AUSTRALIAN CENTRE FOR APPLIED MARINE MAMMAL SCIENCE
FINAL REPORT
(SUBCLAUSE 9 AND SCHEDULE ITEM 5 OF THE FUNDING AGREEMENT)

Project title

Distribution and abundance of the dugong in Gulf of Carpentaria waters: a basis for cross-jurisdictional conservation planning and management

Activity Period

Period of the activity for which this report refers.

March 2007 – April 2008
(*Note: DEWHA agreed to extend the final report date because of the withdrawal of the NT Chief Investigator Keith Saalfeld and the consequent delays in data processing*)

Chief Investigator* / Organisation

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** NT Chief Investigator Keith Saalfeld resigned from NRETA and withdrew from the project*

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1. Activity Summary

A clear summary of approximately 500 words outlining the work undertaken and any significant findings (for publication on the Department's web site)

- This survey provides the first synopsis of the distribution and abundance of the dugong in the Gulf of Carpentaria. The results of previous surveys of parts of this region in both Queensland and the Northern Territory have been difficult to interpret because of the potentially confounding influences of unpredictable dugong movements between areas within the region.

- The results for the 2007 aerial survey of the whole survey region of 35592 km^2 suggest a total population of 12438 $\pm$ s.e.1951 dugongs; 7095 $\pm$ s.e.1565 off Queensland, 5343 $\pm$ s.e.1164 off the Northern Territory.

Overall 30 percent of sightings were in Commonwealth waters.

- This estimate is lower than previous comparable estimates for the Northern Territory and higher than the previous comparable estimate for Queensland. There are methodological reasons for these differences: (1) the methodology used to correct for availability bias was different for the Queensland surveys; (2) the methodology used to correct for both availability bias and perception bias was different for the Northern Territory surveys; (3) the previous surveys had been conducted at different times and so the results were likely confounded by movements between survey regions.

- Standardized comparisons of the results for 2007 with the results of previous surveys suggest that the dugong density averaged over all regions in the Queensland waters of the Gulf of Carpentaria for which such comparisons could be made was not significantly different between 1997 and 2007. However, density varied substantially among regions. The average block differences resulted from the significantly higher density of dugongs in the Wellesley Islands region compared with the Northern Cape York Coast. In addition, too few dugongs were sighted along much of Cape York coast to obtain robust population estimates. There were also significant differences in dugong density among years in the Wellesley Island region where there was a significant increase in dugong density from 1997 to 2007. Dugong density in the Northern Territory did not differ among survey years, and there were no significant differences among survey blocks.

- **Thus the differences in dugong population estimates between surveys should not be used as evidence of a decline in abundance in the Northern Territory (or for an increase in abundance in Queensland)**; but as a starting point for future monitoring. We believe that the methodology adopted in 2007 is more accurate than the methodology used previously because of the improved capacity to correct for dugongs that are unavailable to observers because of water turbidity.

- The between survey comparisons in Queensland suggest considerable movement of dugongs between survey blocks within that region, particularly between the Wellesley Island area and the waters off northern Cape York. A likely reason for the movement of dugongs within the region is the susceptibility of tropical seagrasses to episodic diebacks, the frequency of which may be exacerbated by climate change.

- PBR modelling suggests annual sustainable anthropogenic mortality limits of 82-164 dugongs for the Gulf of Carpentaria as a whole; 33-67 for Northern Territory waters, 44-89 for Queensland waters, and 34-69 for the Wellesley Island area. We suggest that the upper limits of these values would be prudent interim management targets if the management objective for the region is dugong population maintenance.

- The dugong population in the Gulf of Carpentaria region is substantial (~12,500 individuals), making it one of the most important regions for dugongs in Australia and the world. We believe that there is time to work with local Traditional Owners and commercial fishers to develop appropriate management arrangements without dugongs becoming locally extinct within this region.

2. The Outcomes/Objectives

1. To continue standardizing and coordinating long-term abundance and trend information for the dugong across jurisdictions in the Gulf of Carpentaria and to estimate the total sustainable anthropogenic mortality from all causes by:
   - Conducting the first aerial survey of the coastal waters of the entire Gulf of Carpentaria in November 2007 to enable statistical comparisons with the following historical data obtained using comparable techniques: (1) the Gulf of Carpentaria coast of the Northern Territory in 1994 (Saalfeld and Marsh 2004); and (2) the Gulf of Carpentaria Coast of Queensland in1997 (Marsh *et al.* 2000) and the Wellesley Island region in 1991 (Marsh and Lawler 1993).
   - Using data from the 2007 aerial survey to estimate the absolute abundance of dugongs in the Gulf of Carpentaria using the technique developed by Pollock *et al.* (2006) to enable a sustainable level of anthropogenic mortality from all causes to be estimated.
   - Providing the relevant management agencies and local Aboriginal groups with geo-referenced maps of dugong distribution and abundance.

2. To assist in the development and implementation of community-based management of the Aboriginal harvest of dugongs in the Gulf of Carpentaria by presenting the results to the relevant Aboriginal communities in an accessible format

Objective 1 has been achieved in full apart from providing the data to the relevant management agencies and local Aboriginal groups. This component of the objective will be achieved in full by providing these groups with: (1) a copy of this report; (2) access to the metadata and links to a website being established to hold all the dugong aerial survey data; (3) the spatial model of dugong distribution and abundance in the Gulf of Carpentaria which is will be developed in 2008 via a companion project funded by NHT.

Objective 2 will be achieved later in 2008 when the relevant Aboriginal communities will be visited in conjunction with the NHT project.

3. Appropriateness

The appropriateness of the approaches used in the development and implementation of the Activity

1. The approach used for the 2007 aerial survey demonstrated that it is logistically feasible to survey the entire region of ~ 36000km^2 in a single month using two aircraft and two survey crews. Nonetheless, we consider that a survey of this magnitude is at the limit of logistical feasibility given the difficulties in recruiting trained observers and hiring suitable aircraft. In view of the remoteness of the region and the safety issues associated with flying low over water in light aircraft, consideration should be given to

the feasibility of using Unmanned Aerial Vehicles rather than manned aircraft to conduct the surveys from 2012 to: (1) reduce costs, (2) reduce human risk, (3) deliver superior data on species identification. We note the ACAMMS is currently funding an evaluation of the suitability of this technology for dugong surveys.

4. Effectiveness

The degree to which the Activity has effectively met its stated objectives
The project will have effectively *met* all its stated objectives when the relevant management agencies and local Aboriginal groups are provided with copies of the data and the results are presented to the key stakeholders later in 2008

5. Financial Account of the Activity (refer to subclause 9.6, and Schedule Item 5.10 of the Funding Agreement)

To be provided by JCU when the accounts are finalised.

Signature of Chief Investigator	
Name	Helene Marsh
Date	April 4 2008
Signature of Organisation Representative	
Name	Jasper Taylor
Date	

Please forward 4 hard copies, and one electronic Word document of this report to:

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Distribution and abundance of the dugong in Gulf of Carpentaria waters: a basis for cross-jurisdictional conservation planning and management

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Executive Summary

- This survey provides the first synopsis of the distribution and abundance of the dugong in the Gulf of Carpentaria. The results of previous surveys of parts of this region in both Queensland and the Northern Territory have been difficult to interpret because of the potentially confounding influences of unpredictable dugong movements between areas within the region.

- The results for the 2007 aerial survey of the whole survey region of 35592 km^2 suggest a total population of 12438 $\pm$ s.e.1951 dugongs; 7095 $\pm$ s.e.1565 off Queensland; 5343 $\pm$ s.e.1164 off the Northern Territory. Overall, 30 percent of sightings were in Commonwealth waters.

- This estimate is lower than previous comparable estimates for the Northern Territory and higher than the previous comparable estimate for Queensland. There are methodological reasons for these differences: (1) the methodology used to correct for availability bias was different for the Queensland surveys; (2) the methodology used to correct for both availability bias and perception bias was different for the Northern Territory surveys; (3) the previous surveys had been conducted at different times and so the results were likely confounded by movements between survey regions.

- Standardized comparisons of the results for 2007 with the results of previous surveys suggest that overall dugong density was not significantly different between 1997 and 2007 averaged over all regions in the Queensland waters of the Gulf of Carpentaria for which such comparisons could be made. However, density varied substantially among regions. The average block differences resulted from the significantly higher density of dugongs in the Wellesley Islands region compared with the northern Cape York Coast. In addition, too few dugongs were sighted along much of Cape York coast to obtain robust population estimates. There were also significant differences in dugong density among years in the Wellesley Island region where there was a significant increase in dugong density from 1997 to 2007. Dugong density in the Northern Territory did not differ among survey years, and there were no significant differences among survey blocks.

- **Thus the differences in dugong population estimates between surveys should not be used as evidence of a decline in abundance in the Northern Territory (or for an increase in abundance in Queensland)**; but as a starting point for future monitoring. We believe that the methodology adopted in 2007 is more accurate than the methodology used previously because of the improved capacity to correct for dugongs that are unavailable to observers because of water turbidity.

- The between survey comparisons in Queensland suggest considerable movement of dugongs between survey blocks within that region, particularly between the Wellesley Island area and the waters off northern Cape York. A likely reason for the movement of dugongs within the region is the susceptibility of tropical seagrasses to episodic diebacks, the frequency of which may be exacerbated by climate change.

- The data generated using PBR modelling suggest annual sustainable anthropogenic mortality limits of 82-164 dugongs for the Gulf of Carpentaria as a whole: 33-67 for Northern Territory waters; 44-89 for Queensland waters and 34-69 for the Wellesley Island area. We suggest that the upper limits of these values would be prudent interim management targets if the management objective for the region is dugong population maintenance.

- The dugong population in the Gulf of Carpentaria region is substantial (~12,500 individuals), making it one of the most important regions for dugongs in Australia and the world. We believe that there is time to work with local Traditional Owners and commercial fishers to develop appropriate management arrangements without dugongs becoming locally extinct within this region.

Recommendations

Management Arrangements

1. That priority be given to coordinating management across the dugong's range in Australia, preferably under a National Wildlife Conservation Plan as required for a listed marine species such as the dugong under the *EPBC Act Cw'lth 1999*.

2. That the major priority for dugong management in the Gulf of Carpentaria continue to be the development of culturally acceptable and scientifically robust mechanisms to manage Indigenous hunting via the 'National Partnership Approach'. We suggest that initiatives to manage the Indigenous harvest of dugongs and turtles be embedded within generic caring for sea-country initiatives developed in the context of the current social and political reforms for remote Indigenous communities.

3. That funding for community-based initiatives to manage the Indigenous harvest of dugongs and turtles in Northern Australia be continued with high priority and extended to all hunting communities. We suggest that such funding should preferably be performance-contingent, long-term program funding rather than short-term project funding.

4. That relevant management authorities and Traditional Owners hold negotiations to determine the regional objectives for dugong management in the Gulf of Carpentaria, in particular whether the management objective should be population maintenance or recovery. The total allowable catch should depend on the management objective. Such negotiations could be undertaken as part of the development of a National Wildlife Conservation Plan for Dugongs

5. That negotiations be conducted to determine the social and cultural objectives of dugong management in the Gulf of Carpentaria. Such negotiations could be undertaken as part of the development of a National Wildlife Conservation Plan for Dugongs.

6. That the Northern Territory and Commonwealth Governments consider the results of these surveys as part of the current marine planning

initiatives in both jurisdictions. The Queensland government should also consider these results in planning marine protected areas in the Queensland waters of the Gulf of Carpentaria. Because some dugongs are likely to move across these jurisdictions on a daily basis, it is important that planning arrangements for dugongs are coordinated across all three jurisdictions.

Future Aerial Surveys

1. That the dugong aerial surveys of the entire Gulf of Carpentaria be continued at five year intervals with the next survey in 2012. This survey interval is cost-effective and should detect major long-terms trends. If there are further reports of 'sick dugongs', supplementary surveys within this survey interval may be informative.

2. That the Pollock *et al.* (2006) method be used to estimate dugong population size in future surveys.

3. That the correction for availability bias in the Pollock *et al.*(2006) method be reviewed using the data on dugong diving behaviour collected by Sheppard *et al.* (in review), stratified to reflect the time of day of the aerial surveys.

4. That in view of the remoteness of the region and the safety issues associated with flying low over water in light aircraft, consideration be given to the feasibility of using Unmanned Aerial Vehicles rather than manned aircraft to conduct the surveys from 2012 to: (1) reduce costs, (2) reduce human risk, (3) deliver superior data on species identification.

INTRODUCTION

As the only surviving member of the family Dugongidae (Marsh *et al.* 2003), the dugong is a species of high biodiversity value. The dugong is listed as vulnerable to extinction by the IUCN (IUCN 2007). The other three extant species in the order Sirenia, the manatees (family Trichechidae) are also all listed as vulnerable by the IUCN. Anecdotal evidence suggests that dugong numbers have decreased throughout most of their range (Marsh *et al.* 2002). Significant populations persist in Australian waters, which are now believed to support most of the world's dugongs. Consequently, Australia has an international obligation to ensure that dugong stocks are conserved in Australian waters (Bertram 1981).

Dugongs occur along much of the tropical and sub-tropical coast of Australia from Shark Bay in Western Australia to Moreton Bay in Queensland. The Commonwealth, Northern Territory and Queensland waters of the Gulf of Carpentaria support globally significant populations of dugongs (Marsh *et al.* 2002).

Dugongs are of the highest cultural value to Indigenous Australians living in the coastal regions of the Gulf of Carpentaria and the *Native Title Act* 1993 (C'th) states that Indigenous peoples with a Native Title right do not need a permit to hunt under contemporary Commonwealth and State/Territory legislation. The Commonwealth Department of Environment, Water, Heritage and the Arts is now coordinating the implementation of policy entitled *Sustainable harvest of marine turtles and dugongs in Australia - A national partnership approach 2005* (Anon 2005) with the aim of working with Traditional Owners to ensure that hunting is sustainable.

Aerial surveys conducted since the mid 1980s using a standardised methodology have provided spatial information on dugong distribution and abundance in the Gulf of Carpentaria region. However, these surveys were not coordinated across the waters adjacent to Queensland and the Northern Territory. Consequently the results of the previous surveys are likely to be confounded by the large-scale movements of dugongs between survey regions and years. The satellite tracking, genetic and aerial survey evidence all suggest that these movements are substantial (Gales *et al.* 2004, Marsh *et al*. 2004, McDonald 2005, Sheppard *et al.* 2006). In addition, a new methodology (Pollock *et al*. 2006) has been developed to enable aerial surveys to estimate the absolute abundance of dugongs as the basis for modelling sustainable human mortality from all causes. Comparison between the results of the two methodologies suggests that the previous methodology generally over-estimated the size of dugong populations by up to 25% (Marsh *et al*. 2007). However, the new methodology had not been used in aerial surveys of the Gulf of Carpentaria which have not been conducted since 1994 (Northern Territory waters; Saalfeld 2000 in Saalfeld and Marsh 2004) or 1997 (Queensland waters; Marsh *et al*. 2000).

In this project, we addressed the confounding effect of dugongs moving between regions between surveys by surveying the entire inshore waters of the Gulf of Carpentaria from Port Bradshaw in the Northern Territory to Crab Island in Queensland in November 2007. This is the first time that this entire region has been surveyed in the same year. We also addressed the fluctuations in the availability of dugongs to observers using the improved methodology developed by Pollock *et al.* (2006).

This project had the following aims:

(1) To continue standardizing and coordinating long-term abundance and trend information for the dugong across jurisdictions in the Gulf of Carpentaria and to estimate the total sustainable anthropogenic mortality from all causes by:

   a. Conducting the first aerial survey of the coastal waters of the entire Gulf of Carpentaria in November 2007 to enable statistical comparisons with the following historical data obtained using comparable techniques: (1) the Gulf of Carpentaria coast of the Northern Territory in 1994 (Saalfeld and Marsh 2004); and (2) the Gulf of Carpentaria Coast of Queensland in1997 (Marsh *et al.* 2000) and the Wellesley Island region in 1991 (Marsh and Lawler 1993).
   b. Using data from the 2007 aerial survey to estimate the absolute abundance of dugong in the Gulf of Carpentaria using the technique developed by Pollock *et al.* (2006) to enable a sustainable level of anthropogenic mortality from all causes to be estimated.
   c. Providing the relevant management agencies and local Aboriginal groups with geo-referenced maps of dugong distribution and abundance.

(2) To assist in the development and implementation of community-based management of the Aboriginal harvest of dugongs in the Gulf of Carpentaria by presenting the results to the relevant Aboriginal communities in an accessible format

METHODS

Survey Methodology

Surveys prior to 2007

All surveys (Table 1) used the aerial survey technique developed by Marsh and Sinclair (1989) with the following variations. The survey of the Northern Territory waters of the Gulf of Carpentaria conducted by Saalfeld in 1994 used only three observers (one port, two starboard), with the front starboard observer also acting as survey leader. We reanalysed the raw data from this survey for statistical comparisons with the 2007 survey by: (1) calculating the starboard correction factor for perception bias based on the data from the two starboard observers used in 1994, (2) using the sightings of the two portside observers used in the 2007 survey of the Northern Territory to estimate the perception correction factor for the port observer in 1994; (3) assuming that the 1994 survey had been flown at a constant height of 137 m and that the same observers had been used for the entire survey and that they had always sat in the same seats; (4) assuming that the spatial pattern of turbidity was the same in 1994 and 2007; (5) not correcting any of the data for availability bias because of the apparent differences in the methodology used in the 1994 survey and the other surveys.

2007 Survey

<u>Observer training</u>

All observers attended an observer training workshop held in Townsville from October 8-11 2007. Observers were instructed in the theoretical aspects of the aerial survey technique and provided with experience in using the relevant equipment, flying transects in Cleveland Bay and conducting post-survey data editing.

Survey design

We optimized the design of the 2007 aerial survey by: (1) plotting the dugong sightings from all previous dugong surveys of sections of the coastal waters of the Gulf of Carpentaria (Table 1) in a common GIS database, (2) truncating offshore transects over areas where no dugongs have been sighted, and (3) modifying the survey design in coastal areas with persistently low dugong abundance and no seagrass (based on seagrass surveys summarized by Roelofs *et al*. 2005) by using zigzag transects across the depth gradient rather than transects perpendicular to the coast. The result (Figure 1 and Table 2) was a survey design that: (1) covered all known significant dugong habitats in a manner which enabled robust statistical comparisons with previous surveys, (2) enabled us to survey the entire region in one field season for the first time by using two aircraft operating concurrently, an approach that minimized the likelihood of dugong movements between survey blocks during the survey; (3) was cost-effective, and (4) allowed for adaptive sampling if dugongs were found in unexpected places during the low intensity zigzag transects.

The survey was conducted using two 6-seater high-wing aircraft (Partenavia 68B) using the strip transect aerial survey technique detailed in Marsh and Sinclair (1989). This technique has proved more suitable for dugongs than line transect methodology (Pollock *et al*. 2006). Each aircraft was fitted with a GPS and flown at a speed of 100 knots at a height of 137m above sea level. Transects 200m wide on the water surface were demarcated using fibreglass rods attached to artificial wing struts on each side of the aircraft. Tandem teams, each of two observers on each side of each aircraft recorded sightings independently onto separate tracks of a MP3 player. These independent sightings were used to develop survey specific correction factors. The transect on each side of the aircraft was divided into four horizontal strips using markers on the wing struts. Each sighting was designated as being made in one of these sub-strips to determine if simultaneous sightings by members of the same group of tandem observers were of the same group of animals. The primary observers on each side of each aircraft also reported the turbidity of the water at each sighting on a four point scale. The survey leader in each aircraft recorded the turbidity and the sighting conditions (Beaufort sea state, glare see Appendix 2 Table 2) as often as possible during the surveys.

Estimating the Size of the Dugong Population in 2007

The methodology of Pollock *et al.* (2006) was used to estimate dugong abundance. The method attempts to correct for availability bias (animals not available to observers because of water turbidity), and perception bias (animals visible in the survey transect but missed by observers). We believe this methodology to be superior to the previous methodology developed by Marsh and Sinclair (1989) because the correction for availability bias addresses the spatial heterogeneity in sighting conditions within each survey whereas the Marsh and Sinclair (1989) method averages these conditions within surveys and only corrects for differences in availability bias between surveys. In addition, observers find it difficult to determine whether the dugongs sighted are at the surface (or not), as required by the Marsh and Sinclair (1989) method.

Dugong abundance was estimated separately for each of the blocks surveyed for which at least five dugong groups were sighted. Input data were the corrected number of dugongs (in groups of <10 animals) for each side of the aircraft per transect. The standard error estimates incorporated the errors associated with the correction factors. Any dugongs in groups of ≥10 were added to the estimates of population size and density as outlined in Norton-Griffiths (1978). All population estimates are presented as ± standard error.

Statistical Analysis

Differences in dugong density among survey years for the blocks surveyed in 2007 and previously were examined by linear mixed-effects modeling using the raw data in the James Cook University aerial survey data base (Queensland blocks) and provided by the Northern Territory Department of Natural Resources, Environment and The Arts (NRETA; Northern Territory blocks). The data were corrected for perception bias using the method of Marsh and Sinclair (1989), because the data required for the Marsh and Sinclair correction for availability bias had not been collected in a standardized way across surveys. We could not use the improved technique of Pollock *et al.* (2006) because the environmental data required were not collected prior to 2007. Thus our comparison assumes that the regional patterns of water turbidity are the same across surveys.

The survey data for the Gulf of Carpentaria were unbalanced. The 1991 survey was restricted to the Wellesley Island region. The approach used to deal with the imbalance was to model the data for all blocks but excluding the survey year 1991, and then to examine the pattern of temporal change over 1991-2007 in the Wellesley Island region (block QLD2) only. The Northern Territory data from six blocks were balanced over the two survey years 1994 and 2007.

Blocks and years were treated as fixed effects, transects within blocks as a random effect. Mixed effects models were employed to estimate the random components of variance and to provide appropriate tests for differences between years, blocks and the block-year interaction. The parameters of these models were estimated by restricted maximum likelihood. The index of dugong density (corrected for perception but not availability bias) in each transect within blocks for each survey was the response. The data were log transformed (i.e., ln (y + 0.1)) to ensure a constant mean-variance relationship.

Approximate F-ratios were calculated for the fixed effects, however the statistical significance of the fixed effects was determined by simulation using Monte Carlo Markov Chains based on the estimated mixed-effects model parameters and using a uniform prior. Posterior distributions for the model parameters estimated with Monte Carlo Markov Chains were also used to estimate 95% credible intervals for these parameters.

Repeated contrasts (1 d.f.) between sequential pairs of years were used to identify significant changes in density between survey years. This same form of contrast was also used within each block where significant year by block interactions were observed. Where there were significant average differences between blocks, Bonferroni-corrected multiple comparison tests were used to identify which blocks differed from one another.

Estimating the Size of Sustainable Human-induced Dugong Mortality

The maximum numbers of animals, excluding natural mortalities, that may be removed from the following populations: entire Gulf of Carpentaria, Queensland waters of the Gulf of Carpentaria, Northern Territory Waters of the Gulf of Carpentaria, Wellesley Islands area, were calculated for the 2007 survey data using the Potential Biological Removal (PBR) Technique (Wade, 1998) and the dugong population estimates in Table 3. In view of the uncertainty associated with our understanding of dugong life history, we used a range of estimates for both R_{max} (0.01, 0.03, 0.05) and the recovery factor (0.5, 1) following Marsh *et al.* (2004) in Table 5.

Links with Aboriginal Communities in the Region

Brochures explaining the survey objectives and methodology were prepared for relevant Aboriginal communities in Queensland and the Northern Territory (see Appendix 3 for an example). Prior to or during the survey period we had discussions with or made presentations to the following groups: Carpentaria Land Council Aboriginal Corporation (Kelly Gardiner and Bradley Wilson), Burketown Primary School, the Kowanyama Rangers, the Anindilyakwa Land Council and a ranger from Borroloola.

RESULTS

Estimates of Dugong Density and Population Size

During the survey we sighted a total of 464 dugongs including 58 calves (12.5%). About half our sightings were in the waters off the coast of Queensland (50.6%; 235 dugongs including 25 calves (10.6%)); 49.4% in the waters off the coast of the Northern Territory (229 dugongs including 33 calves (14.4%)). The difference in the proportion of calves between the waters off the Northern Territory and Queensland was not significant (Chi Square = 1.5088, d.f.=1; p=0.2193).

Overall 30 percent of sightings were in Commonwealth waters, 38.4 % in Northern Territory waters and 31.5% in Queensland waters. These proportions are not exact because of local differences in survey design but indicate that a significant proportion of the dugongs sighted were in Commonwealth waters.

Most animals were in small groups (mean group size 1.4 ± 0.05 for the entire survey; 1.38 ± 0.08 Queensland; 1.41 ± 0.07 Northern Territory). The only group sighted with more than 10 dugongs was a group of 13 in NT block 5.

Using the method of Pollock *et al.* (2006), the standardized estimate of the dugong population for the 35592 km^2 surveyed in the inshore waters of the Gulf of Carpentaria was 12438 ± 1951 dugongs: 7095 ± 1565 in Queensland, 5343 ±1164 in the Northern Territory (Figure 2 and Table 3). No estimates were calculated for blocks QLD5 and QLD6 in Queensland and block NT8 (Figure 1) in the Northern Territory because the number of dugongs sighted was too low for reliable estimates to be calculated. Dugong densities were highest around the Wellesley Islands (blocks QLD1 and 2) and around the Sir Edward Pellew Islands in the Northern Territory (block NT 2).

Appendix 1 presents maps of the geo-referenced dugong sightings. The raw data on sighting conditions, dugong sightings, group sizes and perception correction factors are listed in Appendix 2.

Comparison with Previous Surveys

Queensland

There were no significant differences in the index of dugong density between 1997 and 2007 averaged over all blocks in the Queensland waters of the Gulf of Carpentaria for which comparisons could be made (Figure 3), but the density index varied substantially among blocks (Table 4). The average block differences were due to the significantly higher density of dugongs around the Wellesley Islands (block QLD2) than in off the northern coast of Cape York (block QLD6) (P = 0.004; Figure 4). There were significant differences in dugong density among years around the Wellesley Islands (block QLD2) (Figure 4 ; Table 4). There was a significant increase in density (P = 0.018) from 0.10 dugongs per km^2 (95% CI = 0.06, 0.16) in 1997 to 0.19 dugongs per km^2 (95% CI = 0.13, 0.28) in 2007.

Northern Territory

Dugong density in the Northern Territory did not differ among survey years (Table 4; Figure 8), and there were no significant average differences among blocks (Table 4).

Estimating a Sustainable Level of Human-induced Mortality for Dugongs in the Northern GBR and Torres Strait

The range of estimates for sustainable anthropogenic mortality (PBR) is summarized in Table 5 for the 2007 estimates of absolute population size The middle value for the estimated maximum rate of increase (R_{max} = 0.03) suggest that a total annual anthropogenic mortality of $\leq$ 82 dugongs would be required for population recovery in the if the recovery factor (RF) was (RF = 0.5); or $\leq$164 for population maintenance (RF = 1) (Table 5). The corresponding figures for the Wellesley Island region are $\leq$34 for recovery, $\leq$69 for maintenance; coastal waters off Queensland ($\leq$44 recovery, $\leq$ 89 maintenance) and the coastal waters off the Northern Territory ($\leq$33 recovery and $\leq$67 maintenance)

DISCUSSION

The results of this survey provide the first synopsis of the distribution and abundance of the dugong for the Gulf of Carpentaria. The results of previous surveys of parts of this region have been difficult to interpret because of the confounding influences of unpredictable dugong movements between areas within the region. The results for the 2006 survey of the whole Gulf of Carpentaria region of almost 36000 km^2 suggest a total population of 12438 ± 1951 dugongs; 7095 ± 1565 off Queensland, 5343 ± 1164 off the Northern Territory. These estimates were generated using the methodology of Pollock *et al.* (2006), which corrects for the spatial heterogeneity of sighting conditions within and between regions and reduces the noise in the data that may otherwise obscure trends in the dugong population.

Status of the Dugong Population of the Gulf of Carpentaria

Population Size

The estimate of the dugong population in the Gulf of Carpentaria from the 2007 survey is much lower than previous estimates for the Northern Territory 16846 ± 3259 in 1985 and 23336 ± 3040 in 1994 and higher than the previous estimate for Queensland 4266 ± 657 in 1997 (see Saalfeld and Marsh 2004). There are methodological reasons for these differences: (1) the methodology used to correct for availability bias was different for the 1991 and 1997 Queensland surveys; (2) the methodology used to correct for both availability and perception bias was different for the 1994 Northern Territory surveys; and (3) the previous surveys had been conducted at different times and so the results were likely confounded by movements between survey regions.

Standardized comparisons of the results of the areas surveyed in 2007 suggest that dugong density was not significantly different between 1997 and 2007 averaged over all regions in the Queensland waters of the Gulf of Carpentaria for which such comparison could be made. However, density varied substantially among regions (Table 4). The average block differences resulted from the significantly higher density of dugongs in the Wellesley Islands region compared with northern Cape York Coast. There were also significant differences in dugong density among years in the Wellesley Island region where there was a significant increase in density from 1997 to 2007. Dugong density in the Northern Territory did not differ among survey years, and there were no significant differences among survey blocks.

The differences in the estimates in dugong population size between the 2007 survey and pervious surveys should not be used as evidence of a decline in abundance in the Northern Territory (or for an increase in abundance in Queensland); but as a starting point for future monitoring. We believe that the methodology adopted in 2007 is more accurate than the methodology used previously because of the improved capacity to correct for dugongs that are unavailable to observers because of water turbidity.

Fecundity

The proportion of dugong sightings that were reported as calves in the Gulf of Carpentaria in our 2007 survey (12.5%, overall; 10.6% in waters off Queensland; 14.4% in the waters off the Northern Territory) is within the range of values recorded for other dugong surveys in northern Australia. The overall result for the Gulf of Carpentaria is similar to the highest value reported previously for the region (Grayson *et al.* 2008). Grayson *et al*. (2008) reviewed temporal and spatial patterns of dugong fecundity in northern Australia using the proportion of dugongs sighted on an aerial survey that were reported as calves as the fecundity index. The data from the 2007 survey of the Gulf of Carpentaria were not included. In regions that were comprehensively surveyed, the proportion of calves ranged from 0.2% in Northern Great Barrier Reef in 1978 to 34% in Northern Great Barrier Reef in 1990. The average proportion of calves over all years in each location ranged from 5.3% in the Gulf of Carpentaria to 11.4% in the Northern Great Barrier Reef.

The relatively high proportion of dugong calves recorded during our aerial survey in 2007 is encouraging given the concerns about the health status of dugongs and green turtles in the Sir Edward Pellew and Wellesley Island areas between 2002 and 2006 (Kwan and Bell 2003, Whiting and Chapman 2006). Traditional owners in these areas reported an unusually high incidence of 'sick' dugongs and green turtles. The dugongs had 'clear bubbly fat', were in poor body condition and allegedly included an atypical number of 'dwarf' animals (Kwan and Bell 2003, Whiting and Chapman 2006). Despite various attempts (which were apparently not co-ordinated across jurisdictions) , a definitive veterinary diagnosis of any pathology associated with these animals was not obtained.

Dugongs in similar condition have been reported before. Many dugongs were reported to have 'water fat' and were in poor nutritional condition following massive flooding in rivers in the Gulf of Carpentaria in 1973-74 (Marsh in Kwan 2002). Cachexia ('water fat') is an indication of severe starvation in dugongs (Eros *et al.* 2007). Sick dugongs with serous atrophy such as reported in the southern Gulf of Carpentaria between 2002 and 2006 also tend to have low pregnancy rates, although this aspect of the syndrome was not investigated in the Gulf of Carpentaria in 2002-2006.

Nietschmann and Nietschmann (1981), Nietschmann (1984) and Johannes and MacFarlane (1991) reported that a high proportion of dugongs caught in Torres Strait during the 1970s were lethargic with limited and poor-tasting fat, coincident with oral history reports of a large-scale seagrass dieback. The Islanders attributed this unusually high proportion of 'wati dangal' to inadequate food availability (Johannes and MacFarlane 1991). Hunters based in Daru in Torres Strait did not record any pregnant dugongs in the 35 females caught between October 1976 and July 1977 (Hudson 1986) and Marsh and Kwan (in press) provide further convincing evidence of recruitment failure at that time.

Traditional owners from the southern Gulf of Carpentaria were naturally concerned that the 'sick' dugongs and green turtles may have resulted from anthropogenic pollution. Torres Strait Islanders in the 1970s also blamed pollution resulting from the grounding of the oil tanker, *Oceanic Grandeur*, in 1970 for the seagrass dieback and 'wati dangal' in the mid-1970s (Johannes and McFarlane 1991). It is likely that in both cases, the dugongs (and green turtles) were suffering from food shortage caused by seagrass loss due to extreme weather events rather than anthropogenic pollution.

In the Gulf of Carpentaria the seagrass loss in the early part of this century (if it occurred) could have been caused by elevated sea water temperatures in 2002 (Kwan and Bell 2003) and/or turbidity caused by flooding, both of which can have adverse impacts on tropical seagrass communities (Waycott et al. 2007). Unfortunately, there are no comprehensive time series of data on the state of seagrass in the southern Gulf of Carpentaria to enable a firm conclusion.

Taylor *et al*. (2007a) surveyed the intertidal seagrasses of the Wellesley Islands in August 2007 after the main reports of 'sick' dugongs had abated. Like Roelofs *et al.* (2005) who surveyed other regions of the Gulf of Carpentaria in November 2004, Taylor *et al*. (2007a) reported that widespread evidence of heavy dugong feeding in intertidal and subtidal meadows of the Wellesley Islands, a result consistent with the high density of dugongs we observed in this region in November 2007. The seagrasses in this area had last been surveyed in 1984. Taylor *et al.* (2007a) were reluctant to make direct comparisons between the two surveys because of differences in mapping techniques but noted some differences in seagrass species composition, which they attributed to dugong feeding pressure but which could also have been caused by extreme weather events.

Grayson *et al.* (2008) found a significant negative relationship between the proportion of calves and: (1) the wet season rainfall, (2) their index of the wet season rainfall anomaly, and (3) the Southern Oscillation Index, each lagged by two years in the Northern Great Barrier Region. It is possible that similar relationships exist for other regions including the Gulf of Carpentaria but the data are not yet adequate to confirm them statistically (Type 2 error). This relationship between dugong fecundity and rainfall lagged by two years is congruent with our knowledge of dugong life history and the dynamic responses of the coastal seagrasses on which dugongs feed to changes in water turbidity and sediment deposition, which in turn are linked to extreme rainfall events (Preen and Marsh 1995, Preen *et al.* 1995, Larcombe and Woolfe 1999, Longstaff and Dennison 1999, Waycott *et al.* 2007). The negative relationship between the proportion of calves and rainfall with a two/three-year lag is presumably a result of: (1) the negative impact of increased turbidity on some of the coastal seagrass species eaten by dugongs (Preen et al. 1995, Longstaff and Dennison 1999); (2) the need for dugongs to be in good condition prior to and during pregnancy and lactation (Kwan 2002, Marsh and Kwan in press) and (3) the life history of the dugong: pregnancy lasts approximately 14 months and lactation up to 18 months (Marsh et al. 1984 b, Boyd *et al.* 1999, Kwan 2002). Marsh and Kwan (in press) also found a negative relationship between dugong fecundity and seagrass dieback in Torres Strait where seagrass dieback is thought to be caused by sediment resuspension resulting from prolonged periods of strong winds (Saint-Cast in press).

The dugongs of tropical Australia are clearly prone to episodic low fecundity (and in extreme instances high natural mortality (Preen and Marsh 1995)) as a result of seagrass dieback caused by extreme weather events. The frequency of such events is expected to increase with climate change (Waycott *et al.* 2007). Incorporating at least some high density dugong areas in the large-scale marine planning initiatives being undertaken in the Gulf of Carpentaria region should increase the resilience of dugong populations in the region to climate change.

Key Anthropogenic Threats to Dugongs in the Gulf of Carpentaria

Dugongs are long-lived, slow to mature and subject to a number of threats. If these threats persist, they will threaten the integrity of wild populations of dugongs in Australia and elsewhere (Marsh *et al.*, 2002). The main human-induced threats to dugongs in the Gulf of Carpentaria are believed to be (in no particular order):

1. bycatch of dugongs in commercial gill net fisheries;
2. harvest by Indigenous Australians;
3. illegal poaching by Australians and foreign fishers;
4. marine debris such as ghost nets.

The numbers of dugongs killed is not known for any of these threats in the Gulf of Carpentaria making it impossible to evaluate their relative impact without additional data.

Desirability of Further Management Intervention in Association with Large-Scale Marine Planning Initiatives

Experience with other large mammals (Johnson 2006) demonstrates that even very low-levels of anthropogenic mortality can drive long-lived slow-breeding species such as the dugong to extinction if all individuals in the prey population are exposed to mortality at some stage of their lives. This situation is most likely if: (1) animals are exposed to anthropogenic mortality in all the habitats in which they live, (2) human population size does not depend strongly on access to megafauna, and (3) animals in low density populations are still exposed to the risk of being killed. The second of these conditions certainly applies to dugongs in the Gulf of Carpentaria. Condition (3) also applies as dugongs are hunted incidentally by turtle hunters or caught incidentally in commercial gill nets.

In order to ensure that dugongs are not exposed to anthropogenic mortality in all the habitats in which they live in the Gulf of Carpentaria, it would be prudent for the planners involved with establishment of a network of marine protected areas in Northern Territory waters (Ward *et al*. 2008) , the Commonwealth's Northern Marine Bioregional Plan and future planning to established marine protected areas in the Queensland waters of the Gulf of Carpentaria negotiate with key stakeholders including Traditional Owners and commercial fishers to close examples of the following types of area to commercial gill netting: (1) at least some areas which support significant numbers of dugongs and where Indigenous hunting does not occur; and (2) at least some areas which support significant numbers of dugongs and where Indigenous hunting does occur.

We suggest that such closures should be additional to the management measures which are already in place to reduce fishing impacts on dugongs in the Gulf of Carpentaria and which include: (1) closure of 17 of the 27 rivers in the Queensland coast of the Gulf of Carpentaria to commercial fishing; (2) the establishment of the Wellesley Islands Protected Wildlife Area, which prohibits the use of gill nets (apart from barramundi nets) around the islands and adjacent mainland; (3) the joint strategy developed by the Northern Land Council and the Northern Territory Fishing Industry Council to minimize accidental capture of dugongs in barramundi nets in the area from Bing Bong Creek to Pelican Spit; (4) the information kits prepared by the Northern Territory Fishing Industry Council and the Queensland Seafood Industry Council outlining specific practices and precautions when fishing in dugong areas; (5) the closure of many seagrass areas within the Gulf of Carpentaria to prawn trawling by the Northern Prawn fishery (see Smyth *et al*. 2006) for details. These measures have largely been developed as *ad hoc* responses to particular incidents and circumstances and have not been coordinated across jurisdictions as part of a large-scale regional planning approach to reducing fishing impacts on dugongs.

Banning netting from key hunting areas should also assist negotiations between Traditional Owners and management agencies about the management of dugong hunting. Traditional owners feel strongly about giving up hunting rights in the absence of action against other human mpacts. The spatial model of dugong distribution and abundance in the Gulf of Carpentaria which we will develop in 2008 via a project funded by the Australian Government's Natural Heritage Trust (NHT) should assist such planning initiatives. Information on the spatial distribution of the threats listed above should be available to the planners involved in the development of the networks of the marine protected areas being for the region. Planners could consider using a spatial risk assessment approach along the lines of that developed by Grech and Marsh (in press) as a basis for negotiating arrangements to reduce the risk to dugongs in areas of high conservation value in the Gulf of Carpentaria that we will identify in our spatial model of dugong distribution in 2008 as outlined above.

Management Options Specific to Indigenous Hunting

We consider that the major priority for dugong management in the Gulf of Carpentaria should be the development of culturally acceptable and scientifically robust mechanisms to manage Indigenous hunting. The Northern Territory government outlined options for managing dugong hunting in its Draft *Management Program for the Dugong in the Northern Territory 2003-2008,* which aims to provide for the long-term conservation of dugongs within the Northern Territory. We understand that this plan is still in draft. The Queensland Environment Protection Agency has made agreements to limit hunting with some individual communities e.g. an agreement with the Angumothimaree people restricts dugong and turtle hunting in the Pine Rivers near Weipa to four months per year (Smyth *et al*. 2006). The agreement introduces a permit system controlled by traditional owners which allows the catch of one male dugong per permit during the months of December through to March.

The *'National Partnership Approach*' to the management of Indigenous hunting of turtles and dugongs, which is being implemented by the Commonwealth Department of the Environment, Water, Heritage and the Arts in cooperation with the Queensland and Northern Territory governments (Anon 2005), has the potential to deliver a strategic and coordinated approach to the management of dugong and turtle hunting. The implementation of this 'National Partnership Approach' is being achieved, in part, by NHT grants to the North Australian Indigenous Land and Sea Management Alliance (NAILSMA). In an example of a NAILSMA project of particular relevance to the Gulf of Carpentaria, the Carpentaria Land Council Aboriginal Corporation nominated the sea country of the Wellesley Islands and adjacent mainland as a trial site under the north Australia-wide Dugong and Marine Turtle Management Project coordinated by NAILSMA. Traditional Owners developed a Regional Activity Plan that set out their concerns, aspirations and detailed activities regarding dugong and marine turtle management.

We understand that funding for the NAILSMA Dugong and Turtle Project is scheduled to end in June 2008. We consider that it will be very important to continue funding for community-based initiatives to manage the Indigenous harvest of dugongs and turtles in the Gulf of Carpentaria. We suggest that this funding should preferably be performance-contingent, long-term program funding rather than short-term project funding. It is regrettable that the initiatives to date have not had sufficient funds to cover nearly all the hunting communities in the Gulf of Carpentaria. In addition, developing a Regional Activity Plan is just the first step in effective community-based management. The real challenge is plan implementation which will require long-term investment in supportive policies, employment, capacity building, and infrastructure. On several occasions, previous governments have made the mistake of limiting their investment to planning and such exercises have invariably failed to make a difference and have left concerned Traditional Owners frustrated and disillusioned.

We suggest that such initiatives should be embedded in generic caring for country initiatives developed in the context of the current social and political reforms such as the ‘Caring for Country’ programs being developed as part of the government’s strategy of ‘Closing the Gap’. The commitment by the government to invest $90 million over five years to train and employ up to an additional 300 Indigenous rangers on Indigenous lands and waters should also make a difference to community-based management of dugong hunting if some of the rangers are deployed in dugong and turtle hunting communities.

The priorities of Indigenous peoples and government agencies are almost certainly different, as Nursey-Bray (2006) has convincingly documented in her evaluation of the development and implementation of the Hope Vale Aboriginal community’s Green Turtle and Dugong Hunting Management Plan. Nursey-Bray demonstrated that Indigenous people prioritize social justice community and culture whereas management agencies prioritize biodiversity conservation and species viability. Consequently, a process needs to be developed to promote the development of management initiatives that satisfy the needs of both groups with an associated increase in mutual understanding and trust. A wide range of tools is available for consideration by communities including:

- Agreeing on a total allowable catch shared between communities and families and/or designated (permitted) hunters within communities and monitored by methods such as: (1) data sheets; (2) monitoring at designated butchering sites. If this adoption is adopted it will be very important to monitor hunting effort and technology as changes in these factors can greatly influence hunting success. The appropriate total allowable catch will depend on the management objective and will be higher for population maintenance than population recovery.
- Adopting closed areas, seasons or times (e.g. banning night hunting). The spatial information on dugong distribution based on the aerial surveys could be used to identify candidate areas for closed areas in association with the cultural mapping to be conducted as part of a NHT grant to our research group as explained below.
- Limiting hunting to the Traditional sea country of each community or clan group.
- Limiting hunting to the provision of food for special occasions only.
- Adopting gear restrictions such as pre-European contact technology.

In developing management arrangements, the various management tools such as those listed above should be evaluated against agreed criteria which recognise the differing values of Indigenous communities and government. These criteria and likely to include:

- Cultural acceptability to local Indigenous peoples and wider community
- Local capacity required for effective implementation
- Cost of effective implementation
- Socio-economic cost/benefit to local community
- Effect on target species in jurisdiction and neighbouring jurisdictions
- Effect on the whole ecosystem including other harvested marine species, especially green turtles.

The relative importance of these criteria will differ for Indigenous peoples and government policy makers. These differences are legitimate and need to be recognized in an evaluative process.

If the communities wish to consider spatial closures as a management tool, the spatially explicit dugong population model that we will develop using the techniques developed by Grech and Marsh (2007) could inform the design of closure areas. In 2008, we will conduct cultural mapping in the Anindilyakwa communities on Groote Island. The outputs will be integrated with the spatially explicit dugong population model and other scientific information such as maps of the seagrass resources of the region (Roelofs *et al*. 2005; Taylor *et al*. 2007a) to form a GIS-based decision support system, which will be returned to the communities in an accessible format to assist Traditional Owners develop strategies for managing the dugongs in their sea country.

Need for Co-ordinated Management at an Ecologically-Appropriate Scale

Recent research using mitochondrial DNA (which is maternally inherited) demonstrates some regional differentiation of dugong populations across Australian waters (Blair *et al.* in review). Nonetheless, the genetic, satellite tracking and aerial survey data all indicate that the appropriate ecological scale for management is some hundreds of kilometres (Blair *et al.*in review; Sheppard *et al.*, 2006). Thus effective dugong management in the Gulf of Carpentaria will require initiatives to be co-ordinated across the jurisdictions of Queensland, the Northern Territory and the Commonwealth. In addition, it will be important to: (1) coordinate management across the dugong's entire range in Australia, preferably under a National Wildlife Conservation Plan as required for a listed marine species such as the dugong under the *EPBC Act Cw'lth 1999*.

The relevant management authorities and Traditional Owners need to decide whether the regional objective for dugong management in the Gulf of Carpentaria should be population maintenance or recovery as the technical details of management arrangements cannot be negotiated or evaluated without clear objectives. The social and cultural objectives of management also need to be negotiated at regional as well as local scales. Such negotiations could be undertaken as part of the development of the National Wildlife Conservation Plan for Dugongs.

Options for Future Monitoring of Dugongs in the Gulf of Carpentaria

Review of the Aerial Survey Design and Methodology

The approach used for the 2007 aerial survey demonstrated that it is logistically feasible to survey the entire region of ~36000 km^2 from in a single month using two aircraft and two survey crews. Nonetheless, we consider that a survey of this magnitude is at the limit of logistical feasibility given the difficulties in recruiting trained observers and hiring suitable aircraft. Given the relatively large number of dugongs sighted on the western side of Mornington Island in 2007, we suggest amending the survey design used here (Appendix 1 Figure 3) and flying transects on the western side of Mornington Island as done in 1991 (Marsh and Lawler 1993) and 1997 (Marsh *et al*. 2000).

We consider that the correction for availability bias developed by Pollock *et al*. (2006) is superior to the earlier methodology on Marsh and Sinclair (1989) as explained above. Nonetheless, a declining trend in dugong numbers has not been detected for the dugong in Torres Strait despite aerial surveys over 20 yeas, despite a substantial discrepancy between the estimated sustainable catch and anecdotal catch estimates (see Kwan 2002, Marsh *et al.* 2004, Kwan *et al.* 2006). One explanation for this result is that the Pollock *et al.* (2006) methodology may be underestimating dugong population size. Sheppard *et al.* (in press) has recently demonstrated using GPS satellite technology that dugongs tend to be closer to shore at night than during the morning when the aerial surveys are conducted, a result which concurs with traditional knowledge. Chilvers *et al.* (2004) could find no diel differences in dugong diving behaviour and the availability correction factors developed by Pollock *et al.* (2006) were based on dugong diving records across the diel cycle. The new data of Sheppard *et al.* (in press) suggest that the method for estimating the availability ccorrection factor should be reviewed using the dive data collected between 8 am and 3 pm only (the times when the aerial surveys are conducted) from both the 15 dugongs sampled by Chilvers *et al* (2004) and the additional 12 dugongs tracked by Sheppard *et al.* (in press).

Taylor *et al.* (2007b) suggest ways in which the power of surveys to detect trends in the abundance of marine mammals can be improved. We review the aerial surveys of dugongs in the context of her suggestions below.

1. <u>To increase the precision of the population estimates</u>. The precision of the dugong population estimates (16% for the Gulf of Carpentaria region as a whole) is already quite high for marine mammal surveys (see Taylor *et al.* 2007b) and will not be improved without a significant increase in survey sampling effort with a concomitant increase in cost and logistical difficulties. However, surveying the combined region reduces the precision without increasing costs (Table 5).
2. <u>To reduce the noise which obscures trends</u>. The Pollock *et al.* (2006) method addresses this problem by accounting for the spatial and temporal heterogeneity in sighting conditions. However, this approach does not reduce the noise resulting from dugong movements in and out of the survey region. Although dugongs have not been confirmed to move between the Gulf of Carpentaria and Torres Strait or the Gulf of Carpentaria and the northern coast of the Northern Territory, it is likely that they do so because individual dugongs have been recorded moving hundreds of kilometres in a few days (Sheppard *et al*. 2006). However, given that it would be logistically impossible to survey the dugong's entire range in Australia in a single field season (there are not enough conventional light aircraft or Unmanned Aerial Vehicles (see below) available), there is little that can be done to overcome this problem at this time.
3. <u>To reduce the area surveyed and increase the effort in the chosen area</u>. This approach requires the strong assumption that the proportion of the total population in the area surveyed is constant across time (Taylor *et al.* 2007b). This assumption is not valid for dugongs as evidenced by Figure 4 and the data from Gales *et al.* (2004), Marsh *et al.* (2004, 2006 and 2007) and Holley *et al.* (2006). Taylor *et al.* (2007b) point out an additional danger with this approach: changes in conditions may result in distributional shifts with a declining trend in population abundance.
4. <u>To identify demographically independent populations and survey at the level of these stocks</u> The new data on the regional differentiation of dugong stocks in Australia needs further investigation and may provide a basis for improving the design of future aerial surveys.

Taking all these factors into consideration we recommend:

1. That the dugong aerial surveys of the entire Gulf of Carpentaria be continued at five year intervals with the next survey in 2012. This survey interval is cost-effective and should detect major long-terms trends. If

there are further reports of 'sick dugongs', supplementary surveys within this survey interval may be informative.

2. That the Pollock *et al.* (2006) method be used to estimate dugong population size in future surveys.

3. That the correction for availability bias in the Pollock *et al.*(2006) method be reviewed using the data on dugong diving behaviour collected by Sheppard *et al.* (in review), stratified to reflect the time of day of the aerial surveys.

4. That in view of the remoteness of the region and the safety issues associated with flying low over water in light aircraft consideration be given to the feasibility of using Unmanned Aerial Vehicles rather than manned aircraft to conduct the surveys from 2012 to: (1) reduce costs, (2) reduce human risk, (3) deliver superior data on species identification. We note the ACAMMS is currently funding an evaluation of the suitability of this technology for dugong surveys.

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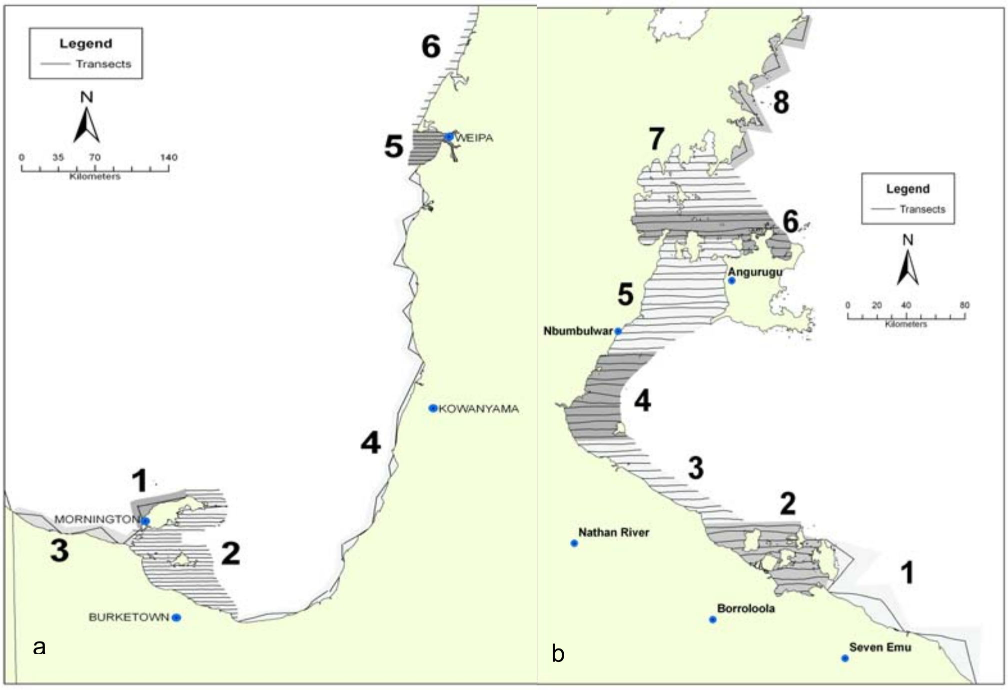


Figure 1. Maps showing the blocks and transects surveyed during the aerial survey for dugongs conducted in November 2007 in (a) the Queensland coast and (b) the Northern Territory coast of the Gulf of Carpentaria.

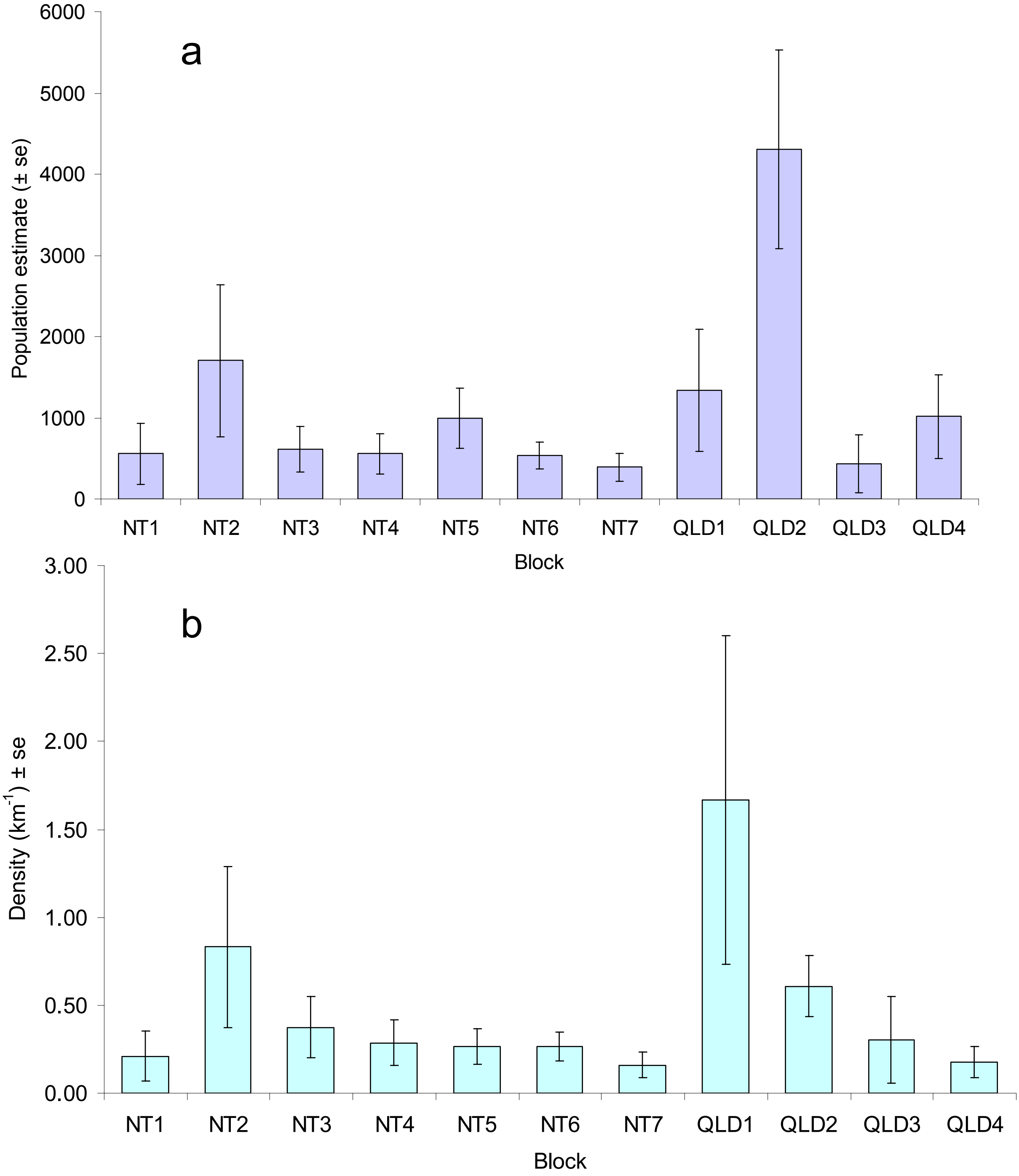


Figure 2. Estimated (a) dugong numbers and (b) dugong density (per km^2) for the 2007 Gulf of Carpentaria survey calculated using the Pollock *et al*. (2006) method for each survey block. Error bars represent 95% confidence intervals. Estimates were not calculated for blocks QLD5 and 6 and NT8 because the number of groups of dugongs sighted was too low for robust estimates. See Figure 1 for block locations. Note: These density estimates are corrected for availability bias and are not comparable with those presented in Figures 3-5.

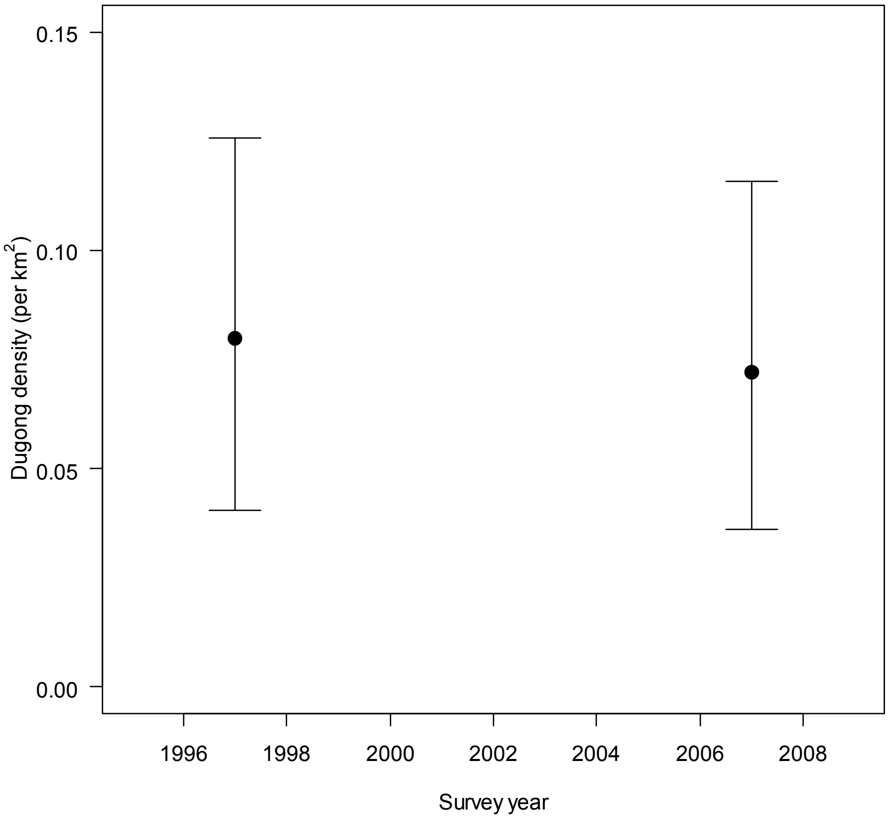


Figure 3 . Estimated index of dugong density (per km^2) in the coastal waters of the Gulf of Carpentaria off Queensland (blocks QLD 2, 5, and 6) that could be compared in 1997 and 2007. Error bars represent 95% credible intervals. Note this index of density is not corrected for availability bias and the density estimates are not comparable with those presented in Figure 2.

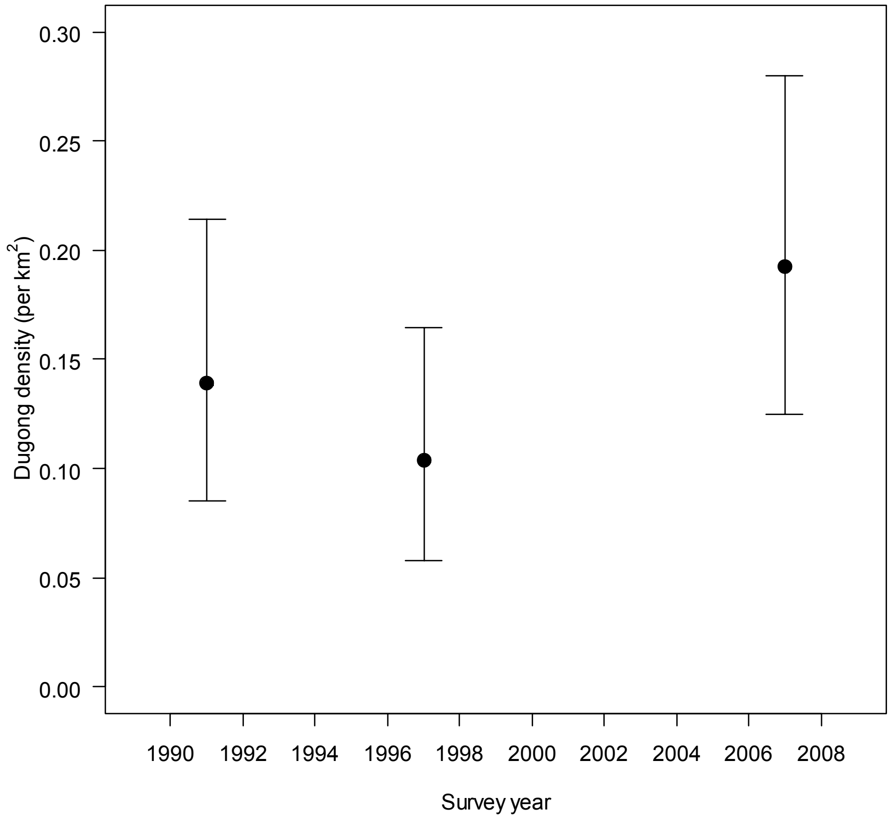


Figure 4. Estimated dugong density (per km^2) averaged over the survey years 1991, 1997 and 2007 for the Wellesley Island region (block QLD2) only. Error bars represent 95% credible intervals. Note this index of density is not corrected for availability bias and is not comparable with the data presented in Figure 2.

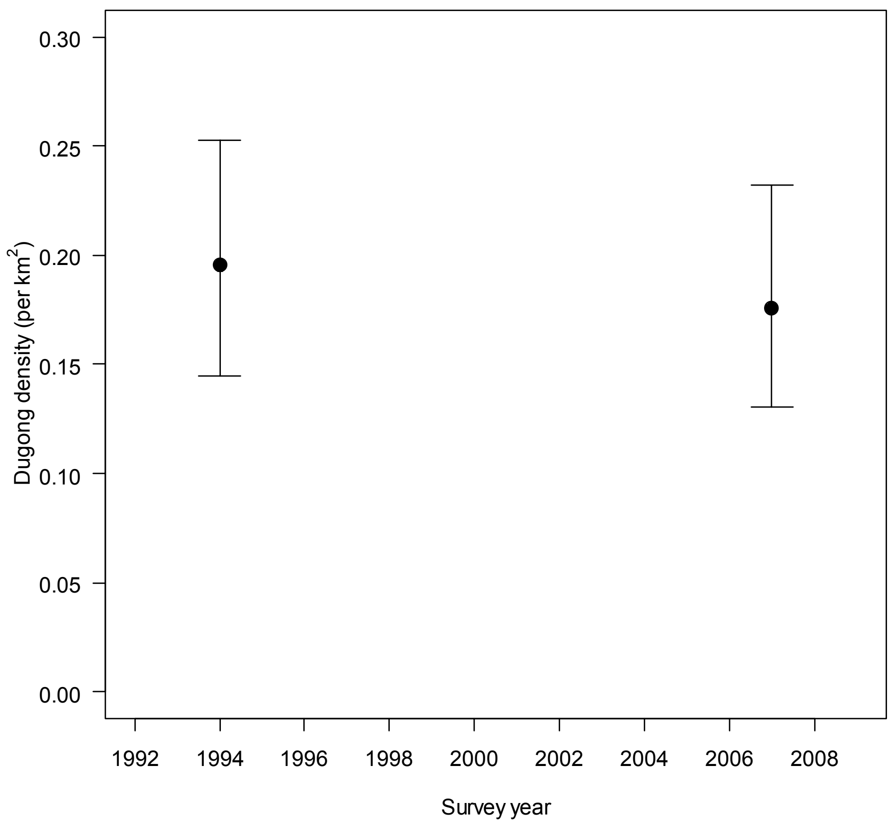


Figure 5. The estimated index of dugong density (per km²) over survey blocks (NT 1-7) off the Northern Territory for the 1994 and 2007 surveys. Error bars represent 95% credible intervals. Note this index of density is not corrected for availability bias and is not comparable with the data presented in Figure 2.

Table 1:. Details of the quantitative aerial surveys for dugongs in the Gulf of Carpentaria conducted prior to 2007 for which the raw data were available and the correspondence between the blocks surveyed and the 2007 blocks

Month, Year	Block	Area in km^2	Sampling Intensity	Encompassing 2007 Block
December, 1991, Marsh and Lawler 1993	1	1457	0.08	QLD1
	2	1585	0.08	QLD2
	3	620	0.08	QLD2
	4	3432	0.08	QLD2
	5	1754	0.09	QLD2
November 1994, Saalfeld 2000 in Saalfled and Marsh 1994	NT1	2342	0.09	NT1
	2	2767	0.10	NT2
	3	2767	0.08	NT3
	4	2950	0.08	NT4
	5	3112	0.09	NT5
	6	3420	0.08	NT5
	7	3197	0.08	NT6
	8	2342	0.09	NT7
December, 1997 Marsh *et al*. 2000	1	1506	0.09	QLD1
	2	2622	0.09	QLD2
	3	612	0.09	QLD2
	4	3612	0.09	QLD2
	5	2505	0.09	QLD2
	6	10166	0.04	QLD4
	7	10133	0.04	QLD4/5/6
	8	1869	0.08	QLD2/3

Table 2: Areas of survey blocks and sampling intensities for the aerial survey conducted in 2007. For locations of blocks see Figure 1.

Region	Block	Sampling Intensity	Area (km^2)
Northern Territory	1	0.03	2631
	2	0.11	2046
	3	0.09	1631
	4	0.09	1937
	5	0.09	3734
	6	0.09	2021
	7	0.10	2435
	8	0.06	1310
Queensland	1	0.04	803
	2	0.08	7068
	3	0.03	1446
	4	0.05	5832
	5	0.08	1160
	6	0.05	1538
Total		0.07	35592

Table 3: Dugong population estimates (standard errors) for the various blocks surveyed in the Gulf of Carpentaria in November 2007. Note: population estimates for blocks QLD1, 3-4 and NT1 are based on zig-zag transects and the results may be less robust than for the other blocks. No estimates were calculated for blocks QLD5 and 6 and NT8 as to few dugong groups were counted.

Block	Population Estimate	SE
NT1	556	376
NT2	1702	936
NT3	612	281
NT4	555	251
NT5	994	372
NT6	534	165
NT7	389	174
NT total	5343	1164
QLD1	1340	749
QLD2	4304	1223
QLD3	434	356
QLD4	1017	516
Qld total	7095	1565
Gulf total	12438	1951

Table 4: Results of linear mixed effect analyses examining the index of dugong density among surveys.

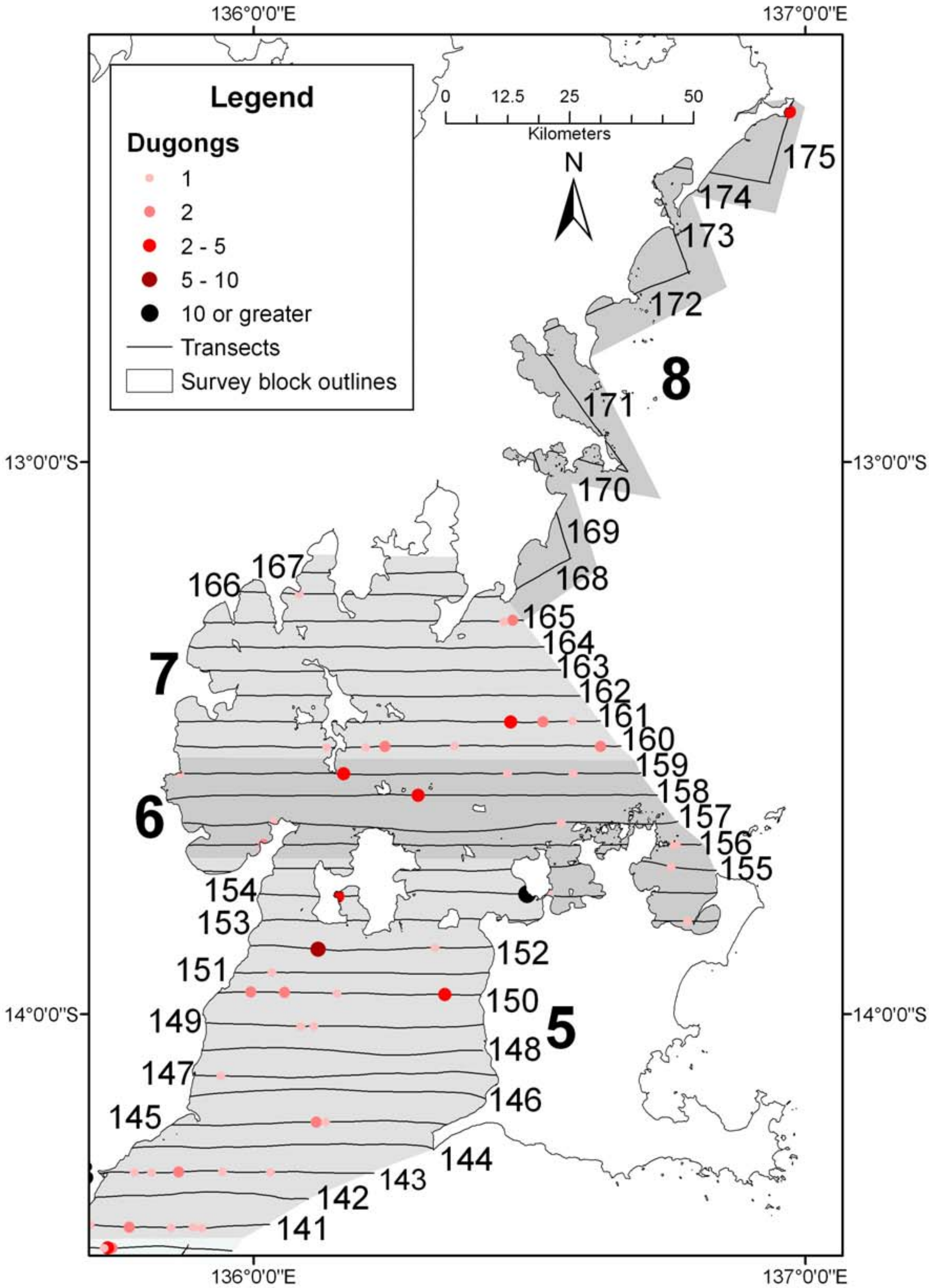
Source of variation	Num. DF	Denom. DF	F	MCMC P-value	Variance component
Queensland waters of Gulf of Carpentaria 1997 and 2007 for blocks QLD 2,5,6					
Block	2	53	5.40	<0.0001	
Among transect within block					0.147
Year	1	53	1.95	0.295	
Block x Year	2	53	3.09	0.085	
Residual (among transect within block variation among years)					0.316
Block “QLD2” only 1991, 1997 and 2007					
Among transect within block					0.213
Year	2	60	2.78	<0.0001	
Residual (among transect within block variation among years)					0.355
Northern Territory 1994 and 2007 for blocks NT 1-7					
Block	5	58	1.30	0.283	
Among transects within block					0.091
Year	1	58	0.37	0.585	
Block x Year	5	58	1.15	0.442	
Residual (among transect within block variation among years)					0.428

Table 5. Estimates of the total sustainable anthropogenic mortality (Potential Biological Removal *sensu* Wade, 1998) for the coastal waters of various sub-regions of the Gulf of Carpentaria including: (1) the Wellesley Islands, (2) off Queensland, and (3) off the Northern Territory and (4) the whole region for a range of estimates of R_{max} and assuming value for the Recovery Factor of 0.5 and 1.0. The values for the PBRs are based on the population estimate derived using Pollock *et al.* (2006) because this method should provide more accurate population estimates than the Marsh & Sinclair (1989) method.

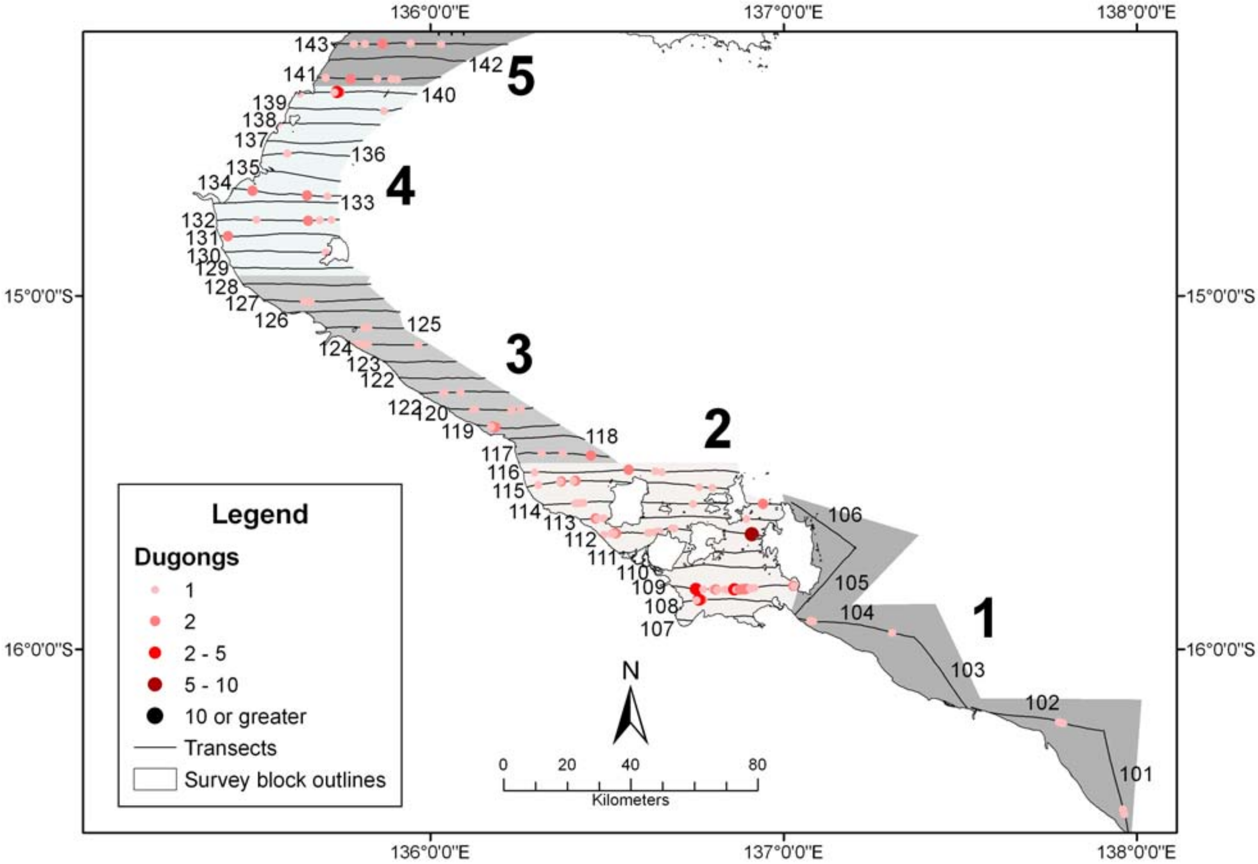
Recovery Factor	Population estimate (SE)	SE	C.V	N min	Potential Biological Removal [2]		
					R_{max}=0.01	R_{max}=0.03	R_{max}=0.05
Coastal waters off Wellesley Islands (QLD Blocks 1 and 2)							
0.5	5644	1434	0.25	4572	11	34	57
1.0					23	69	114
Coastal waters off Queensland							
0.5	7095	1565	0.22	5095	15	44	74
1.0					30	89	148
Coastal waters off Northern Territory							
0.5	5343	1164	0.22	4457	11	33	56
1.0					22	67	111
Coastal waters of Gulf of Carpentaria							
0.5	12438	1951	0.16	10908	27	82	136
1.0					55	164	273

Appendix 1: Supplementary Figures

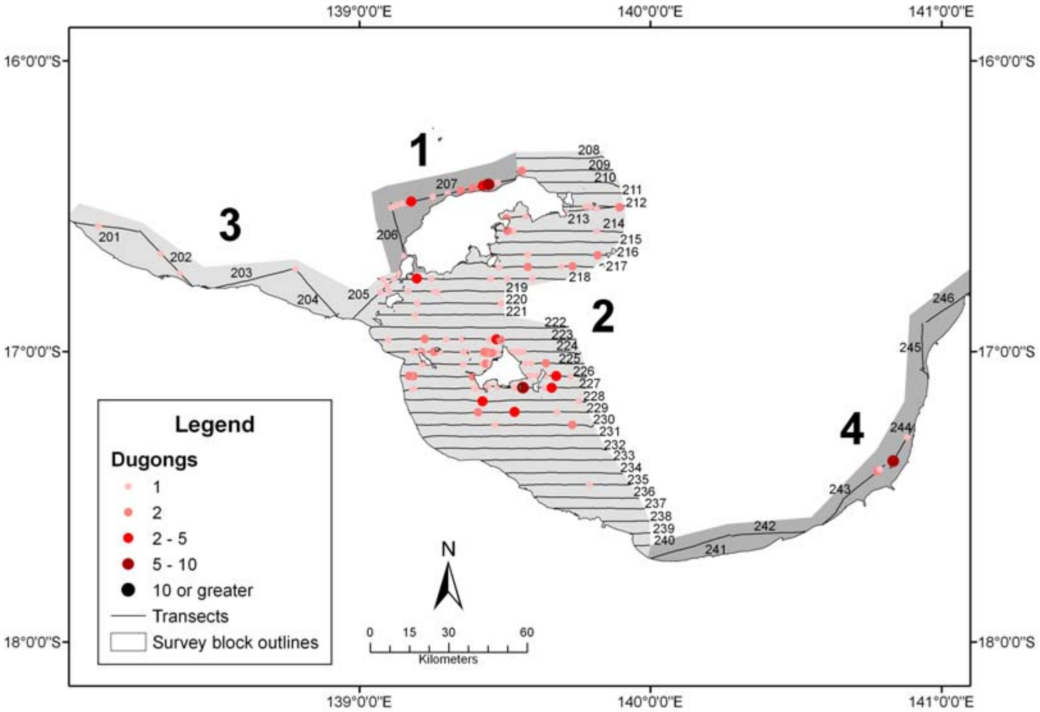
Figures showing the GPS tracks of transects flown in the Gulf of Carpentaria during the aerial survey in November 2007, showing the positions and sizes of the dugong groups sighted and the transect numbers**.**



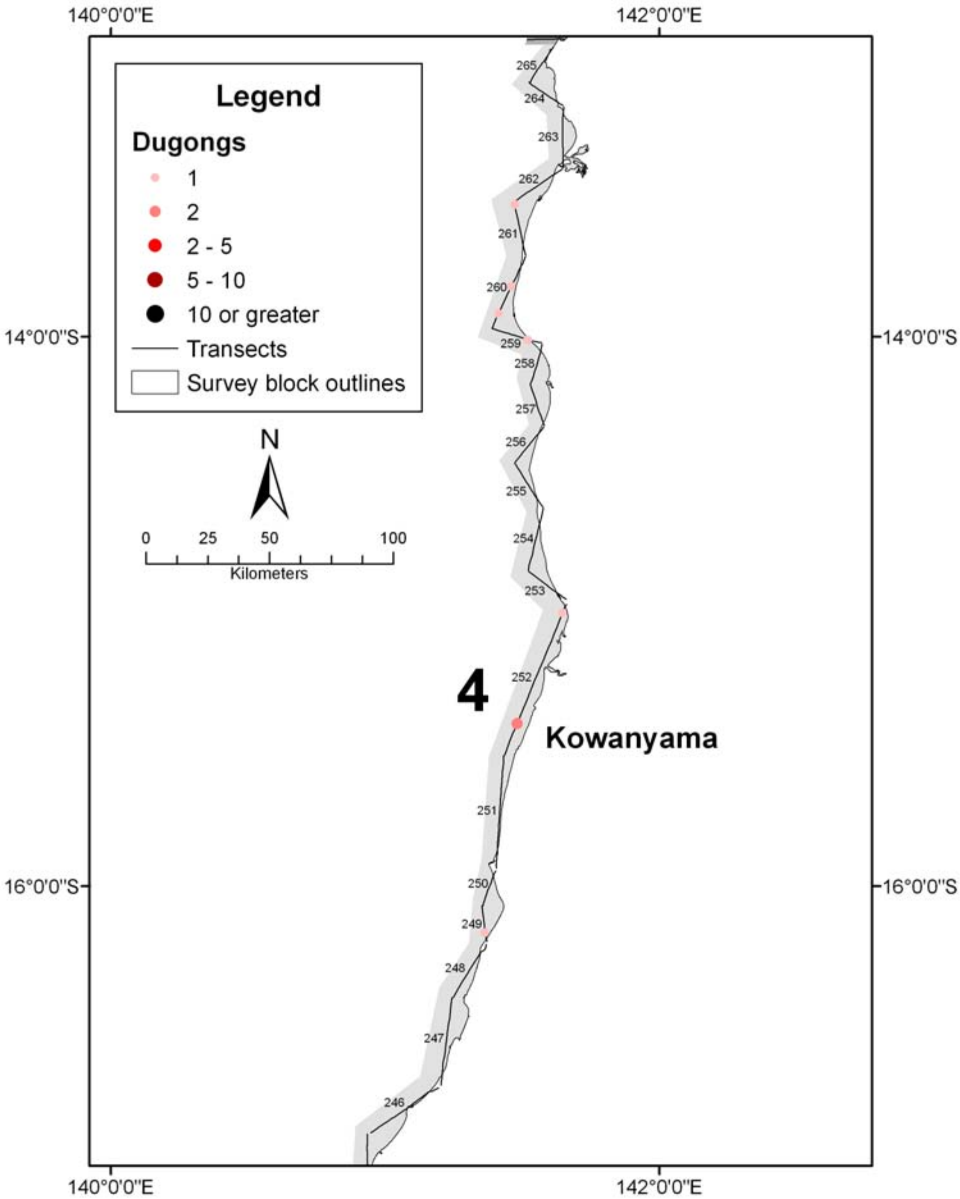
Appendix Figure 1. GPS tracks of transects flown in blocks in the waters off the Northern Territory along the western coast of the Gulf of Carpentaria during the aerial survey in November 2007 showing the positions and sizes of the dugong groups sighted and the transect and block numbers.



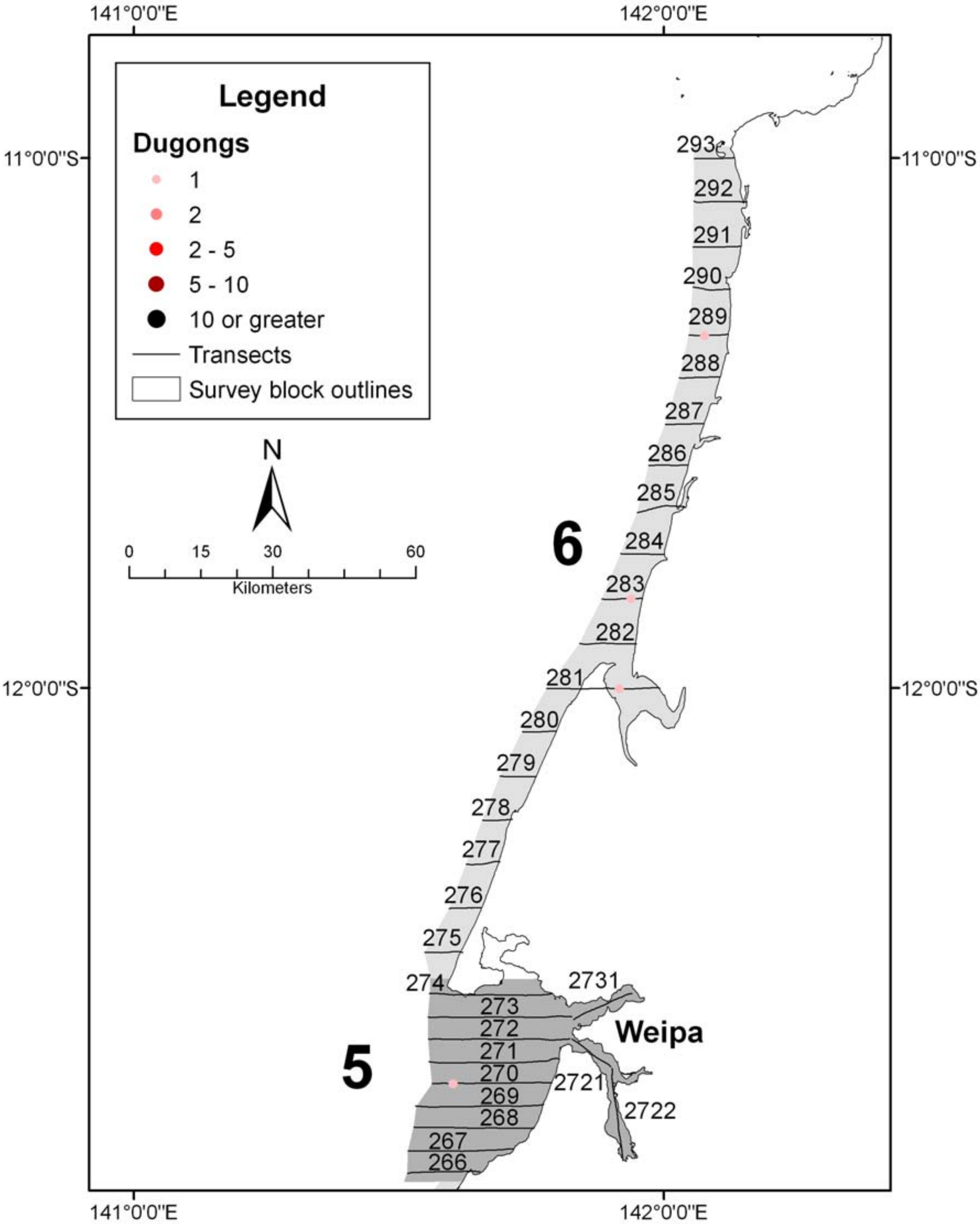
Appendix Figure 2. GPS tracks of transects flown in blocks in the waters off the Northern Territorys along the southern coast of the Gulf of Carpentaria during the aerial survey in November 2007 showing the positions and sizes of the dugong groups sighted and the transect and block numbers.



Appendix Figure 3. GPS tracks of transects flown in blocks in the waters off the southern Queensland coast of the Gulf of Carpentaria during the aerial survey in November 2007 showing the positions and sizes of the dugong groups sighted and the transect and block numbers. Note: in future surveys east west transects should be flown off the western coast of Mornington Island.



Appendix Figure 4. GPS tracks of transects flown in the south eastern waters of the Gulf of Carpentaria adjacent t o Queensland during the aerial survey in November 2007 showing the positions and sizes of the dugong groups sighted and the transect and block numbers.



Appendix Figure 5. GPS tracks of transects flown in blocks along the north eastern waters of the Gulf of Carpentaria adjacent t o Queensland during the aerial survey in November 2007 showing the positions and sizes of the dugong groups sighted and the transect and block numbers.

Appendix 2: Supplementary Tables of Weather Conditions and Raw Data.

Appendix Table 1. Weather conditions encountered during the 2007 survey of the Gulf of Carpentaria in comparison with previous surveys of the same areas. Historical data for the 1991 survey of the Wellesley Islands from Marsh and Lawler (1993); 1997 survey of Queensland waters of the Gulf of Carpentaria from Marsh *et al.*(2000). Comparable data are not available for the 1994 survey of the Northern Territory.

	Wellesley Islands 1991	QLD 1997		QLD 2007	NT 2007
		Aircraft 1 (Blocks 6,7)	Aircraft 2 (Blocks 1-5,8)		
Wind speed (km.h^{-1})	≤10	0-18	9-13	0-20	0-10
Cloud cover (oktas)*	0-7	0-8	0-2	0-8	0-6
Minimum cloud height*	2000-8000	600	2000-7000	1800-25000	2000-10000
Beaufort sea state[#] (range)	1.7(0-4)	2.3 (0-4)	1.8 (0-3.5)	2.0 (0-4)	1.1 (0-4)
Glare North[•#]	1.5(0-3)	1.1 (0-2)	1.1 (0-3)	1.4 (0-3)	1.0 (0-3)
Glare South[•#]	2.1(0-3)	1.9 (0-3)	1.3 (0-3)	1.4 (0-3)	0.9 (0-3)
Visibility (km)*	≥20	>20	>20	3- >20	>10

* Range

[#] Means of modes for each transect

• 0-none, 1 <25% of field of view affected, 2 <25-50%, 3 >50%

Appendix Table 2. Beaufort sea state and glare for each transect of the 2007 aerial survey for dugongs. See Appendix Figures 1-5 for transect locations.

Block	Transect	Beaufort Sea State			Glare South/West			Glare North/East		
		Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
NT1	101	1	1	1	0	0		1	3	1
NT1	102	1	1	1	1	1		0	0	0
NT1	103	0	1	1	0	0		0	1	0
NT1	104	1	1	1	0	0		0	0	0
NT1	105	0	2	1	0	1	0	3	3	3
NT1	106	1	1	1	0	1		0	1	1
NT2	107	0	3		0	2		1	1	1
NT2	108	0	2	2	0	2		1	1	
NT2	109	0	3	0	0	3	0	1	2	1
NT2	110	0	2	0	1	1		0	1	
NT2	111	0	0	0	0	1	1	0	2	
NT2	112	0	0	0	0	1	0	0	0	0
NT2	113	0	1	0	0	1	0	0	2	1
NT2	114	0	1	1	0	1	0	0	0	0
NT2	115	0	0	0	0	1	0	0	0	0
NT2	116	0	1	1	0	0		0	2	1
NT3	117	0	1	1	1	1		0	1	1
NT3	118	1	1	1	0	1		1	2	1
NT3	119	0	1		0	1		0	0	0
NT3	120	1	1	1	1	1	1	1	3	2
NT3	121	2	3	2	2	2		1	2	1
NT3	122	2	2	2	2	3		2	2	2
NT3	123	2	2	2	1	1		1	2	1
NT3	124	1	1	1	1	1		0	0	0
NT3	125	1	1	1	0	0		0	1	0
NT3	126	0	1	1	0	0		0	0	0
NT3	127	1	1	1	0	0	0	0	1	0
NT3	128	0	1	1	0	0	0	0	0	0
NT4	129	0	1	1	0	1	0	0	2	0
NT4	130	0	1	1	0	0		0	0	0
NT4	131	1	1	1	0	0	0	0	1	0
NT4	132	0	1	1	0	0	0	0	0	0
NT4	133	1	2	2	1	2		1	2	2
NT4	134	1	2	2	2	2		0	0	0
NT4	135	1	2	2	2	2		1	2	1
NT4	136	1	2	2	1	2	2	0	0	0
NT4	137	1	1	1	0	1	1	2	2	2
NT4	138	0	1	1	2	2		0	1	0
NT4	139	1	1	1	0	0		1	2	2
NT4	140	0	4	1	0	1		0	1	0
NT5	141	0	1	1	0	1	0	0	2	1
NT5	142	1	1	1	1	1	1	0	1	0
NT5	143	0	1	1	0	0		1	2	1
NT5	144	1	3	1	0	2	1	0	2	2
NT5	145	1	3	1	0	2	2	0	3	2
NT5	146	1	3	2	1	2	2	1	2	2
NT5	147	1	3	2	1	2	2	0	3	2

Block	Transect	Beaufort Sea State			Glare South/West			Glare North/East		
		Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
NT5	148	1	3	2	2	2	2	1	3	2
NT5	149	2	3	3	2	2	2	0	2	1
NT5	150	0	1	0	2	2	2	0	2	0
NT5	151	0	1	1	0	2	1	0	3	0
NT5	152	0	1	1	1	2	2	0	2	2
NT5	153	0	2	1	0	2	0	0	2	2
NT5	154	1	2	2	1	1	1	0	0	0
NT5	155	1	1	1	0	1	0	0	2	1
NT6	153	1	2		1	1		0	2	
NT6	154	1	2	2	1	1	1	0	0	0
NT6	155	1	1	1	1	1	1	1	2	2
NT6	156	0.5	4	1	1	2	1	0	1	0
NT6	157	1	1	1	0	2	1	1	3	2
NT6	158	0.5	2	0.5	0	1	1	0	2	1
NT6	159	0.5	2.5	0.5	0	2	2	0	1	0
NT7	160	0	1	1	0	2	0	0	3	1
NT7	161	0	2	0	0	3	3	0	1	0
NT7	162	1	2	1	0	1	1	2	3	3
NT7	163	0	2	1	1	3	3	1	2	2
NT7	164	1	2	2	2	3	2	1	3	3
NT7	165	0	2	2	1	3	2	1	3	2
NT7	166	0	2	0	0	1	0	0	1	0
NT7	167	0	1	1	0	1		0	0	0
NT8	168	1	1	1	0	0	0	2	3	3
NT8	169	0	1	1	0	0	0	2	2	2
NT8	170	1	1	1	0	0	0	1	1	1
NT8	171	1	1	1	0	1	1	0	2	2
NT8	172	0	1	1	0	0	0	1	2	2
NT8	173	0.5	1	1	0	0	0	0	1	0
NT8	174	0	1	1	0	1	0	0	1	1
NT8	175	0.5	1	1	0	1		2	3	3
QLD1	206	2	2.5	2	0	0	0	3	3	3
QLD1	207	1	2.5	2	1	2		1	2	
QLD2	209	2	2.5	2.5	2	3	3	2	2	2
QLD2	211	1	2	1	0	0	0	0	1	
QLD2	212	1	1	1	0	0		2	2	
QLD2	213	0	3	2	1	3	3	3	3	3
QLD2	214	1	3	1	2	3	3	1	3	2
QLD2	215	1	1	1	0	1	0	0	1	0
QLD2	216	0	1	1	0	0	0	2	2	2
QLD2	217	0	4	1	0	2	1	0	1	0
QLD2	218	0	4	0.5	0	2	1	0	2	2
QLD2	219	0.5	2	1	0	2	2	0	1	1
QLD2	220	0	4	1	0	2	0	0	2	2
QLD2	221	0.5	3	3	1	2	1	0	3	2
QLD2	222	1	3	3	2	3	2	1	2	2
QLD2	223	1	3	1.5	0	2	2	1	2	1
QLD2	224	2	2	2	2	3		0	1	1
QLD2	225	0.5	2.5	2	1	2	1	0	2	
QLD2	226	0	2	2	2	2	2	0	0	0
QLD2	227	0.5	2.5	2	0	1	1	0	2	2
QLD2	228	1	2	2	0	3	2	0	1	0

Block	Transect	Beaufort Sea State			Glare South/West			Glare North/East		
		Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
QLD2	229	1	3	2	0	1	1	1	3	2
QLD2	230	2	3	3	1	3	3	0	1	0
QLD2	231	2	3.5	3.5	0	1	0	1	2	1
QLD2	232	2.5	3	3	2	3	3	1	1	1
QLD2	233	1	4	3	0	2	0	0	1	1
QLD2	234	2	3	3	2	2		3	3	
QLD2	235	1	3	2.5	0	2		1	1	1
QLD2	236	2.5	2.5	2.5	2	2		3	3	
QLD2	237	2	3	2	1	2	2	1	1	1
QLD2	238	2	4	2	2	2		3	3	
QLD2	239	1	2.5	1	1	1	1	2	2	
QLD2	240	2	2		2	2		3	3	
QLD3	201	3	3.5	3	2	2		1	1	
QLD3	202	3	3.5	3	3	3		0	0	
QLD3	203	2	3	3	1	1		1	1	
QLD3	204	2	3	3	3	3	3	0	0	0
QLD4	241	1	2	1	1	1		1	1	
QLD4	242	1	1.5	1	2	2	2	1	2	
QLD4	243	1	1	1	1	1	1	1	2	
QLD4	244	1	1		3	3		3	3	
QLD4	245	2	4	2	1	3		0	0	
QLD4	246	2	2.5	2.5	3	3		3	3	
QLD4	247	2.5	3	2.5	3	3		1	1	
QLD4	248	3	4	3	2	2		0	0	
QLD4	249	2.5	3	3	3	3		0	0	
QLD4	250	3	3		3	3		2	2	
QLD4	251	3	3	3	3	3		0	0	
QLD4	252	2	3	2	3	3	3	1	1	1
QLD4	253	1.5	1.5	1.5	0	0	0	1	2	
QLD4	254	1.5	1.5	1.5	1	1		2	2	
QLD4	255	1	1.5		0	0	0	1	2	
QLD4	256	1.5	1.5	1.5	1	1		3	3	
QLD4	257	1	1.5	1	1	1		2	2	
QLD4	258	1	2	1.5	1	1		3	3	
QLD4	259	1.5	2	2	1	1	1	1	1	
QLD4	260	1	2	2	1	1		2	2	
QLD4	261	1	1	1	0	0		1	1	
QLD4	262	1	1	1	1	1		1	1	
QLD4	263	0	2		1	2	2	1	2	
QLD4	264	2	2	2	2	3		1	2	
QLD4	265	1.5	2	2	3	3	3	3	3	3
QLD5	266	1.5	2	2	0	0	0	1	1	
QLD5	267	1	4	1	0	0	0	2	2	
QLD5	268	1.5	1.5	1.5	0	0		1	1	
QLD5	269	1.5	2	1.5	1	1		2	2	
QLD5	270	2	2	2	1	1		1	1	
QLD5	271	1	2.5	2	1	2		1	2	
QLD5	272	1	2.5	2	0	1		1	1	
QLD5	272.1	1	1		3	3		0	0	
QLD5	272.2	1	1	1	3	3		0	0	
QLD5	273	1	2.5		2	2		2	2	
QLD5	273.1	1	4	1	0	0		0	0	

Block	Transect	Beaufort Sea State			Glare South/West			Glare North/East		
		Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
QLD5	274	2	2	2	1	1	1	2	2	2
QLD6	275	1	4	1	2	3	2	1	3	
QLD6	276	1	1	1	1	1		1	1	
QLD6	277	0	0.5		2	2		0	0	
QLD6	278	1	1	1	0	0		1	1	
QLD6	279	2.5	3	2.5	3	3		2	2	
QLD6	280	2.5	2.5	2.5	2	2		3	3	
QLD6	280.1	0	1	1	0	0	0	0	2	
QLD6	281	0	2.5	2.5	0	3	3	0	2	
QLD6	282	2.5	4	2.5	1	2		3	3	3
QLD6	283	2.5	2.5	2.5	3	3		2	2	
QLD6	284	2.5	3		1	1		3	3	
QLD6	285	2.5	3	3	3	3		2	2	
QLD6	286	2.5	2.5		1	1		3	3	
QLD6	287	2.5	2.5	2.5	3	3		2	2	
QLD6	288	2	2.5		2	2		3	3	
QLD6	289	2.5	2.5	2.5	3	3		2	2	
QLD6	290	2.5	2.5	2.5	1	1		3	3	
QLD6	291	2.5	2.5	2.5	2	2		1	1	
QLD6	292	2	3		0	0		3	3	
QLD6	293	2	2.5	2.5	0	3		0	0	

Appendix Table 3. Raw data for sightings of dugong groups for each transect in each block surveyed in 2007
as used to estimate population size. See Appendix Figures1-5 for transect locations.

Block	Transect	Adjusted Transect Height	Transect Length	Transect Area (km2)	# Groups Port	# Groups Starboard
NT1	101	475	37.2	15.7	0	2
NT1	102	467	40.1	16.6	2	1
NT1	103	500	29.8	13.2	0	0
NT1	104	500	38.1	16.9	2	1
NT1	105	510	30.5	13.8	0	0
NT1	106	513	23.4	10.7	0	0
NT2	107	525	24.5	11.4	0	0
NT2	108	567	26.6	13.4	1	4
NT2	109	508	39.2	17.7	15	10
NT2	110	513	38.3	17.4	0	0
NT2	111	500	43.2	19.2	0	0
NT2	112	520	50.2	23.2	9	7
NT2	113	538	60.2	28.7	3	1
NT2	114	525	72.9	34.0	4	3
NT2	115	506	61.4	27.6	3	1
NT2	116	536	65.6	31.3	3	1
NT3	117	500	27.7	12.3	1	2
NT3	118	417	23.3	8.6	0	0
NT3	119	500	26.0	11.6	3	0
NT3	120	500	25.7	11.4	3	1
NT3	121	465	27.4	11.3	3	0
NT3	122	450	26.5	10.6	0	0
NT3	123	500	22.6	10.0	0	0
NT3	124	500	23.6	10.5	3	1
NT3	125	500	23.6	10.5	1	1
NT3	126	500	35.4	15.7	0	0
NT3	127	500	37.1	16.5	2	0
NT3	128	500	38.2	17.0	0	0
NT4	129	500	37.1	16.5	0	0
NT4	130	500	32.4	14.4	1	1
NT4	131	510	37.3	16.9	1	0
NT4	132	500	37.7	16.8	4	0
NT4	133	488	38.2	16.6	0	0
NT4	134	500	31.2	13.9	2	1
NT4	135	500	22.3	9.9	0	0
NT4	136	500	27.1	12.1	0	1
NT4	137	500	29.2	13.0	0	0
NT4	138	500	31.3	13.9	1	0
NT4	139	507	34.7	15.7	1	0
NT4	140	500	38.1	16.9	3	1
NT5	141	500	36.6	16.3	5	0
NT5	142	500	42.3	18.8	0	0
NT5	143	500	51.0	22.7	3	2
NT5	144	519	59.1	27.2	0	0
NT5	145	508	54.7	24.7	1	1
NT5	146	478	58.1	24.7	0	0
NT5	147	523	59.0	27.4	1	0
NT5	148	500	55.3	24.6	0	0
NT5	149	517	54.2	24.9	1	1

Block	Transect	Adjusted Transect Height	Transect Length	Transect Area (km2)	# Groups Port	# Groups Starboard
NT5	150	500	52.0	23.1	3	1
NT5	151	500	50.2	22.3	0	1
NT5	152	506	47.4	21.3	2	0
NT5	153	500	34.7	15.4	0	0
NT5	154	500	40.7	18.1	1	0
NT5	155	506	40.9	18.4	0	0
NT6	153	450	13.0	5.2	1	0
NT6	154	471	24.5	10.3	1	0
NT6	155	500	25.0	11.1	0	1
NT6	156	530	77.7	36.6	1	2
NT6	157	498	97.0	42.9	1	1
NT6	158	513	96.2	43.8	2	0
NT6	159	498	90.9	40.2	3	2
NT7	160	515	87.1	39.9	3	1
NT7	161	505	82.7	37.1	1	1
NT7	162	521	67.5	31.3	0	1
NT7	163	519	70.7	32.6	1	0
NT7	164	516	69.7	31.9	0	0
NT7	165	481	62.9	26.9	2	0
NT7	166	496	52.1	23.0	2	0
NT7	167	481	31.2	13.3	0	0
NT8	168	500	15.0	6.7	0	0
NT8	169	520	23.7	10.9	1	0
NT8	170	500	19.5	8.7	0	0
NT8	171	485	32.5	14.0	0	0
NT8	172	508	33.2	15.0	0	0
NT8	173	520	23.5	10.9	0	0
NT8	174	500	24.3	10.8	0	0
NT8	175	500	17.7	7.9	0	0
QLD1	206	445	24.5	9.7	1	1
QLD1	207	447	47.8	19.0	8	4
QLD2	209	460	35.1	14.3	0	1
QLD2	211	463	23.4	9.6	0	0
QLD2	212	480	22.3	9.5	3	0
QLD2	213	436	44.5	17.2	3	2
QLD2	214	453	46.0	18.5	1	1
QLD2	215	462	44.4	18.2	0	0
QLD2	216	448	43.8	17.4	0	2
QLD2	217	470	35.9	15.0	2	3
QLD2	218	455	68.7	27.8	5	2
QLD2	219	449	46.3	18.5	3	2
QLD2	220	460	46.3	18.9	1	1
QLD2	221	459	46.3	18.9	0	1
QLD2	222	455	71.7	29.0	0	0
QLD2	223	456	74.0	30.0	3	5
QLD2	224	447	71.6	28.4	24	15
QLD2	225	462	65.6	26.9	5	8
QLD2	226	448	68.4	27.2	8	4
QLD2	227	471	66.9	28.0	11	9
QLD2	228	452	66.3	26.6	0	2
QLD2	229	453	65.1	26.2	1	2
QLD2	230	453	65.2	26.2	1	2

Block	Transect	Adjusted Transect Height	Transect Length	Transect Area (km2)	# Groups Port	# Groups Starboard
QLD2	231	446	64.7	25.6	2	0
QLD2	232	454	62.8	25.4	0	0
QLD2	233	455	47.7	19.3	0	0
QLD2	234	452	42.9	17.2	0	0
QLD2	235	461	40.1	16.4	1	0
QLD2	236	465	37.3	15.4	0	0
QLD2	237	460	33.9	13.8	0	0
QLD2	238	450	17.5	7.0	0	0
QLD2	239	435	6.5	2.5	0	0
QLD2	240	460	5.2	2.1	0	0
QLD3	201	445	28.4	11.2	0	1
QLD3	202	448	31.5	12.6	1	1
QLD3	203	444	37.0	14.6	0	0
QLD3	204	441	28.3	11.1	1	1
QLD4	241	457	34.1	13.8	0	0
QLD4	242	435	30.8	11.9	0	0
QLD4	243	490	35.7	15.5	2	0
QLD4	244	450	30.9	12.4	2	0
QLD4	245	450	29.0	11.6	0	0
QLD4	246	440	32.7	12.8	0	0
QLD4	247	440	36.5	14.3	0	0
QLD4	248	463	25.8	10.6	0	0
QLD4	249	450	15.1	6.0	0	1
QLD4	250	450	16.0	6.4	0	0
QLD4	251	450	45.5	18.2	0	0
QLD4	252	453	67.0	27.0	0	2
QLD4	253	400	19.6	7.0	0	0
QLD4	254	460	25.9	10.6	0	0
QLD4	255	460	21.2	8.7	0	0
QLD4	256	453	18.7	7.5	0	0
QLD4	257	440	17.3	6.8	0	0
QLD4	258	447	17.3	6.9	0	0
QLD4	259	447	21.2	8.4	0	1
QLD4	260	480	31.9	13.6	1	1
QLD4	261	453	22.4	9.0	1	0
QLD4	262	453	23.2	9.3	0	0
QLD4	263	473	25.3	10.7	0	0
QLD4	264	453	16.7	6.7	0	0
QLD4	265	473	20.8	8.8	0	0
QLD5	266	443	14.8	5.8	0	0
QLD5	267	448	20.7	8.2	0	0
QLD5	268	470	24.6	10.3	0	0
QLD5	269	445	26.0	10.3	0	0
QLD5	270	458	24.2	9.9	0	1
QLD5	271	452	26.3	10.6	0	0
QLD5	272	470	29.0	12.1	0	0
QLD5	272.1		10.3	0.0	0	0
QLD5	272.2	420	18.0	6.7	0	0
QLD5	273	443	29.0	11.4	0	0
QLD5	273.1	483	13.5	4.3	0	0
QLD5	274	475	25.2	10.6	0	0
QLD6	275	453	7.2	2.9	0	0

Block	Transect	Adjusted Transect Height	Transect Length	Transect Area (km2)	# Groups Port	# Groups Starboard
QLD6	276	460	6.6	2.7	0	0
QLD6	277	465	6.5	2.7	0	0
QLD6	278	450	5.8	2.3	0	0
QLD6	279	450	7.3	2.9	0	0
QLD6	280	460	7.2	3.0	0	0
QLD6	280.1	470	10.3	4.3	0	0
QLD6	281	446	23.0	9.1	1	0
QLD6	282	475	11.3	4.8	0	0
QLD6	283	450	8.1	3.3	0	1
QLD6	284	460	9.0	3.7	0	0
QLD6	285	467	8.7	3.6	0	0
QLD6	286	480	8.0	3.4	0	0
QLD6	287	440	8.2	3.2	0	0
QLD6	288	460	8.6	3.5	0	0
QLD6	289	460	8.0	3.3	1	0
QLD6	290	440	7.5	2.9	0	0
QLD6	291	433	10.1	3.9	0	0
QLD6	292	450	11.0	4.4	0	0
QLD6	293	480	8.2	3.5	0	0

Appendix Table 4. Details of group size estimates and perception correction factors used in the population estimates for
dugongs in the various surveys of the Gulf of Carpentaria using the Method of Marsh & Sinclair (1989).

Block	1991		1994		1997		2007	
	PCF (CV) Port, Starboard	Group Size (CV)	PCF (CV) Port, Starboard	Group Size (CV)	PCF (SE) Port, Starboard	Group Size (CV)	PCF (CV) Port, Starboard	Group Size (CV)
NT2				1.32 (0.09)				1.34 (0.08)
NT3				1.41 (0.17)				1.24 (0.09)
NT4			1.33 (0.01), 2.06 (0.2)	1.2 (0.09)			1.07 (0.01), 1.04 (0.01)	1.41 (0.11)
NT5				2.58 (0.3)				1.74 (0.17)
NT6				1.38 (0.13)				1.53 (0.21)
NT7				1.21 (0.07)				1.5 (0.15)
QLD1								1.71 (0.25)
QLD2	1.06 (0.02), 1.08 (0.02)	1.26 (0.05)			1.01 (0.01), 1.02 (0.01)	1.26 (0.06)	1.24 (0.05), 1.18 (0.04)	1.34 (0.06)
QLD5						1.25 (0.2)		1
QLD6						1 (0)		1 (0)

Appendix 3: Example of Community Extension Material.

A corresponding brochure was prepared for Queensland communities.

:

Aerial Surveys to Count the Number of Dugongs in the Gulf of Carpentaria in November 2007

Scott Whiting

Project Title
The distribution and abundance of the dugong in Gulf of Carpentaria waters: a basis for cross jurisdictional conservation planning and management
Funded by Australian Centre for Applied Marine Mammal Science (ACAMMS) – Australian Government

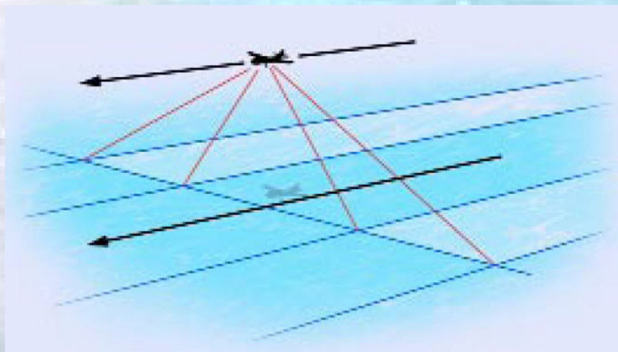
Researchers
James Cook University, Qld and NRETA, NT

Summary
This project proposes to use aerial surveys to count dugongs along the coast across the entire Gulf of Carpentaria in November 2007.

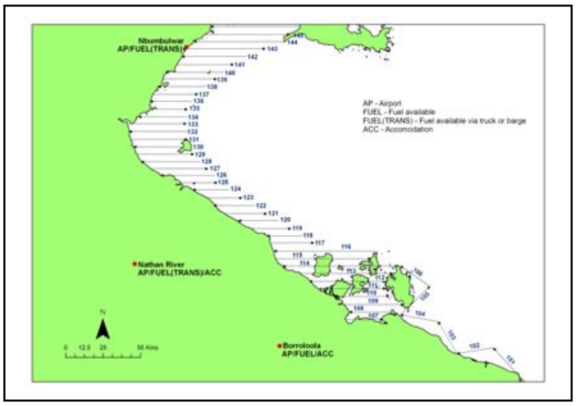
Counts of dugongs from fixed -wing planes are the most efficient method to assess the distribution and abundance of dugongs. The aircraft flies along transect lines that run perpendicular to shore and four observers count dugongs within a 200m wide strip of water on each side of the aircraft. The counts of dugongs are then adjusted for the number of dugongs that may be missed by an observer, as well as the number of dugongs that may be under the water and not visible due to turbid or dirty water. Counts of sea turtles and dolphins will be conducted at the same time.

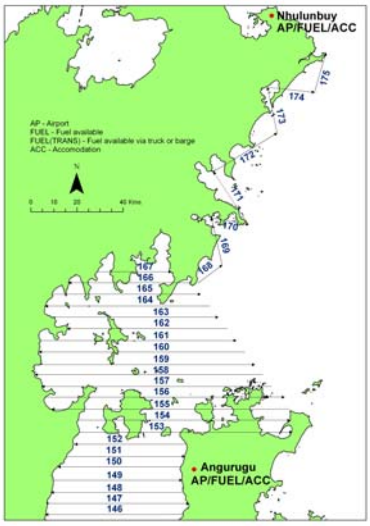
Two planes will be used; one flying from the NT /Qld border north east to the tip of Cape York, while the other will fly from the NT/Qld border north-west to Nhulunbuy (Gove). It is estimated that each section will require 7 days flying time but 21 days has been allocated to allow survey stoppages due to windy conditions. Each plane will include a pilot, a team leader and four observers. Up to 6 hours of surveys will be conducted each day.

The last surveys of this type were conducted in 1994 for the NT and 1997 for Qld.



From CRC Reef Brochure





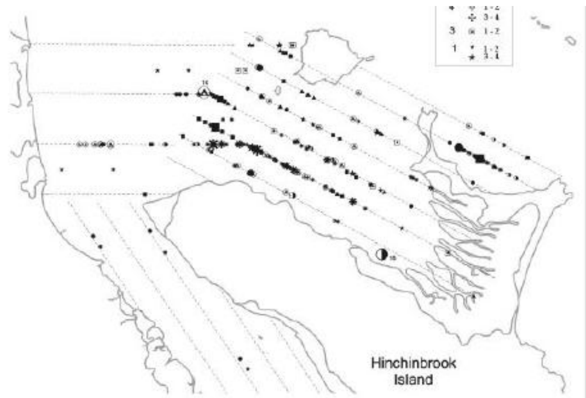
Proposed transects for south-west Gulf of Carpentaria

Proposed transects for north-west Gulf of Carpentaria

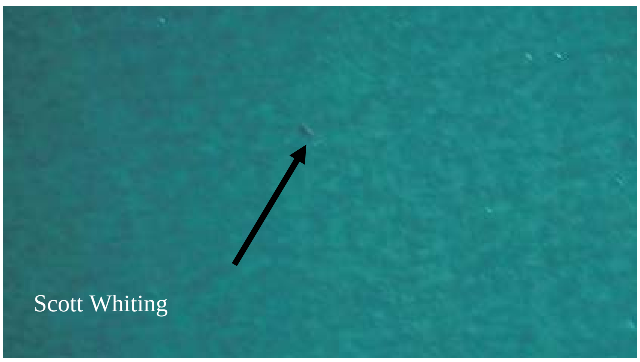
Results and Community Extension Material

The results of the surveys and their relevance will be delivered to Indigenous communities through an extension program that will include community workshops. A total of $10,000 has been allocated to help support the cost of extension activities.

Results will include maps of the where the dugongs were sighted and total population estimates for each block of transects.



Example of outputs of survey results with the locations of dugongs shown on each transect line – from Preen (1999)



Dugong as seen from the air

Outcomes for Communities

Results of this study will help communities and Sea Ranger Groups develop management plans for dugongs by having an additional data (in addition to Traditional and local knowledge) to help understand how many dugongs are in their areas and where they are located.

Transect sighting markers attached to aircraft.

Dugong