4	49.65	0	0	0.000	0.000	0.000
101	5	44.46	0	0	0.000	0.000	0.000
102	4	51.46	0	0	0.000	0.000	0.000
102	5	48.97	0	0	0.000	0.000	0.000
103	3	35.42	0	0	0.000	0.000	0.000
103	4	13.47	0	0	0.000	0.000	0.000
103	5	52.80	0	1	2.891	0.000	2.891
104	3	32.02	0	0	0.000	0.000	0.000
104	4	20.20	1	0	0.000	2.891	2.891
104	8	7.05	0	0	0.000	0.000	0.000
105	3	30.77	0	0	0.000	0.000	0.000
105	4	18.58	0	0	0.000	0.000	0.000
105	8	24.67	0	0	0.000	0.000	0.000
106	3	26.48	0	0	0.000	0.000	0.000
106	4	26.28	0	0	0.000	0.000	0.000
106	8	35.25	0	0	0.000	0.000	0.000
107	2	52.85	1	0	0.000	2.891	2.891
107	3	8.86	0	0	0.000	0.000	0.000
107	4	27.06	0	0	0.000	0.000	0.000
108	2	52.91	1	3	8.672	2.891	11.563
109	2	55.80	0	1	2.891	0.000	2.891
110	2	56.46	1	3	8.672	2.891	11.563
111	2	56.35	0	0	0.000	0.000	0.000
112	2	51.87	2	0	0.000	5.781	5.781
113	2	31.42	1	1	2.891	2.891	5.782
114	2	32.06	1	0	0.000	2.891	2.891
115	2	41.12	1	0	0.000	2.891	2.891
116	1	53.00	0	0	0.000	0.000	0.000

Transect number	Block	Transect Length (km)	Raw count dolphins - stbd	Raw count dolphins - port	Adjusted count dolphins - port	Adjusted count dolphins - stbd	Adjusted count dolphins - total
116	2	52.36	1	1	2.891	2.891	5.782
117	1	53.65	1	0	0.000	2.891	2.891
117	2	52.38	0	1	2.891	0.000	2.891
118	1	53.62	0	0	0.000	0.000	0.000
118	2	1.54	0	0	0.000	0.000	0.000
119	1	37.37	1	1	2.891	2.891	5.782
120	1	26.01	0	2	5.781	0.000	5.781
121	1	23.25	0	0	0.000	0.000	0.000
122	1	20.45	0	1	2.891	0.000	2.891
123	1	16.68	0	0	0.000	0.000	0.000
124	1	17.01	0	0	0.000	0.000	0.000
124	8	90.50	0	1	2.891	0.000	2.891
125	1	14.64	0	0	0.000	0.000	0.000
125	8	82.60	1	1	2.891	2.891	5.782
126	4	14.68	0	0	0.000	0.000	0.000
126	8	65.59	0	1	2.891	0.000	2.891
127	8	24.07	0	0	0.000	0.000	0.000
128	8	22.29	0	0	0.000	0.000	0.000