Marine and Tropical Science Research Facility
Interim Projects 2005-06

FINAL Report

Project 2: Dugong distribution and abundance on the urban coast of Queensland: a basis for management**.**

Investigators:
Professor Helene Marsh
Dr Ivan Lawler

Work Undertaken to Date

The transitional funding from MTSRF plus supplementary funding from CRC Reef and CRC Torres Strait enabled the first survey of the entire urban coast of Queensland for dugongs to be carried out in November 2005. In addition, a reference block in Torres Strait was surveyed to provide a context for the survey of the urban coast. The results of the 2005 surveys are being presented to Traditional Owners and stakeholders at a series of workshops.

The results of the 2005 survey have been analyzed in the context of results of pervious surveys of various parts of this coast since the mid 1980s using comparable techniques. The results of the 20 year time series of surveys suggest that dugong numbers are now stable at the scale of the entire urban coast of Queensland although populations fluctuate at the level of individual survey blocks (usually bays), probably largely due to natural changes in seagrass habitats.

The results of the surveys indicate that it will be important to: (1) develop cross-jurisdictional objectives for the management of dugongs at the scale of the entire region, and (2) co-ordinate management at both culturally and ecologically relevant scales.

Benefits of Project

The project provided the first synopsis of the distribution and abundance of the dugong on the urban cost of Queensland from Cooktown to the Queensland – NSW border. The results of previous surveys of subsets of this region have been difficult to interpret because of the confounding influences of unpredictable dugong movements between bays within the region in response to changes in their seagrass habitats.

Outcomes of Project
The Project has resulted in the following recommendations being made to the Great Barrier Reef Marine Park Authority and the Department of Environment with regard to the management of the dugong on the urban coast of Queensland from Cooktown to the Queensland –NSW border.

Recommendations

1. That the mechanisms to protect dugongs on the urban coast of Queensland be formally co-ordinated through the development of a single 'Dugong Management Plan for the Urban Coast of Queensland'. This Plan should address all anthropogenic impacts on dugongs in the region in partnership with other management initiatives such as the 'Sustainable harvest of marine turtles and dugongs in Australia - A national partnership approach 2005', Traditional Use Marine Resource Agreements and East Coast Inshore Finfish Fishery Management Plan.

2. That the 'Dugong Management Plan for the Urban Coast of Queensland' have explicit ecological, social and cultural objectives, developed in consultation with Traditional Owners and stakeholders.

3. That the success of achieving these objectives be formally monitored and reported to the Great Barrier Reef Ministerial Council.

4. That the 'Dugong Management Plan for the Urban Coast of Queensland':
    a. specify whether the overall objective of dugong management on the urban coast of Queensland is to maintain the dugong population at its 2005 level or to facilitate the recovery of the dugong population to historic levels;
    b. indicate the priorities for dugong management and whether or not these priorities reflect the Australian Law Reform Commission's priorities of: (1) conservation; (2) traditional use, (3) recreational and commercial use;
    c. recommend that the level of human-induced mortality of dugongs be monitored through the Queensland Marine Wildlife Stranding Program;
    d. recommend that the dugong population along the urban coast of Queensland continue to be monitored every five years using the aerial survey design and methodology used in the 2005 survey;
    e. recommend that an education program be developed to explain the diversity of management initiatives used to protect dugongs on the urban coast of Queensland, emphasizing that the Dugong Protection Areas are but a part of theses initiatives.

5. That if the ecological objective of the 'Dugong Management Plan for the Urban Coast of Queensland' is to maintain the population at the 2005 level, the plan:

   a. continue the present management initiatives used to protect dugongs in the Great Barrier Reef Marine Park, the Great Barrier Reef Coastal Marine Park, the Hervey Bay Marine Park and the Moreton Bay Marine Park;
   b. aim to ensure that the total human-induced mortality of dugongs is less than about 40 per year;
   c. determine how this mortality is divided among the various sources of mortality.

6. That if the ecological objective of 'Dugong Management Plan for the Urban Coast of Queensland' is facilitate the recovery of the dugong population, the Plan:
   a. strengthen the network of no-take areas which protect dugongs by increasing the proportion of habitats which consistently support high densities of dugongs in the Hervey Bay Marine Park and the Moreton Bay Marine Park, that are zoned as 'no-take';
   b. increase surveillance of initiatives to reduce dugong deaths from vessel strike;
   c. aim to ensure that the total human-induced mortality of dugongs is less than 10 per year (effectively aim for zero human-induced mortality);
   d. continue to encourage Traditional Owner not to hunt dugongs along the urban coast (south of Cooktown)
   e. recommend that the management agencies not endorse the hunting of dugongs (either through accrediting, TUMRAs, granting permits or entering into MOUs).

7. That while the objectives of the 'Dugong Management Plan for the Urban Coast of Queensland' are negotiated with Traditional Owners and stakeholders, the management agencies:
   a. continue to encourage Traditional Owner not to hunt dugongs along the urban coast (south of Cooktown);
   b. not endorse the hunting of dugongs (either through accrediting, TUMRAs, granting permits or entering into MOUs).

8. That the East Coast Inshore Finfish Fisheries Management Plan:
   a. have a focus on multispecies impacts and solutions to entanglement using the best available independently peer-reviewed and published scientific research;
   b. implement all the past GBR Ministerial Council recommendations in relation to dugong conservation.
9. That an education program be developed to explain the diversity of management initiatives used to protect dugongs on the urban coast of Queensland, emphasizing that the Dugong Protection Areas are but a part of theses initiatives.
10. That a plan be developed and co-ordinated across-jurisdictions to monitor the status of dugongs throughout their range in Australia using the revised aerial survey design and methodology used in this project.

11. That the Queensland Marine Wildfire Monitoring Program be continued with high priority to provide the relevant managers with essential information on the successor otherwise of the management initiatives to protect marine wildlife.

Outcomes/Objectives

Objective 1: To provide an essential component of the scientific basis of the National Approach to Sustainable and Segal Indigenous Harvest of Dugongs in Australia, the development of Traditional Use Marine Resource Agreements in the southern Great Barrier Reef region and the 2006 review of the Inshore Finfish Fishery including the evaluation of Dugong Protection Areas by conducting an aerial survey using the standard techniques developed and refined since the mid 1980s across the area between Cooktown and the Queensland New South Wales border.

This objective has been achieved in full and has been effective resulting in advice to the GBRMPA Senior Management Team which has briefed the Minister for Environment and Heritage on the implications of the results. We understand that the recommendations will be considered by the Conservation, Heritage and Indigenous Partnerships Reef Advisory Committee of GBRMPA and Marsh has been asked to brief the Committee (of which she is a member) at each meeting of August 31 2006.

Objective 2: To communicate the results of the survey to Traditional Owners and stakeholders in the survey region via a series of workshops in communities along the urban coast of Queensland.

This objective has only been partially achieved to date but should be fully achieved by mid September 2006 as detailed below. The delay has been caused by:

1. The logistical difficulty of conducting the workshops during the survey as planned because one of the three aircraft we hired became unavailable at the last minute. This logistical constraint greatly reduced the flexibility of the survey dates. As a result we were unable to conduct the workshops during the survey because despite numerous attempts, we were unable to identify dates which were mutually convenient to the survey teams and the relevant Traditional Owners.
2. The request from GBRMPA Executive Director Jon Tanzer to delay briefing the Traditional Owners in May 2006 as planned until the GBRMPA Senior Management Team and the Minister for Environment and Heritage had been briefed.
3. The prior commitments in June –July 2006 of Traditional Owners and Professor Helene Marsh and the consequential difficulties of identifying mutually convenient dates for the workshops..

Appropriateness of the approaches used in the development and implementation of the Project

Aerial Survey
The approach used for the aerial survey was very successful. With input from statisticians and a stakeholder workshop in 2004, we rationalized the design of the 2005 aerial survey by: (1) plotting the dugong sightings obtained from all previous surveys on a common GIS database, and by (2) using the following rules:

1. Offshore transects were truncated if they extended out to areas where no dugongs were sighted on previous surveys.
2. The survey design was modified in areas without management initiatives to protect dugongs and with records of persistently low dugong abundance.

Only one dugong was sighted in the areas of persistently low dugong abundance surveyed using the low intensity zig-zag transects across the depth gradient. It was therefore not necessary to revert to the former more intensive survey design for these areas.

Workshops
In retrospective, it was probably unrealistic to timetable the workshops during the survey – the logistical constraints were too great. It has also proved difficult to identify dates for the workshops which are mutually convenient to Marsh and the Traditional Owners. The GBRMPA Community Partnerships Group is now facilitating the workshops, assistance which is proving invaluable. However, Executive Director of GBRMPA was not prepared to support this arrangement until after the Minister had been briefed.

.
Transferability of the research

As outlined above, we recommend that a plan be developed and co-ordinated across-jurisdictions to monitor the status of dugongs throughout their range in Australia using the revised aerial survey design and methodology used in this project which should become the standard for dugong aerial surveys in Australia. This resultant information on dugong distribution abundance and population trends could inform the development of a series of cross-jurisdictional management plans as outlined below.

In addition, we suggest that clear objectives for dugong management be developed at ecologically relevant spatial scales around the dugong's range in Australia perhaps thought the development of cross-jurisdictional management plans at ecologically relevant scales. e.g. urban cost of Queensland, Cape York coast of the Great Barrier Reef World Heritage Area, Torres Strait, Gulf of Carpentaria, northern coast of the Northern Territory, Kimberley Coast of Western Australia, Shark Bay –Ningaloo Coast of Western Australia. Each of these plans should address the imperative to co-ordinate dugong management at ecologically and culturally relevant scales to inform policy such as the 'Sustainable harvest of marine turtles and dugongs in Australia - A national partnership approach 2005'.

Project Milestones:

Milestone	Date Due	Completion Date	Comments
Appointment of part-time project officer to organise survey	31/12/05	31/12/05	
Training of observers for main survey.	31/12/05	31/12/05	
Progress Report 1 provided to and accepted by the Department by 31 December 2005	31/12/05	31/12/05	
Progress Report 2 provided to and accepted by the Department by 31 March 2006	31/03/06	31/03/06	
Completion of survey and community workshops	31/12/05	31/12/05	Survey completed; community workshops in progress following delay requested by GBRMPA Senior Management
Data analysis, report writing & education evenings completed.	31/03/06	31/03/06	Data analysis, report writing complete, education evenings not yet completed but planned see below
Final paper for publication submitted	30/06/06	28/07/06	Date changed by Department to 28/07/06
Final Report provided to and accepted by the Department by 30 June 2006	28/07/06	28/07/06	Date changed by Department to 28/07/06

Communication / demonstration activities

1. Workshops with traditional owners and other stakeholders in various towns between Cooktown and Moreton Bay during survey.

Despite attempts, these workshops were not completed because of the logistical constraints outlined above.

2. Education evenings traditional owners and other stakeholders in various towns between Cooktown and Moreton Bay.

Progress in arranging briefings Traditional Owner and others regarding the results of the dugong aerial survey is outlined below.

Activity	Date	Status
Presentation to GBRMPA Senior Management Team	May 8 2006	Completed
Presentation to Board Executive of TSRA	July 7 2006	Partially completed. Presentation focused on MTSRF projects at last minute request of Board Executive
Presentation to community at Dunwich North Stradbroke Island including Qunadamooka Traditional Owners	June 28 2006	Completed
Presentation to Butchella Traditional Owners in Hervey Bay	June 21 2006	Cancelled at last minute by Traditional Owners to be rescheduled
Townsville; presentation to Forging Partnerships workshop attended by traditional owners from Torres Strait and Hope Vale	July 27 2006	Completed
Townsville; presentation to Conservation, Heritage and Indigenous partnerships Reef Advisory Committee	Scheduled August 31 2006	
Ma:Mu (Innisfail)	Scheduled 10 August 2006	
Girringun (Cardwell)	Contacted date not yet confirmed- possibly on August 31 in Townville	
Townsville	Burdekin Dry Tropics NRM have been asked to assist and are exploring options.	
Mackay & Whitsunday	Tentatively scheduled for Monday 28 August 2006	
Durhambul (Rockhamption)	Tentatively scheduled for September 11 to 14	
Bailai (Gladstone)	Tentatively scheduled for 6-8 September 2006	

Products and Publications

<u>Products and publications generated from this Project.</u>

Publication submitted to journal Animal Conservation.

Marsh, H., Lawler, I.R. Hodgson, A. and Grech, A. in review. Is dugong management in the coastal waters of urban Queensland effective species conservation? Animal Conservation.

The aerial survey results have also been incorporated into two additional publications which are in review:

Grech A, and Marsh H. in review a. Can large, comprehensive and representative multiple-use MPA protect a mobile marine mammal? Conservation Biology.

Grech A, and Marsh H. in review b. Prioritising areas for dugong conservation in a marine protected area using a spatially explicit population model. Applied GIS.

Electronic versions of all materials which were direct products of this Project.

1. An electronic version of the journal article prepared from this project for submission to Animal Conservation is at Attachment 1.

2. Electronic version of maps showing the GPS tracks of transects flown during the aerial survey in November 2005 illustrating the positions and sizes of the dugong groups sighted and the transect numbers are at Appendix Figures 1-9.

3. Electronic version of the tables of raw data and supplementary material are at Appendix Tables 1-6.

4. Electronic versions of the briefings to GBRMPA and the Quandamooka people of Moreton Bay on the outcomes of the project is also provided on CD.

Attachment 1.
Paper prepared for submission to journal Animal Conservation plus references to the appendices provided to this report as Attachment 2

Is dugong management in the coastal waters of urban Queensland effective species conservation?

Helene Marsh, Ivan Lawler, Amanda Hodgson, and Alana Grech

School of Tropical Environment Studies and Geography, James Cook University, Douglas, Townsville, 4811 and CRCs Reef and Torres Strait P.O.Box 772 Townsville 4801, Australia

ABSTRACT

The dugong, *Dugong dugon*, is listed as vulnerable to extinction in Queensland, Australia. Triggered by the anecdotal and scientific evidence of dugong decline along the urban coast of Queensland between 15° 30'S and 28° S, generic conservation concerns and their statutory responsibilities, management agencies are attempting to address human impacts on dugongs through initiatives including banning the dugong oil industry in the 1960s; marine park zoning; controls on fisheries, shark netting, vessel movements and speeds; phasing out the use of high explosives in the Great Barrier Reef region; partnerships with Traditional Owners at culturally-relevant scales to manage Indigenous hunting; and initiatives to improve water quality. The conservation outcomes of these initiatives for dugongs have been monitored by aerial surveys of dugong distribution and abundance in various parts of the region since the mid 1980s. In this context, the results of the first survey of the whole

region in November 2005, suggest that dugong numbers are now stable at the scale of the entire urban coast although populations fluctuate at the level of individual bays, probably largely due to natural changes in seagrass habitats. However, it is impossible to evaluate the cumulative success of the management initiatives because policy is silent on whether population maintenance or recovery is the objective of dugong management. The results of the surveys indicate that it will be important to: (1) develop cross-jurisdictional objectives for the management of dugongs at the scale of the entire region, and (2) co-ordinate management at both culturally and ecologically relevant scales.

INTRODUCTION

In its ‘Programme of Work for Protected Areas’, the Convention on Biological Diversity, calls on Parties to ‘develop and adopt appropriate methods, standards, criteria, and indicators for evaluating management effectiveness and governance by 2008, and to assess at least 30% of their protected areas by 2010’ (Convention of Biological Diversity 2004). Attention is increasingly being focussed on measuring the effectiveness of the management of protected areas (e.g. Hockings et al. (2000), including marine protected areas (MPAs). For example, ‘Ensuring Effective Management’ was a theme at the First International Marine Protected Areas Congress (IMPAC1 2005) in October 2005 and a recent edition of the journal MPA News featured ‘Measurement of Management Effectiveness - The Next Major Stage in MPAs?’ (MPA News 2006a). Some initiatives assess Marine Management Areas rather than Marine

Protected Areas per se in order to include a wider breadth of sites and to avoid the political implications of 'marine protected areas' (MPA News 2006b).

We define the urban coast of Queensland Australia as the coast from Cooktown (15^{o} 29'S, 145^{o} 15'E) to the Queensland – NSW border (28^{o} 10'S; 145 44'E) (Figure 1). Over the last 30 years or so, the coastal waters of this region have been increasingly protected by the progressive establishment and upgrading of an extensive system of large scale multiple use MPAs including part of the Cairns Section and the Southern and Central Sections of the Great Barrier Reef Marine Park (e.g., Fernandes et al. 2005), the associated sections of the Great Barrier Reef Coast Marine Park (EPA 2006 a), the Great Sandy Marine Park (incorporating Hervey Bay; EPA 2006b) and the Moreton Bay Marine Park (EPA 2006c), plus other measures such as fisheries management plans developed by the Queensland Government and initiatives to mange Indigenous hunting (Marsh 1996, Havemann et al. 2005).

The urban cost of Queensland supports globally significant populations of the dugong, *Dugong dugon,* a coastal marine mammal that feeds mainly on seagrasses (Marsh et al. 2002). The significance of the Great Barrier Reef Region for dugongs was a reason for its World Heritage listing (GBRMPA 1981) and the status and trends in the distribution and abundance of dugongs is a critical information need for the management of the World Heritage Area (GBRMPA 2005). Dugong conservation has also been a priority in Hervey Bay (Marsh 2000) and Moreton Bay (Chilvers et al. 2005).

IUCN, the World Conservation Union, and the *Queensland Nature Conservation Act 1992*, both list the dugong as vulnerable to extinction (IUCN 2006). Both anecdotal information and an analysis of changes in the catch per unit effort of dugong bycatch in a government shark control program (Marsh et al. 2005) indicate that: (1) the urban coast of Queensland supported far fewer dugongs in the mid 1990s than in the 1960s, the first date for which any reliable indices of dugong abundance are available for this region, and (2) the decline largely occurred before the aerial surveys for dugongs reported here were established in the mid 1980s..

The relative importance of the various causes of the long-term decline in dugong numbers along the urban coast of Queensland cannot be quantified and probably varies in both space and time (Marsh et al. 1996). The likely causes include the commercial dugong oil industry, traditional hunting, poaching, incidental drowning in commercial gill nets as well as the shark nets set for bather protection, vessel strike, and habitat loss (Marsh et al. 1996). Triggered by the overall evidence of dugong decline, their statutory responsibilities and more generic conservation concerns, the relevant management agencies are attempting to address all known human impacts on dugongs by a comprehensive series of management interventions as detailed in Marsh (2000), Chilvers et al.(2005) and Marsh et al. (2002 and 2005). These initiatives include generic initiatives to protect the marine environment such as the establishment and rezoning of the MPAs listed above and interventions to improve water quality the GBR region and Moreton Bay (Schaffelke et al. 2001; GBRMPA 2006, Moreton Bay Waterways and Catchments Partnership 2006). In addition, as detailed by Marsh et al. (2005), there have been a series of more dugong-relevant initiatives including: (1) banning the commercial dugong oil industry in the 1960s; (2) partnerships between management agency staff and Traditional Owners to develop a mutually acceptable, legal framework for sustainable dugong hunting at culturally-relevant scales (Marsh 1996, Havemann et al. 2005; Anon 2005); (3) the replacement of shark nets by drum lines at most locations after reviews of the Shark Control Program (Anon 1992); (4) the establishment of Dugong Protection Areas in the Great Barrier Reef Region and Hervey Bay in 1997 (Marsh 2000), (5) voluntary vessel lanes and/or speed restrictions to protect dugongs from vessel strikes in several major dugong habitats (Marsh et al. 2002); (6) a review of the use of the herbicide diuron, which has been detected in both dugong tissues and the sediments associated with seagrass beds (Haynes et al. 2000) ; (7) a marine wildlife carcass salvage program (e.g. Greenland and Limpus 2005); and (8) a dugong research strategy which includes a dugong monitoring program based on aerial surveys (Oliver and Berkelmans 1999; Hodgson in press).

Marsh et al. (2005) point out that determining how these initiatives might individually or collectively contribute to measurable changes in trends in dugong abundance is challenging for several reasons including: (1) the lack of understanding of the spatial boundaries to dugong populations; (2) the lack of quantitative understanding of the relative importance of and spatial variation in the historical causes of dugong decline; (3) the fact that the initiatives described above have been implemented using the Precautionary Principle rather than as part of a controlled experiment in adaptive management sensu Walters (1997); and (4) the difficulty in detecting trends in population size in a timeframe relevant to management agencies (Gerrodette 1987, Marsh 1995). Nonetheless, if these management interventions are effective, we would expect the dugong population decline that occurred from the early 1960s (Marsh et al. 2005) to be halted or reversed. However, policy is silent on which of these outcomes is the objective of dugong management in the region e.g. the Great Barrier Reef World Heritage Area 25 Year Strategic Plan (GBRMPA 1994).

In this paper, we analyze the results of the first comprehensive aerial survey for dugongs across the entire region of the urban coast of Queensland in the context of the various aerial surveys conducted in parts of the region since 1986 using a standardized methodology. The latest survey was conducted in November 2005 using three aircraft to minimize the risk of the survey results being confounded by dugongs moving within the survey region during the survey. The objective of the survey was to measure the effectiveness of dugong management in the region and to inform policy such as the 'Sustainable harvest of marine turtles and dugongs in Australia - A national partnership approach 2005' (Anon 2005), the development of the East Coast Inshore Finfish Fisheries Management Plan (CRC Reef Research Centre 2005) and reviews of the various other management arrangements.

METHODS

Survey methodology

Surveys prior to 2005

All surveys used the aerial survey technique detailed in Marsh and Sinclair (1989). Various parts of the eastern coast of Queensland between the Queensland-NSW border and Cooktown were surveyed in different years as funding permitted using a standardized design as follows:

Moreton Bay: 1988 (Marsh and Saalfeld 1990a);1995 (Lanyon 2003); 2000 and 2001 (Lawler 2001).

Hervey Bay: 1988, 1992, 1993, (Marsh and Saalfeld 1990a, Preen and Marsh 1995); 1994 (Marsh et al. 1996), 1999 (Marsh and Lawler 2001); 2001 (Lawler 2001).

Central and Southern Sections of the Great Barrier Reef Marine Park: 1986/87 (Marsh and Saalfeld 1990b); 1992 (Marsh et al. 1994), 1994 (Marsh et al. 1996); 1999 (Marsh and Lawler 2001).

Cairns Section of the Great Barrier Reef Marine Park south of Cooktown: 1987 Marsh and Saalfeld (1990b); 1999 Marsh and Lawler (2001); 2000 (Marsh and Lawler (2002).

To minimize any seasonal effects, these surveys were conducted in November - December except for: (1) the 1988 Moreton Bay and Hervey Bay surveys which were conducted in August (Marsh and Saalfeld 1990a); and the 2001 aerial survey of Moreton Bay and Hervey Bay which was conducted in April (Lawler 2001). Lanyon's (2003) surveys of Moreton Bay were conducted on a bimonthly basis throughout 1995. We have used the results of her December 1995 survey to facilitate temporal comparisons.

2005 Survey

With input from statisticians and a stakeholder workshop in 2004 (Stokes 2004), we rationalized the design of the 2005 aerial survey by: (1) plotting the dugong sightings obtained from all previous surveys on a common GIS database, and by (2) using the following rules:

3. Offshore transects were truncated if they extended out to areas where no dugongs were sighted on previous surveys.
4. The survey design was modified in areas without management initiatives to protect dugongs and with records of persistently low dugong abundance (see Figure 1 for an example).

Funding was obtained to allow for adaptive sampling i.e. to enable reversion to the former higher density survey design if significant numbers of dugongs were encountered during the areas surveyed using the modified survey design.

This rationalisation and the use of three aerial survey teams and two aircraft operating concurrently enabled us to survey the entire region from the NSW-Queensland border (28^{o} 10’S; 145 44’E) to Cooktown (15^{o} 29’S, 145^{o} 15’E) in November 2005 as illustrated in Figure 1 and Appendix Figures 1-8. In addition, we surveyed a reference block in Torres Strait (see Figure 1 and Appendix Figure 9) to provide a context for the survey in the light of the satellite tracking (Sheppard et al. 2006) and aerial survey evidence (Gales et al. 2004; Marsh et al. 2004) of large-scale dugong movements at scales of hundreds of kilometers.

The Torres Strait reference block had previously been surveyed in November-December 1987, 1991, 1996, 2001 (see Marsh et al. 1997, 2004).

The total area surveyed in 2005 was 37163 km^2 along the east coast of Queensland and 4238 km^2 in Torres Strait The sampling intensity in the survey bocks surveyed using transects perpendicular to the coast ranged from approximately 11% in Block H3 to 50% in Block M4 (see Figure 1 and Appendix Table 1). The sampling intensity in the areas with records of persistently low dugong abundance (see Figure 1 and Appendix Table 1) ranged from 1.5% (Block C9) to 7.4% (Block H6).

Estimating the size of the dugong population

Estimates of dugong abundance were obtained using two methods: (1) Marsh and Sinclair (1989), which provides standardized relative estimates of dugong abundance (all surveys); and (2) Pollock et al. (2006), which provides an absolute estimate of dugong abundance on which to base the estimate of the total sustainable anthropogenic mortality from all causes (2005 survey only).

Both methods corrected for the following survey biases: availability bias (animals not available to observers because of water turbidity), and perception bias (animals visible in the survey transect but missed by observers; Marsh and Sinclair 1989)). The population estimates obtained using the method of Pollock et al*.* (2006) should be more accurate than the estimates obtained using the methods of Marsh and Sinclair (1989) because the corrections for availability bias are based on empirical data obtained from: (1) experiments to determine zones of detectability for dugongs over a range of depths, turbidities and sea states using fibreglass models of dugongs as ‘secchi disks’, and (2) dive profiles obtained from time depth recorders on 15 wild dugongs, enabling the probability of a dugong being available to be estimated for different depths, water turbidities, and sea states (Pollock et al*.* 2006).

Dugong abundance was estimated separately for each block surveyed using transects perpendicular to the coast using the Ratio Method (Jolly, 1969; Caughley and Grigg, 1981). 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 all the correction factors described above. Any dugongs in groups of $\geq$10 were added to the estimates of population size and density as outlined in Norton-Griffiths (1978). All population estimates are given $\pm$ standard error.

Statistical analysis

Differences in dugong density among survey years for the blocks surveyed using the same design over time were examined by analysis of variance using the data generated by the method of Marsh and Sinclair (1989). Blocks and years were treated as fixed effects, transects within blocks as a random effect. Mixed-effects models were employed using SPSS to estimate the random components of variance for this analysis 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

(REML). Dugong density 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. Beaufort Sea State was included as a single degree of freedom covariate in the analysis to account for the effect of sea state on dugong availability. The term estimating the linear association of Beaufort Sea State with density was conditional on the other terms in the model. The Satterthwaite approximation was used to determine the appropriate degrees of freedom for each test. When the analyses showed that the differences between years was significant, a posteriori Least Significance Tests were used to explore these differences by testing the dugong density in the area of interest for each survey against the corresponding density for every other survey in the time series for which comparable data were available.

Estimating the size of sustainable human-induced dugong mortality from all causes

Previous surveys of the whole Southern Great Barrier Reef region have shown that on average 77% of the dugongs were found in the areas covered by our rationalized design (see Appendix Table 6a). As the Pollock et al. (2006) method allows us to estimate absolute population size, we have: (1) assumed that the total population for this region should be divided by 0.77 and (2) used the uncorrected population estimates generated by the method of Pollock et al. (2006) for Hervey Bay and Moreton Bay.

The Potential Biological Removal (PBR) is defined as the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population, which is defined as a population level between carrying capacity and the population size at maximum net productivity. Thus the specific goal of the PBR is to allow each stock to reach or maintain a level at or above the maximum net productivity level (MNPL) (Wade 1998). The PBR was calculated using the following formula:

$$PBR = N_{min} \times 0.5\ R_{max} \times RF \text{ (Wade 1998)}$$

The minimum population estimate of the stock N_{min} is defined as the 20th percentile of a log-normal distribution based on an absolute estimate of the number of animals N in that stock.

R_{max} is the maximum rate of increase and 0.5 R_{max} is a conservative surrogate for R_{MNPL} because 1/2 R_{max} will always be < R_{MNPL} if MNPL is $\geq$ carrying capacity (Wade 1998). The estimates of R_{max} are based on empirical estimates of age of first reproduction and fecundity obtained by Boyd et al. (1999) and Kwan (2002) and a pattern of natural mortality based on that obtained from longitudinal studies of manatees (Eberhardt and O'Shea, 1995; Langtimm, *et al.*, 1998). In view of the uncertainty associated with these estimates, we used a range of estimates for R_{max} (0.01, 0.03, 0.05).

A recovery factor (RF) of < 1 allocates a proportion of expected net production towards population growth and compensates for uncertainties that might prevent population recovery, such as biases in the estimation of N_{min}, and R_{max} or errors in the determination of stock structure. The value of the recovery factor depends on the conservation goal. We used recovery factors of 0.1 (because of the evidence that the population is severely depleted, Marsh et al. 2005), 0.5 (the default value, Wade 1998) and 1.

RESULTS

The 2005 survey was conducted in good to excellent weather conditions comparable to conditions encountered in previous surveys as summarized in Appendix Tables 2a, 2b and detailed in Appendix Table 3.

Aerial survey estimates of dugong density and population size for blocks surveyed over the time series

The raw data for sightings of dugong groups for each transect in each block surveyed in 2005 used to estimate population size are detailed in Appendix Table 4 and Appendix Figures 1-9. Appendix Table 5 details the group size estimates and correction factors used to generate the dugong population estimates for the various regions in 2005 using the method of Marsh and Sinclair (1989).

Moreton Bay

Using the method of Marsh and Sinclair (1989), the estimated size of the dugong population in 2005 (Figure 2a) was 454 $\pm$41 which was very similar to the corresponding estimates for the same blocks and transects in 1988 (442 ± 69; Marsh and Saalfeld1990a) and November 2001 (493 ± 45, Lawler 2001) but much lower than the corresponding estimate (968 ±44) derived by Lanyon (2003) in December 1995 (Figure 2a) and higher than the estimates of Lawler (2001) in 2000-1 (344 ± 88, December 2000; and 366 ±41, April 2001) (see also Appendix Tables 6 b and c for details).

There was a significant difference between the years for which raw data were available (2000, April and November 2001 and 2005) in the estimates of dugong density in the survey blocks (Table 1) flown on each of these surveys. However, no individual pair-wise comparison was significant (all P>0.1) a result of the relatively weak power of such tests. The year*block interaction was also not significant suggesting that the spatial differences between blocks were robust over time (Table 1). The random variance component corresponding to the among transect within block variation is much larger than the corresponding value for the variance among transects within blocks among years (error) suggesting that the use of habitat within blocks by dugongs is also relatively constant over time (Table 1).

Hervey Bay

Using the method of Marsh and Sinclair (1989), the estimated size of the dugong population in 2005 was 2547 ± 410 compared with 2175 ± 419 in 1988, 1088 + 382 in 1992, 524 ± 124 in 1993, 695 ±140 in 1994, 1653 ±248 in 2001 (Figure 2b) see also Appendix Tables 6 b and c for details). This result suggests that the dugong population in Hervey Bay has recovered from the loss of 1000 km^2 of seagrass habitat in 1992 (Preen and Marsh 1995).

Surprisingly, the differences between years for which the raw data are available for Hervey Bay (1994, 1999, April 2001, November 2001 and 2005) in the estimates of dugong density were not significant (Table 1) indicating the relatively weak power of surveys to detect trends unless they are very large (Gerrodette 1987). However, when the analysis was repeated at the scale of the Southern GBR and Hervey Bay combined for 1994, 1999 and 2005, the difference between years was significant (Table 1) and pair-wise comparisons indicated that the density for the whole region in 1994 was lower than that for 1999 and 2005 which were not significantly different from each other (P=0.088).

The year*block interaction for the Hervey Bay analysis was also not significant (P= 0.079) but Figure 3 suggests some temporal variation in the spatial differences between blocks, especially Block 2, a region severely affected by the seagrass dieback following the floods and cyclone in 1992 (Preen et al. 1995). The random variance component corresponding to the among transect within block variation among years (error) for Hervey Bay alone is much larger than the corresponding value for the variance among transects within blocks suggesting that, unlike the situation in Moreton Bay, dugongs also make substantial small-scale movements within blocks in Hervey Bay over time (Table 1).

Central and Southern GBR regions

Using the method of Marsh and Sinclair (1989), the estimated size of the dugong population in 2005 in the 11 GBR blocks and transects which had been surveyed in all years of the time series (Figure 1) was 2580 ± 271 compared with the corresponding estimates for the same blocks and transects in 1986/87 (2294 ± 291), 1992 (1121 ± 238), 1994 (1177 ±203), and 1999 (2519 ± 559) (Figure 2c; see also Appendix Table 6a for details).

There was a significant difference between years (1986/87, 1992, 1994, 1999, 2005) in the estimates of dugong density in these 11 survey blocks (Table 1). Pair-wise comparisons indicate that the density in 2005 was significantly ($P<0.05$) higher (than that for every year except 1999, where the difference approached significance ($P=0.054$). The year*block interaction was significant suggesting that these spatial differences vary with time, especially in Block C6 (Upstart Bay) and Block C10 Hinchinbook (Table 1 and Figure 4). The random variance component corresponding to the among transect within block variation among years (error) is much larger than the corresponding value for the variance among transects within blocks suggesting that, as in Hervey Bay, dugongs also make substantial small-scale movements within blocks over time.

Torres Strait Reference Block

Using the method of Marsh and Sinclair (1989), the estimated size of the dugong population in 2005 in Blocks 2A (Figure 1) was 4251 ± 819, compared with 6424 ±1679 in 1987, 9313 ±1798 in 1991, 10869 ±1600 in 1996, and 3504

± 403 in 2001 (Figure 2d). The difference in dugong density between years was significant and the pair-wise comparisons indicted that the density in 2005 was significantly lower than that for 1991 and 1996 ($P<0.05$) but not significantly different from the value for 1987 or 2001 ($P \geq 0.75$).

Aerial survey observations in areas of persistently low dugong abundance

Only one dugong was sighted in the areas of persistently low dugong abundance surveyed using the low intensity zig-zag transects across the depth gradient (see Appendix Figures 1-8). It was therefore not necessary to revert to the former more intensive survey design for these areas.

Comparison between methodologies

All the population estimates for 2005 using the method of Pollock et al. (2006) were lower (80-95%) than the corresponding estimates using the older less accurate methodology of Marsh and Sinclair (1989; Table 2).

Estimating a sustainable level of human-induced mortality for dugongs along the urban coast of Queensland

The range of estimates for sustainable anthropogenic mortality (Potential Biological Removal) are summarized in Table 3 for the 2005 estimates of dugong population size calculated using the method of Pollock et al. (2006) . The middle value for the estimated maximum rate of increase R_{max} (=0.03) suggest that a total annual anthropogenic mortality of no more than seven dugongs would be required for population recovery if the recovery factor were set at a conservative 0.1; whereas a total annual anthropogenic mortality of 34 dugongs would allow recovery if the recovery factor was set at 0.5; 69 if the recovery factor was set at1.

DISCUSSION

Comparison of the results of the 2005 survey with the corresponding results from the previous surveys of various parts of the urban coast of Queensland since the 1980s (Figure 2a-c) suggests that dugong numbers are now stable at the scale of the whole urban coast and over a time frame of two decades. Nonetheless, dugong populations fluctuate at the level of individual bays and over shorter time periods (Table 1 and Figures 2 - 4), probably largely due to natural changes in seagrass habitats. For example, 1000 km^2 of seagrass was lost from Hervey Bay following two floods and a cyclone in 1992 (Preen and Marsh 1995; Preen et al. 1995). Twenty-one months after the cyclone, the estimated size of dugong population was less than a quarter of the corresponding 1988 estimate (Preen and Marsh 1995) a result of both mortality and emigration. Unprecedented numbers of dugong carcasses were recovered along the coast in the months following the cyclone and the aerial surveys of Moreton Bay (using a standardized technique different from that reported here) suggests that some dugongs successfully relocated from Hervey Bay to nearby areas (Preen and Marsh 1995).

Comparison of the 2005 results with those from previous surveys of various parts of the urban coast (Table 1 and Figures 2-4) adds to the aerial survey evidence of significant large-scale dugong movements in the following regions: (1) the urban coast (Marsh and Lawler 2001), (2) northern Great Barrier Reef (Marsh and Lawler (2002), (3) Western Australia (Gales et al. 2004, Holley et al. 2006) and (4) Torres Strait (Marsh et al.1997, 2004). Large-scale movements of individual dugongs have been confirmed by satellite tracking (Marsh and Rathbun 1990, Sheppard et al, 2006). While some dugong movements are explained by known changes in seagrass habitats (Preen and Marsh 1995, Gales et al. 2004), others are not. For example, we do not know what caused the decline in dugong numbers in the southern Great Barrier Reef region in the mid 1990s (Figure 2c), although undocumented changes to seagrass habitats cannot be ruled out as a stimulus to dugong movements. We also do not know how much of the change can be attributed to dugong mortality rather than emigration. However, the inverse changes in dugong numbers in Moreton Bay (Preen and Marsh 1995, Lanyon 2003 and a 2), and Torres Strait (Marsh et al. 2004 and Figure 2d) suggest that movement between regions is a plausible explanation for at least part of the change. This conclusion is consistent with the genetic evidence of limited dugong population structure along the Australian coast (McDonald 2005) and satellite tracking records of individual dugongs moving hundreds of kilometres in a few days (Marsh and Rathbun 1990, Sheppard et al. 2006).

Need for co-ordinated management at an ecologically-appropriate scale

The genetic, satellite tracking and aerial survey evidence all indicates that for dugong management to be effective, initiatives must be co-ordinated across jurisdictions**.** Genetically-appropriate clear spatial boundaries for implementing co-ordinated dugong management within Australian waters have not been identified (and may not exist). Nonetheless, the genetics and movement data both indicate that the appropriate ecological scale for management is some hundreds of kilometres (McDonald 2005; Sheppard et al, 2006). In view of this uncertainty, we suggest that it may be appropriate to define the scale of dugong management in Queensland on the basis of the human impacts on dugongs and their habitats, differentiating dugong management of the urban coast between Cooktown and the Queensland-New South Wales border from that of the remoter areas off Cape York, in Torres Strait and in the Gulf of Carpentaria where the relative importance of the human impacts is different. This approach could be implemented by the Queensland Government and the Great Barrier Reef Marine Park Authority developing a single dugong management plan for the urban coast of Queensland. The Queensland Government conservation plan for the dugong (Anon 1999) is dated 1999-2004 making such an approach timely.

The dugong management plan for the urban coast of Queensland should address all anthropogenic impacts on dugongs in the region in partnership with other management initiatives such as the ‘Sustainable harvest of marine turtles and dugongs in Australia - A national partnership approach 2005’ (Anon 2005), the Traditional Use Marine Resource Agreements being developed between the Great Barrier Reef Marine Park Authority and groups of Traditional Owners (Havemann et al. 2005) and the East Coast Inshore Finfish Fishery Management Plan currently being developed by the Queensland Government. The greatest area of concern in the inshore fishery is bycatch of non-target animals such as dugongs in gill-nets set to catch fish such as barramundi and threadfin salmon (CRC Reef Research 2005). Havemann et al. 2005) suggest superimposing a dugong management plan onto the local area-based approach of Traditional Use Resource Management Agreements to enable the management of Indigenous hunting of dugongs which is developed at the culturally-appropriate scales of the sea country of Traditional Owners to be co-ordinated at an appropriate ecological scale.

Is the current management of dugongs on the urban coast of Queensland effective species conservation?

Our capacity to use the results of the time series of aerial surveys reported here to assess the effectiveness of dugong management along the urban Queensland coast is compromised by the lack of explicit objectives against which to assess the species conservation outcome. If the objective of the current management arrangements is dugong population maintenance then these arrangements appear successful; if the objective is population recovery they are not. The ecological objectives of dugong management should be defined during the development of a dugong management plan for the urban coast of Queensland, along with the social and cultural objectives of the plan.

Because of the difficulties in estimating trends in the population size of marine mammals such as the dugong, Wade (1998) developed the Potential Biological Removal (PBR) method of setting targets for sustainable levels of anthropogenic mortality. As explained above, a recovery factor of < 1 allocates a proportion of expected net production towards population growth and compensates for uncertainties and biases in the data that might prevent population recovery, including errors in estimating population size (which should be less for dugongs using the method of Pollock et al (2006) than the earlier method of Marsh and Sinclair (1989) (Table 2)).

Given that the Great Barrier Reef Region is a World Heritage Area and that the dugong is explicitly listed as a World Heritage Value (GBRMPA 1981), some stakeholders will argue for a conservative recovery factor of 0.1 in a planning process. Others may argue for the default value of 0.5 or even a value of 1. We strongly advise against the last as it does not allow for uncertainty in the data. The resultant estimates of the PBR for urban coast of Queensland range from 2 to 114 (Table 3, illustrating the importance of stakeholder consensus about the appropriate level of the recovery factor.

If the agreed recovery factor is 0.1, management should be implemented with the aim of achieving an anthropogenic mortality target of zero. This approach would have the following consequences: (1) the Traditional Owners would have to be encouraged not to hunt dugongs as at present; (2) the inshore gill net fishery would probably be closed in all dugong habitats; and (3) measures to reduce vessel strike would have to be upgraded. If the agreed recovery factor were 0.5, the measures to minimize human-induced mortality of dugongs on the urban coast of Queensland would be less stringent but management priorities would need to be determined across the human impacts on dugongs.

The Australian Law Reform Commission (1986) considered the tensions between conservation and traditional hunting and suggested the following principles in the following order of priority: (a) conservation and certain other identifiable overriding interests; (b) traditional hunting and fishing; (c) commercial and recreational hunting and fishing. The Law Reform Commission report was superseded by the Native Title Act 1993 (Cth), and has never been implemented. Nonetheless, we suggest that these priorities should be discussed by stakeholders in the process of developing a dugong management plan for the urban coast of Queensland.

As discussed in Marsh et al. (2005), progress in achieving an agreed anthropogenic mortality target could be monitored through the Queensland Government carcass salvage program (e.g. Greenland and Limpus 2004). The following inadequacies would have to be acknowledged: (1) this program will inevitably fail to recover an unknown proportion of carcasses, (2) an unknown proportion of carcasses will result from natural mortalities, and (3) the cause of death of a significant fraction of carcasses will be unable to be determined. An advantage of this approach is that the necropsy program potentially allows managers to evaluate their initiatives by tracking the relative importance of the various sources of mortality (assuming that the resultant carcasses are equally available). The major justification for aerial surveys at regular intervals (say every five years) would then be to update the sustainable anthropogenic mortality target using the PBR technique (Wade 1998).

Grech and Marsh (in review a) applied a different approach to assess the effectiveness of the current dugong management regime in the GBR World Heritage Area only. Using all the information from all the aerial surveys, including the November 2005 survey, Grech and Marsh (in review b) developed a spatially explicit dugong population model to prioritize conservation initiatives for dugongs in the GBR World Heritage Area. They then used the resultant map of dugong conservation value of the Area as a spatial parameter to determine the potential effectiveness of the current management regime. With the assistance of a focus group, they ranked five anthropogenic activities with the potential to have an adverse impact on dugongs and their seagrass habitats: netting, trawling, Indigenous hunting, vessel activity and terrestrial runoff. Using a spatial risk assessment approach, Grech and Marsh (in review a) quantified the protection afforded to dugongs by the current management arrangements, and evaluated options for further protection. They concluded that the present management arrangements gave a high level of protection to all of the high value dugong areas on the urban coast; 95% of the medium value dugong areas and 42% of the low value areas. However, they were unable to evaluate this result in the context of management effectiveness because of the lack of objectives for the arrangements to protect dugongs in the GBR World Heritage Area. Grech and Marsh (in review a) stressed the importance of cross-jurisdictional multi-agency co-ordination to enable all dugong's anthropogenic impacts to be addressed, reinforcing the findings of this paper.

Implications for measuring the effectiveness of marine species conservation initiatives

Our attempt to evaluate the effectiveness of the initiatives to conserve dugongs in the coastal waters along the urban coast of the Queensland has generic implications for the conservation and management of marine wildlife. Many iconic marine wildlife species cross jurisdictional boundaries. This tendency means that it is essential to co-ordinate management across jurisdictions and at both ecologically and culturally-relevant spatial scales. Finally in order to assess the success of management interventions, it is essential to work with stakeholders to determine clear management objectives. This is a major challenge in World Heritage Areas such as the Great Barrier Reef where the imperative to conserve World Heritage Values should necessitate a statutory regime that is far more stringent than those of adjacent areas.

Various authors including Dayton et al. (1998), Roman and Palumbi (2003) and Marsh et al. (2005) have commented on the difficulties associated with developing appropriate conservation and restoration goals for marine ecosystems and species. The assessment of whether management actions are achieving their objectives ultimately requires the capacity to measure the effectiveness or otherwise of management actions against agreed and realistic targets. However, if the management objective is recovery, appropriate interim performance indictors could be: (1) population increase (rather than decline or maintenance), which may be an insensitive performance indicator because of the difficulty in detecting trends (Gerrodette 1987); or (2) an anthropogenic mortality target that is sufficiently conservative to ensure recovery using a modelling technique such as that developed by Wade (1998).

ACKNOWLEDGMENTS

The survey was funded by transition funding from the Marine and Tropical Scientific Research Facility, CRC Reef and CRC Torres Strait. We thank the following people for their invaluable assistance with the survey and/or the subsequent report:

- Our observers: Isabel Beasley, Susan Crocetti, Katrina Goudkamp, Ellen Hines, Jillian Grayson, Lucy Marcus, Adrian McMahon, Sarah Salmon, Fernandinha Sarto, Heidi Schuttenberg, Josh Smith;
- The management and staff of Cape York Air andand Sherwell Aviation, especially our pilots Charlotte Hillenbrand and Max Davy;
- Kirstin Dobbs from GBRMPA for her support and for arranging for two GBRMPA staff members to be available as observers;
- Steve Delean, Matt Allldredge, Ken Pollock and Lachlan Marsh for assistance with data analysis;

- Lachlan Marsh and Keith Saalfeld for developing the data logging software;
- Chloe Schauble for project management;
- Adella Edwards for assistance with the maps;
- Rachel Groom for assistance with tables and data management.

REFERENCES

Anon. 1992. Review of the operation and maintenance of shark meshing equipment in Queensland waters. Report of the Committee of Enquiry. Queensland Department of Primary Industries, Brisbane, Australia.

Anon 1999. Dugong conservation strategy Environmental Protection Agency Queensland (1999) Conservation and management of the dugong in Queensland 1999-2004. Environmental Protection Agency, Queensland, Brisbane.

Anon. 2005. Sustainable harvest of marine turtles and dugongs in Australia - A national partnership approach 2005. Available from the Internet. URL:http://www.deh.gov.au/coasts/species/turtles/national-approach.html#download.

Australian Law Reform Commission. 1986. The recognition of Aboriginal customary laws. Reports of the Australian Law Reform Commission 31(2). AGPS, Canberra.

Boyd I. L., Lockyer, C., and Marsh, H.D. 1999. Reproduction in Marine Mammals. Pages 218-286 in J.E. Reynolds and J.R. Twiss, editors. Marine Mammals. Smithsonian Institution Press, Washington, D.C., USA.

Caughley, G. and Grigg G. C. 1981. Surveys of the distribution and density of kangaroos in the pastoral zone of South Australia, and their bearing on the feasibility of aerial surveys in large and remote areas. Australian. Wildlife Research . 8: 1-11.

Convention of Biodiversity. 2004. Seventh meeting of the conference of the parties to the Convention on Biological Diversity (COP 7). February 2004 Kuala Lumpar Malaysia. Decision vii/28 protected areas (articles 8 (a) to (e)) URL**:** http://www.biodiv.org/decisions/default.aspx?dec=vii/28.

Chilvers B.L., Lawler, I.R., Macknight, F, Marsh, H., Noad, M., and Paterson, R. 2005. Moreton Bay, Queensland, Australia: an example of the co-existence of significant marine mammal populations and large-scale coastal development. Biological Conservation 122: 559-571.

CRC Reef Research. 2005. Queensland's east coast inshore finfish fishery. in ‘fisheries of Queensland's east coast: current state of knowledge’. URL http://www.reef.crc.org.au/research/fishing_fisheries/ statusfisheries/ statusinshore.htm.

Dayton, P.K., Tegner, M., Edwards, P.B. and Riser, K.L.. 1998. Sliding baselines, ghosts and reduced expectation in kelp forest communities. Ecological Applications 8: 309-322.

Eberhardt, L. L. & O'Shea T. J. 1995. Integration of manatee life-history data and population modeling. In Population Biology of the Florida Manatee (Trichechus manatus latirostris): 269-279. O'Shea, T.J., Ackerman, B.B.

& Percival, H.F. (Eds.). National Biological Service, Information and Technology Report 1.

EPA. 2006 a. GBR Coastal Marine Park. URL: http://www.epa.qld.gov.au/ parks_and_forests/marine_parks/gbr_coast_marine_park/

EPA. 2006 b. Great Sandy Marine Park. URL: http://www.epa.qld.gov.au/ parks_and_forests/marine_parks/great_sandy_marine_park/

EPA. 2006 c. 2006c. Moreton Bay Marne Park. URL: http://www.epa.qld.gov.au/ parks_and_forests/marine_parks/ /marine_parks/moreton_bay/

Fernandes, L., Day, J., Lewis, A., Slegers, S., Kerrigan, B., Breen, D., Cameron, D., Jago, B., Hall, J., Lowe, D., Innes, J., Tanzer, J., Chadwick, V, Thompson, L, Gorman, K, Simmon, M, Barnett, B, Sampson, K., De'ath, G., Mapstone, B., Marsh, H., Possingham, H. , Ball, I., Ward, T. , Dobbs, K., Zumend, J., Slater, D., and Stapleton, K. 2005. Establishing representative no-take areas in the Great Barrier Reef: large-scale implementation of theory on marine protected areas. Conservation Biology: 19 1733-1744.

Gales, N., McCauley, R., Lanyon, J. and Holly, D. 2004. Change in the abundance of dugongs in Shark Bay, Ningaloo and Exmouth Gulf, Western Australia: evidence for large-scale migration. Wildlife Research 31: 283-290.

GBRMPA. 1981. Nomination of the Great Barrier Reef by the Commonwealth of Australia for inclusion on the World Heritage List. UNESCO 37 pp.

GBRMPA. 1994. The 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area. URL: http://www.gbrmpa.gov.au/corp_site/ about_gbrmpa/25-year_strategic_plan.html

GBRMPA 2005. Research Needs for the Protection and Management of the Great Barrier Reef Marine Park.URL: http://www.gbrmpa.gov.au/corp_site/ info_services/science/research_priorities/database/

GBRMPA 2006. Water Quality. http://www.gbrmpa.gov.au/ corp_site/ key_issues/water_quality/index.html

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology 68: 1364-1372.

Grech A, and Marsh H. in review a. Can large, comprehensive and representative multiple-use MPA protect a mobile marine mammal? Conservation Biology

Grech A, and Marsh H. in review b. Prioritising areas for dugong conservation in a marine protected area using a spatially explicit population model. Applied GIS.

.Greenland, J. A. and Limpus, C. J..2005. Marine Wildlife Stranding and Mortality Database Annual report 2004. I. Dugong. Conservation technical and data report 2004(1) ISSN 1449-194X. Queensland Government environment Protection Agency, Brisbane, 27pp.

Havemann, P., Thiriet, D., Marsh, H., and Jones, C. 2005. Decolonising conservation? Traditional use of marine resources agreements and dugong hunting in the Great Barrier Reef World Heritage Area. Environmental and Planning Law Journal. 22: 258-280.

Haynes, D., Ralph, P., Pranges, J.. and Dennison, B.. 2000. The impact of the herbicide diuron on photosynthesis in three species of tropical seagrass. Marine Pollution Bulletin 41:288-293.

Hocking, M., Stolton, S. and Dudley, N. 2000. Evaluating effectiveness :A framework for assessing the management of protected areas. IUCN, Gland, Switzerland and Cambridge, UK. 121pp.

Hodgson, A. in press. A Dugong Research Strategy for the Great Barrier Reef World Heritage Area. GBRMPA Research Publication. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Holley D, Lawler I.R., Gales, N. 2006. Summer survey of dugong distribution and abundance in Shark Bay reveals additional key habitat area. Wildlife Research 33:243-250.

IMPAC1 (2005) Conference website: the First International Marine Protected Areas Congress Geelong, Australia 23-28 October 2005 http://www.impacongress.org/.

IUCN 2006. IUCN Red List of threatened species. URL: www.iucnredlist.org.

Jolly, G. M. 1969. Sampling methods for aerial censuses of wildlife populations. East African Forestry Journal. 34: 46-49.

Kwan, D. 2002. Towards a Sustainable Indigenous Fishery for Dugongs in Torres Strait: A Contribution of Empirical Data and Process. Unpublished PhD thesis, James Cook University, Townsville, Australia.

Langtimm, C. A., O'Shea, T. J., Pradel, R. and Beck, C. A. 1998. Estimates of annual survival probabilities for adult Florida manatees (Trichechus manatus latirostris). Ecology 79: 981-997.

Lanyon, J. M. 2003. Distribution and abundance of dugongs in Moreton Bay, Queensland, Australia. Wildlife Research 30: 389-396.

Lawler I.R.2001. Distribution and abundance of dugongs and other megafauna in Moreton Bay and Hervey Bay between December 2000 and November 2001. Unpublished report to Queensland Parks and Wildlife Service, Brisbane.

Marsh, H. 1995. Limits of detectable change. Pages 122- 130 in: G.Grigg, P.Hale and D. Lunney editors. Conservation through Sustainable Use of Wildlife. Surrey Beatty & Sons, Sydney.

Marsh, H. 1996. Progress towards the sustainable use of dugongs by Indigenous peoples in Queensland. Pages 139-151 in T. M. Bomford and J. Caughley, editors. The sustainable use of wildlife by Aboriginal and Torres Strait Islander people. AGPS, Canberra, Australia.

Marsh, H. 2000. Evaluating management initiatives aimed at reducing the mortality of dugongs in gill and mesh nets in the Great Barrier Reef World Heritage Area. Marine Mammal Science 16: 684-694.

Marsh, H. and Lawler, I. R. 2001. Dugong distribution and abundance in the Southern Great Barrier Reef Marine Park and Hervey Bay: Results of an aerial survey in October-December 1999. GBRMPA Research Publication 70. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Marsh, H. and Lawler, I. R. 2002. Dugong distribution and abundance in the Northern Great Barrier Reef Marine Park: November 2000. GBRMPA Research Publication 77. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Marsh, H. and Rathbun, G.B. 1990. Development and application of conventional and satellite radio -tracking techniques for studying dugong movements and habitat usage. Australian Wildlife. Research 17: 83-100.

Marsh, H., and Saalfeld, W.K. 1990a. The distribution and abundance of dugongs in southern Queensland. Unpublished final report to the Queensland Department of Primary Industries, Fisheries Management Branch, September 1990.

Marsh,H. and Saalfeld, W. K. 1990b. The distribution and abundance of dugongs in the Great Barrier Reef Marine Park, south of Cape Bedford. Australian Wildlife Research 17: 511-524.

Marsh, H. and Sinclair, D.F. 1989. Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. Journal of Wildlife Management 53: 1017-1024.

Marsh, H. Breen, B. and Preen, A.R. 1994.. *The status of dugongs, sea turtles and dolphins in the Great Barrier Reef region, south of Cape Bedford.* Unpublished report to the Great Barrier Reef Marine Park Authority, January 1994.

Marsh, H., Corkeron, P., Lawler, I. R., Lanyon, J. M.and Preen, A. R. 1996. The status of the dugong in the Southern Great Barrier Reef Marine Park. Great Barrier Reef Marine Park Authority Research Publication 41. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Marsh, H., Harris, A.N.M. and Lawler, I.R. 1997. The sustainability of the Indigenous dugong fishery in Torres Strait, Australia/Papua New Guinea. Conservation Biology. 11: 1375-1386.

Marsh, H., Penrose, H. Eros, C. and Hugues, J.. 2002. The Dugong (Dugong dugon) Status Reports and Action Plans for Countries and Territories in its Range. United Nations Environment Programme, Early Warning and Assessment Report Series, 1. UNEP, Nairobi, Kenya.

Marsh, H., Lawler, I., Kwan, D., Delean, S., Pollock, K. and Alldredge, M. 2004 Aerial surveys and the potential biological removal technique indicate that the Torres Strait dugong fishery is unsustainable. Animal Conservation. 7: 435-443.

Marsh, H., De'Ath, G., Gribble, N., and Lane, B. 2005. Historical marine population estimates: Triggers or targets for conservation? The dugong case study. Ecological Applications 15: 481-492.

Mc Donald, B. 2005. Population Genetics of Dugongs around Australia; implications for contemporary management. Unpublished PhD thesis, James Cook University, Townsville, Australia.

Moreton Bay Waterways and Catchments Partnership 2006. URL:http://www.healthywaterways.org/PAGE170551PMF2B8MG.html.

MPA News. 2006a. Special Feature: Measurement of Management Effectiveness - The Next Major Stage in MPAs? MPA News 7(10). May 2006.

MPA News. 2006b. Research Spotlight: Project Seeks Answers to What Makes an MPA Effective, Among Other Questions. MPA News 8(1).July 2006.

Norton-Griffiths, M. N. 1978. Counting Animals. Africa Wildlife Leadership Federation.

Oliver, J. and Berkelmans, R. 1999. A Dugong Research Strategy for the Great Barrier Reef World Heritage Area and Hervey Bay. GBRMPA Research Publication 58. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Pollock, K., Marsh, H., Lawler, I., and Alldredge, M. 2006. Modelling availability and perception processes for strip and line transects: an application to dugong aerial surveys. Journal of Wildlife Management 70:255-262.

Preen A. and Marsh, H. 1995. Response of dugongs to large-scale loss of seagrass from Hervey Bay, Queensland, Australia. Wildlife Research 22:507-519.

Preen, A. R., Lee Long, W. J. and Coles, R. G.1995. Flood and cyclone related loss, and partial recovery, of more than 1000 km^2 of seagrass in Hervey Bay, Queensland, Australia. Aquatic Botany 52: 3-17.

Roman, J. and. Palumbi, S. H. 2003. Whales before whaling in the north Atlantic. Science 301: 508-510.

Schaffelke, B., Waterhouse, J. and Christies, C. 2001. A review of water quality issues influencing habitat quality in dugong protection areas. Great Barrier Reef Marine Park Authority Research Publication 66. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Sheppard J, Preen A.R., Marsh H., Lawler I.R., Whiting S, and Jones R.E. Movement heterogeneity of dugongs, Dugong dugon (Müller) over large spatial scales. Journal of Experimental Marine Biology and Ecology 334 :64–83.

Stokes, T. 2004. Report of a Workshop on Future Aerial Surveys for dugongs in Queensland and the Torres Strait held at the CRC Reef Research Centre on Friday 12 March 2004. Unpublished report to CRC Reef Research.

Wade, P.R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science 14): 1-37.

Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Conservation Ecology [online]1(2):1. URL: http://www.consecol.org/vol1/iss2/art1.

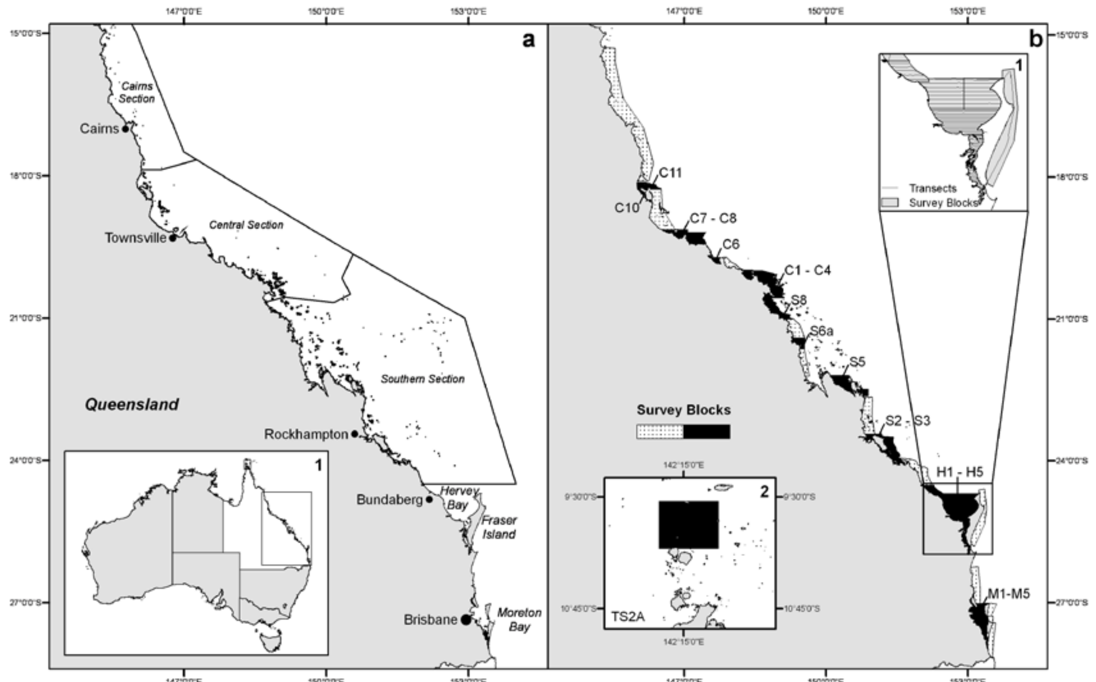


Figure 1. Maps showing the region surveyed during the aerial survey for dugongs conducted in November 2005. (a) The urban coast of Queensland, Australia (see inset a 1) showing the locations of the major cities and towns, the relevant Sections of the Great Barrier Reef Marine Park, and the locations of the major dugong habitats south of the Great Barrier Reef Region; (b) the locations of the survey blocks: the blocks surveyed using transects parallel to the coast (see inset b1 for an example) are black; those checked using zig zag transects across the depth gradient are stippled (see inset b1 for an example along the outside of Fraser Island). The Torres Strait Index Block is marked in inset b2. Details of the parallel transects flown are also provided in Marsh and Saalfeld (1990) and Marsh et al. (2004).

[redacted]

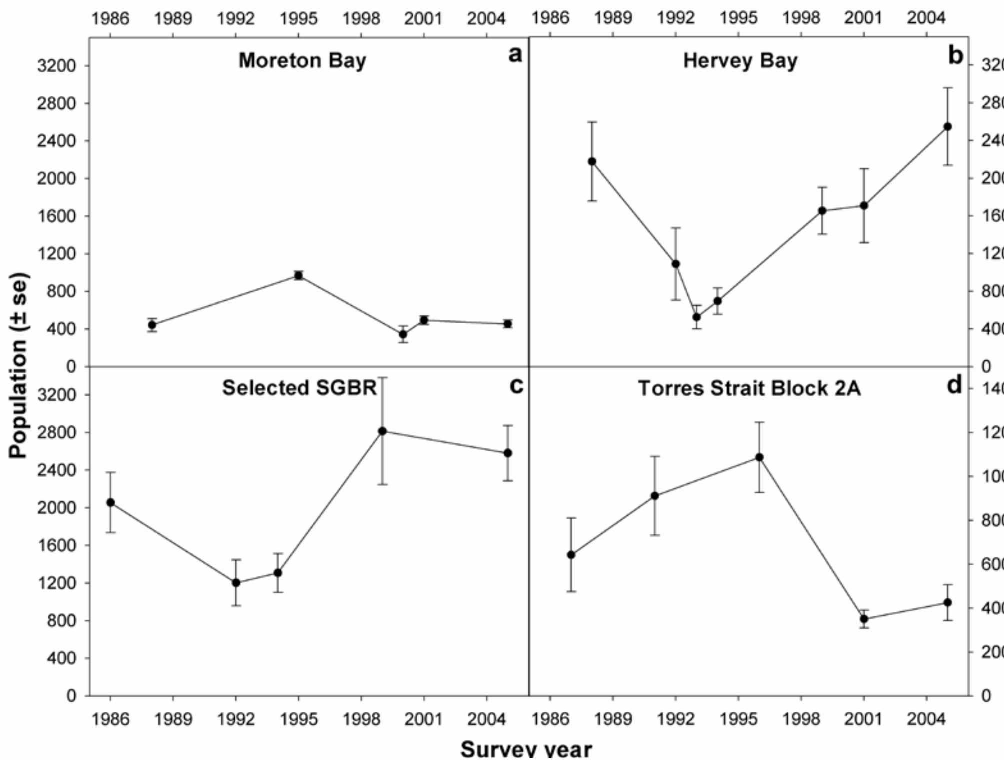


Figure 2. Graphs showing the time series of population estimates obtained from standardized aerial surveys of various parts of Queensland including the 2005 survey reported here. All estimates analysed using the techniques of Marsh and Sinclair (1989): (a) Moreton Bay (historical data from Marsh et al.(1990) Lanyon (2003 data for December 2005); Lawyer (2001); (b) Hervey Bay (historical data from Marsh et al., (1990), Preen and Marsh (1995), Marsh and Lawler (2000), Lawler (2001); (c) survey blocks in Southern and Central Sections of the Great Barrier Reef Marine Park surveyed in 2005 (historical data from Marsh and Saalfeld 1990; Marsh et al, 1996; Marsh and Lawler 2000); (d) Torres Strait Block 2A (historical data from Marsh et al. 1997, 2004). Note scale of y axis of (d) differs from y axes of (a), (b) and (c).

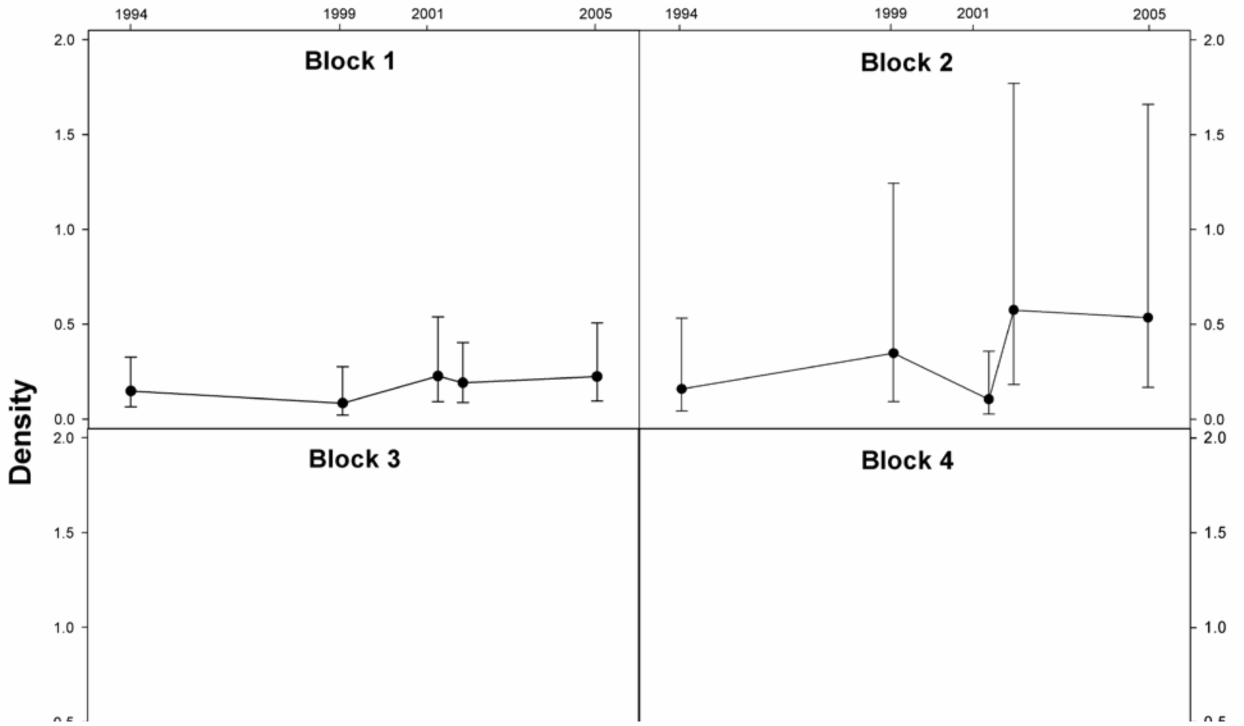


Figure 3. Estimated mean density (± 95% confidence interval) for Hervey Bay Blocks 1-4 for survey years 1994, 1999, April 2001, November 2001, 2005. The data for all surveys have been generated using the method of Marsh and Sinclair (1989).

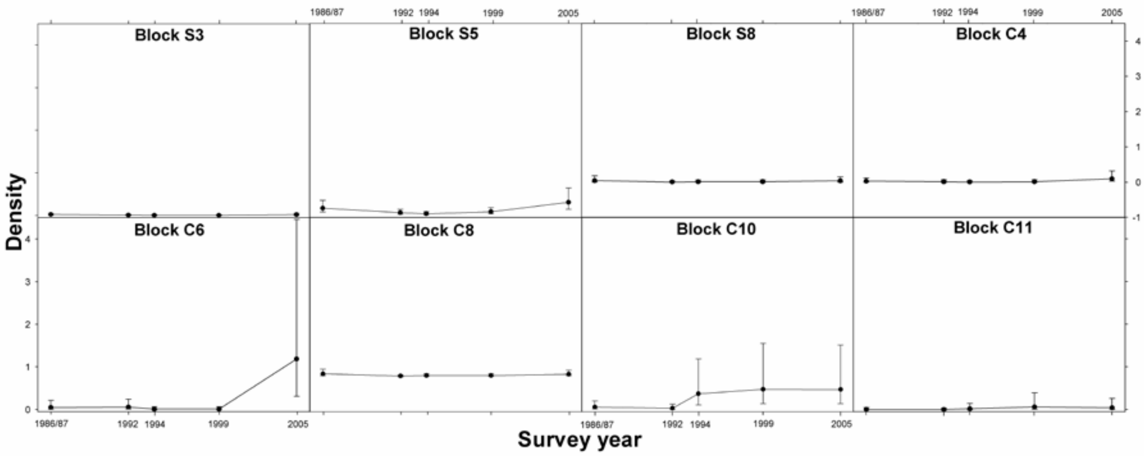


Figure 4: Estimated mean density (+ 95% confidence interval) for Blocks S3,S5, S8, C4, C6, C8, C10, and C11 in the Southern and Central Sections in the Great Barrier Reef Park in each survey year for the surveys conducted in 1986/87, 1992, 1994, 1999 and 2005. The data for all surveys have been generated using the method of Marsh and Sinclair (1989).

Table 1. Result of five analyses of variance examining dugong density among surveys. The variance components were calculated from the mixed effects analyses.

Source of variation	Num. DF	Denom. DF	F	Significance F	Variance component
Moreton Bay December 2000, April 2001, November 2001, 2005					
Block	6	52.24	29.814	0.000	
Among transect within block					2.115
Year	4	157.09	3.583	0.015	
Block x Year	24	155.77	1.468	0.124	
Beaufort Sea State	1	207.849	4.072	0.045	
Residual (among transect within block variation among years)					0.153
Hervey Bay 1994, 1999, April 2001, November 2001 and 2005					
Block	4	52.520	17.433	0.000	
Among transects within block					0.194
Year	4	195.540	1.235	0.297	
Block x Year	15	194.590	1.591	0.079	
Beaufort Sea State	1	246.751	0.619	0.432	
Residual (among transect within block variation among years)					3.620
Southern and Central Sections of GBR and Hervey Bay November 1994, 1999 and 2005					
Block	15	177.216	12.423	0.000	
Among transects within block					0.547
Year	2	349.993	15.988	0.000	
Block x Year	30	349.904	2.469	0.000	
Beaufort Sea State	1	535.364	2.101	0.148	
Residual (among transect within block variation among years)					2.521
Southern and Central Sections of GBR November 1986-1987, 1992, 1994, 1999 and 2005					
Block	10	132.044	10.466	0.000	
Among transects within block					0.460
Year	4	528.165	7.973	0.000	
Block x Year	40	528.046	2.213	0.000	
Beaufort Sea State	1	648.732	8.148	0.004	
Residual (among transect within block variation among years)					2.706
Reference Block (2A)Torres Strait November -December 1987, 1991, 1996, 2000, 2005					
Year	4	42.877	5.299	0.001	
Beaufort	1	53.237	0.918	0.342	
Residual (among transect within block)					0.705

Table 2. Comparison of the population estimates (standard errors) for dugongs for various regions of the survey conducted in November 2005 obtained using the methods of Marsh and Sinclair (1989) and Pollock et al. (2006)

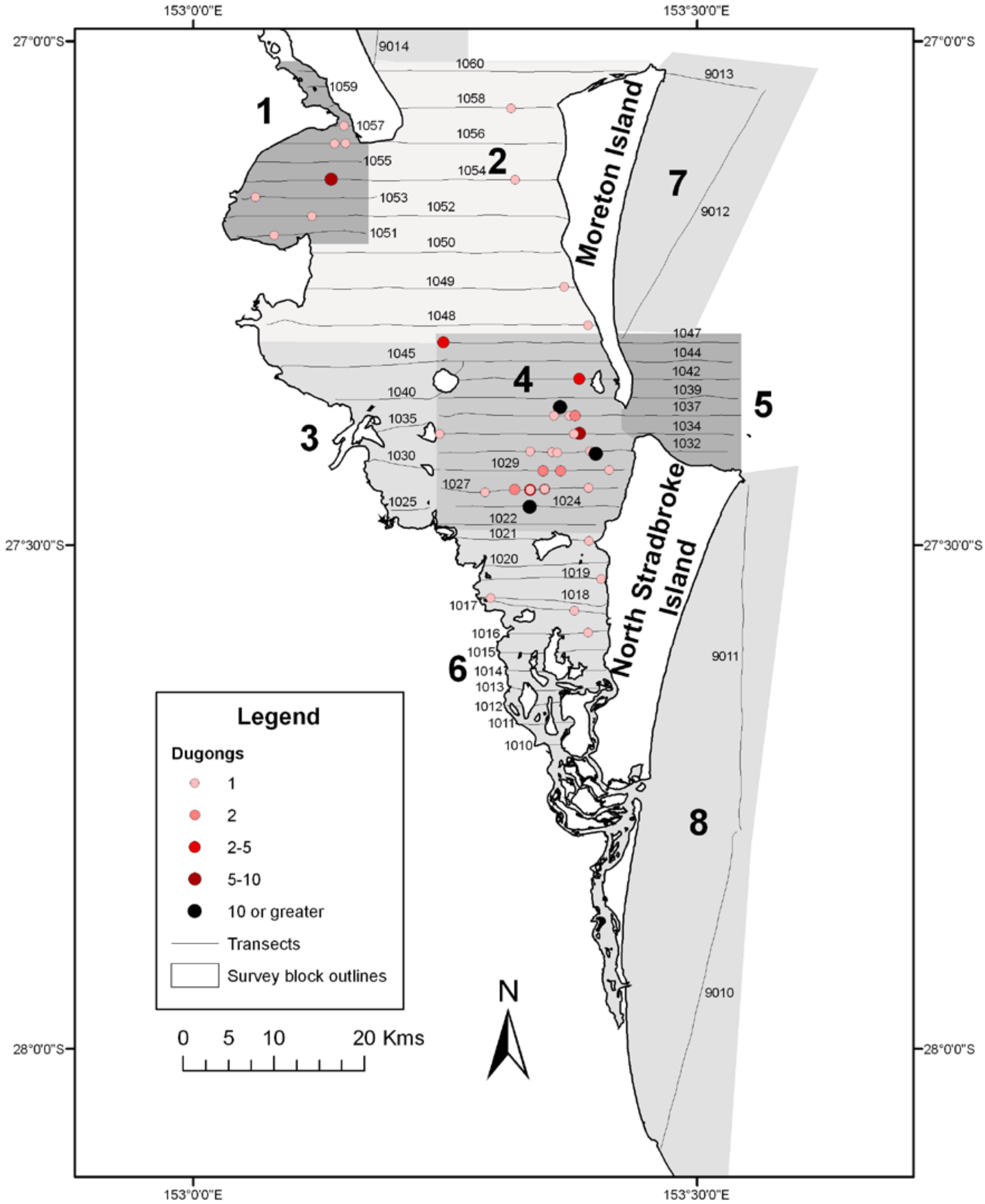
Block	Population estimate (SE) Marsh and Sinclair (1989) method	Population estimate (SE) Pollock et al. (2006) method	Pollock estimate as % of Marsh and Sinclair estimate
Moreton Bay	454 (41)	421 (60)	92.7
Hervey Bay	2547 (410)	2077 (543)	81.5
Southern and Central Sections GBR	2580 (271)	2059 (413)	79.8
Torres Strait Block 2A	4251 (819)	4042 (671)	95.1

Table 3. Estimates of the total sustainable anthropogenic mortality (Potential Biological Removal sensu Wade, 1998) for various components of the survey region on the urban coast of Queensland for a range of estimates of R_{max} and assuming value for the Recovery Factor of 0.1 and 0.5. The values for the PBR are based on the population estimate derived using Pollock *et al.* (2006) because this method should provide more accurate population estimates than the Marsh and Sinclair (1989) method.

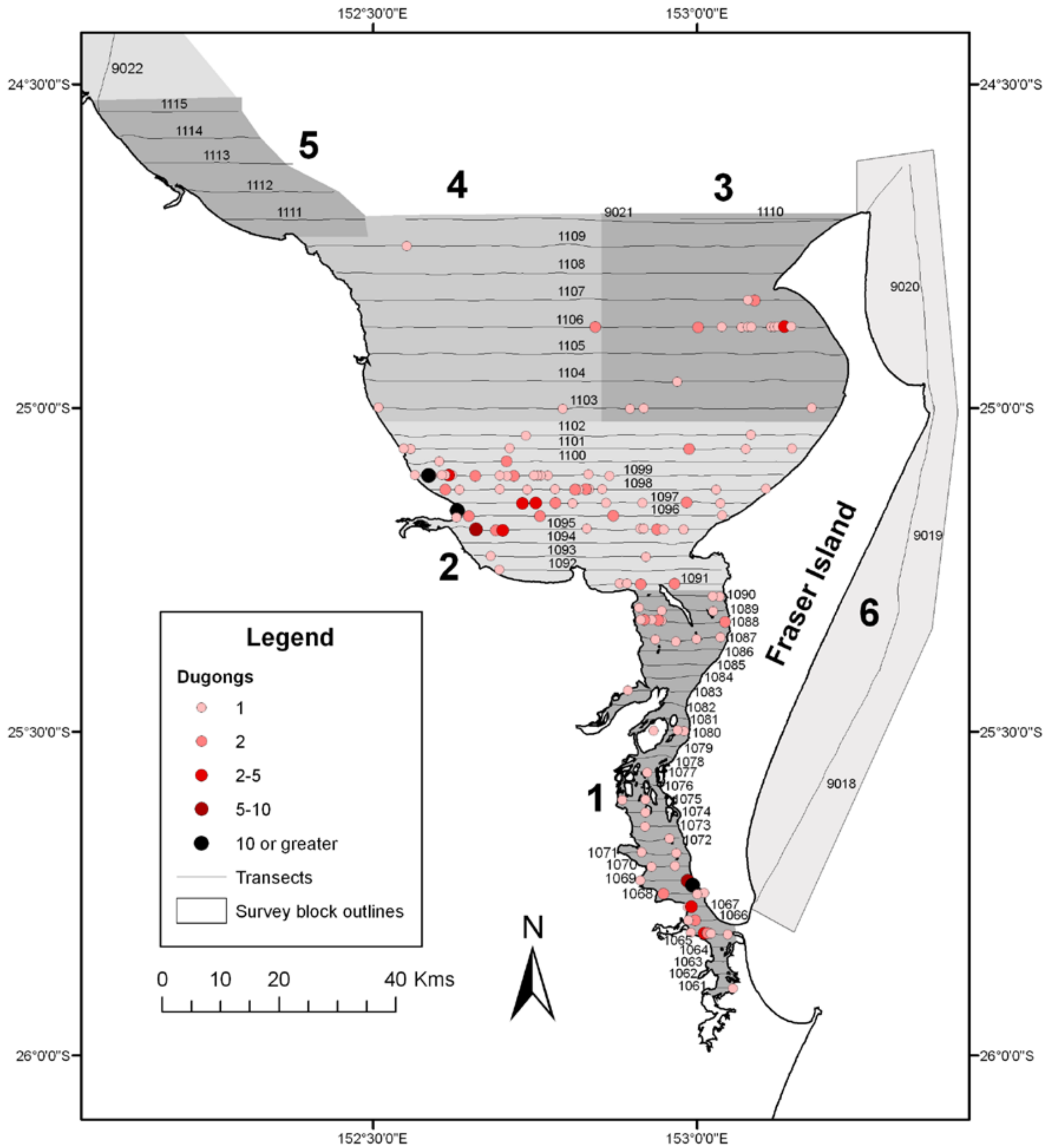
Recovery Factor	Population estimate (SE)	SE	C.V	N min	Potential Biological Removal [2]		
					R_{max}=0.01	R_{max}=0.03	R_{max}=0.05
Moreton Bay							
0.1	421	60	0.142518	374	<1	1	1
0.5					1	3	5
1.0					2	6	9
Hervey Bay							
0.1	2077	543	0.261435	1673	1	3	4
0.5					4	13	21
1.0					8	26	42
Blocks surveyed Southern and Central Sections GBR							
0.1	2059	413		1742	1	3	4
0.5					4	13	22
1.0					8	26	44
SGBR assuming survey blocks 77[1]% of population[1]							
0.1	2674	536	0.200449	2262	1	3	6
0.5					6	17	28
1.0					12	34	57
Urban coast of Qld assuming SGBR survey blocks 77[1]% of population[1]							
0.1	5172	766	0.148105	4569	2	7	11
0.5					11	34	57
1.0					22	69	114

[1]Average from data obtained from surveys conducted in 1986/7, 1992, 1994, 1999; [2] Rounded to nearest whole number

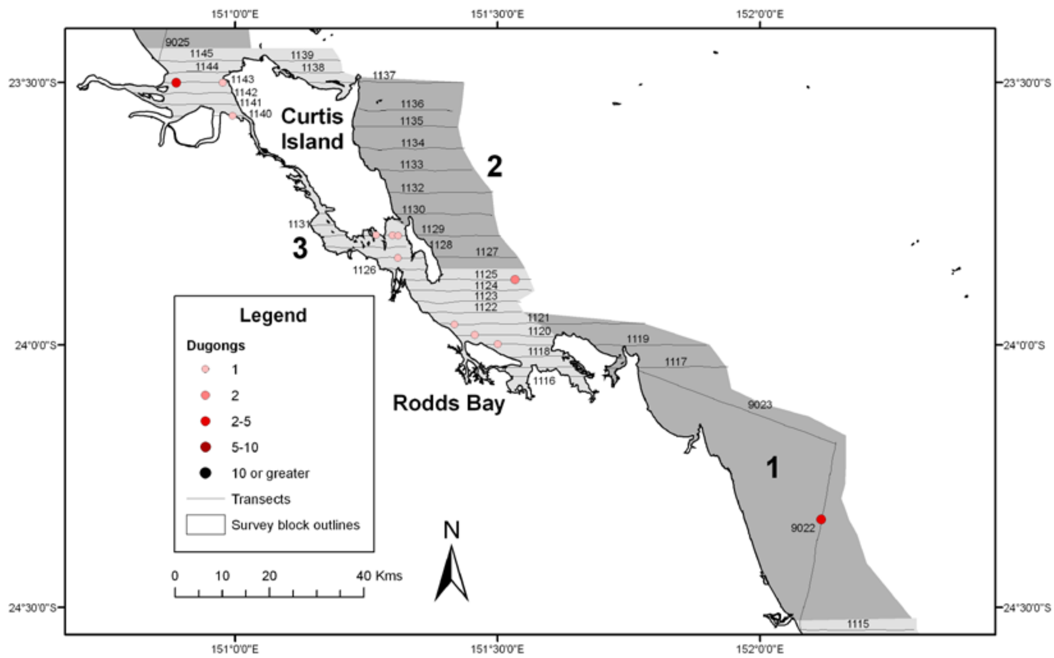
Attachment 2: Appendix figures showing the GPS tracks of transects flown in Blocks 1-8 in Moreton Bay during the aerial survey in November 2005 showing the positions and sizes of the dugong groups sighted and the transect numbers



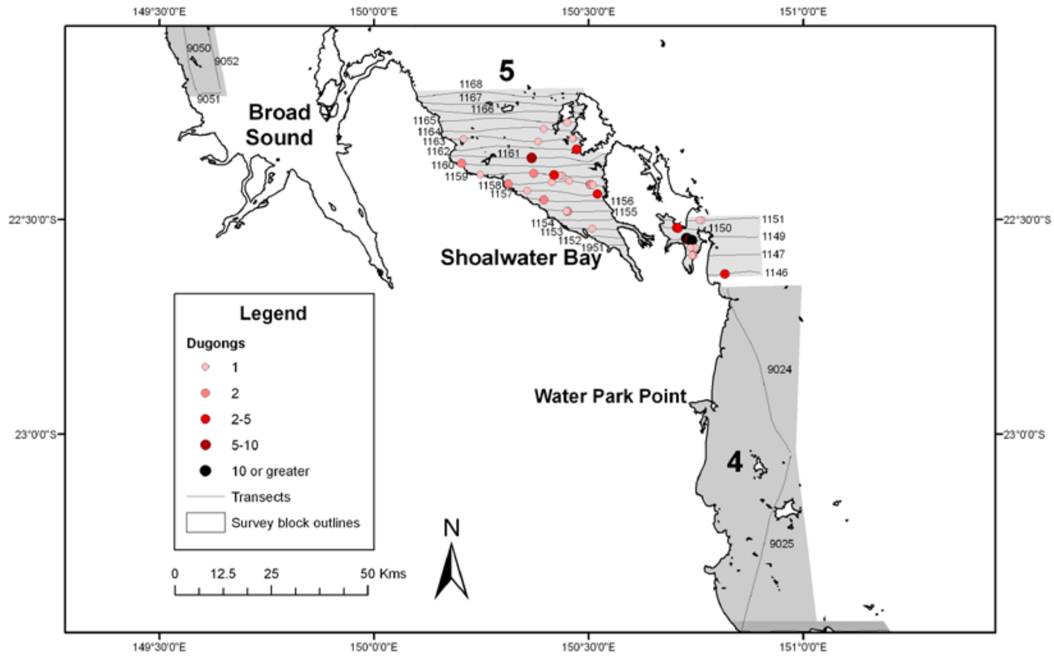
Appendix Figure 1. GPS tracks of transects flown in Blocks 1-8 in Moreton Bay during the aerial survey in November 2005 showing the positions and sizes of the dugong groups sighted and the transect numbers.



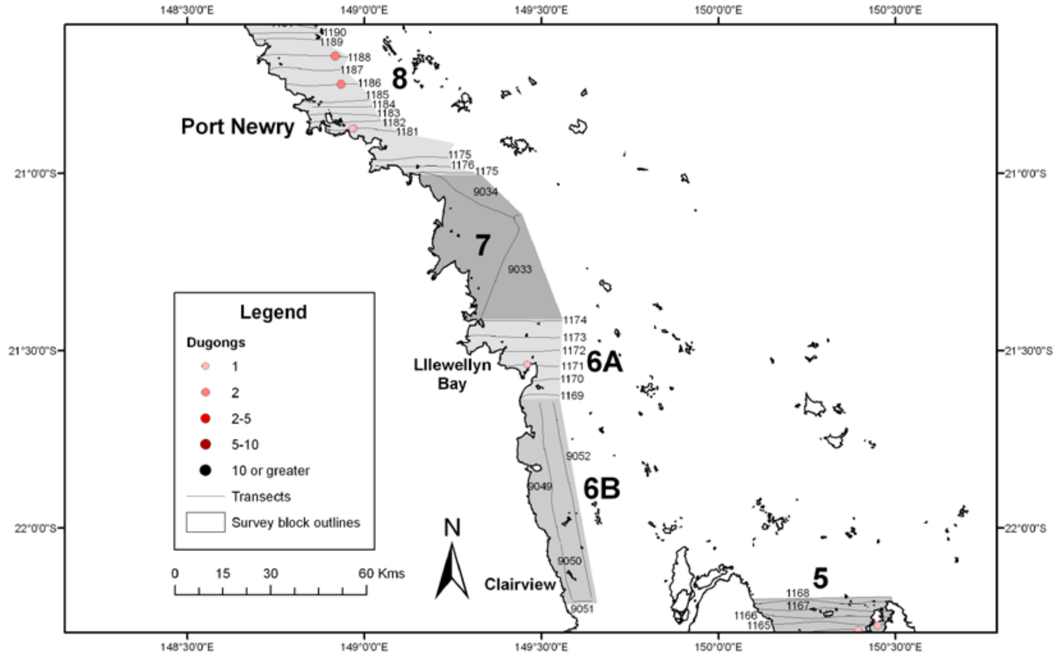
Appendix Figure 2. GPS tracks of transects flown in the Hervey Bay Blocks H1-H6 during the aerial survey in November 2005 showing the positions and sizes of the dugong groups sighted and the transect numbers.



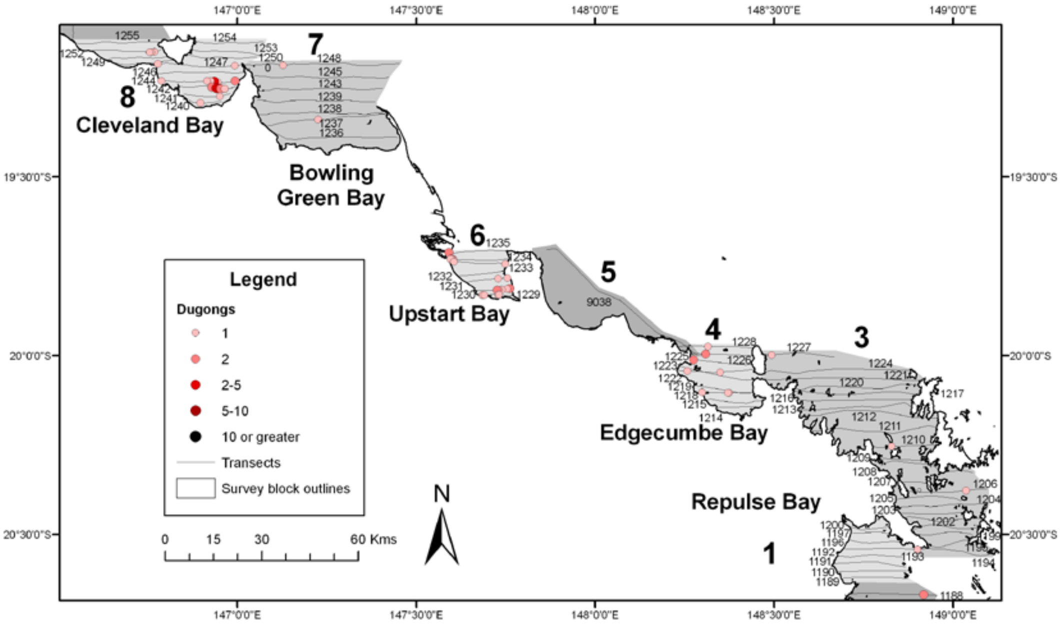
Appendix Figure 3. GPS tracks of transects flown in Blocks S1-3 in the Southern Section of the Great Barrier Reef Marine Park during the aerial survey in November 2005 showing the positions and sizes of the dugong groups sighted and the transect numbers.



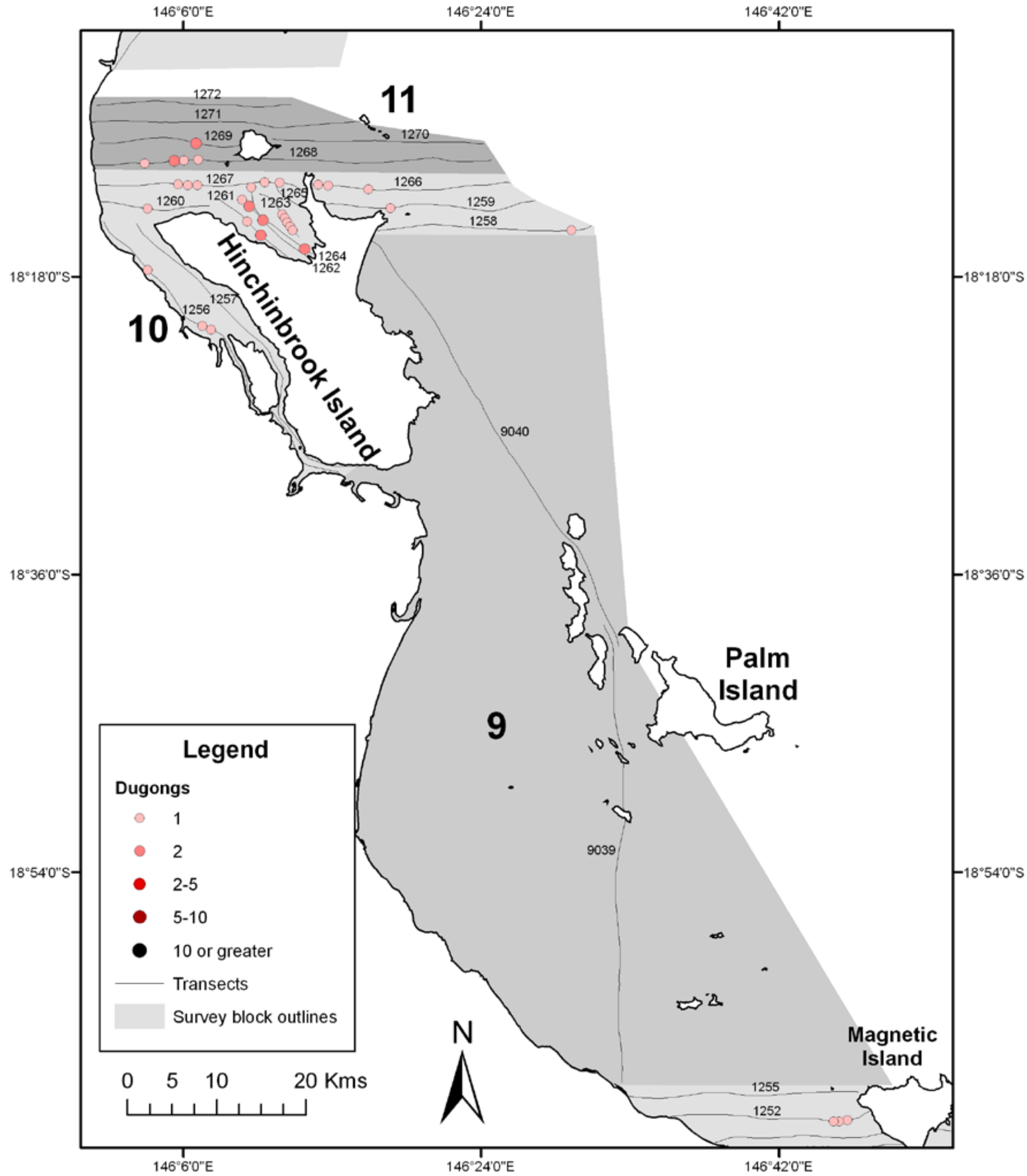
Appendix Figure 4. GPS tracks of transects flown in Blocks S4-S5 in the Southern Section of the Great Barrier Reef Marine Park during the aerial survey in November 2005 showing the positions and sizes of the dugong groups sighted and the transect numbers.



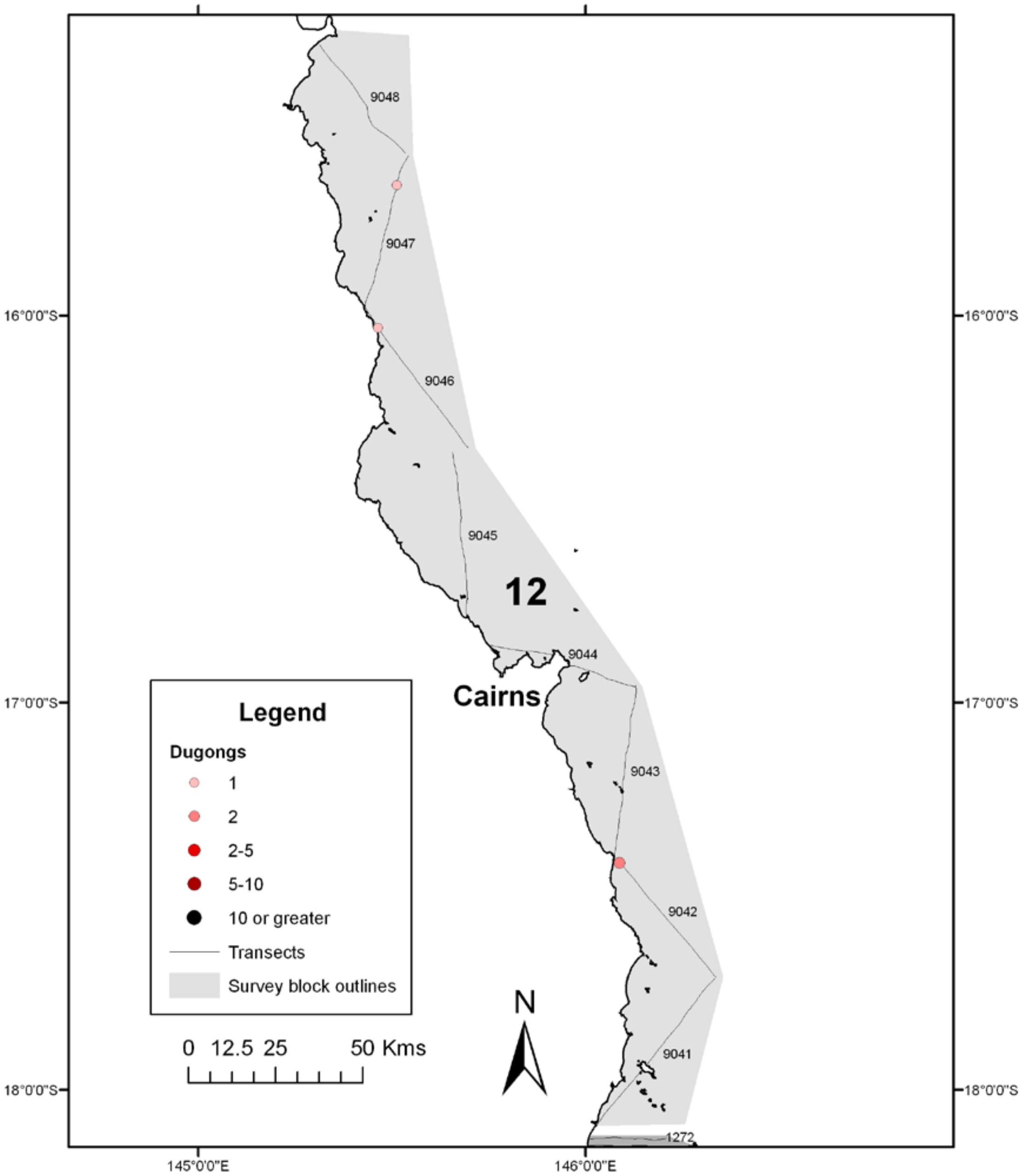
Appendix Figure 5. GPS tracks of transects flown in Blocks S6B-S8 in the southern Section of the Great Barrier Reef Marine Park during the aerial survey in November 2005 showing the positions and sizes of the dugong groups sighted and the transect numbers.



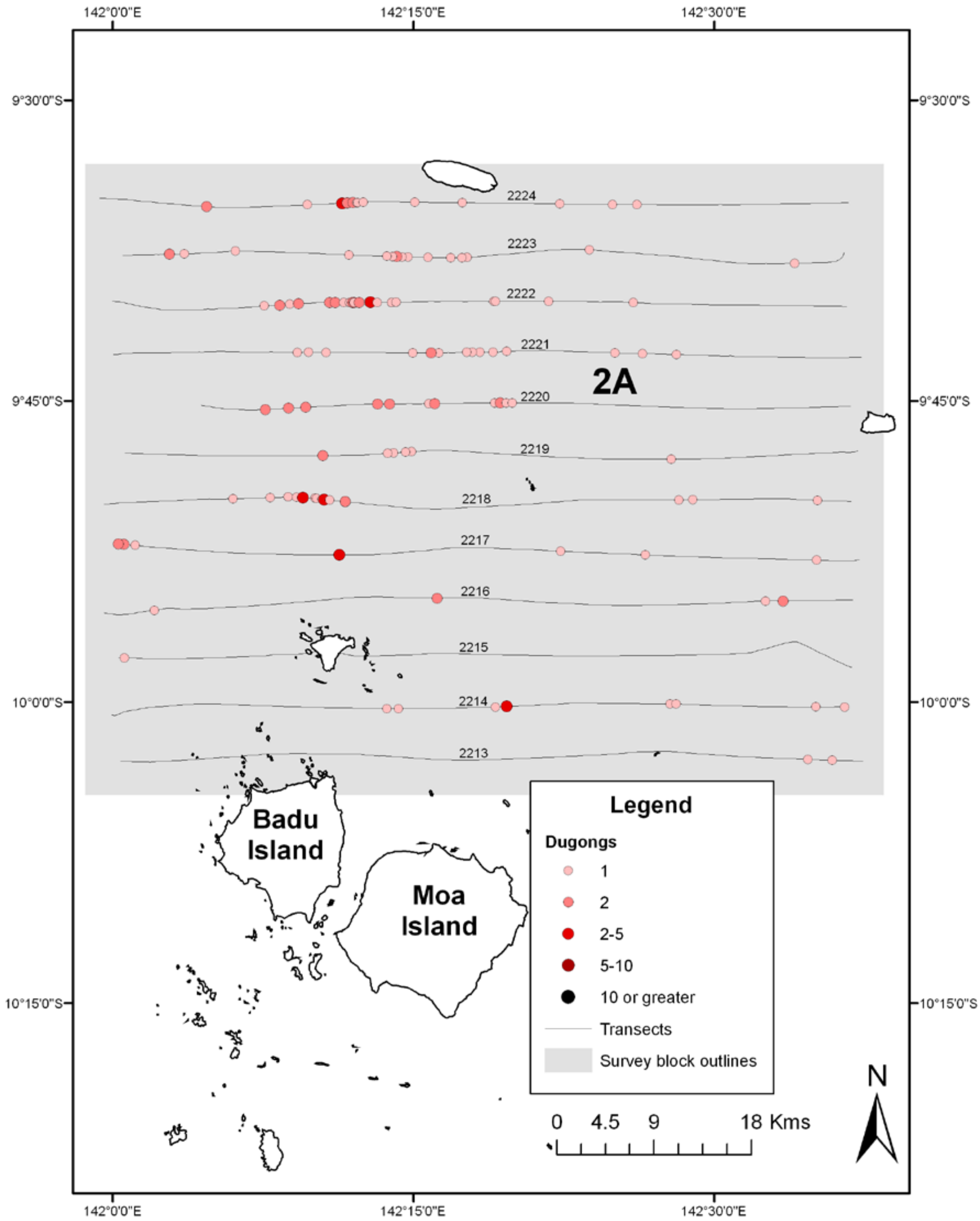
Appendix Figure 6. GPS tracks of transects flown in Blocks C1-C8 in the Central Section of the Great Barrier Reef Marine Park during the aerial survey in November 2005 showing the positions and sizes of the dugong groups sighted and the transect numbers.



Appendix Figure 7. GPS tracks of transects flown in Blocks C9-C11 in the Central Section of the Great Barrier Reef Marine Park during the aerial survey in November 2005 showing the positions and sizes of the dugong groups sighted and the transect numbers.



Appendix Figure 8. GPS tracks of transects flown between Rockingham Bay and Cooktown during the aerial survey in November 2005 showing the positions and sizes of the dugong groups sighted and the transect numbers.



Appendix Figure 9. GPS tracks of transects flown in the Index Block 2A in Torres Strait during the aerial survey in November 2005 showing the positions and sizes of the dugong groups sighted and the transect numbers.

APPENDIX TABLES

Appendix Table 1. Areas of survey blocks and sampling intensities forthe aerial survey conducted in 2005. For locations of blocks see Figure 1.

Block	Area (km^2)	Sampling Intensity (%)
	Morton Bay	
M1	166	24.74
M2	691	13.45
M3	389	50.07
M4	155	24.97
M6	226	29.67
	Hervey Bay	
H1	517	25.31
H2	1414	20.3
H3	1235	11.18
H4	1224	11.44
H5	546	10.86
	Southern Section of Great Barrier Reef Marine Park	
S2	836	10.86
S3	1021	21.12
S5	1271	21.8
S8	796	17.92
	Central Section of Great Barrier Reef Marine Park	
C1	371	18.23
C3	1733	14.61
C4	466	19.57
C6	244	23.35
C7	579	23.70
C8	620	32.64
C10	288	23.64
C11	351	18.06
	Torres Strait	
2A	3808	10.75

Appendix Table 2a. Weather conditions encountered during the 2005 survey in comparison to the following previous surveys of the same areas. Historical data from Marsh and Saalfeld (1990); Marsh et al, (1996); Marsh and Lawler (2000).

	SGBR Northern Sector Blocks C1-C11		SGBR Whitsunday Sector BlocksS6-8		SGBR Shoalwater Bay Sector BlockS 5		SGBR Southern Sector Blocks S1-4		Southern GBR All sectors			
Year of survey	2005	1999	2005	1999	2005	1999	2005	1999	2005	1994	1992	1986-87
Wind speed (km.h^{-1})	<30	<10	<10	<10	<10	<10	<10	<10	<10	<15	<37	<37
Cloud cover (oktas)	0-7	0-3	0-3	0-6	1-5	0-6	0-6	0-6	0-5	0-5	0-5	0-4
Minimum cloud height	1500	3000	700	2500	2000	2000	150	1500	1000 - 4000	2000-5000	2500	300
Beaufort sea state (range)	1.67 (0-4)	1.45 (0-4)	1.59 (0-3)	1.55 (0-3)	0.83 (0-2)	1.87 (0-4)	1.66 (0-4)	1.95 (0-3)	1.48 (0-4)	1.87 (0-4)	1.0 (0-4)	1.0 (0-3)
Glare[5]												
North	1.29	0.67	1.07	1.10	0.87	0.53	2.63	1.76	1.5	1.44		
South	1.31	0.70	1	1.32	0.96	1.08	2.63	1.85	1.5	1.29		
Overall	1.3	0.69	1.33	1.21	0.92	0.80	2.63	1.80	1.5	1.36	2	2
Visibility (km)	>30	>20	>10	>20	>10	>20	>10	<10	>10	>15	N/A	>20

Appendix Table 2b. Weather conditions encountered during the 2005 surveys of Moreton Bay, Hervey Bay and Block 2A in Torres Strait in comparison to the prior surveys of the same areas: historical data from Marsh and Saalfeld 1990; Marsh et al, 1996; Marsh and Lawler 2000, Marsh et al, 1997 and 2004.

	Moreton Bay			Hervey Bay					Torres Strait				
Year of survey	2005	1999	1988	2005	1999	1994	1993	1988	2005	2001	1996	1991	1987
Wind speed (km.h^{-1})	<10	<10	<10	<10	<10	<10	<20	<28	<10	<15	<10	<15	<15
Cloud cover (oktas)	0-6	0-3	0-8	1-7	0	1-3	1-4	1-6	0-3	0-7	0-7	0-5	1-8
Minimum cloud height	2000	3500	3500	2000	N/A	2000-5000	460-1800	610-2400	2500-4000	2000-5000	1000-5000	460-750	270-4000
Beaufort sea state (range)	1.8 (1-4)	0.87 (0-3)	2 (0-4)	2.2 (1-3)	1.67 (0-4)	1.94 (1-3)	1.2 (0-3)	2.1 (0-4)	0.92 (0-2.5)	1.4 (0-3)	1.1 (0-3)	1.9 (0-4)	1.3 (0-4)
Glare[5] North South Overall	 1.76 1.23 1.49	 1.42 1.23 1.32	 0-3 0-3 0-3	 1.44 1.27 1.35	 1.92 1.86 1.89	 0.92 1.08	 1.4	 0.9 (0-3)	 0.79 (0-2) 1.59(0-3)	 0.9 (0-3) 1.3 (0-3)		 1.7 (0-3) 2.3 (0-3)	 1.4 (0-3) 0.75 (0-3)
Visibility (km)	>10	>20	N/A	>10	>30	>20	N/A	N/A	>10	>20	>10	>20	N/A

Appendix Table 3. Beaufort sea state and glare for each transect of the 2005 aerial survey for dugongs. See Appendix Figures 1-9 for transect locations.

		Beaufort				Glare[1]				
						North		South		
				Moreton Bay						
Block MB1										
	1051	2	2	2	2	3	3	1	3	2
	1052	1	1	1	1	2	1	1	2	1
	1053	1	2	1	1	1	1	0	3	1
	1054	1	1	1	1	4	1	1	2	2
	1055	1	2	2	1	2	1	0	3	2
	1056	1	1	1	1	1	1	0	2	0
	1057	1	2	1	1	1	1	0	3	1
	1058	1	1	1	1	1	1	1	1	1
	1059	1	2	2	0	3	2	1	2	1
	1060	1	1	1	1	1	1	0	0	0
Block MB2										
	1048	1	2	1	1	3	1	0	2	2
	1049	1	2	1	1	2	3	1	3	3
	1050	2	2	2	1	3	2	1	4	1
	1051	2	2	2	2	3	3	1	3	2
	1052	1	1	1	1	2	1	1	2	1
	1053	1	2	1	1	1	1	0	3	1
	1054	1	1	1	1	4	1	1	2	2
	1055	1	2	2	1	2	1	0	3	2
	1056	1	1	1	1	1	1	0	2	0
	1057	1	2	1	1	1	1	0	3	1
	1058	1	1	1	1	1	1	1	1	1
	1059	1	2	2	0	3	2	1	2	1
	1060	1	1	1	1	1	1	0	0	0

Block MB4		1	2	2	0	1	1	0	3	0
	1022	3	4	3	3	3	3	2	2	2
	1023	3	4	3	1	3	3	2	2	2
	1024	3	3	3	3	3	3	0	3	0
	1025	3	3	3	3	3	3	0	3	3
	1026				7	7	7			
	1027	3	3	3	0	3	0	0	2	0
	1028	3	3	3	0	3	3	2	2	2
	1029	2	3	3	0	3	0	0	2	0
	1030	2	3	3	3	3	3	0	2	2
	1031	2	2	2	3	7	3	2	2	2
	1032	1	3	2	0	3	0	0	2	0
	1033	1	3	2	3	3	3	1	2	1
	1034	1	3	2	0	3	0	0	10	0
	1035	1	3	2	3	3	3	0	2	2
	1036	2	2	2	3	7	3	2	2	2
	1037	1	2	2	0	3	0	0	2	1
	1038	1	2	2	0	3	2	1	2	1
	1039	1	2	2	0	3	3	0	3	0
	1040	1	2	2	0	3	3	0	3	1
	1041	3	3	3	2	2	2	1	6	6
	1042	1	2	2	0	11	0	1	1	1
	1043	1	2	2	1	3	3	1	1	1
	1044	1	2	1	0	3	3	0	2	0
	1045	1	2	1	0	3	3	0	2	0
	1046	3	3.5	3	3	6	3	1	1	1
	1047	1	2	1	0	3	1	0	2	0
	1048	1	2	1	1	3	1	0	2	2
	1049	2	2	2	0	3	1	0	4	1
	1050	2	2	2	0	3	1	1	3	2
	1051	1	1	1	1	2	1	0	3	1

	1052	1	2	1	0	1	1	0	3	1
	1053	1	1	1	0	4	0	0	2	1
	1054	1	2	2	0	2	1	0	3	0
	1055	1	1	1	1	1	1	0	2	0
	1056	1	2	1	0	1	1	0	8	1
	1057	1	1	1	0	1	0	0	1	0
	1058	1	2	2	0	5	1	0	2	1
	1059	1	1	1	0	1	0	0	0	0
	1060	1	2	2	0	1	1	0	6	1
Block MB6										
	1010	2	2	2	3	3	3	2	7	2
	1011	2	2	2	3	0	3	2	7	2
	1012	2	2	2	2	7	2	1	1	1
	1013	2	2	2	1	2	2	1	7	2
	1014	2	2	2	2	7	3	1	1	1
	1015	2	3	2	2	2	2	2	7	2
	1016	2	2	2	2	2	2	2	7	2
	1017	2	3	2	2	2	2	2	6	3
	1018	2	3	2	2	7	3	2	3	3
	1019	3	3	3	3	7	3	1	1	1
	1020	2	3	3	2	7	2	2	2	2
	1021	2	2	2	2	3	2	1	2	1
					Hervey Bay					
Block HB1										
	1061	3	3	3	0	7	3	0	3	0
	1062	2	3	2	2	3	2	0	6	3
	1063	3	3	3	2	7	2	2	3	2
	1064	2	2	2	3	3	3	3	6	3
	1065	3	3	3	0	7	0	0	3	0
	1066	2	3	2	0	3	0	1	6	3
	1067	3	3	3	0	7	0	0	3	0
	1068	3	3	3	0	3	0	0	8	0

	1069	3	3	3	0	7	0	0	3	0
	1070	3	3	3	0	3	3	0	5	2
	1071	2	3	2	0	3	0	0	7	0
	1072	2	3	3	0	7	0	0	3	0
	1073	2	2	2	0	3	2	0	6	0
	1074	2	2	2	0	7	0	0	2	0
	1075	2	2	2	0	7	0	0	2	0
	1076	2	2	2	3	3	3	0	6	1
	1077	1	1	1	0	7	0	1	1	1
	1078	1	1	1	3	3	3	0	6	0
	1079	2	2	2	0	7	3	0	0	0
	1080	2	2	2	0	2	0	0	6	0
	1081	2	2	2	0	6	0	2	3	2
	1082	2	2	2	3	3	3	0	6	3
	1084	2	2	2	0	3	3	0	7	0
	1085	2	2	2	0	7	0	2	3	2
	1086	2	2	2	3	3	3	0	7	1
	1087	2	2	2	0	6	0	0	6	0
	1088	2	2	2	0	3	0	0	6	0
	1089	1	1	1	0	6	0	0	2	0
	1090	2	3	2	0	3	0	0	6	0
Block HB2										
	1091	1	3	2	0	6	0	0	2	0
	1092	1	2	2	0	3	3	0	7	0
	1093	2	3	3	0	7	0	0	3	3
	1094	2	3	2	3	3	3	0	7	0
	1095	1	2	2	0	12	0	0	3	0
	1096	1	2	2	0	3	3	0	7	0
	1097	1	2	1	0	7	1	0	3	0
	1098	1	2	2	0	3	0	0	6	1
	1099	1	2	2	0	6	0	0	7	1
	1100	1	2	2	0	6	1	0	3	0

	1101	1	2	2	0	3	0	0	6	1
Block HB3										
	1103	1	2	2	0	3	0	0	21	1
	1104	1	3	1	0	7	1	0	3	3
	1105	1	3	3	2	3	3	2	3	3
	1106	2	3	3	3	5	3	3	3	3
	1107	3	3	3	3	3	3	3	3	3
	1108	2	3	3	3	3	3	3	3	3
	1109	2	3	2	3	3	3	3	3	3
	1110	2	3	2	3	3	3	3	3	3
Block HB4										
	1103	1	2	2	0	3	0	0	21	1
	1104	1	3	1	0	7	1	0	3	3
	1105	1	3	3	2	3	3	2	3	3
	1106	2	3	3	3	5	3	3	3	3
	1107	3	3	3	3	3	3	3	3	3
	1108	2	3	3	3	3	3	3	3	3
	1109	2	3	2	3	3	3	3	3	3
					Southern Section GBR					
Block S3		Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
	1116	1	1	1	1	3	1	2	4	2
	1117	1	1	1	3	4	3	1	3	2
	1118				3	4	3	3	3	3
	1119	0	1	1	2	2	2	2	3	2
	1120	0	0	0	2	2	2	2	5	3
	1121	0	1	1	3	3	3	2	3	3
	1122	0	2	1	2	3	2	2	3	3
	1123	0	2	2	3	3	3	3	3	3
	1124	0	3	2	3	3	3	1	3	2
	1125	0	1	1	2	3	3	3	3	3
	1126	1	3	2	1	3	1	3	3	3
	1127	0	3	1	3	3	3	1	3	2

	1128	1	3	2	3	3	3	1	3	2
	1129	0	2	2	2	7	3	1	3	3
	1130	0	0	0	5	5	5	5	5	5
	1131	2	3	2	3	3	3	3	3	3
	1132	0	0	0	1	2	1	0	7	2
	1133	2	2	2	1	7	3	2	3	1
	1134	2	3	3	3	3	3	3	5	2
	1135	2	3	2	3	7	3	3	3	3
	1136	3	3	3	3	3	3	3	5	3
	1137	3	3	3	3	5	3	3	3	3
	1138	1	2	2	3	4	3	3	3	3
	1139	1	3	2	3	3	3	3	4	3
	1140	0	1	1	2	5	3	1	2	2
	1141	2	2	2	2	3	2	2	5	2
	1142	1	2	2	1	4	1	1	3	3
	1143	1	2	2	2	3	2	1	4	2
	1144	2	2	2	3	3	3	3	4	3
	1145	2	4	3	3	3	3	1	3	3
Block S5										
	1146	0	1	1	1	1	1	1	1	1
	1147	0	1	1	1	1	1	1	1	1
	1148	0	0	0	0	0	0	1	1	1
	1149	0	1	0	1	1	1	1	1	1
	1150	0	0	0	1	1	1	0	0	0
	1151	0	1	1	1	1	1	1	1	1
	1152	0	1	0	1	1	1	1	1	1
	1153	0	1	0	1	0	1	1	1	1
	1154	0	1	1	0	0	0	1	1	1
	1155	1	1	1	0	1	1	1	1	1
	1156	1	1	1	1	1	1	1	1	1
	1157	0	1	1	0	1	1	1	1	1
	1158	1	1	1	0	1	1	1	1	1

	1159	1	1	1	1	1	1	1	1	1
	1160	1	1	1	1	1	1	1	1	1
	1161	1	1.5	1	1	1	1	1	1	1
	1162	1	2	1	1	1	1	1	1	1
	1163	1	2	1	1	1	1	1	1	1
	1164	1	1	1	1	1	1	1	1	1
	1165	1	2	1	1	1	1	1	1	1
	1166	1	2	1	1	1	1	1	1	1
	1167	1	2	1	0	0	0	1	1	1
	1168	1	2	2	1	1	1	1	1	1
Block S8										
	1177	1	2	2	1	1	1	1	1	1
	1178	1	2	2	1	2	1	1	1	1
	1179	2	2	2	1	1	1	1	1	1
	1180	2	2	2	2	2	2	1	1	1
	1181	1	2	1	1	1	1	1	1	1
	1182	0	1.5	1	1	1	1	1	1	1
	1183	1	1	1	1	1	1	1	1	1
	1184	1	1.5	1	1	1	1	1	1	1
	1185	1.5	1.5	1.5	1	1	1	1	1	1
	1186	1	2	1.5	1	1	1	1	1	1
	1187	2	2	2	1	2	1	1	1	1
	1188	2	3	3	1	2	1	1	1	1
	1189	2	3	2.5	1	1	1	1	1	1
	1190	2	3	3	1	1	1	1	1	1
	1191	2	2.5	2.5	1	1	1	1	1	1
	1192	1.5	2	2	1	1	1	1	1	1

Central Section GBR

Block C4									
1214	1	2	1	1	1	1	1	1	1
1215	1	2	1	1	1	1	1	1	1
1218	1	1	1	1	1	1	1	1	1
1219	0	1	1	1	1	1	1	1	1
1222	1	2	1	1	1	1	1	1	1
1223	1	2	1	1	1	1	1	1	1
1224	2	3	2	1	2	2	1	2	1
1225	1	1	1	1	1	1	1	1	1
1226	2	2	2	1	1	1	1	1	1
1227	1	1	1	1	1	1	1	1	1
1228	1	2	1	1	1	1	1	1	1
Block C6									
1229	2	2	2	1	1	1	1	1	1
1230	2	3	2	2	2	2	2	2	2
1231	2	3	2	1	1	1	1	1	1
1232	3	3	3	1	2	1	1	2	2
1233	2	3	3	1	1	1	1	2	1
1234	1	3	3				2	2	2
1235	3	3	3	1	2	1	1	1	1
Block C8									
1240				2	2	2	1	1	1
1241	1	1.5	1	1	1	1	1	1	1
1242	1	2	1	0	1	1	1	2	1
1243	1	2.5	2	1	3	2	1	2	2
1244	1	2	1	0	1	1	0	2	1
1245	1	2	1	2	3	2	1	2	2
1246	0	2	2	1	2	2	0	2	1
1247	1	2	2	1	2	1	1	2	1
1248	1.5	2	2	2	3	2	1	2	2

	1249	1	2	2	0	1	0	1	2	1
	1250	1	2	2	1	2	2	1	2	2
	1251	2	2	2	1	2	2	2	2	2
	1252	1	2.5	2	0	1	1	1	1	1
	1253	1.5	2	2	1	2	2	2	3	2
	1254	2	2	2	1	2	1	2	2	2
	1255	2	2.5	2	1	3	1	2	2	2
Block C10										
	1256	1	2	2	0	2	2	1	3	1
	1257	1	2	1	1	3	2	0	2	2
	1258	1	1	1	1	2	1	2	3	2
	1259	1	1	1	1	3	2	1	2	1
	1260	0.5	0.5	0.5	0	2	0	0	1	1
	1261	0.5	1	1	1	1	1	0	0	0
	1262	0.5	1	1	0	0	0	0	1	0
	1263	1.5	4	2	1	2	1	1	1	1
	1264	1	1	1	0	0	0	1	2	1
	1265	1.5	1.5	1.5	3	3	3	1	1	1
	1266	1	2	2	2	2	2	2	2	2
	1267	0.5	2	0.5	1	1	1	0	1	1
Block C11										
	1268	0.5	1.5	1.5	0	2	1	1	2	1
	1269	0	1	1	0	1	1	0	1	0
	1270	1	2.5	1.5	1	1	1	1	2	1
	1271	0.5	1.5	1	0	2	1	0	2	2

Torres Strait

Block 2A	Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
2213	1	2.5	2	1	1	1	0	3	1
2214	0.5	2	2	0	1	1	1	2	2
2215	1	2	1	0	2	1	0	3	2
2216	0.5	1.5	1	0	1	1	1	2	2
2217	0.5	1	1	1	1	1	0	2	2
2218	0.5	1	1	0	2	1	1	2	1
2219	0	0.5	0	0	1	0	1	1	1
2220	0	1	0	0	1	0	1	2	1
2221	0	1	0.5	0	2	0	0	2	0
2222	0.5	1	0.5	0	1	1	1	1	1
2223	0	1	0.5	0	1	0	1	1	1
2224	0.5	1	0.5	0	2	0	1	2	1

[1] Glare scale: 0 – no glare; 1 – 0#25%; 2 – 25#50%;3 - >50%

Appendix Table 4: Raw data for sightings of dugong groups for each transect in each block surveyed in 2005 as used to estimate population size.

Block, Transect Number	Adjusted transect height	Transect length (sea section only)	Transect area (km^2)	# groups port	# groups starboard
		Moreton Bay			
Block MB1					
1052	425	14.1	6.8	1	
1054	450	12.2	6.2	1	
1056	420	9.0	4.3	1	1
1058	472	1.9	1.0		
1060	425	2.5	1.2		
1051	443	13.9	7.0	1	
1053	450	13.1	6.7	1	
1055	445	11.2	5.6		
1057	450	1.9	1.0		
1059	450	2.5	1.3		
Block MB2					
1048	424	33.8	16.3		
1049	440	26.9	13.4		1
1050	510	25.1	14.5		
1052	450	19.6	10.0		
1054	472	18.6	9.9		1
1056	443	19.3	9.7		
1058	445	15.9	8.0		1
1060	373	26.3	11.1		
Block MB4					
1022	450	16.6	8.5		
1023	450	18.1	9.2		
1024	470	18.3	9.8		
1026	450	18.5	9.4		
1027	458	18.8	9.8	4	5
1028	450	19.1	9.7		
1029	433	19.3	9.5	4	1
1031	450	19.5	9.9		
1032	469	19.3	10.3	3	1
1033	450	19.4	9.9		
1034	450	19.0	9.7	1	3
1036	450	18.3	9.3		
1037	450	18.3	9.3	3	
1038	450	18.4	9.4		
1039	458	17.5	9.1		
1041	450	17.9	9.1		
1042	458	17.8	9.3	1	
1043	450	17.5	8.9		

	1044	428	17.1	8.3		
	1046	450	16.6	8.4		
	1047	436	16.2	8.0		
	1048	424	33.8	16.3		
	1049	440	26.9	13.4		1
	1050	510	25.1	14.5		
	1052	450	19.6	10.0		
	1054	472	18.6	9.9		1
	1056	443	19.3	9.7		
	1058	445	15.9	8.0		1
	1060	373	26.3	11.1		
Block MB6						
	1010	450	5.7	2.9		
	1011	450	7.7	3.9		
	1012	467	9.8	5.2		
	1013	450	10.5	5.3		
	1014	450	10.0	5.1		
	1015	425	10.8	5.2		
	1016	475	9.9	5.3		1
	1017	450	10.1	5.1	1	
	1018	475	12.9	6.9	1	
	1019	467	12.5	6.6		1
	1020	488	15.0	8.3		
	1021	463	13.6	7.2	1	
			Hervey Bay			
Block HB1						
	1061	438	3.2	1.6		1
	1062	413	3.2	1.5		
	1063	450	2.9	1.5		
	1064	450	3.4	1.7		
	1065	450	5.5	2.8	1	4
	1066	450	5.1	2.6	2	
	1067	450	3.4	1.7	2	1
	1068	450	6.9	3.5	1	2
	1069	475	8.5	4.6	1	2
	1070	500	7.6	4.3		2
	1071	450	10.5	5.4	1	3
	1072	450	7.3	3.7		
	1073	450	7.1	3.6	1	
	1074	450	8.2	4.2	1	
	1075	463	8.2	4.3		2
	1076	450	6.3	3.2		
	1077	450	7.7	3.9		1
	1078	450	6.2	3.2		
	1079	450	7.6	3.9		
	1080	500	9.5	5.4	1	2

	1081	463	12.7	6.7		
	1082	450	11.7	6.0		
	1083	450	10.2	5.2		
	1084	435	9.0	4.4	1	
	1085	450	11.0	5.6		
	1086	483	13.2	7.3		
	1087	463	13.5	7.1	2	2
	1088	425	14.7	7.1	2	4
	1089	450	14.8	7.6	1	2
	1090	450	14.5	7.4	1	1
Block HB2						
	1091	433	21.7	10.7	2	3
	1092	443	36.1	18.1	1	
	1093	458	39.0	20.3		2
	1094	450	37.0	18.8		
	1095	438	41.0	20.3	2	8
	1096	465	43.3	22.8	1	4
	1097	450	46.8	23.9	8	
	1098	390	53.7	23.8	7	6
	1099	447	58.1	29.4	11	5
	1100	439	61.8	30.7	1	1
	1101	465	64.7	34.1	3	5
	1101	446	67.5	34.2	1	1
Block HB3						
	1103	463	37.5	19.6	2	3
	1104	452	38.5	19.7	1	
	1105	467	38.5	20.4		
	1106	450	35.4	18.1	4	6
	1107	450	31.8	16.2	2	
	1108	450	28.9	14.7		
	1109	450	32.5	16.6		
	1110	450	25.1	12.8		
Block HB4						
	1103	450	35.7	18.2	1	1
	1104	450	37.3	19.0		
	1105	450	36.7	18.7		
	1106	450	37.4	19.1		1
	1107	450	38.9	19.9		
	1108	450	42.2	21.5		
	1109	450	46.3	23.6	1	
		Southern Section GBR				
Block S3						
	1116	463	10.2	5.3		
	1117	455	18.5	9.5		
	1118	450	14.8	7.5		
	1119	471	17	9.1		1

1120	450	13.7	7		1
1121	450	21.5	11	1	
1122	475	22.2	12		
1123	458	20.4	10.6		
1124	463	21.7	11.4		
1125	463	26.7	14	1	
1126	500	27.2	15.4		
1127	450	9.9	5	1	
1128	450	9.3	4.7		
1129	450	18.5	9.4		3
1130	442	16.7	8.4		
1131	500	5	2.8		
1132	450	1.9	1		
1133	450	1.3	0.7		
1137	463	8	4.2		
1138	463	14.4	7.5		
1139	317	14.8	5.3		
1140	467	15.9	8.4	1	
1141	450	18.3	9.3		
1142	450	22.1	11.3		
1143	450	14.5	7.4	1	1
1144	463	14.1	7.4		
1145	475	18.5	10		
S5					
1146	437	0.6	0.3		1
1147	446	2.3	1.1	1	1
1148	440	4.4	2.2	1	
1149	458	8.1	4.2		1
1150	450	10.9	5.6	2	
1151	470	3.6	1.9	2	
1152	440	8.2	4.1		
1153	470	18.1	9.6		1
1154	473	15.3	8.2		
1155	460	17.7	9.2	2	
1156	450	19.3	9.8		1
1157	453	23.8	12.2	1	1
1158	465	26.7	14.1	2	4
1159	450	31.6	16.1	3	1
1160	443	35	17.6	1	
1161	460	40.6	21.2	1	
1162	458	32.8	17	1	
1163	452	35.7	18.3	2	2
1164	468	34.9	18.5	1	
1165	460	36.1	18.8	1	
1166	460	39.5	20.6		
1167	473	41.2	22.1		

	1168	476	39	19.9		
	Block					
S8						
	1177	463	23.3	0.0		
	1178	450	23.5	0.0		
	1179	455	23.0	0.0		
	1180	475	17.7	0.0		
	1181	444	27.7	0.7	1	1
	1182	450	21.1	0.0		
	1183	480	22.1	0.0		
	1184	485	23.3	0.0		
	1185	510	20.2	0.0		
	1186	463	22.9	0.2		1
	1187	467	23.0	0.0		
	1188	470	22.0	0.2	1	
	1189	490				
	1190	450		0.0		
	1191	477		0.0		
	1192	299		0.0		
		Central Section GBR				
Block C4						
	1214	455	13.0	6.7		
	1215	485	18.5	10.2		
	1218	440	17.5	8.7	1	2
	1219	453	18.4	9.4		
	1222	410	21.0	9.8		
	1223	485	24.7	13.6		2
	1225	425	21.4	10.3	1	
	1226	466	20.1	10.6		1
	1228	450	23.4	11.9	1	
Block C6						
	1229	430	10.4	5.1	4	1
	1230	425	11.9	5.7	2	4
	1231	500	14.7	8.3	1	1
	1232	483	15.1	8.3		
	1233	513	17.1	9.9	3	2
	1234	410	19.0	8.8		1
	1235	437	21.8	10.8	1	
Block C8						
	1240	450	11.2	5.7	1	
	1241	460	17.1	8.9	1	
	1242	450	21.0	10.7	2	3
	1244	460	25.1	13.1	2	5
	1246	450	27.5	14.0		
	1247	458	27.6	14.3	1	1
	1249	445	20.0	10.1		
	1250	463	23.8	12.5		

	1251	2625	21.2	63.1		
	1252	473	25.5	13.7	1	2
	1253	440	22.2	11.1		
	1254	460	22.2	11.6		
	1255	457	26.4	13.7		
Block C10						
	1257	384	38.6	16.8		
	1256	451	39.6	20.3	3	
	1260	443	12.1	6.1		1
	1261	460	9.7	5.1		2
	1262	450	10.6	5.4	1	2
	1263	450	9.1	4.6		5
	1264	248	6.2	1.7		2
	1265	510	3.2	1.8		
	1267	455	12.1	6.2	1	4
Block C11						
	1268	454	45.1	23.2	1	3
	1269	450	15.8	8.1		1
	1270	392	30.8	13.7		
	1271	375	22.2	9.4		
			Torres Strait			
Block 2A						
	2214	465	67.6	35.7	3	4
	2215	418	65.2	30.9	1	
	2216	453	67.5	34.6	4	1
	2217	450	67.5	34.4	1	5
	2218	452	67.4	34.5	8	10
	2219	450	67.4	34.4	3	3
	2220	461	67.4	35.2	3	8
	2221	457	67.3	34.9	9	5
	2222	459	67.3	35.0	11	16
	2223	455	67.2	34.7	8	5
	2224	399	67.2	30.4	12	2

Appendix Table 5. Details of group size estimates and correction factors used in the population estimates for dugongs in the 2005 survey of Moreton Bay, Hervey Bay, the southern Great Barrier Reef Region and Torres Strait Block 2A using the Method of Marsh and Sinclair (1989).

Blocks: Transects	Groups size (C.V)	Number of observers		Perception correction factor estimate (C.V)		Availability correction factor estimate (C.V)
		Port	Starboard	Port	Starboard	
Moreton Bay						
1:1052-1059, 2:1048-1060, 4:1022-104, 6:1010-1021	1.610 (0.092)	2	2	1.120 (0.023)	1.058 (0.012)	2.006 (0.129)
Hervey Bay						
1:1061-1090, 2: 1091-1102 , 3:1103-1110 , 4: 1111-1115	1.610 (0.092)	2	2	1.120 (0.023)	1.058 (0.012)	2.006 (0.129)
Southern Section						
3: 1116-1145, 5: 1146-1951, 8: 1177-1192	1.56338 (0.082)	2	2	1.26 (0.073)	1.216 (0.069)	2.973 (0.140)
Central Section						
4: 1214-1228, 6: 1229-1235,	1.56338 (0.082)	2	2	1.26 (0.073)	1.216 (0.069)	2.973 (0.140)
8: 1240-1255, 10:1257-1267, 11: 1268-1272	1.349 (0.037)	2	2	1.042 (0.010)	1.066 (0.014)	2.593 (0.126)
Torres Strait 2A	1.349 (0.037)	2	2	1.042 (0.010)	1.066 (0.014)	2.593 (0.126)

Appendix Table 6a. Estimates of dugong numbers for each survey block in the Southern and Central Sections of the Great Barrier Reef Marine Park for various surveys conducted between 1986-2005 inclusive All surveys were in November-December unless otherwise indicated. The block locations are in Appendix Figures 3-7.

Block	Population (s.e.) *Marsh and Sinclair (1989)*					Population (s.e) *Pollock et al (2006)*
Southern Section GBR	1986	1992	1994	1999	2005	2005
S1	tfe[1]	122 (71)	0	0	zzt	zzt
S2	0	94 (50)	0	0	tfe	tfe
S3	301 (95)	91 (60)	104 (56)	55 (37)	183 (66)	116 (64)
S4	51 (48)	tfe	67 (44)	0	zzt	zzt
S5	765 (161)	566 (185)	406 (78)	628 (162)	1033 (101)	898 (295)
S6	542 (293)	tfe	82 (60)	dd	dd	dd
S6A	dd[2]	dd	dd	0	tfe	tfe
S6B	dd	dd	dd	0	zzt	zzt
S6C	dd	dd	dd	tfe	ns	ns
S7	0	0	0	0	zzt	zzt
S8	240 (104)	Tfe	38 (37)	69 (63)	tfe	tfe
Central Section GBR	1987	1992	1994	1999	2005	2005
C1	31 (35)	70(59)	0	90 (57)	tfe	tfe
C2	65 (69)	0	0	n/s	ns	ns
C3	0	35 (27)	tfe	353 (211)	tfe	tfe
C4	173 (77)	40 (24)	tfe	445 (236)	234 (79)	145 (86)
C5	312 (122)	0	tfe	203 (90)	ns	ns[3]
C6	171 (87)	91 (46)	tfe	tfe	494 (175)	331 (190)
C7	136 (120)	58 (50)	54 (38)	270 (96)	tfe	tfe
C8	360 (92)	106 (56)	183 (29)	361 (157)	211 (84)	216 (129)
C9	0	257 (105)	157 (77)	424 (159)	zzt	zzt
C10	184 (110)	141 (89)	377 (154)	748 (432)	322 (118)	280 (130)
C11	100 (71)	86 (72)	107(71)	213 (118)	103 (34)	73 (50)

C!2	tfe	tfe	tfe	tfe	zzt	zzt
			Southern and Central Sections GBR			
Totals all blocks	3431 (456)	1757 (286)	1575 (233)	3911 (637)		
Totals 2005 blocks only	2461 (317)	1284 (252)	1269 (204)	3232 (608)	2580 (271)	2059 (413)
% 2005 Blocks /Total	71.7	73.1	80.6	82.6		

[1] too few to estimate: <5 dugongs sighted – data from prior publications modified to reflect this; [2] not surveyed: slightly different design; [3] not surveyed

Appendix Table 6b. Estimates of dugong numbers for each survey block in Moreton Bay and Hervey Bay and the Index Block In Torres Strait for various surveys conducted between 1986-2005 inclusive. All surveys were in November-December unless otherwise indicated. The block locations are in Appendix Figures 1, 2 and 9. Historical data from Marsh and Saalfeld (1990); Marsh et al, (1996); Marsh and Lawler (2000), Marsh et al, (1997) and (2004).

Block			Population (s.e.)			Population (s.e)
			Marsh and Sinclair (1989)			*Pollock et al (2006)*
Moreton Bay	1988 (Aug)			1995[4]	2005	2005
M1	tfe			25 (16)	97 (18)	95 (37)
M2	0			tfe	tfe	tfe
M3	0			tfe	298 (28)	301 (43)
M4	442 (69)			921 (35)	60 (24)	26 (21)
M5	tfe			0	0	0
M6	tfe			22 (21)	tfe	tfe
M7	0			ns	zzt	zzt
M8	0			ns	zzt	zzt
Totals	442 (69)			968 (44)	454 (41)	421 (60)

Hervey Bay	1988 (Aug)	1992	1993	1994	1999	2005	2005
H1	269 (147)	943 (377)	193 (52)	287 (79)	373 (96)	649 (110)	389 (130)
H2	1753 (388)	71 (40)	257 (85)	408 (115)	875 (196)	1331 (261)	1143 (353)
H3	153 (59)	tfe	tfe	tfe	113 (71)	566 (296)	545 (392)
H4	tfe	74 (50)	74 (74)	tfe	112 (76)	0	0
H5	ns	ns	ns	tfe	180 (53)	0	0

H6	ns	ns	ns	ns	0	0	zzt
Totals	2175 (419)	1088 (382)	524 (124)	695 (140)	1653 (248)	2547 (410)	2077 (543)
Torres Strait	1987	1991		1996	2001	2005	2005
Block 2A	6424 (1679)	9313 (1798)		10869 (1600)	3504 (403)	4251 (819)	4042 (671)

[1] too few to estimate: <5 dugongs sighted – data from prior publications modified to reflect this; [2] not surveyed: slightly different design; [3] not surveyed; [4] mean estimate is between 499 and 549 see Preen and Marsh (1995); [5] from Lanyon (2003) minus data from zones where < 5 dugongs sighted; note Lanyon's estimates in other months of 1995 range from 503 (64) to 1019 (166)

Appendix Table 6c. Estimates of dugong numbers for each survey block in Hervey Bay and Moreton Bay for various surveys conducted by Lawler (2001) in 2000-2001. The block locations are as in Appendix Figures 1 and 2.

Block	Dec 2000 Population (s.e.)	Apr 2001 Population (s.e.)	Nov 2001 Population (s.e.)
	Moreton Bay		
1	tfe[1]	tfe	Tfe
2	tfe	tfe	Tfe
3	tfe	tfe	Tfe
4	344 (88)	366 (41)	493 (45)
5	tfe	tfe	Tfe
6	tfe	tfe	Tfe
Total	344 (88)	366 (41)	493 (45)
	Hervey Bay		
1	ns[2]	416 (68)	446 (112)
2	ns	348 (110)	1263 (375)
3	ns	155 (68)	Tfe
4	ns	tfe	Tfe
5	ns	ns	Tfe
Total		919 (146)	1708 (392)

[1] too few to estimate: <5 dugongs sighted – data from prior publications modified to reflect this; [2] not surveyed.